

1. Integrated Weed Management (IWM) in Unpuddled Direct Seeded Rice (DSR). Pijush Mukherjee¹, Swapan Maity¹; ¹Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal, India

The area is located at latitude: 25°57'SN - 27°N and longitude: 88°25'SE - 89°54'SE where rice is specifically grown as rainfed transplanted crop during rainy season. However, aberrant climatic behaviour causing late onset, early termination of monsoon and heavy down pour followed by long dry spell exposed the crop on moisture stress condition at different growth stages during past several years. This in turn reduced the productivity of crop significantly and it became 2.2 tones/ha. Direct seeding in unpuddled condition has been found an effective option and success depends on weed control and forecasting of onset of monsoon. In order to develop IWM in DSR the concept of brown manuring was introduced in which *Sesbania rostrata* grown in inter row spaces of paired row rice having the spacing of 15cm within the pair and 30 cm between the pairs was killed by 2,4-D at 25 days after sowing (DAS). Dried *Sesbania* was incorporated with the help of wheel hoe. Brown manuring was used in integration with four soil applied herbicides (pre-plant surface applicator) viz. butachlor 1.5 kg/ha, pretilachlor 0.75 kg/ha, pendimethalin 0.6 kg/ha, benthocarb 1.5 kg/ha, one post emergence herbicide 2,4-D 0.5 kg/ha at 40 DAS and hoeing at 30 DAS. These altogether constituted eleven treatment combination tested in RCBD with three replications during rainy season of 2006-07 and 2007-08 on the University research farm and in farmers fields on participatory mode at 2nd year. *Cynodon dactylon*, *Cyperus rotundus*, *Cyperus iria* and *Ludwigia parviflora* constituted dominant weed flora in which *Cyperus rotundus* and *Cyperus iria* had narrow emergence profile whereas *Cynodon dactylon* and *Ludwigia parviflora* had long emergence profile. In IWM treatments, brown manuring + butachlor + 2,4-D registered highest weed control efficiency (89%) resulting in higher grain yield of 3.0 tones/ha and 3.9 tones/ha in two succeeding years, respectively. Sowing of pre-germinated seeds at 10 days before onset of monsoon caused higher yield in 2nd year. In farmers field this treatment recorded grain yield of 4.4 tones/ha with net profit of Rs 22,476 per hectare and benefit cost ratio of 1.49.

2. Studies on Ecological Control of Weeds in the Orchard of Yunnan. Yiqing Guo¹, Guojing Zhao¹, Xiangdong Li¹; ¹Yunnan Academy of Agricultural Sciences, Kunming, Yunnan Province, China (Peoples Republic of)

Yunnan Province is situated at the southwest of China. It is a low-latitude plateau with mountainous area accounting for 97%. In Orchard, weeds are of the most important infestations. Weeds not only compete with the fruit trees for fertilizer, water and space but also provide as

hosts for insects and disease organisms. They can also grow quickly to cover the orchard, resulting in shade and less aeration. Generally, the measures for weed control usually are carried out after the weed infestation and result in soil erosion during rainy seasons.

This study focused on weed control through chemical combined with ecological measures with a purpose to improve the ecological environment of the orchard by covering with straw or planting vegetation such as clover or short-stalk legume. There were used two experimental plots. One was apple garden at Kunming, about 1850-1920 m above the sealevel with average 15 C temperature and 900 mm rainfall. The other plot was orange garden in Shiping with the elevation of 1420 m above the sealevel, and with average 18 C temperature and 1000-1100 mm rainfall.

The results showed that, after covering with white clover for 3 years at apple garden, the effect of eco-control amounted 95% for annual weeds, 75-80% for perennial weeds. Soil moisture was increased by 18-35% during dry season. Available nitrogen was increased by 189 kg/ha a year, and water and soil loss was reduced by 5167.5 kg/ha a year. At the orange garden, in case of straw-cover for 2 years, the eco-control effect was 95% for annual weeds, and 75-85% for perennial weeds. Soil moisture was increased by 15-25% during dry season. The content of soil organic matter was also increased by 23.5-49.8%. Thus, it is suggested that chemical control combined with living crop or straw cover can function as a sustainable ecological method for controlling weeds in orchard. This could also provide an example for forest weed control.

3. Fecundity and Management of Annual Ryegrass (*Lolium rigidum* Gaud) in Wide Row Lupin (*Lupinus cosentinii* Guss) Systems within Western Australian Wheatbelt. Abul Hashem¹, Alex Douglas¹, Shahab Pathan¹; ¹Department of Agriculture and Food WA, Northam, WA, Australia

Two experiments were conducted at Wongan Hills (30°48'S, 116°37'E) and Merredin (31°29'S, 118°17'E) in 2006 to examine the intra-row and inter-row weed control, seed production of annual ryegrass (*Lolium rigidum* Gaud) and the risks associated with weed control in wide row lupin (*Lupinus angustifolius* L.) in Western Australia Wheatbelt (WA Wheatbelt).

At Wongan Hills, annual ryegrass density on the inter-rows was reduced 99-100% by inter-row Spray.Seed® (paraquat + diquat) or glyphosate sprayed with spray-shields, 61-63% by inter-row cultivation and 34% by standard practice (simazine at planting and clethodim at 4-leaf stage) in a lupin crop sown at 52 cm wide rows. Crop damage was 1% in inter-row Spray.Seed® application, 6 to 12% in inter-row glyphosate and 29 to 44% in inter-row cultivation treatment. Lupin grain yield loss was 20% in the untreated control, 11 to 14% in inter-row Spray.Seed®, 25 to 31% in inter-row glyphosate and 39 to 55% in inter-

row cultivation treatment. Intra-row seed production of annual ryegrass was reduced 33 to 54% by a banded application of simazine or metolachlor except in one treatment. Inter-row seed production of annual ryegrass was reduced 100% in inter-row glyphosate or Spray.Seed® application, 58 to 68% in the inter-row cultivation and 26% in the standard practice.

At Merredin, annual ryegrass density on the inter-row was reduced 98 to 99% by inter-row glyphosate, 64 to 65% by inter-row Spray.Seed® and 53% by inter-row cultivation and 100% by the standard practice in a lupin crop sown at 66 cm wide rows. Crop damage was 4 to 8% in inter-row glyphosate application, 9 to 14% by inter-row cultivation and no damage was recorded in inter-row Spray.Seed® application. Lupin grain yield loss was 21% in the untreated control, 1 to 3% in inter-row glyphosate, 11 to 14% in inter-row Spray.Seed® and 5 to 14% in inter-row cultivation.

Results showed that glyphosate was as effective as or even more effective on inter-row annual ryegrass than Spray.Seed® but was more damaging to lupins than Spray.Seed®. Previous studies have also demonstrated that Spray.Seed® was highly effective on inter-row annual ryegrass within WA Wheatbelt. These results suggest that Spray.Seed® may be used as an alternative to glyphosate for inter-row weed control in wide row lupins. Given that glyphosate resistance in annual ryegrass is on the rise and paraquat resistance in annual ryegrass has not yet been reported in Australia, this is a promising alternative to manage annual ryegrass populations that have already developed resistance to herbicides including glyphosate.

4. Response of More and Less Competitive Wheat Cultivars to Wild Oat Competition when Plant Density is Increased and Herbicide Rate is Reduced. Mohammad Armin¹, Eskandar Zand², Mohamamad Ali Baghestani²; ¹Islamic Azad University, Sabzevar, Razavi Khorasan, Iran; ²Plant, Pest and Disease Institute (weed branch), Tehran, Iran

To determine optimum density on more and less competitive wheat varieties on interference of wild oat and effect of reduced dose of clodinafop-propargyl, a study was conducted in 2004-2005 and 2005-2006 at the research station of Plant, Pest and Disease Institute of Karaj, Iran. The experiments included wheat varieties (Rooshan and Niknejad), wheat seeding rate (recommended, recommended + 25% and recommended + 50%) (300, 375 and 450 plants m² for Rooshan and 400, 500 and 600 plants m² for Niknejad) and wild oat density (0, 25, 50 and 75 plant m²) in first year and wheat varieties (Rooshan and Niknejad), wild oat density (0, 25, 50 and 75 plant m²) and herbicide doses (0, 0.25, 0.50 and 0.75 g a.i/ha (100%, 66%, 33% and 0% reduce herbicide dose respectively) in second year in factorial trial based on randomized block design with 4 replications. The result indicated that

Niknejad had more yield with and without wild oat interference due to having more fertile tiller and more acceptance density than Rooshan. The maximum yield of Niknejad and Rooshan were achieved at recommended + 25% and recommended density, respectively. As crop density increased, wheat height, spike per area and seed per square meter, aboveground dry matter and leaf-area index (LAI) of wheat increased and aboveground dry matter, LAI, and crop growth rate (CGR) of wild oat decreased. The presence of wild oat in wheat reduced aboveground dry matter, LAI, CGR and grain yield of wheat, and the magnitude of this reduction was dependent on weed density. Wheat yield loss in Rooshan was more in Niknejad when wild oat interference. Second year results indicate that higher control of wild oat with low herbicide dose of clodinafop-propargyl achieved in low wild oat density. The least wild oat biomass was obtain in the recommended rate, and reduce herbicide dose to 66% , 33% and 0 recommended dose caused 66% , 82% and 84% reduce on wild oat biomass; respectively. Two years studies showed that LAI, height, time of canopy closing and more plant density reduced competition of weed. Planting at recommended density in weed presence caused 33% reduce on application of clodinafop-propargyl without decrease in economic yield and net return. This study shows that Niknejad could be planted at recommended + 25% density could tolerate wild oat interference and had more yield when herbicide dose of clodinafop-propargyl reduced.

5. Studies on Integration of Chemical and Manual Weed Control. Inayat Awan¹, Mohammad Khan¹, Gul Hassan², Nawaz Ahmad³; ¹Faculty of Agriculture, Gomal University, Dera Ismail Khan, North West Frontier Province (NWFP), Pakistan; ²NWFP Agricultural University Peshawar, Peshawar, North West Frontier Province (NWFP), Pakistan; ³Ramzan Sugar Mills, Chinoat, Punjab, Pakistan

Rice is grown annually on more than 2 million ha in Pakistan. District Dera Ismail Khan is one of the leading areas famous for rice growing in the country. Due to high intensity of weeds, the production per unit area is lower. Various methods including cultural, mechanical, and chemical are in vogue for weed control in rice. A study was conducted to find out the best possible option for the farmers to minimize weed competition. The aim of this study was to establish an appropriate weed management strategy for effective control of weed flora in direct wet-seeded rice. The experiment was laid out in split-plot arrangement under RBCD (Randomized Complete Block Design) with three replications. Five herbicides namely oxadiazon (Ronstar 12 L) @ 0.24 lit a.i ha-1, oxadiargyl (Top Star) @ 0.80 kg a.i ha-1, pretilachlor (Rifit) @ 0.50 kg a.i ha-1, acetachlor (celor) @ 0.125 kg a.i ha-1 and clomazone (Command 3 ME) @ 0.247 kg a.i ha-1 were

kept in sub-plots, while hand weeding and weedy check were assigned to the main-plots. Hand weeding was performed twice viz. 6 and 9 weeks after sowing (WAS). Data were recorded in weed population, dry weed biomass gm⁻², sterility (%) and ultimately their effect on paddy yield.

Results indicated that pretilachlor, clomazone and acetachlor when followed one hand weeding each after 6 and 9 WAS resulted in highest paddy yield among all the treatments. It resulted in minimum weed density (m⁻²), reduced dry weed biomass (g m⁻²) and minimized sterility (%) than oxadiazon and oxadiargyl and weedy check. However, numerically the highest values for all the parameters were recorded for pretilachlor application. The interaction of pretilachlor herbicide with hand weeding 6 WAS produced maximum paddy yield (8.57 t ha⁻¹). Pretilachlor application followed by hand weeding at 6WAS gave the control of grasses and sedges in the crop. The observation identify the best possible option for weed control in the area, thus increasing rice production and boosting the mechanization level of rice growing farmers.

6. Crop Rotation Effects on *Cyperus rotundus* and *C. esculentus* Population Dynamics in the Low Desert Vegetable Production. Milton McGiffen¹, Guangyao Wang¹; ¹University of California, Riverside, CA, United States of America

Control options for purple and yellow nutsedge (*Cyperus rotundus* and *C. esculentus*) were evaluated within three cropping systems: standard low desert vegetable crop rotation (weed-free control, uncontrolled nutsedge, and cultivation) with spring cantaloupe (*Cucumis melo*) - summer fallow - winter broccoli (*Brassica oleracea*), cover crop rotation (halosulfuron and smother crop) with spring wheat (*Triticum aestivum*) / corn (*Zea mays*) - summer sudangrass (*Sorghum sudanense*) - winter fallow, rotation with solarization (non-solarization and solarization) with spring wheat - summer fallow / solarization - winter broccoli. After two growing seasons, broccoli was planted without any nutsedge control to study the effect of two field seasons of treatment on broccoli yield. Purple nutsedge tubers increased from 0.66 tubers per m² to 1260 tubers per m² in the uncontrolled nutsedge treatment over the course of two growing seasons. Cultivation during the growing season reduced purple nutsedge tubers by 93% compared to the uncontrolled nutsedge plots. Cover crop rotation did not reduce the number of purple nutsedge tubers significantly despite the dense sudangrass canopy effectively shading the soil during most of the summer months. Purple nutsedge was effectively controlled by the solarization treatment. All methods controlled yellow nutsedge effectively, especially when there were no crops growing in the summer. When broccoli was grown after two years of various nutsedge management

strategies, the cultivation treatment showed a 44% yield reduction compared to the weed free control, while the solarization treatment increased broccoli yield by 64% compared to the non-solarization treatment in the purple nutsedge field. Rotations that included sudangrass had low broccoli yield when either purple or yellow nutsedge were present.

7. Determination of the Best Integrated Weed Management System in Maize (*Zea mays*). Mansour Ghorbanpour¹, Iraj Nosratti¹, Mansour Ghorbanpour¹; ¹University of Tehran, Karaj, Tehran, Iran

In order to determine the best integrated management system in maize field experiments were conducted at Tehran in Iran which revealed that maize grain yield in double row (DR) planting pattern was higher than in single row (SR) planting pattern in all plots (up to 1.0 t/ha). Tank mixing atrazine with other preemergence herbicides significantly increased weed control at both planting patterns and the best was atrazine at dose of 1.0 kg ha⁻¹ plus alachlor. Among Sulfonylurea herbicide, nicosulfuron gave the highest grain yield. The most efficient Foramsulfuron dosage was 37 g a.i./ha which had highest grain yield. It was concluded that the best integrated management system in maize is integrating crop competitiveness with reduced herbicidal mixture and appropriate dosage.

8. Characteristics and Integrated Management of *Spirogyra communis* in Rice Field. Fuhua Sun¹, Changshu Sun¹, Wei Shi²; ¹Institute of Binhai Rice Research, Hebei Academy of Agricultural and Forestry Sciences, Tangshan, Hebei Province, China (Peoples Republic of); ²Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing, China (Peoples Republic of)

Spirogyra communi is one of the sinking green algae commonly found in rice field in China. It reduced rice yield by more than 15% if not very well controlled. The objectives of this study were to clarify the characteristics and developed an integrated management of this weed by field experiments from 2002-2006 in BohaiBinhai rice field north east Beijing. The results indicated:

Spirogyra communis decreased field temperature by 2-3°C and 3-4°C in rice tillering stage with 60% and 100% coverage, respectively, which decreased the percentage of reaped ears by 10-20%. The floating weeds also intercepted a large part of fertilizer applied into the rice field and absorbed the nutrition, which caused 20-30% loss in rice yield because less effective ears, less reaped grains with lower grain weight. The suitable ecological conditions for *Spirogyra communis* were salt content 0.1%-0.2% in surface soil and pH 7.3-7.8, large amount of phosphate fertilizer applied year by year and poor ditch

drainage system formed a relatively lenitic condition of water in rice field for a long time.

Both physical and chemical methods helped manage this weed including digging deeper drainage, leaching salt and alkali timely by irrigation so that the whole-salt content is lower than 0.1% and chlorine ion content is lower than 0.09% in the soil, irrigating rice field with fresh active water, applying more organic manure instead of phosphate fertilizers, applying the mixture of Triphenyltin acetate and Cupric sulfate at the dosage of 700g-1000g ai/ha when *Spirogyra communis* floating on the water surface discontinuously with darkgreen and bright looking and 20-30% in coverage in the field and Simetryn at 380g-480g ai/ha 15 days after transplanted. Both herbicides provided 95%-98% weed control efficacy and no rice injuries were observed.

9. A Bioherbicide System for Integrated Management of Torpedograss in Lake Okeechobee, Florida, USA: Summary of Three Years of Field Research. S Chandramohan¹, Raghavan Charudattan¹, James Devalerio¹, Charles Hanlon²; ¹University of Florida, Belle Glade, FL, United States of America; ²South Florida Water Management District, West Palm Beach, FL, United States of America

Torpedograss (*Panicum repens* L.) is one of many invasive weeds that displace native plants in Florida wetlands and choke shallow lakes such as the Lake Okeechobee. Torpedograss is difficult to control because of its tolerance to chemical herbicides and its ability to regrow from rhizomes following chemical control, mowing, or burning. Use of host-specific pathogens as bioherbicides may provide an effective nonchemical option to manage this troublesome weed. We have developed a novel strategy to control weedy grasses by using three fungi indigenous to Florida, *Drechslera gigantea*, *Exserohilum longirostratum*, and *E. rostratum*, which are applied either alone or in a mixture. In tests in greenhouse, torpedograss was susceptible to the bioherbicide system and several nontarget plants tested were unharmed. In this study, we have evaluated the long-term efficacy of the bioherbicide system to manage torpedograss over two years under field conditions, and integrate the bioherbicide system with chemical control being practiced in Lake Okeechobee, FL. In summary, the bioherbicide system effectively and selectively controlled torpedograss under field conditions for 20 months with at least 2 applications per year. Natural recruitment of native plant species occurred in bioherbicide treated plots. The bioherbicide could be integrated with chemical herbicide application (single application of Arsenal at 64oz/A, followed by 2 applications of the bioherbicide in the following year). Chemical herbicide alone (Arsenal at 64oz/A applied aerially once) killed all vegetation present at the field site, and regrowth of both torpedograss and natives occurred about 6 months later. But, bioherbicide application

following chemical application controlled torpedograss selectively, allowing the natives to remain healthy and allow for natural recruitment. We are currently seeking help from any agency or industry partner to license the technology from University of Florida to get the bioherbicide registered and made available for large-scale use.

10. Evaluation of the Effects of Competition of Different Canola (*Brassica napus* L.) Cultivars on the Growth Parameters of Wild Mustard (*Sinapis arvensis* L.). Yahia Abtali¹, Mohamad Ali Baghestani Meibodi,² Esmail Yasari³, Mehdi Abtali⁴; ¹Agriculture and Natural Resources Researches Center of Mazandaran, Iran, Sari, Mazandaran, Iran; ²Plant Protection Institute, Tehran, Iran, Tehran, Iran; ³Payam Nour University, Mazandaran, Iran, Sari, Mazandaran, Iran; ⁴Agricultural Products Insurance Office of Mazandaran, Sari, Mazandaran, Iran

Wild mustard is considered as one of the most aggressive weeds in canola fields. Because of the high percentage of erucic acid in oil and high concentration of glucosinolate in canola meal after oil extraction, besides decreasing in canola seed yield, it causes lessening the canola oil content and quality. The growth parameters of wild mustard in competition with different cultivars of canola therefore, have been evaluated during the cropping season 2005-2006 in Bay-e-Cola Agricultural Research Station, Agriculture and Natural Resources Researches Center of Mazandaran, Iran. The experiment was carried out based on a randomized complete block design (RCBD) with 16 different treatments in 3 replications based on factorial design. The pattern of competition design was based on two factors: Factor A comprising four canola cultivars: Hyola 401, Opcion 500, RGS 003 and PF 7045.91 (Sarigol). Factor B consisting of: wild mustard density in 4 different levels: 4, 8, 12 and 16 plants/m².

During the growth period, samplings were done from a section of 0.5 m² from each plot in an interval of 35 days. After each sampling, dry weight of wild mustard was recorded and used for calculation of Total Dry Matter (TDM), Relative Growth Rate (RGR) and Crop Growth Rate (CGR). The canola seed yield was calculated based on harvesting an area of 3 m² from each plot.

The results showed that with increasing the wild mustard density, the rate of dry matter accumulation and total dry matter in canola plants decreased irrespective of the cultivar and in this point of view there were no significant differences between different cultivars of canola. Evaluation of the weed relative growth rate (RGR) during the canola cropping season showed that RGR linearly decreased with increase in the weed density in all the four cultivars. The analysis of variances for canola seed yield showed that the interaction of cultivar x weed (wild mustard) density as well as the effects of cultivars were not significant at 0.01 level, while canola seed yield decreased with increase in weed density.

11. Influence of Pendimethalin-Based Weed Management Systems on Weed Flora Composition and Diversity in Indian Spinach (*Basella alba* L.) and Okra (*Abelmoschus esculentus* (L.) Moench) in a Humid Tropical Environment.

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Crop growth habit complements weed management method in its effect on weed emergence and growth patterns. In particular, pendimethalin-based integrated weed management systems (P-IWM) are beneficial in both okra [*Abelmoschus esculentus* (L.) Moench Jokoso] and Indian spinach (*Basella alba* L. alba). The preliminary influence of P-IWM systems, namely P1 (pendimethalin at 0.33 kg a.i./ha applied pre-emergence, PE), plus weeding once at 3 weeks after sowing, WAS (P1 + W3), weeding once at 5 WAS (P1 + W5), or PE atrazine at 2.05 kg a.i./ha (P1 + A1), P1 alone, weeding once at 3 + 5 WAS (W2) and no weeding (Wy), on relative weed growth in okra and *B. alba* in a humid tropical environment were compared in a field experiment. A randomized complete block design using three replications per treatment was used. Both crops compared well in ecological weed growth, in terms of weed dominance/relative importance value (RIV) and diversity (H). However, weeds were slightly more important, diverse and varied more widely with P-IWM in okra than in *B. alba*. Okra had distinctly more weed associates (58.8%) and perennial weeds (20%) than *B. alba* (41.2%, 7.1%) during crop establishment. Annual broadleaves and grasses were considerably more in *B. alba* (64.3%, 28.6%) than in okra (50%, 25%). Weed associates of crops were diverse but *Synedrella nodiflora* was distinctly persistent in both crops and more important in *B. alba* (RIV = 42.5%) than in okra (33.1%). It is concluded that differences in ecological weed growth arising from P-IWM were due to crop growth habit, especially canopy cover.

12. Challenges for Integrated *Cyperus rotundus* and *C. esculentus* Management in Irrigated Systems Infested with *Meloidogyne incognita*.

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One factor affecting the sustainability of agriculture in the arid southwestern United States is the management of pest complexes that have developed over time and limit profitable production in many fields. Such persistent interactions among weeds, nematodes, insects and diseases are particularly important to producers who must intensively manage limited irrigated acreage in an economically efficient manner and without the use of nonselective biocides. Lack of knowledge regarding pest interactions increasingly encourages growers to focus on individual

pests rather than broader complexes. Previous research identified relationships between *Cyperus esculentus* L., *Cyperus rotundus* L., and *Meloidogyne incognita* [southern root-knot nematode] occurring simultaneously in sandy soils used to produce *Capsicum annuum* L. [chile pepper]. These pests do not disseminate readily and, unlike their damaging effects on *C. annuum* and most other crops, are well adapted to a mutually beneficial coexistence that sustains and enhances the pest complex. Specifically, these *Cyperus* species host *M. incognita* with little to no effect on vegetative growth, and tuber production is often enhanced. *M. incognita* overwinters in *Cyperus* sp. tubers and is protected from fumigant nematicides. The nematode has an extremely broad host range including most competitive crops that might be grown to suppress *Cyperus* populations. Research was conducted to determine if rotation with a nondormant *M. incognita*-resistant *Medicago sativa*, Mecca II, effectively suppresses the pest complex. *M. sativa* grown for three years suppressed the pest complex compared to *Gossypium hirsutum*. *C. annuum* yields were two times greater after *M. sativa*; however, populations of all three pests resurged to economically damaging levels by the end of the season. Research continued to determine if a two-year rotation of *M. sativa* followed by targeted herbicide treatment in the *C. annuum* crop slowed resurgence of the pest complex. *Cyperus* spp. populations began to resurge in March indicating that two seasons of *M. sativa* did not effectively suppress the weed population compared to the effect three seasons had in previous research. Results indicate that herbicide treatment in the *M. sativa* or three seasons of a *Cyperus* spp./*M. incognita* suppressing crop are needed to obtain initial suppression of the pest complex and additional in-crop management is needed to sustain pest suppression. Rotation schemes must be chosen based on economic return, efficient water use, and effective suppression of the weed-nematode complex.

13. Quackgrass (*Elytrigia repens*) Response to a Hairy Vetch (*Vicia villosa*) Cover Crop in Vegetable Cropping Systems.

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Because of its winter hardiness, hairy vetch (*Vicia villosa*) is a common cover crop used in various cropping systems in temperate regions. Studies have documented the potential allelopathic effects of hairy vetch on weeds and crops. However the information on specific weed species is lacking. Field studies were conducted in 2005-2006 to measure quackgrass response to hairy vetch cover crop in a pickling cucumber production system. The study was established on a site with a natural and uniform population of quackgrass. Treatments included a hairy vetch cover crop and a control without cover crop in a randomized complete block design with four replications.

In all years hairy vetch was seeded in early September (40 kg/ha) and killed with cultivation the following spring (late May). Pickling cucumber was planted two to three weeks after hairy vetch incorporation. Quackgrass populations were assessed prior to hairy vetch incorporation. A grid comprised of 30- by 30-cm squares was used to assess quackgrass populations across the entire field. In each square the quackgrass infestation was rated on a 0 to 10 scale with 0 indicating no weed and 10 indicating total weed cover. This information was used to generate quackgrass distribution maps. Additionally, quackgrass density was evaluated during cucumber growing season in smaller subplots. Hairy vetch suppressed quackgrass populations, with only a few weeds recorded the second year of the experiment. Evaluations conducted in 2006 showed infestation values of 0-1 in the hairy vetch plots and 3-6 in the control plots. Similar results were obtained for evaluations conducted during cucumber growing season. Quackgrass density was reduced by over 70% in the hairy vetch plots compared with the control. Results of this study show that hairy vetch cover crop could be used for integrated management of quackgrass, a perennial and troublesome weed in cropping systems, especially in regions with a temperate climate.

14. Integrated Weed Management: A Key for Herbicide Life Management. Martin Hess¹, Joachim Kaiser¹, Hansjoerg Kraehmer¹, Hubert Menne¹; ¹Bayer CropScience AG, Frankfurt, Hessa, Germany

Weed management in modern cropping systems continues to further lose its diversity of control methods and practices. Despite all efforts to implement Integrated Weed Management (IWM), for most farmers weed management is a synonym for herbicide use. Compared to mechanical weed control, herbicides are more energy efficient and a reduced soil disturbance maintains a higher organic matter content. These advantages will become more important with increasing energy prices and global efforts to reduce atmospheric CO₂. An overall comparison of different measures within the IWM toolbox demonstrates a performance advantage of herbicides concerning criteria such as efficacy, flexibility, time consumption, and economics. However, the heavy reliance on herbicides has led to high infestation pressure of single weed species, thereby promoting the selection of herbicide resistant biotypes. It is therefore in the interest of the agrochemical industry to provide to the farmers stewardship activities to maintain the long term efficacy of herbicides and to prevent evolution of resistance. Recommendations for non chemical weed measurements are prompted to reduce the overall infestation pressure of worst weeds to diminish the probability of resistance development. In this context efficient diagnosis methods to determine the resistance status of weed populations will gain importance, together with specific recommendations within IWM to suppress

herbicide resistant biotypes. New herbicides from Bayer-CropScience entering the markets, such as tembotrione and thiencazabone-methyl isoxaflutole in corn and pyrosulfutole in cereals will provide additional alternatives for successful resistance and product life cycle management. With the introduction of glufosinate-tolerant soybean varieties, this unique mode of action will be available in the major row crops. These products will provide additional weed management alternatives, allowing together with all other IWM options, successful herbicide resistance management strategies.

15. Reproduction and Integrated Management of Canada Thistle (*Cirsium arvense* (L.) Scop.). Joanna Sciegienka¹, Fabian Menalled¹; ¹Montana State University, Bozeman, MT, United States of America

Cirsium arvense is an aggressive, introduced perennial weed that infests crops, pastures, rangelands, roadsides, and non-crop areas throughout the world. Well-known for its deep and creeping root system and colony-forming tendencies, it is a problem in agricultural lands as well as natural systems and rangeland. Although much research has been conducted on individual approaches to manage *C. arvense*, this species remains a highly problematic weed. A strategy that involves a better understanding of the physiology of the plant and the combined effects of various types of management could help reduce the impact of this species. The purpose of this research was to determine whether better *C. arvense* control can be achieved through integrated weed management. Our plan involved a combination of glyphosate, a stem-boring weevil, (*Hadroplontus litura*), and a pathogen, [*Pseudomonas syringae* pv. *tagetis* (PST)], and was tested both in the greenhouse and in the field. In the greenhouse, *C. arvense* roots were grown to rosette stage, then treated with a full factorial combination of glyphosate (none, one-sixth of the labeled rate, or a full labeled rate), insects (absent or present), and PST (none, early application, or late application). Dry root biomass for all the integrated management treatments was lower than that for the control. Shoot number for the combination of reduced rate of glyphosate, pathogen, and insect was significantly lower than the control. In the field, *C. arvense* roots were planted at three different depths (2, 10, and 20 cm). Emergence rates differed across treatments, with the 10 cm roots having the best emergence. Management treatments were applied to plants at the 10 cm depth and included: control, 1/6 of the labeled rate of glyphosate (0.63 kg a.e./ha), the labeled rate of glyphosate (3.78 kg a.e./ha), and a combination of pathogen, 1/6 the labeled rate of glyphosate, and insects. Insects were not available at the time of the experiment in 2007, so they will be applied in spring 2008. All three treatments lowered *C. arvense* shoot biomass with no significant differences across treatments. Results suggest that the integration of mortality factors in

the management of *C. arvensis* may provide efficient control.

16. Effect of *Avena ludoviciana* on Physiological Indices of More and Less Competitive Wheat Cultivars at Different Plant Densities. Mohammad Armin¹, Eskandar Zand², Mohamamad Ali Baghestani²; ¹Islamic Azad University, Sabzevar, Razavi Khorasan, Iran; ²Plant, Pest and Disease Institute (weed branch), Tehran, Iran

A field experiment was conducted in 2004-2005 growing season, at the research station of Plant, Pest and Disease Institute of Karaj to study the Effect of *Avena ludoviciana* on physiological indices of more and less competitive wheat cultivars at different plant densities. The experiment was established as a factorial combination of wheat varieties (Rooshan (as less competitive) and Niknejad (as more competitive)) 3 wheat densities (recommended, recommended + 25% and recommended + 50%) and 4 wild oat densities (0, 25, 50, and 75 plants m²) with 4 replications. Quantitative estimate of these traits was obtained for each experimental unit using nonlinear regression analysis. The result showed that more competitive cultivar had more Leaf Area Index (LAI), more light absorption, less time (GDD) between emergence and 1/2 leaf area index or height and higher proportion of its leaf area in higher layer. Increasing wheat density increased these traits so increasing competition ability and decreased yield loss.

17. Distribution and Management of Weeds in Peanut (*Arachis hypogaea* L.) in Ghana, West Africa. David Jordan¹, Grace Bolfrey-Arku, Israel Dzomeku², Mike Owusu-Akyaw, Mumuni Abudulai³, Rick Brandenburg¹; ¹North Carolina State University, Raleigh, NC, United States of America; ²University for Developmental Studies, Tamale, Ghana; ³CSIR-Savanna Agricultural Research Institute, Tamale, Ghana

A survey was conducted to determine distribution of weeds and practices implemented for their management in peanut in southern Ghana during 2001 and in northern Ghana during 2003-2005. Twenty-four genera of weeds were documented as dominant in northern Ghana, with a distribution of 14 dicotyledonous, 9 monocotyledonous, and 1 parasitic weed. In southern Ghana, these respective classifications revealed 18, 12, and 1 species. In northern Ghana farm size was greater than 3 ha while farm size was generally less than 1 ha in southern Ghana. Yield loss due to weeds was ranked as the first or second most yield-limiting pest relative to disease, insects, and nematodes. The top five most problematic weeds in northern Ghana included *Commelina* spp., *Rottboellia cochinchinensis*, *Striga hermonthica*, *Digitaria horizontalis*, and *Paspalum* spp. In southern Ghana, *Euphorbia heterophylla*, *Digitaria*

spp., *Imperata cylindrical*, *Commelina* spp., and *Tridax procumbens* were listed as the most problematic. In northern Ghana hand hoeing, crop rotation, land fallow, and intercropping peanut with cereals are components of weed management. Fewer than 6% of farmers used herbicides to control weeds in both regions. In southern Ghana, slash and burn land preparation and plowing are followed up with hoeing to manage weeds. Scientists in both regions indicated that development of a cultivar with a semi-spreading growth habit that is more competitive with weeds than commercially available cultivars is an important need to decrease weed interference in peanut. In southern Ghana development of herbicides that can be used while intercropping peanut with corn or cassava would also lead to improved weed control. Continued determination of yield loss from weeds and the relationship between weeds and other pests is important. Greater understanding and implementation of integrated pest management was also defined as a need, especially with respect to local agronomists and extension personnel and farmers. Weed management research in peanut in Ghana is supported through the USAID Peanut CRSP (LAG-00-96-90013-00).

18. Corn (*Zea mays*) and Soybean (*Glycine max*) Strip Crops and Weed Population Dynamics. Darío Verdelli¹, Clarence Swanton², Eduardo Leguizamón¹; ¹National University of Rosario / CONICET, Rosario, Santa Fe, Argentina; ²University of Guelph, Guelph, Ontario, Canada

Concerns about the sustainability of monoculture corn (*Zea mays* L.) and soybean (*Glycine max* [L.] Merr.) systems in central Argentina have been growing and strip cropping has been proposed as a viable alternative. Strip cropping optimizes resource usage and may contribute to increased biodiversity through changes in leaf area and biomass accumulation dynamics, resource utilization, and herbicide use compared to monoculture systems. Experiments were conducted in 2005 and 2006 near Monte Buey, Argentina to determine the potential yield benefit or penalty when corn and soybean were strip cropped with each other and to determine if there were differences in weed population dynamics when compared to monoculture systems. In the first experiment, corn and soybean were planted into 12 row strips with 12 rows of the companion crop strips along each side. Crop height, biomass, leaf area, and photosynthetically active radiation (PAR) were measured. A second experiment of a similar design was conducted to compare weed management strategies in strip crop and monoculture systems using atrazine (in corn) and imazethapyr (in soybean) applied pre-emergence and two post-emergence glyphosate applications. Preliminary results indicated that strip cropped corn and soybean can be a viable alternative to monoculture systems in Argentina. In corn, an edge effect increased

PAR interception within the border strip rows and increased the crop growth rate. This edge effect resulted in the average yield of the corn strips to be 18% greater than corn grown in monoculture. In soybean, a yield penalty was detected in the strip rows bordering corn because of overshadowing by neighbouring corn plants that lowered the amount of intercepted PAR. Yet, this penalty was compensated for by increased yield within the centre of strips since no differences between the overall yield of the soybean strips and monoculture treatment were detected. In the second experiment, when weed management strategies in strip crop and monoculture systems were compared, crop yields and weed population dynamics were not adversely affected among herbicide treatments or cropping systems.

19. Effect of Density and Planting Pattern on Competition Ability of *Zea mays* L. Against *Amaranthus retroflexus* L. Majid Aghaalikhani¹, Alireza Yadavi², Amir Ghalavand¹, Eskandar Zand³; ¹Tarbiat Modares University, Tehran, Tehran Province, Iran; ²Yasuj University, Yasuj, Kohgiluyeh va Boyer Ahmad, Iran; ³Plant Pest and Disease Research Institute, Tehran, Tehran Province, Iran

In order to evaluate competition ability of grain corn (*Zea mays* L.) against *Amaranthus retroflexus* L. (redroot pigweed) a field experiment was conducted at Esfahan province, Iran on 2003. In this research the effect of crop spatial arrangement on yield and yield components of corn (647 Three Way Cross hybrid) under different levels of redroot pigweed infestation was investigated. Treatments were arranged in a factorial split experiment based on randomized complete blocks design with three replications. Factorial arrangement of corn densities (74000 and 111000 plant ha⁻¹) and planting patterns (single row, rectangular twin row and zigzag twin row) formed the main plots. Split-plots referred to pigweed densities (0, 4, 8 and 12 plant m⁻¹). Results showed that both grain and biological yield of corn increased as corn density rates increased but rows number per cob, number of grains per row and 1000 grains weight all decreased. The effects of planting arrangement on yield and yield components despite rows grain in cob, 1000 seeds weight and harvest index were statistically significant. Corn grain yield and yield components decreased significantly by *A. retroflexus* density. The effect of *A. retroflexus* density on corn grain and biological yield loss was predicted using Cousens hyperbolic yield equation. It showed that maximum grain yield loss and biological yield loss happened in single row arrangement and low corn density. Row number per cob and grain number per row in higher corn density treatment showed lower reduction slopes under pigweed competition. In addition, grain row numbers per cob and corn harvest index in twin arrangement treatments decreased lower than single row treatment under pigweed competition. Summarized results of this research expressed that corn

competition ability against redroot pigweed could be increased using dense population (1/5 fold of general density) and zigzag twin row arrangement.

20. Pesticide Interactions Complicate Implementation of Integrated Pest Management Strategies in *Arachis hypogaea* L. (Peanut). Bridget Lassiter¹, David Jordan¹, Rick Brandenburg¹, Barbara Shew¹, Sarah Lancaster², Bridget Lassiter¹; ¹NCSU, Raleigh, NC, United States of America; ²TAMU, College Station, TX, United States of America

Peanut growers in the United States often implement control measures for approximately 5 diseases, 5 insects, and 5 to 10 weeds to prevent yield loss. Four to six fungicide, 3 to 5 insecticide, and 3 to 6 herbicide applications are made annually to manage pests in peanut. Integrated pest management (IPM) strategies are often implemented to control pests, prevent economic loss, reduce production and pest management costs, and minimize environmental impact. Theoretically, implementing IPM strategies increases risk of greater pest damage if reactive control strategies are not available, are minimally effective, or cannot be implemented rapidly. Growers often implement control strategies simultaneously because pests and their resulting damage often occur at the same time during the season. Co-application of herbicides, insecticides, and fungicides enable growers to control multiple pest complexes. Additionally, plant growth regulators and foliar micronutrient products are needed during the same period of time. Interactions among crop protection and management products are not completely understood for peanut.

Scientists and practitioners in disciplines of entomology, plant pathology, and weed science often investigate interactions of pesticides within their respective disciplines. However, a better characterization of pest complexes and pesticide interactions across disciplines is needed. Understanding critical aspects of pest life cycles, assessing economic impact of crop damage, validation of economic thresholds, and defining optimum timing of control tactics is important. Additionally, spray volume, water quality, pest location in the crop canopy, and adjuvant can have a dramatic effect on efficacy and can vary considerably among crop protection products. Differential response to environmental conditions combined with crop and pest stress can influence interactions and further complicates formulation and implementation of IPM strategies.

While interactions of two co-applied pesticides or crop protection products are fairly well understood, especially within pest disciplines, many peanut growers apply three or more products simultaneously with varying degrees of success. Clearly characterizing the system and timing of application that optimizes control of all pests is needed. A decision tool is being developed that includes a crop production calendar characterizing predicted pest infestations and their accompanying damage. In addition,

effective management tools, including pesticides, are overlaid on the calendar. The goal of this decision tool is to aid peanut producers and their advisors in implementing the most effective control strategies while avoiding negative interactions.

21. The Relative Competition of Canola Versus Small Grain Cereals. Kenneth Harker¹, John O'Donovan¹, George Clayton¹, Robert Blackshaw¹, Stewart Brandt¹, Eric Johnson¹, Rick Holm², Ken Sapsford²; ¹Agriculture & Agri-Food Canada, Lacombe, Alberta, Canada; ²University of Saskatchewan, Saskatoon, Saskatchewan, Canada

Canola is the dominant herbicide-resistant (HR) crop in western Canada. Hybrid HR cultivars control most major weeds, facilitate direct-seeding systems, and substantially improve canola competition with weeds. The enhanced competitive ability of the new hybrids may be great enough to warrant comparisons with other crops that are considered to be highly competitive with weeds such as barley and rye. Experiments were conducted in 2006 and 2007 at four to five locations in western Canada each year to compare the relative competitive ability of several open-pollinated- and hybrid-spring canola cultivars with spring barley, rye, triticale, and wheat. Cultivated oat was seeded across all experiments to simulate weed competition and oat biomass was used as the primary determinant of the relative competitive ability of each crop cultivar. Results varied considerably from site to site depending on the associated soil zone and environmental conditions. In some cases, hybrid canola cultivars were at least as competitive as barley and more competitive than triticale or wheat. More competitive canola hybrids were often observed at relatively cool, moist sites such as Beaverlodge and Lacombe as opposed to Lethbridge or Scott. At the latter sites, small-grain cereals were often more competitive than any of the canola cultivars. Most of the data indicate that cereal cultivars, and especially barley, are more competitive than canola, but some environments can lead to exceptions. Crop biomass was usually highly negatively correlated with oat (weed) biomass. At all locations, the hybrid canola cultivars were or tended to be more competitive than the open-pollinated cultivars. The relatively high competitive ability of new canola hybrids allows growers to more effectively implement integrated weed management practices with less dependence on herbicides.

22. Weed Control in Corn Fields with Reduction Eradicane (EPTC) Herbicides in Integrated with Tillage Method. Majid Amini Dehghi¹, Abolfazle Baghbani¹, Mitra Gotbi¹, Reza Tabatabaie Tabatabaie¹; ¹University of Shahed, Tehran/Tehran, Department of Agronomy/Shahed University/Tehran/Ir, Iran

In current year, attention to sustainable agriculture and environmental health, has been caused to try researchers for herbicide reduction via integrated weed management methods (IWM). General method for weed control in corn field is herbicide application and cultivator, but application of each method alone cannot affect completely. Integrated methods not only can control weed but also they increased crop yield and decrease herbicide application. In this order an experiment was conducted in research farm of shahed university in 2006. The experimental design was split plot arrangement in randomized complete block with 3 replications. Three tillage system levels (without cultivator, one cultivator and two cultivator) were randomized to the main plot units and 5 levels of eradicane herbicide (0, 1/5, 3, 4/5, 6 L/ha) was randomized to sub plot units. Eradicane herbicide was used pre cultivation. Cultivator treatments were applied 25 and 38 days after cultivation. Corn variety was single cross 704 with 75000 plant per ha. Results showed that two times cultivator application with high dose of herbicide had the best control on weed so that the highest control percent belonged to two time cultivator application and using 4/5 liter of eradicane herbicide. There were significant differences among treatments for grain dry matter and harvest index. Plants had the highest grain yield at two times cultivator application so that former treatment with 4/5 L herbicide per ha had the most grain yield with 13841.5 kg/ha production. This research showed that integrated weed control methods were better than other methods alone and herbicide rate could be reduced in integrated weed control methods.

23. Herbicide Resistant Weeds: Do Economic Thresholds Still Have a Role in Weed Management? Bridget Lassiter¹, Gail Wilkerson¹, Bridget Lassiter¹, David Jordan¹, Lori Wiles²; ¹NCSU, Raleigh, NC, United States of America; ²USDA-ARS, Fort Collins, CO, United States of America

Concern over the development of herbicide resistant weeds has prompted a closer look at the validity of using economic thresholds (ET) as a basis for making treatment decisions. In situations where herbicide resistance is suspected, growers are often advised to employ control measures to completely eradicate the weed from the field, in order to eliminate seed production. The decision aids HADSS (Herbicide Application Decision Support System) and WeedSite utilize the concept of ET in order to recommend appropriate herbicides for use in a particular crop. The decision aids make recommendations using specific parameters for yield, crop value, and weed competitiveness. These programs could aid growers in determining specific herbicides to attain high levels of weed control as well as high returns within a specific cropping system. Existing weed scouting data from over 200 *Arachis hypogaea* L. (peanut), *Glycine max* (L.) Merr. (soybean), *Gossypium hirsutum* L. (cotton) and *Zea mays*

L. (corn) fields were used in combination with either HADSS or WeedSite to compare efficacy and net returns for different management strategies, assuming either no herbicide-resistant weeds, or one resistant weed species in each field. *G. max*, *Z. mays*, and *G. hirsutum* fields were assumed to have been planted with a glyphosate-resistant cultivar. Data were used to estimate yield loss, weed densities, and net return after treatment for each field under differing assumptions of herbicide resistance. Results indicate that the impact of a resistant weed species on herbicide selection, net return, and yield loss varies considerably from field to field and is affected by crop, the identities and densities of all weed species present in the field, and available herbicide options. In general, the presence of a resistant weed species decreases net return, whether decisions are made based on optimizing net return, minimizing yield loss, or minimizing density of the resistant weed. In some situations, no treatment with maximum efficacy against the resistant weed provided adequate control of the other weed species present in the field. ET models may require modification to include additional herbicide combinations or to allow evaluation of spot treatments following whole-field treatments. With some modification, these models can be used to assist decision makers in evaluating the costs and potential benefits of various resistance management strategies.

24. Evaluation of Wheat Increasing Density Effect on Wheat Yield and Seed Production of Rye. Gholam Abbas Akbari¹, Massoud Mokhtari¹, Zainab Javanmardi¹; ¹Abourayhan College, University of Tehran, Tehran, Iran

Rye (*Secale cereale* L.) is one of the noxious weeds in the wheat fields, in which there is no economically effective control. One of the measures to reduce the effects of rye on wheat is increasing the crop density. To evaluate the effects of rye on wheat yield and its component and to determine the effects of increase wheat density on biomass and seed production of rye, an experiment of bi-varieties factorial based on randomized complete block design with 3 blocks and 24 treatments was conducted in research field of Plant Pest and Diseases Institute in Varamin-Iran. Competitive design of this experiment was kind of complete additive. The experimental factors were density of wheat in 5 levels (0, 350, 450, 550 and 650 plants/m²) and density of rye also in 5 levels (0, 10, 30, 50 and 70 plants/m²) which were interplanted.

Results showed that increasing rye density in each level of wheat decreased significantly economic and biological yield, number of spike in m², harvest index, number of seeds in spike, except the weight of 1000 seeds. Increase in wheat density also reduced the biomass and seed production of rye. Therefore, increasing wheat density in field, where is infested with rye, would reduce the yield loss caused by rye. This could be accepted as a way to control weed based on crop density.

25. Effect of Wheat Cultivars and Seed Rate on Weed and Yield of Wheat. Khan Marwat¹; ¹NWFP Agricultural University, Peshawar, Peshawar, NWFP, Pakistan

An experiment was conducted to study the effect of wheat cultivars and seed rate on weeds and yield of wheat at Agricultural Research Farm, NWFP Agricultural University Peshawar during November, 2006. The experiment was laid out in randomized complete block design (RCBD) with split plot arrangement, having three replications. The wheat seeding rates @ 100, 120 and 140 kg/ha were assigned to main plots while wheat cultivars i.e. Pirsabak-83 (PR-83), Pirsabak-84 (PR-84), Khyber-87, Suleman ? 96 and Saleem - 2000 were assigned to sub plots. Analysis of data showed that most of the parameters were significantly affected by wheat cultivars and non-significantly affected by seed rate. Maximum leaf area (38.66 cm²/plant, number of wheat tillers (119.7 m²), plant height at maturity (100.9 cm), number of spikes (117.77 m²), spike length (11.8 cm), number of spikelets/spike (20.58), 1000-grain weight (-41.8 g), biological yield (10944.4 kg/ha), and grain yield of wheat (20.58 kg/ha) were obtained from wheat cultivar Suleman - 96 which was statistically at par with PR-83. Increasing seed rate of wheat significantly decreased the weed density 30 and 60 days after sowing while different cultivars non-significantly affected the weed density. Overall the results indicated that seed rate as well as different cultivars can be used in integrated weed management package.

26. Weed Science Research on Integration for Improving Weed Management. Ze Pu Zhang¹; ¹Chinese Academy of Agricultural Sciences, Beijing, China (Peoples Republic of)

More than 30 species are the important weeds infesting in rice, wheat, maize, soybeans and cotton fields which account for about 80% of the 123 million hectares of the total cultivated area in China, about 40 million hectares of cropland are heavily infested by weeds. The herbicide application area has been steadily enlarged up to more than 60 million hectares. Chemical weed control has retained high crop yield, but it has caused some crop and environmental problems, for maintaining favorable ecological conditions, integrated weed management are adopted. For preventing weed occurrence or alleviating weed damages, studies on improving and exploring innovation of utilizing agricultural technical measures to weed management are enhanced. The studies are carried on: integrating chemical control with tillage under an intensification; enhancing crop competitiveness through planting crop cultivar relatively at high seeding rates for reducing the impact of weeds on crop yield; approaching the weed-economic threshold to provide information to make long-term management decision for better weed control and use various options in herbicide application for saving operating costs; improving herbicide application

techniques through defining minimal dosage, critical application time, good type of herbicide and its formulation and improving spray implements for raising application quality and raising spray efficacy for economizing the costs in crop production; monitoring the herbicide residues in the agricultural regions to propose a system for controlling the risk of environmental pollution; attaching importance to the new cultivation technologies adopting the methods of crop rotation and cropping system; using allelopathy as a tool for integrated weed management; using biotechnology for improving weed management, inducing into herbicide resistant crops to extend the areas to be applied with herbicides, identifying and regulating the techniques of gene configuration and evaluating the effect on non-target objectives, environmental safety as well as economic benefits; and preventing and delaying the development of herbicide resistant weeds, proceeding research on the level of weed resistance to the herbicides, the relationships between agronomic practices and the development of herbicide resistance, the mode of action of herbicides and screening new effective herbicides for controlling resistant weeds.

27. Investigating of Competition Ability of More and Less Competitive Cultivars of Wheat Against Garden Rocket Weed (*Eruca sativa* L.) at Different Densities of Wheat and Garden Rocket. Mohammad Ali Baghestani¹, Manoochehr Jamnejad¹, Eskandar Zand¹; ¹Iranian Plant Protection Research Institute, Tehran, Iran

In order to determine the optimum density of two more competitive and less competitive wheat cultivars under competition with rocket (*Eruca sativa*) and reduced doses of 2,4-D, two experiments were performed in 2004-2005 and 2005-2006 at the research field of the Iranian Plant Protection Research Institute in Karaj. Treatments were arranged factorially in a randomized complete block design with four replications. In 2004-2005, wheat cultivars Shiraz (more competitive) and Tabasi (less competitive) were studied under three planting densities (recommended density for each cultivar, 25% and 50% higher than the recommended densities) and four densities of rocket (0, 25, 50 and 75 plants m⁻²). In 2005-2006, treatments were same as the first year of experiment except for wheat density which was replaced with 2,4-D dose at 0, 0.5, 0.75 and 1 L ha⁻¹. Results showed that cultivar Shiraz had more competitive ability (CA) than cultivar Tabasi when planted 25% higher than its recommended density under both weed-free and weed-infested conditions. High CA of this cultivar was due to the production of more fertile tiller and spike m⁻². Furthermore, this cultivar had a better distribution of leaf area in its canopy profile. In the highest density of rocket, cultivars Shiraz and Tabasi produced the highest grain yield when planted 25% higher than the recommended density and the recommended density, respectively. Increasing the planting density of

cultivar Shiraz by 25% increased grain yield through increasing plant height, number of spike m⁻² and number of grains m⁻², but more increase in its planting density reduced yield components. In cultivar Tabasi, densities higher than that recommended increased lodging and reduced yield components, resulted in reduction in grain yield. Increase in wheat density increased its leaf area index (LAI), dry matter (DM) and crop growth rate (CGR) but reduced these traits in rocket. By increase in rocket density, wheat yield of cultivar Tabasi reduced more than cultivar Shiraz. Wheat above-ground DM, LAI and CGR were also reduced by increasing weed density. Results of the second year of experiment indicated that a 25% reduction in 2,4-D dose did not result in significant reduction of weed control and grain yield, but more reduction in the herbicide application dose severely reduced weed control efficacy. Rocket density did not have any significant effect on chemical control but an increase in its density increased 2,4-D efficacy. 2,4-D at 0.25, 0.5 and 0.75 of recommended dose reduced rocket DM by 66%, 82% and 84%, respectively. Overall, results indicated that LAI and the ability to change the vertical leaf area distribution are among the most contributing traits to rocket competitive ability. In wheat, tillering ability, good vertical leaf area distribution, high radiation use efficiency are among effective traits in its competitive ability with rocket. Planting wheat to its recommended density increased herbicide application dose. Generally, cultivar Shiraz is a better competitor of weed than cultivar Tabasi

28. Integrated Weed Management in Corn. Mohammad Ali Baghestani¹, Arash Roozbehabi¹, Hamid Rahimian², Ghorban Noormohammadi³, Eskandar Zand¹; ¹Iranian Plant Protection Research Institute, Tehran, Iran; ²Tehran University, Tehran, Iran; ³Azad University, Tehran, Iran

Weeds compete with corn and other crop plants for light, nutrients, and water, especially during the first 3 to 5 weeks following emergence of the crop. It is important to control weeds in a corn field before they are 6 to 8 inches high, which is when they begin to impact corn yields. Herbicides continue to be a powerful tool for controlling weeds. IWM of crops combines a variety of approaches to suppress weeds and reduce herbicide use. Integrated Weed Management (IWM) uses all available weed control options in the best possible way to manage weed populations. Such options include crop rotation, cover crops, agronomical activities, intercropping, manipulation of nitrogen fertility, planting pattern, tillage systems, critical period of weed control, and alternative weed management strategies in conservation tillage systems and economic thresholds. The study was carried out to evaluate the effect of integrated weed management (IWM) aspects on yield and yield components of Corn in 2005 and 2006 at karaj's agricultural research station in

Iran. The experiment was designed as split plot based on randomized complete blocks (RCB) with three replications. In this study treatments such as; Agronomical control (irrigation before seeding and irrigation after seeding) as the main plot, mechanical control or cultivation numbers (No applying of cultivator or controlled, one time at 4 WAP and two times cultivator applying at 4 and 6 WAP) as the sub plot factor, and combination doses of atrazine and alachlor mixture (0% or controlled, 25%, 50%, 75% or reduced dose, and 100% or full dose) as the sub-sub plot factor were arranged respectively. During the growing season weed density and dry matter assessed from some 50 cm quadrates placed randomly in each plot. Within each quadrat, weed species were identified, counted, clipped at ground level, and oven-dried at 75 centigrade for 48 hours, then weighed to determine their dry matter. At harvesting time, corn harvested and then yield and yield components (No of silk/m², No of row/silk, No of grain/row and 100 grain weight) and weed dry matter were measured and analyzed statistically by using the mixed model procedure of SAS. Means comparison were done by Duncan multiple range test at $\alpha = 5\%$ level. The results showed that the effect of all treatments on all traits were significant at $\alpha = 1\%$ statistically. Means comparison showed that among different treatment levels; in the first year irrigation before seeding was superior than irrigation after seeding but in the second year they were the same. Two times applying of cultivator at 4 and 6 WAP and combination doses of atrazine and alachlor mixture (75%, and 100%) were superior to the others and cause to decrease weed dry matter and number and cause to increase yield and yield components of Corn in the first and the second year. Finally it is recommended that in this and the similar regions, above IWM approaches to be applied to suppress weeds, reduce herbicide use, increase yield and yield components of corn and cause to less injurious to the environment.

29. Preliminary Evaluation of Weed Management Method x Crop Variety Interaction on Weed Control and Okra Yield. Muphtha Smith¹, Kudirat Oloyede², Asimiyu Adedeji; ¹The Federal University of Technology, Akure, Ondo, Nigeria; ²University of Ibadan, Ibadan, Oyo, Nigeria

Seedling morphology influences the competitiveness of crop varieties with weeds. The additive effect of weed management method and crop variety interaction on weed control in vegetable crops is desirable for sustainable yield and produce quality. The effects of no weeding (Wy), weeding once at 3 + 5 weeks after sowing, WAS (Wf), pre-emergence (PE) pendimethalin at 0.33 kg a.i./ha (P1) alone, P1 + W3 (weeding 3 weeks after treatment, WAT), P1 + W5 (weeding 5 WAT) and P1 + A1 (PE atrazine at 2.05 kg a.i./ha) on weed control and pod yield of okra

(*Abelmoschus esculentus*) NHAE 47-4 and Jokoso were evaluated. A randomized complete block field experiment with three replications per treatment was used. Okra was sown at 66, 666 plants/ha. Both crop varieties carried diverse weed flora and predominantly annual broadleaves. More weeds infested Jokoso (75.9%) than NHAE (57.7%). Annual weeds were more in NHAE (85%) and perennial weeds in Jokoso (33.3%). Crop variety did not influence weed growth but early weed resurgence, and late weed cover and dry matter differed significantly with weed management method. P1 + A1, P1 + W3 and Wf suppressed early-emerged weeds, late weed cover and weed dry matter most. Early weed cover was most extensive in Wf. Crop growth and yield differed widely with both crop variety and weed management method. Seedling emergence, leaf and pod production were better in NHAE than in Jokoso. Emergence was best in P1 + W5, P1 + W3, P1, Wf and Wy and poorest in P1 + A1. Pods/plant and pod yield were highest in P1 + W5 and Wf, and lowest in P1 + W3, P1 + A1, P1 and Wy. Differences in crop growth and yield response were primarily due to variety, weed association, effectiveness of weed management method and herbicide injury.

30. Comparison of Integrated Weed Management Strategies in Silage Maize. Bo Melander¹, Paolo Barberi, Nicolas Munier-Jolain²; ¹Faculty of Agricultural Sciences / Aarhus University, Slagelse, Denmark; ²INRA, Dijon, France

Silage maize is a widespread row crop in Europe for fodder production. It has a low competitive ability against weeds until it reaches canopy closure. Thus, there is a high demand for weed control in its initial growth phases. Typically two applications of herbicides are applied as the standard chemical solution in many areas: soil applied pre-emergence herbicide plus post-emergence treatment or just post-emergence application twice. However, public pressure in many European countries asks to reduce herbicide use. The aim of this study was to compare two integrated weed management (IWM) strategies to the standard chemical treatment in silage maize (a): an intermediate IWM-strategy (b) and an advanced IWM-strategy (c). To achieve strategies (b) and (c), we integrated knowledge from mechanical weeding strategies developed for organic maize cropping with chemical methods with (c) being the one with lowest herbicide use. The strategies were evaluated in the 2007 growing season at 3 sites: 1) Pisa (Italy), 2) Dijon (France) and 3) Flakkebjerg (Denmark) within the research activities of the EU-funded Network of Excellence ENDURE (www.endure-network.eu). The methods included in the strategies varied among sites according to available equipment, experiences, and agronomic relevance. Reductions in chemical input were achieved through the use of pre-emergence cultivation, reduced herbicide dosages, inter-row hoeing equipped with tools for intra-row weed control and band-spraying. For

strategy (b) and in comparison with strategy (a), the amount of active ingredients was changed by 0% at Pisa, -39% at Dijon, +149% at Flakkebjerg while the figures for number of treatments were 0% at all sites. For strategy (c), the amount of active ingredients were changed by -65% at Pisa, -95% at Dijon, and -91% at Flakkebjerg, and number of treatments by 0% at Pisa, -67% at Dijon, -50% at Flakkebjerg. The higher amount of active ingredients at Flakkebjerg for strategy (b) arose when changing to another compound considered being environmentally friendlier. Strategy (b) at Pisa did not deviate from (a) because the first herbicide application, which was similar for (a) and (b), gave sufficient overall weed control. The environmental impact of the strategies (calculated as the Ipest indeks by Girardin et al., 1999) at the French site were reduced by 43% for strategy (b) and 80% for (c). Strategy (b) resulted in the same weeding effectiveness and provided yield results similar to standard chemical control (strategy (a)) at all sites. Weed control effects following strategy (c) was similar to (a) at Dijon but slightly lower at Pisa and Flakkebjerg with effects in the range of 85-90% compared to effects above 95% for strategy (a). Cob yield was slightly lower after strategy (c) compared to (a) at Pisa with total maize yield being the same. At Dijon the opposite was true with total maize yield being lower following strategy (c). In conclusion, IWM strategies have the potential to reduce reliance on herbicides but large herbicide reductions may be associated by yield declines and higher treatment costs.

31. Effects of Nitrogen Fertilizer Management and Weed Control Strategies on Yield and Quality of Sugar Beet. Afshan Karimi¹; ¹Shahrood University of Technology, Shiraz, Fars, Iran

In order to investigate the effects of nitrogen fertilizer management and weed control strategies on yield and sugar quality of sugar beet, a factorial experiment was conducted with three factors in Shahrood University of Technology in 2006. Experimental factors were included 3 formulation of nitrogen fertilizers (urea, ammonium nitrate and ammonium sulphate), 3 methods of nitrogen application (1/3 at thinning 2/3 one month after thinning, 1/2 at thinning 1/2 one month after thinning and 2/3 at thinning 1/3 one month after thinning) and 2 methods of weed control (inter row control and complete control). The results showed that the effects of different nitrogen fertilizer on root yield (RY), white sugar yield (WSY), sugar content (SC), extraction coefficient of sugar (ECS) and white sugar content (WSC) were non significant. Application of nitrogen fertilizer as 2/3 at thinning 1/3 one month after thinning significantly affected the root and sugar yield. Methods of weed control also had significant effects on RY and WSY. Weed control methods had no effects on SC, WSC and ECS. Nitrogen fertilizer had also significant effects on dry weight and densityweed specie-

s (*Chenopodium album* and *Rapistrum rogosum*). The highest density and dry weight of weeds were related to application of ammonium sulphate and urea respectively. Generally the results showed that nitrogen application as 2/3 at thinning 1/3 one month after thinning could increase sugar beet competition against weed and increase root yield.

32. Comparing the Competitive Ability of Hybrid and Open-Pollinated Rapeseed (*Brassica napus* L.) Cultivars with Wild Mustard (*Sinapis arvensis* L.). Keyvan Hosseinzadeh¹, Hamid Irannejad¹, Eskandar Zand², Assadollah Hejazi¹, Gholam Ali Akbari¹; ¹University of Tehran, Abooreihan Campus, Tehran, Iran; ²Plant Protection Research Institute, Tehran, Iran

To compare the competitive ability of two hybrids (Elite and Ebonite) and six open-pollinated (SLM046, Orient, Zarfam, Okapi, Opera and Licord) rapeseed cultivars against wild mustard, an experiment was conducted in a randomized complete block design with factorial arrangement of treatments and three replications during 2006-2007 growing season at the research field of Abooreihan Campus, University of Tehran, Pakdasht. Each cultivar was grown in the weed-infested and weed-free conditions. Grain, biological and oil yields, harvest index, oil and protein percent, AWC (Ability to Withstand Competition) and WSA (Weed Suppressive Ability) of rapeseed, and seed yield and biomass of wild mustard were studied. The results indicated that grain, biological and oil yields, and HI reduced significantly due to weed competition. However, no significant differences were observed for oil and protein percent between the weed-free and weed-infested conditions. Results also showed significant differences among cultivars in case of all traits. Percent grain yield loss ranged between 6.93% (cultivar Elite) and 50.70% (cultivar Okapi). The highest and lowest amounts of AWC and WSA belonged to cultivars Elite and Okapi, respectively. No significant correlation was found between AWC and grain yield in the weed-free plots. But, significant correlation was observed between AWC and WSA. Overall, cultivar Elite was selected as a more competitive cultivar with respect to the lowest reduction in its grain, biomass and oil yields under weed competition and the highest reduction in the wild mustard seed and biomass yields.

33. Effect of Integrated Weed Management on Weed Density and Biomass on Tomato Yield. Reza Ghorbani¹, E. Kazerooni¹, Alireza Koocheki¹, Mehdi Nassiri¹; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan, Iran

Although, various weed control methods have been developed, weeds pose a permanent threat to the crop production. Field experiments were conducted in Research

Station of Ferdowsi University of Mashhad, Iran, during 2004 and 2005. Treatments were two tillage systems (reduced and conventional) and six weed management methods (herbicide, rotary cultivator, handweeding, herbicide plus rotary cultivator, herbicide plus handweeding and handweeding plus rotary cultivator). The herbicide (Metribuzin), handweeding and rotary cultivator treatments were applied 2, 3, and 6 weeks after transplanting, respectively. The highest and lowest tomato yields were obtained in herbicide plus rotary cultivator and rotary cultivator, respectively. Density and biomass of broadleaf weeds was affected by different weed management strategies. They were controlled by handweeding and its integration with herbicide better than other methods. Different weed management methods showed no significant effect on grass weed density, but their biomass was affected at the end of growing season. Handweeding treatment and its integration with herbicide have also controlled grass weeds better than other treatments.

34. Weed Management in Horse Pastures After Renovation. William Witt¹, Mitchell Blair¹, Thatsaka Saphangthong¹, Daisy Fryman¹; ¹University of Kentucky, Lexington, KY, United States of America

Thoroughbred horse farms in central Kentucky prefer pastures composed of *Poa pratensis* and *Dactylis glomerata* and little, if any, *Lolium arundinacea* for pregnant mares. Renovation of pastures to remove *L. arundinacea* is a standard practice. The purpose of this research was to determine the control of troublesome weeds from *P. pratensis* / *D. glomerata* pastures: when *L. arundinacea* was removed selectively by imazapic; by total renovation by killing existing vegetation with glyphosate and reseeding; and subsequent foliarly applied herbicides. A horse pasture composed of about 50% *P. pratensis* and 50% *L. arundinacea* was selected for this study. Treatments of imazapic and glyphosate applied alone or in combination were applied at different times in 2005 and 2006 to compare *L. arundinacea* control by selective removal with imazapic with a total renovation in which glyphosate was applied to kill all existing pasture grasses. Treatments were: glyphosate at 3.8 kg ae/ha in July 2005; glyphosate at 3.8 kg ae/ha in July and August 2005; glyphosate at 3.8 kg ae/ha in July 2005 plus imazapic at 0.18 kg/ha; in June 2006; imazapic at 0.21 kg/ha in May 2005; imazapic at 0.18 kg/ha in May 2005 fb imazapic at 0.18 kg/ha in June 2005; imazapic at 0.18 kg/ha in May 2005 fb imazapic at 0.18 kg/ha in June 2006; and untreated. Pendimethalin at 1.7 kg/ha was applied to one-half of each plot in May 2006. All treatments decreased the percentage of *L. arundinacea* compared to the untreated. All combinations of glyphosate and two imazapic treatments in one year reduced *L. arundinacea* composition to <3%. Horse farm managers prefer to have less than 10% *L. arundinacea* in broodmare pastures. The drawback to total renovation is the pasture

cannot be grazed for about 9 months after the initial treatment of imazapic. It is important to note that the two imazapic treatments in one year did remove the *L. arundinacea*; however, the plots contained less than 25% useable *P. pratensis* after treatment. The seeding of the desirable grasses resulted in acceptable *P. pratensis*/*D. glomerata* composition one year after seeding. Treatments that contained only imazapic had significantly greater *Muhlenbergia schreberi* infestations than the untreated and glyphosate treatments. The untreated plots contained >50% *L. arundinacea* which inhibited *M. schreberi* growth. The imazapic treatments killed the *L. arundinacea* but allowed *M. schreberi* to establish. Pendimethalin significantly reduced *M. schreberi* infestation in treatments that contained imazapic. These data indicate the potential for pendimethalin to reduce the occurrence of *M. schreberi*. Plots treated with glyphosate in 2005 contained very little *M. schreberi*; the perennial *M. schreberi* plants were controlled and the subsequent establishment of *P. pratensis* and *D. glomerata* inhibited *M. schreberi* emergence. In another renovation study, glyphosate was applied in August 2005 and aminopyralid plus 2,4-D was applied in November 2005 or April 2006. The addition of aminopyralid plus 2,4-D provided 100% control of *Solanum carolinense*, *Taraxacum officinale*, *Cirastium vulgatum*, and *Ambrosia artemisiifolia*.

35. Assessment of Allelopathic Capability of Iranian Barley Cultivars and their Variations over 64 Years Selection. Mostafa Oveisi¹, Hamid Rahimian Mashhadi¹, Hassan Alizadeh¹, Mohamad Baghestani²; ¹The University of Tehran, Karadj, Tehran, Iran; ²Crop Protection Institute, Tehran, Iran

Laboratory experiments were conducted to determine allelopathic potential of seventeen Iranian barley cultivars in four development stages and their variations over last sixty years collections. Imbibed seeds and water leachate of seedling, tillering, stem elongation and heading stage of barley on filter paper and neighboring barley seeds in soil and soil dried barley materials mix were bioassayed for their ability to inhibit germination and seedling growth of *Sinapis arvensis*. Germination rate index (GRI) and emergence of *S. arvensis* were inhibited on both filter paper and soil. The highest inhibitory effect was seen with tillering stage water leachate on filter paper. GRI was decreased in response to imbibed seeds with seed density. Germination was less affected by the presence of barley seeds from soil than its germination on filter paper. GRI of *S. arvensis* seeds were lower in older than in recently developed cultivars. Although there are some fluctuations are seen in GRI value with time, but germination inhibitory effect has decreased as new higher yielding cultivars were released.

36. The Evaluation of N Quantity, Time of N Application, and Herbicide Usage on Spatial Distribution of Lambsquarters Seed Banks of Corn Field. Narges Poortoosi¹, Mohammad Hasan Rashed Mohasel¹, Elmira Mohammadvand¹, Mahdi Nasiri Mahalati¹; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan Razavi, Iran

In order to evaluate the effect of different management on composition, density and distribution patterns, an experiment was conducted in a grain corn field at the Agricultural Research Station, Ferdowsi University of Mashhad 2006 growing season. The treatments consisted of: Application of 25 kg/ha nitrogen fertilizer at the time of corn planting with 2,4-D+MCPA herbicide (533 g. ai./ha 2,4-D+467 g. ai./ha MCPA), Application of 25 kg/ha nitrogen fertilizer at the time of corn planting without herbicide, Application of 25 kg/ha nitrogen fertilizer at the time of corn planting and six-leaf stage with herbicide, Application of 25 kg/ha nitrogen fertilizer at the time of corn planting and six-leaf stage without herbicide, Application of 120 kg/ha nitrogen fertilizer at the time of corn planting with herbicide, Application of 120 kg/ha nitrogen fertilizer at the time of corn planting without herbicide, Application of 120 kg/ha nitrogen fertilizer at the time of corn planting and six-leaf stage with herbicide, Application of 120 kg/ha nitrogen fertilizer at the time of corn planting and six-leaf stage without herbicide. The percentage of weed seed free spaces was zero throughout the season. Application of herbicide was useful in reducing the amount of Lambsquarters seed bank. Semivariograms of seeds were fitted with spherical and exponential models. Semivariogram analysis in the levels of treatments indicated a range of influence of 0.88 m to 45.12 m. The highest spatial correlation was 0.093% and the lowest one was 28.81%. Weed seed bank patches was obvious in maps. Although the nitrogen fertilizer did not have a strong effect on reducing the amount of seed bank but the application of herbicide was a useful factor in reducing weed seed bank.

37. Evaluation of Amount and Time of Nitrogen Application, and Herbicide Usage on Spatial Distribution of Prostrate Pigweed (*Amaranthus blitoides*). Narges Poortoosi¹, Elmira Mohammadvand¹, Mohammad Hassan Rashed Mohassel¹; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan Razavi, Iran

To evaluate the effect of different management on composition, density and distribution patterns of prostrate pigweed and redroot pigweed seed banks, an experiment was conducted in a grain corn field at the Agricultural Research Station, Ferdowsi University of Mashhad 2006 growing season. The treatments consisted of application of: 25 kg/ha nitrogen fertilizer at the time of corn planting with 2,4-D+MCPA herbicide (533 g. ai./ha 2,4-D+467 g. ai./ha MCPA), 25 kg/ha nitrogen fertilizer at the time of

corn planting without 2,4-D+MCPA, 25 kg/ha nitrogen fertilizer at the time of corn planting and six-leaf stage with 2,4-D+MCPA, 25 kg/ha nitrogen fertilizer at the time of corn planting and six-leaf stage without

2,4-D+MCPA, 120 kg/ha nitrogen fertilizer at the time of corn planting with 2,4-D+MCPA, 120 kg/ha nitrogen fertilizer at the time of corn planting without 2,4-D+MCPA, 120 kg/ha nitrogen fertilizer at the time of corn planting and six-leaf stage with 2,4-D+MCPA and 120 kg/ha nitrogen fertilizer at the time of corn planting and six-leaf stage without

2,4-D+MCPA. The percentage of *Amaranthus blitoides* seed free spaces was zero throughout the season. Application of herbicide was useful in reducing *A. blitoides* seed bank. Semivariograms of seeds were fitted with spherical and exponential models. Semivariogram analysis in the levels of treatments indicated a range of influence of 1.17 m to 50.21 m for prostrate pigweed and 1.15 m to 44.98 m for redroot pigweed. The highest spatial correlation for prostrate pigweed was 1.91% and the lowest one was 32.37%. Weed seed bank patches was obvious in two species maps. The nitrogen fertilizer did not have a strong effect on reducing the amount of seed bank but the application of herbicide was a useful factor to reducing weed seed bank.

38. Validation of a Model Relating Yield Loss to Weed Time of Emergence and Removal in Late Winter Sown Maize. Roberta Masin¹, Antonio Berti¹, Stefan Otto², Giuseppe Zanin¹; ¹Padova University, Padova, Italy; ²National Research Council (CNR), Institute of Agro-environmental and Forest Biology, Padova, Italy

Knowledge of the evolution over time of yield losses due to the weed infestation is essential for a proper timing of weed control actions and thus for an efficient use of herbicides. The optimum timing of weed control depends on the relationships between time of emergence, time of removal and yield loss, as well as on weed competitive load, crop potential yield and the pattern of weed emergence. In recent years, there has been a tendency in northern Italy to anticipate maize sowing from mid-April to mid-March. This leads to many agronomic advantages but, at the same time, greatly affects the weed flora composition, density, time of emergence, and crop and weed relative growth. Thus, altering the sowing date of maize requires a better understanding of the competitive relationship between crop and weeds. A dynamic approach considering the different weed competitiveness depending on weed emergence and density should be better adapted to identify the time window when weed control is more effective and profitable.

Berti et al. (1996) developed a model relating crop yield to weed emergence pattern and timing of weed control and allowing the identification of the optimal weed control time windows. The equation expressing crop yield as a

function of the maximum yield of the crop kept weed-free, the weed competitive load and time of weed emergence and removal has recently been reconsidered (Berti et al. 2007) on the basis of data from different crops grown in different environments in north-central Italy. The analysis showed that the yield loss caused by mixed infestations can be predicted by a single set of parameters. The objective of this study is to validate the model with independent data from experiments in late winter sown maize, supporting the idea that this model is robust enough to be used as a prediction tool for forecasting yield losses in a variety of conditions.

Five experiments on the relationships between crop yield and weed time of emergence and removal were carried out from 2001 to 2005 in northern Italy. All the experiments were conducted with natural infestation, and, in sample areas in the season-long weedy plots, weed seedlings were counted and removed weekly.

The results showed that the model predictions agreed closely with yields observed in the field, thus supporting its use as the base for developing an effective Decision Support System (DSS) for a wide range of cropping conditions.

39. A Simulation Study of Competitive Ability of *Cicer arietinum* Cultivars with *Sonchus oleraceus*. Zahra Cici¹; ¹University of Guelph, Guelph, Ontario, Canada

The aim of this research is to use a three-dimensional (3D) architectural plant modelling approach to simulate possible ways to improve the aboveground competitive ability of *Cicer arietinum* L. (chickpea) with *Sonchus oleraceus* L. (sowthistle).

To capture the 3D architecture of the *C. arietinum* and *S. oleraceus*, plants were grown separately in a sandy, well watered and fertilized soil. A sonic digitizer system was then used to record a number of changes in plant morphological, topological, and geometrical changes in a non-destructive way over time. The resulting data sets were analysed and used to develop a realistic, dynamic architectural model for each of the two species.

Plant architectural (virtual) models were created using the mathematical formalism of Lindenmayer Systems. The virtual plant models were verified for growth and development, using an independently produced data set. A quasi-Monte Carlo ray tracing program was employed to estimate the light availability under different architectures of the virtual *C. arietinum* plants in a 'chickpea-light environment' model. Since the aim was to simulate the effect of the *C. arietinum* canopy manipulation on *S. oleraceus* morphogenesis, observation of the effect of light availability on sowthistle were used to calibrate the morphogenesis of virtual *S. oleraceus* and then this light-sensitive virtual *S. oleraceus* was incorporated into the chickpea-light environment model.

In the final 'chickpea-light environment-sowthistle' (CLES) model the virtual *C. arietinum* plants were modified to replicate the architecture of five different cultivars (Macarena, Bumper, Jimbour, 99071-1001, and 96033-1014). The models were run over time and both visualizations and numerical output were produced to examine their competitive ability with *S. oleraceus*. To validate the results of the CLES model, an experiment using the same five *C. arietinum* cultivars with a *S. oleraceus* growing under their canopy was conducted. The simulation results were found to be in good agreement with the empirical data. The growth of sowthistle, in both in silico and empirical experiments was reduced most by 99071-1001 a cultivar with short phyllochron and early branching feature. The second rank of competitive ability in both simulated and observed data belonged to Macarena and Bumper while Jimbour and 96033-1014 were the least competitive. Both the simulation and experiment results supported the hypothesis that morphogenesis of a weed can be suppressed under specific canopy architectures of crops.

Some practical applications of the developed model are discussed and it is shown that the developed model can be used to explore a number of different agronomic practices such as choice of cultivar and seeding rate in weed management systems. The practical implication of these simulation studies is how a management system that uses quick canopy closure can provide sufficient suppression of weeds in *C. arietinum*. The study also demonstrates the versatility of the 3D plant architectural modelling approach especially when combined with a light environment model to predict how the plant breeder might genetically improve the crop canopy architecture and how the agronomist might modify planting rules, to improve the competitive ability of crops with weeds.

40. Quantifying the Effectiveness of Cultural Weed Management. Lammert Bastiaans¹; ¹Wageningen University, Wageningen, Netherlands

Cultural weed control is often mentioned as an important component of integrated weed management strategies, particularly in organic farming systems. Many different measures exist, and though it is obvious that most measures do contribute to a reduction of the weed problem, the extent of this contribution is often unclear. One reason is that many measures do not just contribute to weed management in the current season, but also have carry-over effects on forthcoming seasons, through their effect on weed population dynamics. Moreover, cultural weed control is not necessarily targeting weed seedlings, but is often directed towards other life cycle stages of the weed. To be able to better appreciate the true value of different measures, a mathematical framework was constructed. This framework consists of a weed population model in which crop-weed competition is accounted

for. In the model the most important life cycle stages of the weed are represented by species-specific parameters. Based on these demographic parameters, and after accounting for the weed kill resulting from curative control, an equilibrium weed density can be calculated. Similar calculations performed for a range of weed control levels result in a function that relates weed control effort to the remaining weed density and yield loss. Major shifts in the fore mentioned relations, such that equal curative control efforts result in lower weed density levels and less yield loss, are characteristic of successful cultural weed control. Given the newly developed framework, the evaluation of cultural control measures consists of three main steps. The first step is to identify which demographic parameters are affected by a specific control measure. In the second step, the size of these effects is quantified by estimating the parameter changes experimentally. In the final step, the consequence of cultural control is established by determining the shift in the control effort - yield loss relation. Obviously, effective measures result in a substantial shift. The framework thus allows the results of short-term field experimentation to be put in a long-term perspective, providing an added value to already existing information. Apart from quantifying the benefit of specific measures, the model can be used to identify the most sensitive life cycle stages of a weed species. Ultimately this improved quantitative insight should result in a better utilization of cultural weed control measures and serve as a basis for optimization of integrated weed management strategies.

41. Spatial Modeling of Wind Dispersal of Weed Seeds.

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Abstract

The ability of a weed species to spread within a field has significant implications for management (Woolcock, 2000). Mathematical modeling of wind dispersal of weed seeds can improve the description of seed shadow and provide knowledge and insight into population dynamics (Anderson, 1991). A major advantage of mathematical modeling compared to empirical models that predicts e.g. the mean dispersal distances (Kuparinen, 2006), is the possibility to incorporate factors (e.g. wind) affecting seed dispersal. This approach can be used to describe and to gain new knowledge about the dispersal patterns as dynamic and spatial processes of different weed species e.g. in different crops. The objective of this paper is to introduce a spatial and mechanistic model of annual weed seed dispersal.

Methods and Material

Seed dispersal of weed species can be described by a two-dimensional stochastic variable (X, Φ) , where X ($X \geq 0$) be the distance of seed dispersal and Φ ($0 \leq \Phi < 2\pi$) be the wind direction. Let $F(X < r, \Phi < \theta) = P\{X < r, \Phi < \theta\}$ be the distribution function of (X, Φ) and $f(r, \theta)$ be the density function of (X, Φ) . Let $f^1(r)$ be the marginal density of (X, Φ) with respect to X and $f^2(\theta)$ be the marginal density of (X, Φ) with respect to Φ . It was, in this article, assumed that Φ follows a uniform distribution and X is independent of Φ . Accordingly, distribution function is $F(X < r; \mu < \theta) = \int \int f^1(t, \varphi) ds = \int f^1(t) f^2(\varphi) ds = \int f^1(t) ds$

$$DDD (1)$$

$$2\pi$$

In order to obtain distribution functions of seed dispersal of three annual weed species (*Apera spica-venti*, *Alopecurus myosuroides*, *Bromus sterilis*) under different wind velocity conditions, we designed an indoor experiment of seed dispersal by wind. In one experiment, the 100 seeds of one weed species at the height 100cm were released under a certain horizontal wind velocity condition. There were eight kinds of wind velocities approximately controlled (0.5m/s, 1m/s, 2m/s, 3m/s, 4m/s, 5m/s, 6m/s, 8m/s) in the experiment.

Results

The results showed that the density functions of seed dispersal for three species have a form described by formula (2)

$$f(r, \theta) = \alpha \exp(-0.5(r - \beta)^2 / \sigma^2) (2)$$

These seed dispersal models of three weed species were divided into three types according to the coefficient $\beta < 0, \beta = 0, \beta > 0$. Well-known Howard et al.'s model (Howard et al, 1991) of *Bromus sterilis* seed dispersal is an especial example of the model (2) when $\beta = 0$.

Conclusion

1. Dispersal of annual weed seed in any direction fits a Gaussian distribution model approximately, i.e. in cylindrical coordinates system (three-dimensional space), their density functions have a form described by formula (2) (unit of r is centimeter);

2. Mean distance of seed dispersal from its parent plant increased with an increase of seed size when wind velocity was larger under the experimental conditions; The parameters of the distribution model changed with variation of wind velocity;

3. Simulation analysis showed that herbicide usage can be reduced using the knowledge from mathematical modeling in site specific weed management

42. Directionality and Dispersion Analysis on Branching Patterns in *Melastoma malabathricum* L. Mahdi Faravani¹, Baki Bakar¹; ¹Malaya University, Kuala Lumpur, WP, Malaysia

Straits Rhododendron, *Melastoma malabathricum* L. is a scourge in arable lands, abandoned farmlands, secondary forest openings and derelict areas in Malaysia. We assessed

branching patterns of Straits Rhododendron at three planting densities through directionality and dispersion analysis using circular statistics with ORIANA and S-Plus computer softwares. Plants of *M. malabathricum* at the density of 1 (D1), 2 (D2), and 3 (D3) plant/box were raised until maturity in wooden boxes measuring 1 m x 1 m and 30 cm in depth, previously filled with garden soil. Plant height; primary, secondary, and tertiary branch lengths, numbers, and their respective angles and lengths were measured to assess branching patterns as influenced by density. The position of each branch was characterized by three parameters: horizontal rotation (branch azimuth), vertical rotation (branch base inclination), and translation (branch height). The number of branches for each 50 cm interval through plant height was also recorded. The azimuth of the branch was measured within 45°, using a circular protractor, divided into 8 angular sectors and orientated clockwise. All azimuth angles were measured from the north direction (0°) and the leaf base height above the soil was measured using a rule tape. These plants, either singular or in competition with neighbours did not display any preferential expansion into the gap, but showed morphological plasticity in the lateral growth. No preferential directionality in the distribution of branches of the crown mass center from the stem base positions upwards. Most branches were concentrated in the opposite direction and away from each other with a mean vector of 212.9°. The Rayleigh's uniformity tests showed the distribution of the branch azimuths was centrally symmetrical in plants at the densities D1, D2 and D3 registering respective *r* values of 0.032, 0.047 and 0.014. The computed *r* values were so small hence, no significant direction of orientation of the branches in a particular preferential direction after 161 days from seedling stage. The vertical rotation angles were not uniformly distributed in the plant canopy. The highest circular-linear correlation ($r = 0.59$, $p < 0.01$) between the axial angle and the length of the branch in different plant densities was observed in the top of canopy, in excess of 150 cm of plant height. The registered mean vector (μ) for each 50 cm intervals of plant height up to 250 cm were 249°, 176°, 231°, 76° and 90°. Watson-Williams F-tests indicated that the vertical rotation angle mean was not different between plants at densities D1 and D2, but were significantly different from D3, whereby branches became progressively more erect from 52.27° until 41.81° with the increase in density from D1 to D3. Circular linear correlation tests indicated there were significant ($p < 0.01$) correlations between branch axial angle and the length of branch in different plant densities as $r = 0.63$, $r = 0.527$, $r = 0.488$ in plant densities D1, D2 and D3, respectively. No significant correlations at $p < 0.05$ between the horizontal rotation angle and the length of branch in any categories of branches or plant densities were registered.

43. Using Stochastic Efficiency Analysis to Factor Distribution of Weed Escapes into Weed Management Decisions.

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Weeds in patches may be more easily managed than the same number of weeds spread throughout the field. We explored choosing weed management strategies based on both net return and the distribution of weed escapes within a field. Expected net returns with several different postemergence herbicides often are similar for a field; however, the distribution of escapes may vary. A grower might be willing to ©pay© (forgo net return) for a distribution of weeds that is perceived to be easier to manage. Our goals were to examine variability of distributions of weed escapes among postemergence herbicides and investigate techniques to present information about those distributions so a grower may choose based on both net return and a preference for weed escapes in patches. Our approach is borrowed from methods used to evaluate risk in crop production. Risk is evaluated by ranking alternative management strategies based on how much income each produces relative to the variability in income. We explored the ranking of herbicide strategies based on net return and variability of weed counts for the population of escapes. Weeds typically grow in patches. Consequently, with good weed control, the variability of counts of escapes within a field provides information about the spatial distribution. We simulated weed counts of escapes using weed management decision models for corn, peanuts and soybean and weed counts collected prior to postemergence application in actual fields. We compared rankings of herbicide strategies with efficiency analysis based on net return and simple measures of the distribution of weed counts or competitive load. Our measures included variance, Green's index, kurtosis and the *k* parameter of the negative binomial distribution. We also adapted methods for rankings based on more detailed information about the distributions. These methods included maximizing utility and stochastic dominance with respect to a function. The strategies compared minimized weed escapes for a field or generated the top ten values of net return for a field. Several of the simple measures, except variance, produced similar rankings. The methods based on utility and stochastic dominance allowed us to more precisely describe preference for patchiness of escapes. A stop light chart of distributions of competitive load, expressed as percent yield loss, was a simple, visual method to present the tradeoff between net returns and the distributions of escapes.

44. Effect of Common Cocklebur (*Xanthium strumarium* L.) on Yield of Sesame (*Sesamum indicum* L.). Ahmet Uludag¹, Bekir Bukun², Abdalbaki Bilgic²; ¹Ministry of

Agriculture and Rural Affairs, Alsancak, Izmir, Turkey;
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Turkey

Turkey is among the foremost sesame producers. Sesame is grown as main crop or second crop. The sesame plant is very sensitive to environmental conditions and abiotic stress factors including weeds. Common cocklebur (*Xanthium strumarium*) is the most prevalent weed in sesame in Turkey. Economic thresholds are included in decision making processes. Thresholds are generally based on competition between crop and weed. They also vary with herbicide/control measure cost, efficacy of method and price of crop. Economic threshold can be estimated using break even elasticity with respect to the weed density at a single cell point and at the mean value of the weed density. Break-even point is free of the impact of both crop yield price and total weed control costs. The elasticity of the break-even yield loss is obtained from the value of the weed density. The elasticity is a measure of the percentage change in the break-even in response to an infinitesimal percentage change in the weed density given that all other factors remaining equal. There is little information in the literature on weed competition in sesame crop. The effect of common cocklebur, prevalent weed in sesame fields, densities, on sesame yield and cocklebur biomass accumulation is presented in this paper. In addition, relation between cocklebur biomass and sesame yield is studied. A new approach break-even point to find our economic threshold not regarding to control costs or crop prices is discussed. Experiments were conducted using natural cocklebur densities in 2004 and 2006. Cocklebur plants were thinned to 0, 1, 3, 4, 6, 10, 14 and 28 plants per 4 m of crop row. The cocklebur density and sesame yield data fitted hyperbolic crop yield loss relationship function. A non-linear logistic function was fitted to relationship between cocklebur biomass and the weed densities. The relationship between the sesame yield and common cocklebur biomass accumulation is modeled as an exponential function. Sesame yield was decreased by the increasing densities of common cocklebur. The asymptotic weed-free yield of sesame was 1863 kg/ha in 2004 and 1931 kg/ha in 2006, while the yield was estimated 239 kg/ha and 380 kg/ha at the 7 plant/m crop row of common cocklebur density in 2004 and 2006, respectively. Common cocklebur dry biomass per plant decreased as the weed density increased although total weed dry biomass per meter of crop row increased with the weed density. The common cocklebur biomass accumulation per plant decreased on average by 2.9 g per plant with a one percent increase in the weed density. The sesame yield was adversely affected by common cocklebur dry biomass accumulation too. One percent increase in the weed density would increase the break-even threshold level by 0.69% and 0.50% and decrease the sesame yield 0.9% and 0.7% in 2004 and 2006, respectively.

45. Yield Losses and Economic Thresholds from Rice-Weed Competition on Transplanted Rice. Jong Gun Won¹;
¹Gyeongbuk ATA, Daegu, Gyeongbuk, Korea, South

Mathematical modes that summarize the quantitative knowledge of the impact of weed interference on crop yield can provide useful information to support weed management decisions. This study was carried out to predict the rice yield loss and to determine the economic thresholds levels for late transplanted rice from competition between the most serious broad leaf weeds, *Monochoria vaginalis* (pickerelweed) and *Sagittaria trifolia* L.(arrowhead) in Daegu and Milyang of Korea. The rice yield loss models of *Monochoria vaginalis* were predicted as $y(\text{Daegu}) = 4.81/(1 - 0.00111x)$, $R^2 = 0.939$ and $y(\text{Milyang}) = 4.40/(1 - 0.00126)$, $R^2 = 0.861$, and those of *Sagittaria trifolia* L. were predicted as $y(\text{Daegu}) = 4.61/(1 - 0.00396x)$, $R^2 = 0.841$ and $y(\text{Milyang}) = 4.45/(1 - 0.00337)$, $R^2 = 0.920$. In comparison of the competitiveness represented by parameter \hat{a} that of *Monochoria vaginalis* was very low as ranged from 0.0011 to 0.0013 and that of *Sagittaria trifolia* L. was higher than three times as ranged from 0.0034 to 0.0040. Economic thresholds calculated using Cousens' equation was negatively related with the competitiveness of weed. So that the economic thresholds of *Monochoria vaginalis* was very high as ranged from 27.9 to 28.0, however, that of *Sagittaria trifolia* L. was relatively lower as ranged from 8.0 to 9.3 plants per m² depending on different regions. Our results can be used to aid decision-making for weed control in rice cultivation by providing simple answers, such as rice yields, economic threshold weed density and whether or not to apply herbicide. However, it has limitation to predict the rice yield by multispecies weeds infections in realistic field. Therefore, further studies are required to define hyperbolic yield loss models, derived by multispecies weeds infections.

46. Branching Patterns of *Melastoma malabathricum* L. as Influenced by Density Regimes. Mahdi Faravani¹, Baki Bakar¹; ¹Malaya University, Kuala Lumpur, WP, Malaysia

We assessed branching patterns and developed architectural models of *Melastoma malabathricum* describing branching networks, directionality and dispersion with respect to the mother plant as influenced by density. Matured plants of *M. malabathricum* at the density of 1, 2, and 3 plant box -1 were raised in wooden boxes measuring 1 m x 1 m and 30 cm in depth, previously filled with garden soil of the Malacca series. The primary, secondary and tertiary branches, their respective angles and lengths were measured to assess branching patterns as influenced by density. Mean vectors of branches concentration were measured for every 50 cm intervals of plant pressure of the neighbors. Circular statistics was applied to test whether the plant in a high density would preferentially bend

towards the incoming solar radiation or otherwise. Most branches were concentrated in the opposite direction and away from each other with a mean vector of 212.9°. Rayleigh's test (z values) showed the branches were distributed uniformly in different direction (0° - 360°) throughout the plant height around the mother plant. An increase in plant density has led to parallel increase in modular competition affecting distribution of branch modules, their directionality and dispersion, registering respective mean vectors of 222°, 208.9° and 214.2° for plants at the densities of 1, 2 and 3 plants per box. The concentrations of branch modules were quite uniform around the mother plant. We found that the concentrations of axial branch modules devolved away from the maximum competitive pressure in terms of branch axial angle was higher among neighbors at the density of 3 plants per box compared with those plants at the respective densities of 1 or 2 plants per box. The resultant spatial pattern of competing plants displaying reduced overlapping of branches was a manifestation of the competitive vectors integrating neighbor effects between them.

47. Social and Economic Aspects Shaping the Adoption of Bioherbicides in Canada: A Research Perspective. Susan Boyetchko¹, Karen Bailey¹; ¹Agriculture and Agri-Food Canada, Saskatoon, Saskatchewan, Canada

Decades of investment in research and development of microbial biopesticides has progressed tremendously since the first bioherbicides were registered in North America. The process of developing these early prototypes used similar approaches as chemical herbicides but with some modifications due to the living nature of the active ingredient. Despite the early success of the first generation of bioherbicides, it took several more years before additional bioherbicides reached the marketplace. Changing attitudes and perceptions of government departments (regulatory and research), public consumers, and industry are generating greater support and interest in biopesticides in Canada. Biopesticides are classed by Health Canada as reduced risk products which are deemed less hazardous to human health and safer to the environment than conventional pest control products, thus representing new pest management tools with novel modes of action. They therefore symbolize an emerging field in pest management for tackling issues related to resistance management, de-registration of synthetic pesticides, ineffective chemical control measures for some weed-crop systems, and reducing chemical pesticide load in the environment. In addition, the expanding organic and health food industries will be major advocates for biological control, with sales of organic food expected to increase by 25-30% per annum. The current global biopesticide market is estimated at \$350-400 million, with Bt products comprising the bulk of the market. While the synthetic pesticide market has decreased by 12% over the

last 5 years, demand for biopesticides is expected to exceed \$1 billion in sales by 2010. Societal concern for the environment and greater public demand for fewer chemical pesticides in the food chain have stirred political debate and legislative amendments to Canada's Pest Control Products Act, requiring greater pesticide risk reduction and the expedition of new, lower-risk pest control products. Many urban municipalities in Canada are banning the use of chemical pesticides and several chemicals are being de-registered due to risk and economic considerations. Additional socio-economic factors that are changing the Canadian agriculture landscape are related to environmental sustainability, biofuels, climate change and public health. This presentation will delve into the changing social and economic perceptions and attitudes that are shaping the outlook and adoption of bioherbicides in Canada.

48. The Problems of Federal Capital Territory Rural Farmers in Nigeria. Michael Adedotun¹; ¹Federal Capital Territory Administration, Federal Capital Territory, Abuja, Nigeria

This paper gives detailed information related to the problems peasant farmers have with weed control in the Federal Capital Territory. Also investigated in this paper are the problems associated with the use of chemicals to control weeds, how farmers obtain chemicals and the extension agents ability to provide information related to weed control technology to the farmers. In addition, weed control training programs could perhaps be facilitated by developed countries in order to aid the developing countries.

49. Building Collaborative Community Action to Manage Established Weeds and Prevent the Introduction of New Weeds. Helen Anderson¹; ¹Dept Primary Industries, Hamilton, Victoria, Australia

Weeds don't respect boundaries. Successful long term management requires a multidisciplinary approach and collaborative coordinated action. By developing and maintaining effective partnerships with the many land custodians whose activities impact on or influence the management of weeds on private land, Victoria can prevent the introduction of new weeds and reduce the cost and impacts of existing weeds.

Tackling Weeds on Private Land (TWOPL) was a \$9 million, three-year, Victorian Government initiative encouraging land managers to work collaboratively to manage weeds. Over the past three years TWOPL has worked with five stakeholders whose activities significantly influence how weeds impact on and are managed on private land; Local government, linear managers (road and

rail), Catchment Management Authorities, the garden industry and the fodder industry.

TWoPL has built on the momentum of a range of existing programs by lifting the profile of weed management as a core component of business operations. A range of tools including; information, education, engagement, research and legislation have been combined to promote weed management responsibilities, share knowledge, build capacity that will extend beyond the life of the initiative and ensure integrated and cooperative approaches to preventing new weeds and managing existing problems.

Significant measured increases in stakeholder awareness, acceptance and action on weeds have been achieved. As a small sample, working through partnerships has achieved; development of industry standards for weed management along Victorian rail corridors, development of a Hygiene Code of Practice by the Fodder Industry, production of a booklet on suitable alternatives to invasive garden plants by the Garden Industry, identification of 410 Victorian Alert Weeds and implementation of some 89 weed projects by Local Government including; community education and awareness; weed spread prevention training; weed mapping and marker systems; development of weed hygiene protocols, planning guidelines and local laws.

50. Herbicide Resistance is Not a Concern for Farmers of a Developing Country. Hani Ghosheh¹; ¹Jordan University of Science and Technology, Irbid, Jordan

While investigations around herbicide resistant in weeds continue to dominate the scientific community, pioneer date palm farms of Jordan are barely concerned. Observations from a weed management specialist assigned to focus on weed infestations problems within a farm specialized in producing high quality date palms (*Phoenix dactylifera*), grapes (*Vitis* spp.), citrus (*Citrus* spp.), and *Asparagus officinalis* in the Jordan valley indicated that weed management practices are totally inappropriate. On one hand, farm operations ensure harvesting high quality products that met the strict international standards with professional utilization of post harvest technologies. On the other hand, weeds heavily infested all crops despite the continuous mechanical and chemical control efforts. The researcher observed through his surveys many causes for weed infestations outbreaks. Farm managers never tackled the reasons for such outbreaks and the producers have no clue why their weed management efforts were failing. Irrigation runoffs were very obvious from both trees basins and irrigation pipelines. Weeds were allowed to heavily infest side fences and alleys, which ensured a continuous re-infestation reservoir of seeds. Contact herbicides were used ineffectively on fully developed weeds. Systematic herbicides were used frequently without any scientific rationale. Weeds were allowed to go into flowering in all crops. These observations demonstrated how weak are weed management extension programs in a

developing country, and how much efforts are needed to force producers to recognize a science dealing with weeds. The researcher will identify reasons for weed science ignorance in a developing country and suggest procedures to raise public awareness in that regard.

51. The Value of Herbicides in US Crop Production. Leonard Gianessi¹; ¹CropLife Foundation, Washington, DC, United States of America

The vast majority of crop hectares in the United States are treated with chemical herbicides annually. The adoption of herbicides for weed control was rapid in the 1950s and 1960s. Herbicides replaced the use of millions of workers to pull and hoe weeds by hand and greatly reduced the use of tillage for weed control. Costs of production were reduced and crop yields increased because herbicides were cheaper and more effective than hand weeding and cultivation. Organic crop growers cite weed control as their greatest difficulty in crop production because they are not permitted the use of chemical herbicides. They substitute hand weeding and cultivation for herbicides at a greatly increased cost and with reduced effectiveness. Aggregate studies that estimate the value of herbicides assume that growers would substitute a certain amount of hand weeding and tillage if chemicals were not used, which would not be sufficient to prevent yield losses totalling about 20% of US crop production.

52. Training in Identification of Weed Seeds in Mexico. José Torres¹; ¹SAGARPA-SENASICA, México, Distrito Federal, Mexico

Samples of lots of imported crop seed are analyzed in order to prevent entry of alien weeds to Mexico. Analysis of seeds for quarantine purposes is provided by accredited laboratories by government. Technicians involved in weed seed exam must be able to identify weed seeds as requisite to get accreditation. The training necessary to reach that goal is provided by the Official Laboratory via courses, taught individually or in small groups previous request. The activities focus on: legislation, morphology of seeds and identification of weed seeds. In classroom, a brief rationale is given for each activity and a practice in laboratory. At the end of each course, an evaluation is made. Seven laboratories are accredited now but we expect a bigger number in a near future. These courses are scheduled, at least twice a year, and the program of training is open to anyone interested.

53. Weed Management in Guyana Vegetable Production: An Assessment and Preliminary Recommendations. Rakesh Chandran¹; ¹West Virginia University, Morgantown, West Virginia, United States of America

A farmer-to-farmer volunteer assignment to the Republic of Guyana, South America, through the United States Agency for International Development (US-AID)-funded Partners of the Americas was undertaken in 2006 to assess weed management practices followed by vegetable farmers in the coastal Georgetown area, to document needs, and to provide recommendations that would enhance their farming ability. Guyana is a developing country with a population of roughly 700,000 and a tremendous potential for agricultural production. Weeds form a major group of pests limiting productivity of crops grown in Guyana. Weed infestations can reduce vegetable yields typically by 40-60%. Vegetables produced included hot pepper (*Capsicum chinense*), sweet pepper (*Capsicum annuum*), tomato (*Solanum lycopersicum*), pak-choy (*Brassica rapa chinensis*), bora (*Vigna unguiculata* subsp. *sesquipedalis*), cabbage (*Brassica oleracea*), boulanger (*Solanum melongena*), okra (*Abelmoschus esculentus*), and cassava (*Manihot esculenta*). Holding size averaged 2 acres and ranged from half an acre to 10 acres. Typically, vegetable farmers resorted to hand-weeding, use of simple tools like machete, hoe, and different mulches to manage weeds. A few herbicides are available and used to limited extents by progressive farmers. Problems related to phytotoxicity and related crop loss discouraged farmers from using herbicides extensively. Sources of information related to weed management to farmers included pesticide dealers, National Agricultural Research Institute (NARI), Ministry of Agriculture, and Partners of the Americas. Active outreach efforts on weed management were seldom available for vegetable farmers. Farmers welcomed efforts to introduce technology, especially, to overcome shortages of labor. Widespread dismay existed among the farmers in the current method of information transfer between the research/extension system and the end-user. Guyana's economy would benefit through advances made in vegetable production. A weed science program was clearly missing and a well-defined systematic approach to initiate and establish such a program would be of help to the Guyanese vegetable farmer. Expertise from the private sector is available for major crops like rice and sugarcane, but such resources are virtually unavailable to vegetable farmers in Guyana.

54. Potential (Trans) Gene Movement from Flax (*Linum usitatissimum* L.) to Weedy and Wild Relatives in North America. Amit Jhala¹, Linda Hall¹, Jocelyn Hall¹; ¹University of Alberta, Edmonton, Alberta, Canada

Flax is being genetically modified for the bio-industrial and food markets. One of the regulatory concerns is pollen mediated gene flow from transgenic flax to wild and weedy species and the effect of the transgenes on these populations. Information on potential inter specific hybridization in flax is required by regulators before the unconfined release of any novel flax in Canada. Flax

belongs to the family Linaceae which has 22 genera and about 300 species. Studies indicate that transgenic flax can hybridize with at least nine wild or weedy species in the world. There are about 64 species reported in North America, including eight in Canada. Three related species (*L. lewisii*, *L. rigidum* and *L. sulcatum*) are found in the Canadian Prairie provinces, the largest flax growing area in the world. There is no data available on hybridization of these three species with cultivated flax, but based on other reported interspecific hybridizations and similarity in chromosome numbers, we predict that novel flax may hybridize with *L. sulcatum* (n=15) and *L. rigidum* (n=15). Nine other wild relatives of flax sharing the same chromosome number as cultivated flax (n=15) are distributed in several regions of North America, but with the exception of *L. corymbiferum*, outcrossing to these species has not been reported. Based on the evidence of the interspecific hybridization, (trans) gene movement may be possible from transgenic flax to these related species depending on their sexual compatibility, population dynamics and sympatry. However, more studies are required on reproductive biology, local occurrence, interspecific hybridization, fecundity and genome affinity of North American flax wild relatives.

55. Farm-Scale Economic Evaluation of Glyphosate-Resistant Sugarbeet in Wyoming, USA. Andrew Kniss¹; ¹University of Wyoming, Laramie, Wyoming, United States of America

Approximately 800 ha of glyphosate-resistant sugarbeet was grown in Wyoming in 2007. This represents the largest commercial production of a biotechnology-derived sugar crop in the world to date. Previous research on glyphosate-resistant sugarbeet predicted that growers could afford to pay nearly \$479/ha for the technology due to reductions in weed management costs and increases in production that the technology allows. However, research conducted prior to 2007 has been done in small-plots, and it is unclear how estimates derived from small-plot research would relate to commercial scale production by sugarbeet growers. A study was conducted in 2007 in Wyoming in order to quantify the economic gain or loss to sugarbeet growers who adopted this technology. In May of 2007, 20 glyphosate-resistant sugarbeet fields in commercial production were paired with nearby fields of conventional sugarbeet. Each pair of fields was managed by the same grower, had similar soil types, irrigation methods, and cropping histories. In many cases the pairs consisted of a single field where glyphosate-resistant and conventional sugarbeet cultivars were planted side by side. For each field selected for this study, data on field operations, herbicide applications, and yield data were collected. Net economic returns were then calculated for each field. On average, the glyphosate-resistant production system resulted in a \$222/ha decrease in costs related to weed

management compared to conventional production system, largely due to reductions in hand-labor for weed removal. Glyphosate-resistant sugarbeet resulted in an increase in gross return of \$328/ha when compared to conventional sugarbeet due to increased production. This represents a net economic gain to sugarbeet growers who adopted glyphosate-resistant sugarbeet in 2007 of \$550/ha. In addition, inter-row cultivation and the number of herbicide applications was reduced by 50% and 12%, respectively, in glyphosate-resistant sugarbeet compared to conventional sugarbeet.

56. South African Way of Conducting Weed Risk Assessment. Ntakadzeni Jaqualine Tshidada¹; ¹Department of Agriculture, Pretoria, Gauteng, South Africa

The Directorate Plant Health (D:PH) of the Department of Agriculture (DOA) regulates importation of plants and plants products in terms of Agricultural Pest Act, 1983 (Act No. 36 of 1983). This act safe guards agricultural resources as well as the environment in South Africa by preventing the introduction of potential harmful foreign pests including weeds. South Africa is a member of World Trade Organization on application of Sanitary and Phytosanitary measures (WTO-SPS Agreement) as well as the International Plant Protection Convention (IPPC) which is recognized by World Trade Organization as a standard setting body for phytosanitary (plant health) issues. The IPPC established International Standards of Phytosanitary measures (ISPMs) to provide norms for safe and fair international trade.

Before plants and plant products are imported to South Africa the importer should apply for an import permit. A weed risk assessment will be conducted as part of the Pest Risk Analysis process which aims to prevent the introduction and spread of a plant that is likely to become weed in South Africa. The weed risk assessment process is design to detect which species is permitted and which are prohibited entries.

57. Rapid Analysis of Target-Site Resistance in Blackgrass Using Pyrosequencing® Technology. Jean Wagner¹, Bernd Laber¹, Hubert Menne¹, Hansjörg Kraehmer¹; ¹Bayer CropScience AG, Frankfurt, Hessen, Germany

The first case of herbicide resistance in populations of blackgrass (*Alopecurus myosuroides* Huds.) was reported 25 years ago. At present it is the most important herbicide-resistant weed in Europe, particularly with regard to ACCase inhibiting herbicides. Target-site resistance is caused by various single nucleotide polymorphisms (SNPs) and can be detected using molecular technologies. In this application the Pyrosequencing® technology was adapted for the rapid analysis of TSR in black-grass. The intention was to support agricultural practice with rapid informa-

tion about the status of TSR in fields. In 2007 advisers in Great Britain were encouraged to collect leaves from up to ten individual plants from fields where failures of ACCase inhibiting herbicides appeared and send them to the Bayer CropScience laboratory. There the genetic material of black-grass leave samples was analyzed for the occurrence of SNPs known to be responsible for TSR to ACCase inhibitors. Samples from more than 100 sampling sites were assessed in this way. TSR was detected in 68% of all samples tested. The results confirm that an isoleucine to leucine exchange at position 1781 is the most widespread mutation in TSR black-grass. It was detected in 91% of all cases of identified TSR. The spatial distribution of analysed target-site resistance in *A. myosuroides* from Great Britain was illustrated with the help of a Geographic Information System (GIS) and is presented herein.

58. Glyphosate Resistance in *Lolium multiflorum* of California: Distribution, Expression, and Molecular Evidence for an Altered Target Enzyme. Marie Jasieniuk¹, Riaz Ahmad¹, Anna Sherwood¹, Jeffrey Firestone¹, Alejandro Perez-Jones², W. Thomas Lanini¹, Carol Mallory-Smith², Zachary Stednick¹; ¹University of California, Davis, California, United States of America; ²Oregon State University, Corvallis, Oregon, United States of America

Selection by herbicides has resulted in widespread evolution of herbicide resistance in agricultural weeds. In California, resistance to glyphosate was first confirmed in *Lolium rigidum* in 1998. The objectives of this study were to determine the current distribution and level of glyphosate resistance in annual *Lolium* spp. of California, and to assess whether resistance could be due to an altered target site. Seeds were sampled from 118 populations and seedlings treated with glyphosate at 866 g ae per ha. Plants from 64 populations did not survive glyphosate treatment. In the remaining 54 populations, the percentage of surviving plants ranged from five to 95%. One susceptible (S) population, four populations with high percentages of vigorous surviving plants, and one S accession from Oregon were used for pot dose response experiments, shikimic acid analyses, and DNA sequencing. For dose response experiments, seedlings were treated with glyphosate at eight rates ranging from 108.25 to 13,856 g ae per ha. Shoot biomass was evaluated 3 wk following glyphosate treatment and fit to a log-logistic regression equation. Based on GR50 values, seedlings from putatively R populations were roughly two to 15 times more resistant to glyphosate than S plants. Shikimic acid accumulation was similar in all plants prior to glyphosate treatment but at four and seven DAT, S plants from California and Oregon accumulated approximately two and three times more shikimic acid, respectively, than R plants. Sequencing of a cDNA fragment of the EPSPS coding region revealed two different codons, both of which encode proline at amino acid position 106 in S individuals. In

contrast, all R plants sequenced exhibited missense mutations at site 106. Plants from the population exhibiting the lowest level of resistance in dose response experiments revealed a nucleotide substitution translating to replacement of proline with serine at EPSPS amino acid position 106. Plants from the remaining R populations exhibited a mutation corresponding to replacement of proline with alanine at site 106. Our results indicate that glyphosate resistance is widespread in annual *Lolium* populations of California, and that resistance is likely due to an altered target enzyme.

59. Herbicide Resistance Management Recommendations Based on Detailed analysis of Monitoring and Innovative Molecular Technologies in Blackgrass. Hubert Menne¹, Jean Wagner², Hansjörg Kraehmer¹; ¹Bayer CropScience AG, Frankfurt/Main, Hessen, Germany; ²University of Hohenheim, Stuttgart, Baden-Württemberg, Germany

Herbicide resistance in blackgrass (*Alopecurus myosuroides* Huds.) populations to different modes of action is of increasing concern in the intensive winter wheat producing areas in Europe. The implementation of integrated weed management strategies to delay resistance is difficult due to economical reasons and missing information on site specific resistance characteristic. The combination of bioassays of seed samples with modern molecular technologies has the potential to provide a more individual resistance profile of fields. In addition, the analysis of agronomic data, field histories, and their geographical location complete the knowledge to derive more precise management recommendations.

Since 2002 more than 1700 blackgrass biotypes were monitored. The comparison of histories and resistance status showed basic differences between winter wheat producing areas in Europe. Various facets of resistances, cross- and multiple-resistances evolved in different fields and are presented. Furthermore, molecular technologies were established to support the monitoring bioassays and provide more precise information about resistance mechanisms. In most cases analysis of the molecular investigations correlated with the monitoring results of bioassays. The main features of the fields indicate a high influence of the production system and lack of weed management diversification on the establishment and distribution of herbicide resistance. A well-balanced management of the most active herbicides, in combination with optimized production techniques on farm level, provides an adequate management of grass weed infestation and a delay in the selection of resistance.

60. Resistance to ACCase-Inhibiting Herbicides in Sprangletop (*Leptochloa chinensis*) and Barnyardgrass (*Echinochloa crusgalli*) in Thailand. Chanya Maneechote¹, Pruchaya Ekatin¹, Sansanee Jamjod²; ¹Ministry of Agri-

culture and Co-operatives, Chatuchak, Bangkok, Thailand; ²Chiang Mai University, Moeng, Chiang Mai, Thailand

In 2006 survey of herbicide resistance was conducted in Central and Loer North regions of Thailand to establish the distribution of ACCase herbicide resistance in two grass species, sprangletop (*Leptochloa chinensis*, LEPCH) and barnyardgrass (*Echinochloa crusgalli*, ECHCR). Seeds from 241 rice fields with >50% infestation of those two grass weeds were collected. Suspected populations were screened in agar with three ACCase herbicides which are commonly used for the control of both grass weeds. It was found that major populations of both grass weeds contain plants resistant to ACCase herbicides. Of total 188 LEPCH populations, 85%, 57% and 45% were resistant to cyhalofop, fenoxaprop and profoxydim, respectively. Only 2% of LEPCH populations remained susceptible to those three herbicides. This survey also determined that 80% of 53 ECHCR populations exhibit resistance to fenoxaprop and cyhalofop and 42% developed multiple-resistance to quinclorac. Survey in 2007 revealed that the frequency of resistance to ACCase herbicides was increased in both grass species. These results suggested that the reliance on only ACCase herbicides to control grass weeds in rice growing system would lead to higher frequencies of herbicide-resistant weed populations. Recently, hand weeding has become expensive and shortage so that herbicides are widely used in wet-seeded rice cultivation to reduce weed competition. Rotation of herbicides with alternative modes of action is a need to manage problem of herbicide resistance in rice growing system in Thailand.

61. Engineering Soybean Resistance to the Dicamba Herbicide. Paul Feng¹, Marianne Malven¹, Sio Wai Hoi¹, Ronald Brinker¹; ¹Monsanto Co, Chesterfield, MO, United States of America

Dicamba is a member of the synthetic auxin family and has provided efficacious control of dicotyledonous weeds since the 1960's. Dicamba is effectively used in corn, which is naturally tolerant. In contrast, soybeans are extremely sensitive showing typical auxin injury from low levels of dicamba. The dicamba resistant trait would permit the use of dicamba for effective control of dicotyledonous weeds in soybeans and expand weed control options for the growers. In this presentation, we will describe our efforts to engineer dicamba resistance in soybeans through a deactivation mechanism. Soybean plants transformed with a microbial mono-oxygenase gene withstood high rates of dicamba (> 0.55 kg/ha) showing no visible injury in multi-year, multi-location field trials.

62. Low Glyphosate Rates can Rapidly Lead to Evolution of Glyphosate Resistance. Roberto Busi¹, Stephen Powles¹; ¹WAHRI - Western Australian Herbicide Resistance Initiative, Perth, Western Australia, Australia

Glyphosate is currently the world's most important and widely used herbicide. All the documented cases of evolved glyphosate resistance in weeds thus far reported are due to a major single gene. However, recurrent selection with low (sub-optimal) herbicide rates can favor the enrichment of several minor genes (polygenic quantitative resistance). To test the potential for low glyphosate rates to select for glyphosate resistance a susceptible population of *Lolium rigidum* (ryegrass) was subjected to recurrent glyphosate selection. After three cycles of selection the progeny of the herbicide-susceptible population has shifted towards being resistant. Similar results were obtained with the same *L. rigidum* population selected with low rates of diclofop-methyl. This ryegrass population is undergoing further glyphosate selection to establish the level of resistance endowed by polygenic-based glyphosate resistance.

63. Development of Imidazolinone-Tolerant Rice Variety in Malaysia. Azmi M.¹, Azlan Shaari², Lim F. W.³, Hadzim K.², George V.⁴; ¹Malaysia Agriculture Research and Development Institute (MARDI), Kepala Batas, Penang, Malaysia; ²MARDI, Kepala Batas, Penang, Malaysia; ³BASF (Malaysia), Shah Alam, Selangor, Malaysia; ⁴BASF (Malaysia) Sdn. Bhd., Shah Alam, Selangor, Malaysia

Herbicide-tolerant rice (HTR) cultivars may hold the answer to effective management of problem weeds especially weedy rice in direct-seeded rice (DSR). Weedy rice poses perhaps the greatest threat to DSR because of the close similarity between weedy rice and the cultivated variety. Farmers in Malaysia have considered weedy rice of special importance since no selective herbicide was available prior to the advent of HTR. Introduction of these cultivars is justified by the need to offer new alternatives to manage weedy rice (*Oryza sativa* complex) in wet-sown culture. Development of the HTR resistant to imidazolinone herbicides started in the main-season (September to February) 2003/04 at MARDI Experimental Station in Seberang Perai, Malaysia. Clearfield Rice Line No. 1770 from United States was crossed with two local popular rice cultivars i.e. MR 211 and MR 220, and a potential line MR 249. Three backcrosses were made starting from the off-season (March to August) 2004 to the off-season 2005. Seed multiplication of B3F1 materials were carried out to obtain bulk populations in main season 2005/06. Individual plant selection was carried out in the off and main season 2006 (B3F2 and B3F3 population). By the off-season 2007, five imidazolinone tolerant lines (B3F4 materials) namely B 55 and B 64 (recurrent parent, MR 220) and A 73 and A 81 (recurrent parent, MR 249)

and C 25 (recurrent parent MR 211) were selected and planted in the fields for line selection, purification and evaluation for resistance against the major pests and diseases. One line from each recurrent parent was then selected for further evaluation on yield, agronomic performances and physical and chemical properties of the grain. The locally developed HTR cultivars are expected to be released to rice farmers in the off-season 2009. The use of the HTR may benefit the rice industry in Malaysia by providing an alternative management of weedy rice and other weeds. The introduction of HTR cultivars will also help to decrease the cost of weed management in the short and medium-term. It will allow the farmer more flexibility in the timing of herbicide application to control weeds not controlled by conventional means or products.

64. A Review on Grass Weed Resistance to ACCase Herbicides in Wheat in Iran: Current Situation and Future Challenges. Eskandar Zand¹; ¹Plant Protection Institute, Tehran, Iran

Herbicide resistance in recent decades, which could be attributed to improper consumption of herbicides, has caused great problems in weed control programs around the world. The same problem also exists in Iran especially in wheat fields which caused us to do a broad survey on possible challenges that wheat production in the country might face in the following years with respect to weed control. Among different weed species infest this crop, wild oat (*Avena ludoviciana*), canarygrass (*Phalaris* spp.), and ryegrass (*Lolium rigidum*) are the most problematic throughout the country. Herbicides have been the main means of these weeds control for more than 30 years. Among 22 herbicides registered for use on wheat in Iran, 9 are grass herbicides, 8 are broadleaf herbicides and 5 are dual-purpose herbicides. Fenoxaprop-p-ethyl, clodinafop-propargyl and diclofop-methyl (all as ACCase herbicides) have been the most important herbicides for control of grass weeds. However, unsatisfactory control of these weeds has been reported from some areas in recent years which were attributed to the possible resistance of these weeds to herbicides. The first report on herbicide resistance in wheat fields was published in 2006 in which 12 suspected to resistance wild oat populations which were gathered from three provinces were studied. This survey indicated that 3 of the populations in Khuzestan province had become resistant to all three grass herbicides mentioned above but only one population was found in Fars province which was resistant to fenoxaprop-p-ethyl only. In the next study in the same year, the distribution of resistant populations of wild oat in Khuzestan province was mapped. The studies continued in 2007 by mapping the distribution of resistant populations of the same weed species within some other main areas of wheat production. Results indicated that out of 63 suspected to resistance

canarygrass, wild oat and ryegrass populations studied (37, 18 and 8, respectively), 28 populations were completely resistant (12, 11 and 5, respectively), and 10 populations were semi-resistant (4, 3 and 3, respectively). With identification of the resistant populations, the mechanisms of resistance to clodinafop propargyl were investigated in 2007 and results indicated that change in the site of action and high metabolism of this herbicide by these populations were the cause. According to the obtained results, it was suggested that the best herbicide options for control of susceptible wild oat populations are clodinafop propargyl, pinoxaden, prosulfocarb, and isoproturon plus diflufenican. However, the best options for control of resistant populations with modified site of action are pinoxaden, sulfosulfuron, sulfosulfuron plus metsulfuron-methyl, and iodosulfuron plus mesosulfuron while those for populations with higher level of metabolism are sulfosulfuron plus metsulfuron, and isoproturon plus diflufenican. Overall, studies are still in progress to identify weeds resistant to currently applied herbicides in wheat fields and their mechanism of resistance.

65. Frequency and Distribution of Herbicide Resistance in *Avena* spp Populations from the Western Australian (WA) Wheatbelt. Mechelle Owen¹, Stephen Powles¹; ¹University of Western Australia, Perth, Western Australia, Australia

Avena is a major weed of world agriculture and the third major weed of cropping systems in Australia. There is little information available on the distribution of *Avena* in Australia and its herbicide resistance status. In 2005, a random survey was conducted across the Western Australian (WA) wheatbelt to quantify the presence of *Avena* spp.(wild oats) in cropping fields and then evaluate the extent and frequency of resistance in *Avena* populations infesting crop fields. Six hundred and seventy seven fields were visited across the WA wheat belt, encompassing a 14 million hectare crop production region. Crop fields were visited at random with 5 km intervals (geo-referenced) in each of 15 agronomic zones in the wheat belt (interspersed pasture fields were not sampled). Samples were collected just prior to harvest, and screened the following growing season with a range of herbicide groups. In total, 150 *Avena* spp populations were collected and subsequently screened with herbicides that are commonly used for *Avena* control in cropping systems. These herbicides were; diclofop-methyl, fenoxaprop, clodinafop, sethoxydim, tralkoxydim, clethodim, pinoxaden, triallate, glyphosate and flamprop-methyl.

The presence of *Avena* spp in cropping fields varied across the wheatbelt according to location, rainfall and soil type. Of the 677 fields visited, *Avena* was present in 43% of the fields, however only 22% contained enough plants for testing. More than half of the samples collected came from the high and medium rainfalls zones in the central agricultural region. Screening of these *Avena* populations

revealed high levels of resistance to the fop herbicides, in particular diclofop-methyl and low levels of resistance to the dims. Populations were found to be susceptible to all other herbicides tested.

This survey across a vast cropping region established widespread resistance to some fop ACCase herbicides. However the dim herbicides and other mode of action herbicides (glyphosate, triallate) provide very good control options for those populations with fop resistance. Generally the areas with high density populations had high resistance levels; however, overall, *Avena* resistance was low in Western Australia. Farmers have the opportunity to maintain their low resistance status by controlling patches with alternative mode of action herbicides and using alternative control options to reduce the risks of resistant seed dispersion.

66. Utilizing R Software Package for Dose Response Studies: The Concept and Data Analysis. Stevan Knezevic¹,², Christian Ritz²; ¹Univ of Nebraska, Concord, NE, United States of America; ²Royal Veterinary and Agricultural University (KVL), Copenhagen, Denmark

Advances in statistical software allow both standard and more complex statistical methods for non-linear regression analysis of dose response curves to be carried out conveniently by non-statisticians. One such statistical software is the freely available program R with the drc extension package. The drc package can: (1) simultaneously fit multiple dose-response curves, (2) compare curve parameters for significant differences, (3) calculate any point along the curve as the response level of interest, commonly known as an effective dose (eg. ED30, ED50, ED90), and determine its significance, (4) generate graphs for publications or presentations. We believe that when it comes to dose response data, the drc package has advantages over many currently available statistical software programs for non-linear regression analysis. Therefore, our objectives are to: (1) provide a review of few common issues in dose response curve fitting, (2) facilitate the use of up-to-date statistical techniques for analysis of dose response curves and (3) invite further debate on the subject (sknezevic2@unl.edu).

67. Glyphosate Resistance: Is Selection on this New Adaptive Trait Altering the Genetic Structure of *Lolium* (Poaceae) Populations within California?. Anna Sherwood¹, Marie Jasieniuk¹; ¹University of California Davis, Davis, CA, United States of America

The first population of glyphosate resistant *Lolium* in the United States was identified in an almond orchard near Chico CA in 1998. Today, glyphosate resistance is present in many *Lolium* populations within the Central Valley of California. Given the rapid increase in the resistant

phenotype, a corresponding significant change is expected across the genome. Resistance evolution in *Lolium* thus provides a unique opportunity to investigate how selection on an adaptive trait can affect the distribution of the adaptive phenotype, its underlying functional genetic variation, and the structuring of neutral variation within the genome. The objectives of this study were to: (i) identify which environments strongly select for the glyphosate resistant phenotype, (ii) determine if selection for resistance has led to population subdivision in adaptive and neutral genetic variation, and (iii) determine whether there are one or multiple origins of resistance. To address these objectives, we collected leaf and seed samples from individual *Lolium* plants in glyphosate-intensive and organic cropping systems as well as non-cropped areas in California. Seeds were germinated and seedlings treated with glyphosate at 0.5X, 1X, 2X the recommended rate for *Lolium* to determine progeny phenotypes and infer the maternal phenotype. Maternal plants were also genotyped using Simple Sequence Repeat (SSR) markers. In addition, we sequenced the 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) gene from a sub-sample of individuals to assess allelic variation in resistant and susceptible phenotypes. Population structuring of: phenotypic, adaptive genetic, and neutral variation was assessed using a diversity of methods, including individual and population based methods. The presence of glyphosate resistant individuals in *Lolium* populations was strongly associated with glyphosate-intensive weed management practices. However, population subdivision detected using neutral SSR markers was not associated with either selective environment or glyphosate resistant phenotype. In addition, we identified multiple glyphosate resistant alleles suggesting multiple origins of resistance. Lack of strong population subdivision within the neutral genetic data indicates extensive inter-population gene flow between sites within the Central Valley. However, the extensive spatial structuring of resistant and susceptible phenotypes suggests that glyphosate does exert a strong selection pressure.

68. Confirmation and Control of Glyphosate-Resistant Giant Ragweed. Jason Norsworthy¹, Robert Scott¹, Lawrence Oliver¹; ¹University of Arkansas, Fayetteville, AR, United States of America

Glyphosate is the standard herbicide used for broad-spectrum weed control in glyphosate-resistant-soybean (*Glycine max*). Giant ragweed (*Ambrosia trifida*), an annual herbaceous weed that emerges in early spring, was reported at three locations in Arkansas to be surviving multiple applications of glyphosate. Giant ragweed is one of the most competitive weeds with crops and, when not controlled, can result in substantial yield loss. Dose response experiments were conducted to evaluate three accessions (Jefferson County, Mississippi County, and

Greene County) of giant ragweed for resistance to glyphosate relative to two susceptible accessions (Washington County and Lonoke County). Seedlings were treated with eight rates of glyphosate (MON 78623) ranging from 0.035 to 2.24 kg ae/ha plus 0.25% v/v nonionic surfactant. Plant death was recorded 28 days after treatment. The lethal dose needed to kill 50% of each population (LD50) was determined. The LD50 values for the susceptible biotypes were 0.16 and 0.34 kg/ha glyphosate for Lonoke and Washington County, respectively. The Mississippi, Greene, and Jefferson County accessions had an LD50 of 0.68, 0.77, and 1.18 kg/ha glyphosate, respectively. The Jefferson County accession was 7.2 times more tolerant to glyphosate than the Lonoke County accession and was not controlled with field use rates, indicating the evolution of glyphosate-resistant giant ragweed in Arkansas. Additionally, nine herbicides encompassing four modes of action were evaluated for postemergence control of the Washington, Jefferson, and Greene County accessions when applied as a single application to 15- and 30-cm-tall plants. Labeled rates of fomesafen, chlorasulam-methyl, carfentrazone, flumiclorac, and bentazon provided effective control (80 to 100%) of the resistant biotypes when applied at the 15-cm height. Control was variable with most herbicides when applied to 30-cm-tall plants. Giant ragweed is the fourth weed in Arkansas to develop resistance to glyphosate. As glyphosate resistance continues to increase, growers must incorporate older, conventional herbicides back into their weed management programs to provide effective season-long weed control.

69. Proactive Detection of ALS-Based Herbicide Resistance in Weeds. Christophe Délye¹, Karelle Boucansaud¹, Fanny Pernin¹, Cécile Petit¹; ¹INRA, Dijon, France

Acetolactate synthase (ALS) inhibitors are the most broadly used herbicide class worldwide. They are also the most resistance-prone herbicide group. Resistance diagnosis is thus of importance for the optimal use of ALS-inhibiting herbicides. Most resistance cases reported to date are due to mutations at codons 122, 197, 205, 574 or 673 in the gene encoding ALS. DNA-based assays detecting mutant ALS alleles are thus adequate tools for quick and accurate resistance diagnosis. However, these tools can only be developed after resistant plants have been detected by bioassays and mutant ALS sequence has been determined. This is time-consuming and needs to be performed each time a new mutation arises. To promptly detect mutant, resistant ALS alleles without preliminary sequencing, we developed five molecular assays, each one detecting any amino-acid replacement at one of the five ALS codons crucial for herbicide sensitivity. Assays are based upon the derived Cleaved Amplified Polymorphic Sequence (dCAPS) that uses PCR to create a restriction enzyme recognition site in a sequence where none exists.

This enables to detect nucleotide polymorphisms on the basis of the presence of this site in wild-type sequences and of its loss because of the occurrence of a nucleotide substitution in mutant sequences. dCAPS assays were successfully developed for each of the two major grass weeds in winter crops in France, black-grass (*Alopecurus myosuroides*) and rye-grass (*Lolium* sp.). They were used to analyse black-grass and rye-grass plants from fields where ALS inhibitors gave very poor control of these grasses after only three years use (at most six applications). Mutations at codons 197 and 574 were detected in many samples. Mutant ALS alleles sometimes occurred at considerable frequencies (>80% of the plants analysed) in black-grass and in rye-grass samples. Two distinct mutant ALS alleles were detected in some samples, and even in some individual plants. dCAPS results were confirmed by sequencing, thus demonstrating the reliability of the method. Assays similar to those used for black-grass and rye-grass can easily be developed for any other weed species, and the technique can be adapted to automated, high-throughput genotyping. Given the surprisingly fast selection for mutant, resistant ALS alleles that seems to have occurred in the black-grass and rye-grass samples we investigated, dCAPS assays targeting ALS can be expected to prove immensely useful for quick and proactive diagnosis of ALS-based resistance.

70. Synergy of Paraquat with Glufosinate Ammonium and Terbutylazine in the Control of Paraquat-Resistant Rye-grass (*Lolium* spp.). Frederik Eksteen¹, Pieter Pieterse², Andrew Cairns²; ¹Syngenta, Moorreesburg, Western Cape, South Africa; ²University of Stellenbosch, Stellenbosch, Western Cape, South Africa

Overuse of paraquat has resulted in ryegrass becoming resistant to this widely used herbicide in the Western Cape. Glufosinate ammonium at sub lethal dosage rates followed by paraquat gave good control of the paraquat resistant biotypes. The addition of (NH₄)₂ SO₄ and Agral 90® partially overcame the antagonism between glufosinate ammonium and paraquat when applied as a tank mix. The addition of terbutylazine to glufosinate ammonium, paraquat and mixtures of the two products was also investigated. Paraquat was traced radioactively in paraquat resistant plants treated with paraquat and a paraquat/glufosinate ammonium mixture. The paraquat remained immobilized in the plants treated with the paraquat but in the plants treated with the paraquat/glufosinate ammonium mixture the paraquat moved acropetally in the plants after 48 hours. The probable mechanism involved in overcoming the immobilization of paraquat in the leaves of resistant plants is discussed. The effectiveness of the glufosinate ammonium followed by a paraquat treatment was evaluated on a wide range of resistant populations collected in the Western Cape. The

sequential spray gave good control of all the populations tested.

71. Glyphosate Tolerance Mechanism in Italian Ryegrass from Mississippi. Vijay Nandula¹, Krishna Reddy, Daniel Poston, Agnes Rimando, Stephen Duke¹; ¹Mississippi State University, Stoneville, Mississippi, United States of America

A threefold glyphosate tolerance was identified in two Italian ryegrass populations, T1 and T2, from Mississippi. Laboratory experiments were conducted to characterize the mechanism of glyphosate tolerance in these populations. The T1 population absorbed less ¹⁴C-glyphosate (43% of applied) compared to the susceptible (S) population (59% of applied) at 48 h after treatment (HAT). The T2 population absorbed ¹⁴C-glyphosate at levels (56% of applied at 48 HAT) that were similar to both T1 and S populations, but tended to be more comparable to the S population. The amount of ¹⁴C-glyphosate that remained in the treated leaf was significantly higher in both T1 (67% of absorbed) and T2 (65% of absorbed) populations compared to the S population (45% of absorbed) at 48 HAT. The amount of ¹⁴C-glyphosate that moved out of treated leaf to shoot and root was lower in both T1 (25% of absorbed in shoot and 9% of absorbed in root) and T2 (25% of absorbed in shoot and 11% of absorbed in root) populations compared to the S population (40% of absorbed in shoot and 16% of absorbed in root) at 48 HAT. There were no differences in epicuticular wax mass among the three populations. Treating a single leaf with glyphosate solution at the field use rate (0.84 kg ae/ha) as 10 1-ml droplets killed the S plant but not the T1 and T2 plants (33 and 55% shoot fresh-weight reduction, respectively). Shikimic acid accumulated rapidly at higher levels in glyphosate-treated leaf segments of the S population compared to the T1 population up to 100 mM glyphosate. However, above 500 mM glyphosate, the levels of shikimate were similar in both the S and T1 populations. Furthermore, shikimic acid content was three- to six-fold more in whole plants of the S population treated with 0.22 kg ae/ha glyphosate compared to the T1 and T2 populations. No degradation of glyphosate to aminomethylphosphonic acid was detected among the tolerant and susceptible populations. These results indicate that tolerance to glyphosate in the T1 population is partly due to reduced absorption and translocation of glyphosate and in the T2 population it is partly due to reduced translocation of glyphosate.

72. Resistance to Hormone Mimic Herbicides and Aceto-hydroxyacid Synthase-Inhibiting Herbicides in *Sisymbrium orientale*. Chris Preston¹, Mohammed Mohamed Aman¹, Peter Boutsalis¹; ¹University of Adelaide, Adelaide, South Australia, Australia

Sisymbrium orientale L. (Indian hedge mustard) is an important broadleaf weed of cereal cropping in South Australia. *S. orientale* is readily controlled by the sulfonylurea herbicides that inhibit acetohydroxyacid synthase (AHAS). Extensive use of these herbicides has resulted in widespread resistance in this weed in South Australia. To control ALS herbicide-resistant *S. orientale*, farmers have reverted to the hormone mimic herbicides, such as 2,4-D and MCPA.

In 2005, failure of 2,4-D to control *S. orientale* was reported in a wheat field near Port Broughton, South Australia. Dose response experiments were conducted with hormone-mimic herbicides, AHAS-inhibiting herbicides and the phytoene desaturase inhibiting herbicide diflufenican. In these dose response experiments the resistant population proved to be resistant to 2,4-D and MCPA. It was also resistant to the AHAS-inhibiting herbicides metsulfuron-methyl, chlorsulfuron, imazethapyr, metosulam and florasulam. The resistant population could be controlled by diflufenican. When compared to 2 susceptible populations, the resistant population was 20-fold resistant to 2,4-D and MCPA. The resistant population was more than 500-fold resistant to chlorsulfuron, more than 400-fold resistant to metosulam, 32-fold resistant to metsulfuron-methyl, 23-fold resistant to florasulam and 4-fold resistant to imazethapyr.

Resistance to 2,4-D in this population is inherited as a dominant gene meaning it can spread in both pollen and seed; however, levels of pollen mediated gene flow are low. Resistance to hormone mimic herbicides has evolved only slowly in weeds around the world, but such resistance has the potential to greatly reduce the options for the control of broadleaf weeds. The evolution of resistance to hormone mimic herbicides in *S. orientale* is particularly problematic as the evolution of resistance to both hormone mimic and AHAS-inhibiting herbicides in the same population means weed control will be more difficult and more expensive.

73. Respective Prevalences of Resistance to Three ACCase-Inhibiting Herbicides in France in *Alopecurus myosuroides*. Cecile Petit¹, Christophe Délye¹; ¹INRA DIJON, Dijon, France

Alopecurus myosuroides (black-grass), a major grass weed in winter crops in France, has evolved resistance to ACCase inhibitors in numerous fields. This resistance is mostly due to enhanced herbicide metabolism, that is, fast and effective degradation of herbicide molecules by resistant plants. Cross-resistance patterns associated with herbicide metabolism are unpredictable. Herbicide metabolism can confer cross-resistance to herbicides with the same mode of action, or with distinct modes of action. In order to acquire data about cross- or multiple resistance to ACCase inhibitors associated with herbicide metabolism, we compared the respective prevalences of resistance to

three ACCase-inhibiting herbicides (A, B and C) sprayed at field rate in 78 French *A. myosuroides* populations where no known ACCase-based herbicide resistance was detected. Populations consisted of 38 populations sampled across France in fields where applications of ACCase inhibitors failed (resistant sample) and of 40 populations randomly sampled across the administrative district of Côte-d Or (random sample). In populations from the resistant sample, 0 to 100% plants were resistant to A, 0 to 100% to B and 0 to 100% to C. On average, 41%, 49% and 58% of the plants were resistant to A, to B and to C, respectively. In populations from the random sample 0 to 62% plants were resistant to A, 0 to 56% to B and 35 to 98% to C. On average, 4%, 10% and 78% of the plants were resistant to A, to B and to C, respectively. Overall, the proportions of plants resistant to A, to B and to C were 22.5%, 29.5% and 68%, respectively. Cross- or multiple resistances were not systematically observed. High proportions of plants resistant to A were only observed in populations containing high proportions of plants resistant to B, to C or to both herbicides. High proportions of plants resistant to B or to C were observed irrespective of the proportions of plants resistant to the other two herbicides. In particular, several populations containing a high proportion of plants resistant to C, but very low proportions of plants resistant to A or to B were observed in the random sample. These results suggest that different mechanisms of metabolism-based resistance exist in *A. myosuroides* that endow different patterns of cross-resistance. In order to better understand this intricate situation and to be able to diagnose cross-resistances, it is necessary to identify the genes involved.

74. Evaluating the Double Knockdown Technique: Sequence, Application Interval, and Annual Ryegrass (*Lolium rigidum* Gaud.) Growth Stage. Abul Hashem¹, Catherine Borger¹; ¹Department of Agriculture and Food WA, Northam, WA, Australia

Applying glyphosate followed by a mixture of paraquat + diquat in the same season for pre-planting weed control may reduce the risk of developing resistance to either herbicide. Glasshouse and field experiments at Merredin and Beverly, Western Australia, were conducted over 2 seasons to determine the best herbicide application sequence, growth stage of annual ryegrass at which to apply the 2 herbicides, and application time and interval to be allowed between applications for optimum control of annual ryegrass (*Lolium rigidum* Gaud.). Annual ryegrass plants were treated at 3 growth stages with either glyphosate 540 g a.i./ha alone, paraquat + diquat 250 g a.i./ha alone, glyphosate followed by paraquat + diquat 250 g a.i./ha, or paraquat + diquat 250 g a.i./ha followed by glyphosate 540 g a.i./ha (the double knockdown treatment). The herbicides were applied at different times of the day, with varied intervals between herbicides when

applied in sequence. The glasshouse experiment showed that herbicides in sequence more effectively killed annual ryegrass plants at the 3 to 6-leaf stage than a single application of either herbicide. Field experiments showed that applying glyphosate followed by paraquat + diquat provided 98 to 100% control of annual ryegrass plants when applied at the 3- or 6-leaf stage in 2002 and at all 3 growth stages in 2003. Generally, the sequence of paraquat + diquat followed by glyphosate was less effective than the reverse sequence, although the difference was not large. Averaged over 2 seasons, herbicides in sequence were most effective when the first herbicide was applied at the 3- or 6-leaf stage of annual ryegrass. An interval of 2 to 10 days between applications of herbicides was more effective than 1 day or less. The application time did not significantly affect the efficacy of double knockdown herbicides on annual ryegrass plants under field conditions.

75. Silky Bentgrass (*Apera spica-venti* L. Beauv.) Biotypes Resistance to ALS Herbicides - Control under Field Condition. Roman Kierzek¹, Kazimierz Adamczewski¹; ¹Plant Protection Institute, Poznan, Wielkopolska, Poland

Silky bentgrass (*Apera spica-venti* L.) is a one of the most serious weedy grass infecting arable fields in Poland. For control *A. spica-venti* the most popularly are sulfonylurea herbicides, because are efficient and play currently a role crucial in the chemical weed control in winter cereals. During last few years control of this important weed species by sulfonylurea became poor. Resistance biotypes were found in several localities on arable land with common crop rotation and herbicide use. However, it has been reported that sulfonylurea (i.e. chlorsulfuron) fails in efficiently controlling *A. spica-venti* in certain areas of Northern and Southern Poland after regular use. For assessment of resistance, *A. spica-venti* seeds were collected from selected areas where chlorsulfuron was continuously used (at least every second season). The aim of the fields study was to evaluate the activity of different herbicides for control resistant biotypes of *A. spica-venti*. The field experiments were located in the places where a chlorsulfuron resistant biotypes had previously been confirmed in greenhouse tests. During last two years six small and six big plots field experiments were carried out. The baseline for the study was the field trials set up in a complete randomised block design with four replications. The big plot experiments were done in one replication. The studies were conducted to investigate activity following herbicides at recommended doses: isoproturon (Isoguard 500 EC), fenoxaprop-P-ethyl (Puma Universal 069 EW), iodosulfuron (Huzar 05 WG), iodosulfuron + mesosulfuron (Atlantis 04 WG), sulfosulfuron (Apyros 75 WG), chlorosulfuron (Glean 75 WG), pinoxaden (Axial 100 EC) and prosulfocarb (Boxer 800 EC). The herbicides were applied in autumn or in spring.

The biological activity was evaluated after ear emergence of *A. spica-venti*.

The site where field experiments were set up heavy infested by *Apera spica-venti* was observed. The results of two-years field trials in the same sites showed that some ALS inhibitors were not sufficient in controlling of *A. spica-venti*. It means that *Apera* biotypes can display cross-resistance to sulfonylurea herbicides. In all experiments very poor control was obtained after chlorsulfuron and sulfosulfuron application (from 0 to 40 % control). Good control of *Apera spica-venti* by iodosulfuron and iodosulfuron + mesosulfuron were obtained only in two experiments (90%). In other trials control of *A. spica-venti* by those herbicides was poor. In each field experiments very good effect against *A. spica-venti* was received with fenoxaprop-P-ethyl, pinoxaden and prosulfocarb application (85-100%). Control of *A. spica-venti* by isoproturon was not uniform (from poor to very good). In this case the greenhouse experiments showed that populations collected from fields with poor *Apera* control were susceptible to all isoproturon doses. The phenomenon of cross-resistance to ALS inhibiting herbicides in collected *A. spica-venti* populations has been evolving rapidly.

76. Genetic Basis and Implications of Cross-Sensitivity in *Zea mays* L. (Sweet Corn) to Multiple Herbicides Metabolized by Cytochrome P-450 Enzymes. Martin Williams II¹, Jerald Pataky², Dean Riechers²; ¹USDA-ARS, Urbana, IL, United States of America; ²University of Illinois, Urbana, IL, United States of America

Certain *Zea mays* L. (sweet corn) hybrids and inbreds can be injured or killed following postemergence applications of several herbicides metabolized by cytochrome P-450 enzymes. Identification of sensitive hybrids in annual screening trials, the primary means of guiding weed management decisions, is limited because of high turnover of commercial hybrids. In recent years, our research team has pursued a mechanistic understanding of the genetic basis for herbicide sensitivity in *Zea mays*. Classical inheritance studies and segregating mapping populations determined that sensitivity to eight herbicide treatments (foramsulfuron, nicosulfuron, primisulfuron, rimsulfuron, mesotrione, tembotrione, carfentrazone, and dicamba diflufenzopyr) representing four modes of action (ALS-inhibiting, HPPD-inhibiting, PPO-inhibiting, and growth regulating) was simply inherited in inbred Cr1, and that a single gene(or very closely-linked genes) conditioned cross-sensitivity to all herbicides tested. The gene(s) was subsequently mapped to the same region of chromosome 5S as a cytochrome P-450 gene that previously was designated as nsf1 or ben1, which resulted from its ability to condition sensitivity to nicosulfuron and bentazon in *Zea mays* (field corn). Additional research found 45 hybrids and 29 inbreds from 12 different seed and food processing companies were either homozygous or hetero-

zygous for the gene(s) of interest in Cr1. Environment has an influence on level of crop injury, and we found that genotypic classes of *Zea mays* hybrids (i.e., homozygous tolerant, heterozygous, and homozygous sensitive) explained differences in herbicide responses of hybrids in 12 trials from Idaho to Delaware. When injury was observed, homozygous sensitive hybrids were injured severely. Heterozygous hybrids had a response that was intermediate to homozygous sensitive or homozygous tolerant hybrids. Injury to heterozygous hybrids was 1.5 to 2.3 times greater than homozygous tolerant hybrids. These results provide seed companies, herbicide manufacturers, and regulatory agencies information needed to make more informed decisions about risks of crop injury.

77. Some Weeds Resistance to Paraquat in South China (Guangdong) Plantations. Yong Chen¹; ¹South China Agricultural University, Guangzhou, Guangdong, China (Peoples Republic of)

Paraquat has been applied widely in Guangdong Plantations for around 20 years Recently. In tropical and subtropical plantations in Guangdong where paraquat has been intensively used, the resistance to paraquat of some weeds, which were traditionally sensitive to paraquat, have come into being, and become serious.

Questionnaires of some resistant weeds made down to local technicians in early 2006. Field trials were conducted in Guangdong in 2006-2007 to evaluate the efficacy of glufosinate-ammonium (Basta SL, a non-selective herbicide containing glufosinate-ammonium 200g/L), against weeds in banana and papaya plantations. The resistant goose grass (*Eleusine indica*) extent to paraquat has been acquired by greenhouse experiments. The experiments were done twice in a randomized complete block design with 4 replications. ANOVA was done for the indexes from the experiment. The data analyses were done using SPSS and EXCEL software.

The questionnaires showed *E. indica*, *Erigeron canadensis* (*Coryza canadensis*), and *Ipomoea obscura* had been acquired resistance to paraquat in Guangdong Plantations. The field trial results indicated that Paraquat used at normal dosage provided with only 55%, 0% and 28% control of the weeds *E. indica*, *E. canadensis*, and *I. obscura* respectively in Guangdong banana and papaya plantations, where paraquat has been used intensively since around 20 years ago. Basta at normal rate performed >90% control of the weeds including those listed above in Guangdong banana and papaya plantations. The greenhouse showed that: These *E. indica*, which were collected from Guangdong vary Plantations, had acquired different degree resistance to paraquat and survived following sequential paraquat applications; the level of confrontation weed resistance to paraquat is 40.4 from Panyu banana and papaya plantations.

The trial results indicated that, in regions like Guangdong where paraquat has been intensively Sprayed, the three weeds (*E. indica*, *E. canadensis*, and *I. obscura*) mentioned above have acquired resistance to paraquat.

78. Resistance of Silky Bent-Grass (*Apera spica-venti* (L.) Beauv.) to Sulfonylureas has Emerged in Central Europe. Katerina Novakova¹, Josef Soukup¹, Pavel Hamouz¹, Jean Wagner², Miroslav Jursik¹, Veronika Venclova¹, Jaroslav Salava¹; ¹Czech University of Life Sciences in Prague, Prague, Czech Republic; ²University of, Stuttgart, Germany

Rationale

Apera spica-venti is an important weedy grass in winter cereals with an increasing occurrence in the Czech Republic (CZ), Poland, Germany, Denmark, and some other countries. Herbicides (sulfonylureas) that target the enzyme acetolactate synthase (ALS) have been widely and repeatedly used for control of this grass in CZ since 1985 and therefore the resistance has evolved in many populations. The confirmed cases of resistance to sulfonylureas were also reported from surrounding countries: Germany, Poland, and Switzerland. Resistance in this mode of action is serious problem because there are only few modern herbicides that can substitute the role of sulfonylurea herbicides in winter cereals. The aim of this study was to assess the importance, R-population frequency, level, and physiological reasons of resistance in *A. spica-venti* populations across the Czech Republic and compare and discuss it with results reported by collaborating authors from other countries.

Methods

The long-term monitoring and testing on resistance in *A. spica-venti* have been done since 2000. Geographical distribution of R-populations throughout the Czech Republic was mapped using GIS. Resistance level was performed as dose-response whole plant bioassay with commonly used herbicides. In selected R- and S-populations, the target enzyme sensitivity was estimated in vitro using ALS-bioassay. To identify possible mutations of ALS gene causing the resistance, genomic DNA was amplified using PCR and sequenced. The efficacy of alternative herbicides with the same and different mode of actions was tested in situ in the small plot field trials with natural occurrence of resistant *A. spica-venti*.

Results

Resistance was found in 2% of screened populations. Cross-resistance pattern to chlorsulfuron, sulfosulfuron and iodosulfuron was confirmed in whole-plant bioassay (RF=6.7-303). Significant differences between S and R biotypes in response to a range of sulfonylurea herbicides were determined (RF=43.4-3932.7) using ALS-bioassay on enzyme extracted from shoots of *A. spica-venti*. Addition level of herbicide solution to extracted protein revealed that some of the population shown target-site

resistance. The nucleotide sequences of region 1 differed between the resistant and susceptible biotype in 3 nucleotides. In Domain A, a substitution of cytosine by thymine (susceptible: CCC, resistant: TCC) at the position 76 (197) has occurred, that confers an exchange of the amino acid proline in the susceptible to serin in the resistant biotype.

Loss of efficacy and cross-resistance was confirmed for chlorsulfuron, sulfosulfuron, and iodosulfuron in field trials carried out in resistant populations.

Conclusions

High level of resistance to sulfonylurea herbicides was confirmed in *A. spica venti* using various exact detection methods. The populations are randomly distributed and follow the history of herbicides used in single locations. No plant growth reduction occurred in resistant plants in the field and glasshouse experiment at the recommended dose, regardless of active ingredients (chlorsulfuron, sulfosulfuron, iodosulfuron) used. ALS-bioassays and molecular-genetic studies showed that some of the populations are resistant in target-site. Other mechanisms of resistance than target site may also be involved, given the observation that, the resistance pattern at the enzyme level was very low in some cases. Possible alternatives of chemical control were tested under field condition and practical solutions proposed.

79. Reduced Target-Site Sensitivity and Mutations in Resistant Biotypes of Ryegrass to ACCase-Inhibitors Herbicides. Jorge Díaz¹, Rafael Galdames¹, Juan Pedro Ruiz-Santaella², Nelson Espinoza¹, Antonio Franco², Rafael De Prado²; ¹INIA, Temuco, Araucania, Chile; ²Universidad de Córdoba, Córdoba, Spain

Herbicides inhibiting ACCase are used for grass weeds control in several crops. They are characterized for blocking the fatty acid biosynthesis inhibiting the chloroplastic ACCase. The target-site of these herbicides is located in the carboxyl transferase domain (CT) of the ACCase enzyme. In Chile, the intensive use of these herbicides, mainly in wheat, has selected resistant populations of *Lolium*. The more important mechanisms of resistance are the diminution of the concentration of the herbicide in the plant (absorption, translocation and metabolism), and target-site insensibility. This insensibility is due to mutations in the amino acids sequence that change the structure of target proteins, reducing or destroying the ability of the herbicide to interact with the enzyme.

The answer to ACCase-inhibitors herbicides (diclofop and clodinafop) was evaluated in *Lolium multiflorum* and *L. rigidum*. Bioassays made with seeds in petri dishes and in potted plants, indicated elevated resistance levels. The activity in vitro of ACCase with crude extracts was also determined. Extractions were made when the plants had 3-4 leaf (5-6 g). The incubation phase was made with

enzymatic extract, buffer, acid NaH₂CO₃ and concentrations of acid diclofop (0 to 30 µM). The enzymatic activity was determined measuring the ¹⁴C-malonyl-CoA formed by scintillation counting. The data were adjusted to the log-logistic model of regression (SigmaPlot 8.0) in order to calculate the resistance factors (RF = I50R/I50S). The results indicated that the ACCase enzyme was insensible to diclofop with RF of 6.1 and 9.4 for *L. multiflorum* and *L. rigidum*, respectively.

L. multiflorum and *L. rigidum* biotypes were used to identify the molecular basis of the resistance. The obtained DNA from individual plants was quantified and adjusted to a range of concentrations. Two pairs of primers were designed. The nucleotide regions including sites with mutations responsible for resistance were amplified. The amplified fragments were purified and sequenced in both directions. Sequence analysis and alignments were performed using the Lasergen 2006 software. These were compared with sequences of ryegrass available in a gene bank (NCBI). Nucleotides changes were detected and these led to amino acids substitutions in the positions 1781 in *L. mutiflorum*, 2041 and 2078 in *L. rigidum*. These mutations are very likely to confer resistance to ryegrass under the strong selection pressure imposed by the extensive use of the ACCase-inhibitors herbicides in wheat.

80. Relative Competitive Ability of Dicamba-Resistant and Susceptible Biotypes of *Chenopodium album*. Anis Rahman¹, Trevor James¹; ¹AgResearch, Hamilton, Waikato, New Zealand

The steady spread of atrazine-resistant *Chenopodium album* biotype since the 1980s forced New Zealand corn growers to use an additional post emergence herbicide. Of these, dicamba was the most widely employed due to its efficacy, the wide spectrum of weeds controlled and its low cost. Recent studies have confirmed the development of resistance in a biotype of *C. album* to dicamba. This glasshouse study reports on the morphological differences and relative competitive ability of the resistant and susceptible biotypes. Seeds of the two biotypes, collected from field grown plants, were planted in plastic trays. After emergence, seedlings (cotyledon stage, 1-2 cm high) were transplanted in an additive competitive design in plastic crates (30 x 30 x 30 cm) filled with a commercial potting mix with balanced nutrients added (Dalton's Potting Mix). Each crate had 16 plants in 9 different ratios of resistant to susceptible biotypes, viz. 16:0, 14:2, 12:4, 10:6, 8:8, 6:10, 4:12, 2:14 and 0:16. Each ratio was replicated six times. Plants were spaced 8 cm apart in randomly generated patterns in a 4 x 4 lattice. The crates were placed outdoors at ambient temperature and watered as necessary. Regular visual assessments were made on morphological aspects and the vegetative growth of plants. Individual plant heights were measured 40 days after

transplanting and records were made of the time to earliest flowering. After 70 days the above ground biomass of individual plants was determined following oven drying at 80°C for 24 hours.

The dicamba-resistant biotype (R) was morphologically distinct from the susceptible plants (S) being a lighter shade of green and the leaves less dentate. Also, its growth rate, vigor, plant size and above ground biomass (3.41 vs 7.37 g/plant) were significantly lower than those of the susceptible biotype. The resistant biotype was faster to mature with flowers appearing approximately 19 days earlier and the plants were shorter than the susceptible ones (60 vs 71 cm) at flowering.

When growing together in various ratio combinations, both biotypes appeared to benefit from each other and biomass of individual plants was higher in the mixed community than when growing as a monoculture. The average plant weight of the more competitive, susceptible biotype increased as its ratio decreased in the mixture while that of the resistant biotype changed little. Thus overall the total biomass (R S) also increased.

In a separate experiment, soil collected from the same field was used in crates to grow a natural population of *C. album* from the seedbank. Twenty crates were set up, each with about 25 plants but with various naturally occurring ratios of the two biotypes. The biotypes were identified from their leaf shape and this was confirmed later by treating separate pots with dicamba. Generally, results of this experiment confirmed most of the findings outlined earlier. Field studies are underway currently investigating different herbicide options for effective control of the resistant biotype.

81. Simulating the Present and Future State of Glyphosate Resistance in Weeds in Contrasting Environments and Cropping Systems. Art Diggle¹, Fiona Evans¹, John O'Donovan², Andrew Storrie³; ¹Department of Agriculture and Food, Western Australia, Perth, Western Australia, Australia; ²Agriculture and Agri-Food Canada, Lacombe, Alberta, Canada; ³NSW Dept of Primary Industries, Tamworth, New South Wales, Australia

Glyphosate resistance in weeds is an increasing problem but its occurrence is variable between regions and cropping systems. Glyphosate resistance has not been observed in weeds in Canada despite the introduction of glyphosate resistant *Brassica napus*(canola) in 1996, whereas glyphosate resistant *Lolium rigidum* (rigid ryegrass) is widespread on the Liverpool Plains of New South Wales where glyphosate resistant crops have not been used.

We have used a model to simulate the present status of glyphosate resistance in three diverse cropping systems with the aim of predicting the future rate of development. The systems represented are *Lolium rigidum* and *Raphanus raphanistrum* (wild radish) in a *Triticum aestivum* (wheat) / *Lupinus angustifolius* (narrow-leafed lupin) rotation in the

Geraldton region of Western Australia (WA system), *Lolium rigidum* in a *Sorghum bicolor* (sorghum) based cropping system incorporating frequent winter fallows on the Liverpool Plains of New South Wales (NSW system), and *Avena fatua* (wild oat) in a *Hordeum vulgare* (cereal barley) and *Brassica napus* (canola) based cropping system in Central Alberta (Alberta system).

The model represents glyphosate resistance as resulting from a single dominant gene with a fitness penalty. We simulated development of resistance up to now, accounting for crop competition, the pattern of use of glyphosate, and factors, such as germination fraction and timing of weed emergence, that influence the effectiveness of glyphosate.

For an assumed base mutation rate of 10^{-9} and relative fitness levels for resistant individuals of 0.7, 0.8 or 0.9 we get an estimated equilibrium gene frequency before glyphosate was used of 3×10^{-9} , 5×10^{-9} or 1×10^{-8} . For the WA system, based on a typical historical pattern of use of glyphosate we estimate current levels of the glyphosate resistance gene to be between 1×10^{-2} and 3×10^{-4} for *Lolium rigidum* and between 6×10^{-7} and 6×10^{-8} for *Raphanus raphanistrum*. This difference occurs primarily because the annual germination fraction of *Lolium rigidum* is substantially greater than that of *Raphanus raphanistrum*.

For *Avena fatua* in the Alberta system we estimate substantially lower levels of glyphosate resistance when glyphosate resistant canola was introduced than we estimate for *Lolium rigidum* in the WA system now. This occurs because germination of *Avena fatua* in no-till cropping is mostly stimulated by sowing, hence the selection pressure from glyphosate applied before sowing is minimal. Simulation agrees with observation in that the use of glyphosate as a selective herbicide in glyphosate resistant *Brassica napus* since its introduction has not yet caused detectable levels of resistance to develop in *Avena fatua*.

An increased rate of development of resistance is predicted in the NSW system, where glyphosate resistance has already developed in *Lolium rigidum*, because of high selection pressure by glyphosate in fallow.

82. Are Portuguese *Echinochloa* spp. Populations still Susceptible to Propanil? Isabel Calha¹, Fátima Rocha¹; ¹Instituto Nacional dos Recursos Biológicos I.P.(INRB), Oeiras, Portugal

Propanil is the most important herbicide for rice weed management both at world and national level. Rice growers complaining of poor control of *Echinochloa* spp. were monitored in Mondego and Sorraia river valleys, Portugal. Seed samples were collected from the affected area and tested. After the first screening of 37 populations, the sensitivity of six *Echinochloa* spp. populations to propanil was assessed in a growth chamber dose response

study (with seven rates: 0- 7200 g a.i./ha). Fresh weight was assessed 21 days after treatment and data was analysed using non-linear regression analysis and sensitivity indices (SI = ED80, less sensitive/ ED80, most sensitive) calculated for the two regions surveyed. The rates of 50% of plant growth inhibition (ED50) was calculated from the fitted equations. Four populations were confirmed susceptible with ED50 values ranging from 89 to 1866 g a.i./ha. Two other populations presented ED50 values of 6538 and 9536 g a.i./ha. Mondego and Sorraia SI were 2.35 and 21.77 respectively. The pattern of propanil use in the two regions could explain the higher sensitivity of Mondego populations compared to Sorraia populations. The response to a single dose Petri dish bioassay (360 g a.i./L) was similar among the six populations, denoting that this method was not so sensitive as the whole plant assay to discriminate between *Echinochloa* spp. populations. Further studies are needed with more doses and populations since this method allows for an answer within six days, compared with 41 days with the whole plant bioassay.

83. Herbicide Resistance Detection on *Cynosurus echinatus* Biotypes in Chile. Nelson Espinoza¹, Jorge Díaz¹, Rafael Galdames¹, Rafael De Prado²; ¹INIA, Temuco, Región de La Araucanía, Chile; ²Universidad de Córdoba, Córdoba, Spain

Seventeen biotypes of *Cynosurus echinatus* previously found as resistant to ACCase herbicides (CE-3, CE-4, CE-6, CE-7, CE-10, CE-12, CE-13, CE-14, CE-15, CE-16, CE-17, CE-18, CE-19, CE-20, CE-21, CE-22 and CE-23) were collected from wheat fields on different locations of Southern Chile and treated with ACCase-inhibiting herbicides clodinafop propargil (108 g ha⁻¹), haloxyfop-methyl (93.3 g ha⁻¹), and tepraloxymidim (300 g ha⁻¹), ALS-inhibiting flucarbazone-sodium (105 g ha⁻¹) and imazamox + imazapyr (74,3 + 33,8 g ha⁻¹), and EPSP synthase inhibitor glyphosate (1080 g ha⁻¹). The objective was to confirm the eventual presence of resistance and its magnitude. Pre-germinated seeds from all biotypes, plus a sensitive biotype used as control, were sown in pots on October 24, 2007. The plants were grown under natural environmental conditions and were treated with the herbicides on November 26, 2007, during the vegetative stage. Each herbicide was applied at a dose 50% greater than recommended. Aboveground dry matter was determined 34 days after treatment and dry weight reduction was calculated considering and untreated control as reference. All 17 biotypes were resistant to clodinafop propargil, only one was susceptible to haloxyfop-methyl, and only one was susceptible to tepraloxymidim. Only two biotypes were susceptible to flucarbazone-sodium, but all 17 were susceptible to imazamox + imazapyr. None of the biotypes showed resistance to glyphosate.

84. Management of Volunteer *Glycine max* (Soybean) Plants Resistant to Glyphosate. Fernando Adegas¹; ¹EM-BRAPA SOJA, Londrina, Paraná, Brazil

In several areas of Brazil, the climatic conditions allow more than a single grain crop cultivation during the year. After the *Glycine max* crop, which is cultivated in the spring/summer season, *Zea mays*, *Gossypium hirsutum* or *Triticum aestivum* can be sown. However, during *Glycine max* harvesting it is normal for the combine to drop a certain percentage of grains that will germinate later in the season to become volunteer plants infesting other crops in succession. In this situation, the most frequently used chemical control with Glyphosate will not work if the volunteer *Glycine max* plants are Roundup Ready (RR). Therefore, the objective of this work was to study control alternatives for the volunteer RR *Glycine max* plants germinating pre-sowing the winter crops or post-sowing winter *Zea mays*. Six experiments were carried out in the state of Paraná (southern Brazil), between February and May of 2007. The experimental treatments were arranged in a factorial (herbicides x *Glycine max* stage) randomized blocks design with four replications. Four experiments were carried out involving the desiccation operation in pre-sowing of the winter crop, with 15 treatments (g ha⁻¹): Paraquat Diuron (200 100 and 300 150), Diquat (200 and 300), Paraquat (200 and 300), Paraquat Diquat (150 150), Paraquat Atrazine (200 750), Glyphosate Carfentrazone (900 20), Glyphosate 2,4-D (1800 1000), 2,4-D (1,005 and 1,340), Glyphosate Metsulfuron (1,800 2.4), Metsulfuron (3.0) and a check without application. Two other experiments were performed in the post-sowing of winter *Zea mays*, with 10 treatments (g ha⁻¹): Atrazine Oil (400 1980), Atrazine Simazine (750 750), Mesotrione Atrazine Simazine (60 750 750), Mesotrione Atrazine Oil (60 and 120 1200 1980), Nicosulfuron (40), Nicosulfuron Atrazine Oil (16 1200 1980), 2,4-D (670 and 1005) and a check without application. The volunteer *Glycine max* plants received the herbicide application in two growth stages: V2 and V6. Until the stage V6 the most efficient desiccation treatments were Paraquat Diuron (300 150), Diquat (200 and 300), Paraquat (300), the mixture of Paraquat Diquat (150 150) and the mixture of Paraquat Atrazine (200 750). In the winter *Zea mays* the most efficient treatments were Atrazine Oil (400 1980), Mesotrione Atrazine Oil (60 and 120 1200 1980) and Nicosulfuron Atrazine Oil (16 1200 1980). All these treatments are selective for winter *Zea mays*. A phytosociologic scouting for volunteer *Glycine max* plants that was concurrently performed as part of the experiments resulted in a frequency of 0.750 which is equivalent to a density of 8.57 plants m⁻², indicating that these volunteer plants are really an important infestant of the winter crops in southern Brazil.

85. Chemical Control of *Conyza bonariensis* (Hairy Fleabane) Resistant to Glyphosate with Herbicides Sprayed in

Crop Management Operations Performed at Pre-Sowing of *Glycine max* (Soybean). Fernando Adegas¹; ¹EMBRAPA SOJA, Londrina, Paraná, Brazil

In Brazil, the main herbicides used in pre-sowing soybean management operations are those of total action, not selective, mainly Glyphosate and Paraquat. Other herbicides have been added to those two during the crop management operations in order to improve the control spectrum of broadleaf dicotyledonous weeds, especially species considered of difficult control such as *Conyza bonariensis*. Reports on emergence of resistant biotypes of this species to the Glyphosate herbicide already exist. The objective of this work was to investigate alternative ways of controlling *Conyza bonariensis* resistant to Glyphosate that establishes as an infesting species at pre-sowing of soybean crops. The experiment was carried out in the state of Paraná (southern Brazil), using a randomized complete block design, with four replications. Herbicide application was carried out when *Conyza bonariensis* was 30cm high. Herbicide treatments (kg ha⁻¹) were: Glyphosate (1,424 and 5,696), 2,4-D (1,003 and 1,338), Glyphosate 2,4-D (1,424 1,003 and 1,424 1,338), Glyphosate Cloransulam (1,424 0,035), Glyphosate 2,4-D Diclosulam (1,424 0,669 0,025 and 1,424 1,003 0,025), Glyphosate 2,4-D Flumetsulam (1,424 1,003 0,139), Glyphosate Chlorimuron (1,424 0,012), Glyphosate Flumioxazin (1,424 0,040), Glyphosate Carfentrazone (1,424 0,020) and a check without control. The isolated application of the herbicides Glyphosate and 2,4-D and associations of Glyphosate Carfentrazone, Glyphosate Flumioxazin, Glyphosate Cloransulam, Glyphosate Chlorimuron were not effective for controlling *Conyza bonariensis* characterized as resistant to Glyphosate. Treatments that were effective in controlling *Conyza bonariensis* were associations of Glyphosate 2,4-D (1,424 1,338), Glyphosate 2,4-D Diclosulam (1,424 0,669 0,025 and 1,424 1,003 0,025), and Glyphosate 2,4-D Flumetsulam (1,424 1,003 0,139).

86. Nucleotide Substitutions at the Acetyl Coenzyme A Carboxylase Gene Associated to Resistance Herbicide in Chilean Biotypes of *Lolium multiflorum* and *L. rigidum*. Rafael Galdames¹, Jorge Díaz¹, Juan Pedro Ruiz-Santaela², Nelson Espinoza¹, Antonio Franco², Rafael De Prado²; ¹INIA-Carillanca, Temuco, Araucania, Chile; ²Universidad de Córdoba, Córdoba, Spain

Aryloxyphenoxypropionates (APPs) and cyclohexanediones (CHDs) represent two important classes of selective herbicides often used to control grass weeds. These herbicides inhibit the plastid form of the enzyme acetyl-CoA carboxylase affecting the fatty acid biosynthetic pathway. Over the last years, the number of weed species resistant to herbicides has increased significantly in the world. In Chile, enhanced tolerance to effective herbicide to *L. multiflorum* (ryegrass), *L. rigidum* (rigid ryegrass),

Avena fatua (wild oat) and *Cynosorus echinatus* (crested dogtailgrass) populations has been detected since year 2000. For these four grass weeds, 45 resistance biotypes have been confirmed by different bioassays.

We investigated the molecular basis of resistance to ACCase-inhibiting herbicides (diclofop and clodinafop) in five ryegrass biotypes (*L. multiflorum* and *L. rigidum*) from southern Chile. Total DNA was extracted from leaf tissue from individual plants. Two pairs of primers were designed to encompass two parts of the CT domain of the plastid ACCase. Amplicons of 600 bp and 590 bp which allow to include the total nucleotide substitutions involved in resistance to both CDH and APP herbicides, were obtained from 2 plants on each biotype. The fragments were purified using a MinElute PCR Purification Kit (Quiagen) and then directly sequenced on both strands using the same pairs of primers. The alignments were performed using the Megalign module of Lasergene software (DNASTAR, 2006). These were compared with sequences of ryegrass accessions resistant and non resistant available in the NCBI gene bank. Nucleotide numbering to *A. myosuroides* chloroplastic ACCase coding sequence (GenBank accession AJ310767) was used to identify the nucleotide position. *L. multiflorum* biotypes showed nucleotides changes in the position 5341, 6079 and 6233 that led to amino acids substitutions in the positions 1781, 2027 and 2078. In *L. rigidum*, changes in the position 5341 and 6121 produced amino acids substitutions in the positions 2041 and 2078.

Additionally, data of activity in vitro of ACCase with crude extracts (acid diclofop) assessed on each biotype, confirming the relationship between the identified mutation and the insensibility to ACCase enzyme.

87. Metamitron-Resistant *Chenopodium album* L. from Sugar Beet: Cross-Resistance Profile. Tania De Marez¹, Els Mechant¹, Olivier Hermann², Robert Bulcke¹; ¹Ghent University, Gent, O-VI, Belgium; ²KBIVB, Tienen, Belgium

In several European countries, sugar beet growers are being confronted with unsatisfactory control of *Chenopodium album* L. (fat hen), a key weed in *Beta vulgaris* L. (sugar beet) and various other crops in the rotation. Resistance to metamitron, a key herbicide in the modern low rate weed control programs in *B. vulgaris*, was found in several 'suspected' *C. album* populations collected from *B. vulgaris* fields in Belgium, France and Sweden. So far, in metamitron-resistant (Rm) *C. album* collected from *B. vulgaris* fields, two *psbA* mutations have been identified: Ser-264-Gly (Belgian and French populations) and Ala-251-Val (Swedish population).

Since cross-resistance, particularly negative cross-resistance or reversed resistance, is known to play a major role in resistance management, it is important to define the cross-resistance profile of the Rm *C. album* biotypes.

Therefore, in 2007, several greenhouse bioassays were conducted. Selected 'suspected' populations from *B. vulgaris* fields with unacceptable control of *C. album* were subjected to a range of herbicides used in *B. vulgaris* and/or in rotational crops and their response was compared to that of reference populations. The 'suspected' populations were confirmed to be Rm and they had the Ser-264-Gly mutation. Herbicides from different chemical families representing different modes of action, were applied pre-plant incorporated into the soil or post-emergence. Two to four weeks after treatment the number of plants in each pot were counted and the foliage fresh weight per pot was measured.

The tested Rm *C. album* populations responded comparably to the herbicides studied. Negative cross-resistance was found for acetonitrile and clomazone (both HRAC-group F3 herbicides). This implies that these herbicides, with a mode of action different from that of metamitron and atrazine (both C1), may have potential to control the Rm *C. album* populations in *B. vulgaris* (clomazone) and/or in some other crops (both herbicides). The Rm populations and the atrazine-resistant reference were slightly less sensitive to linuron (C2) and dimethenamid-P (K3) than the sensitive references. However, both herbicides still reduced foliage fresh weight significantly. The Rm *C. album* populations examined also expressed sensitivity to bentazon (C3), pendimethalin (K1) and pethoxamid (K3). These herbicides still have a potential to control the Rm *C. album*.

Further bioassays will be conducted to determine the resistance-index of the herbicides with (negative) cross-resistance and more herbicides used in *B. vulgaris* and/or in other crops in the rotation will be examined.

88. Efficacy of Herbicides in Winter Wheat to Control Resistance *Centaurea cyanus* in South-West Poland. Henryka Rola¹, Katarzyna Marczevska¹; ¹Institute of Soil Science and Plant Cultivation, Wroclaw, Poland

The problem of resistance to sulfonylurea herbicides has been confirmed since 2000 (ROLA and MARCZEWSKA 2002). Resistance biotest of *Centaurea cyanus* biotypes were conducted in the greenhouse conditions. Chlorosulfuron was applied at the four-leaf stage of the development at rates ranging from 11,3 to 360 g/ha. In confirmation of resistance to chlorosulfuron as identified in biological test, and the chemical analyses (HPLC) were performed. The chemical analyses investigated the influence of different doses of chlorosulfuron on free amino acids content in the aboveground part of resistant and susceptible *Centaurea cyanus*. In the resistant biotype followed the increase of valine, leucine plus isoleucine concentration in comparison with untreated plants and with those susceptible to chlorosulfuron biotype. The field experiments were carried out in 2001-2004. The aim of the research was to establish such chlorosulfuron dose and another herbicides that

would be effective for *Centaurea cyanus* and not be phytotoxic for winter wheat. The experiments were conducted using randomized blocks method with 3 reapplications. Chlorosulfuron was applied at rates ranging from 1 to 4,5 times higher than recommend field dose (11,25-67,5g a.s./ha) and another herbicides in recommend field dose.

Conclusions

Chlorosulfuron was a very selective for winter wheat as an active ingredient. The application of 67.5 g/ha of the herbicide was not harmful for growth and yielding of winter wheat. Unfortunately, even this dose of the herbicide was ineffective in control *Centaurea cyanus*. The higher effectiveness of the weed control was observed after use of: 2,4-D tank mixture with fluroxypyr flurosulam, metosulam tank mixture with MCPA dicamba, mecoprop, also chlortoluron and clopyralid.

89. Clomazone Resistance in Late Watergrass (*Echinochloa phyllopogon*): Role of Herbicide Metabolism. Hagai Yasuor¹, Albert Fischer¹; ¹University of California, Davis, Davis, California, United States of America

Echinochloa phyllopogon (late watergrass, LWG) is a major weed of California rice. Since populations of this weed with known metabolically-based resistance to multiple herbicides have been poorly controlled by clomazone, we conducted cross-resistance studies, assessed the involvement of enhanced P450 detoxification or of possible photooxidative stress tolerance. Low-level cross-resistance to clomazone (R/S near 2.0) was found in several LWG biotypes with known resistance to multiple herbicides. A resistant biotype (R) showed similar R/S level for clomazone as for its active metabolite, 5-ketoclomazone, thus resistance should relate to a differential ability to cope with 5-ketoclomazone. Adding a P450 inhibitor (disulfoton or ABT) to clomazone treatments protected both R and S plants from injury. Disulfoton protected 5-ketoclomazone-treated S plants from injury but did not protect R plants, suggesting that P450-mediated metabolism of this compound may produce yet other herbicidally-active intermediates in S plants, and that these toxic 5-ketoclomazone metabolites are either not formed or are rapidly detoxified by R plants. ABT did not significantly synergize 5-ketoclomazone toxicity to R plants, suggesting resistance to clomazone involves non-P450-dependent mechanisms. HPLC analysis of ¹⁴C-clomazone-treated plants showed that both biotypes metabolized clomazone similarly. Clomazone, 5-ketoclomazone, and an unknown polar metabolite that eluted 10 min before clomazone were the main labeled compounds eluted. In addition, 30% of the radioactivity probably corresponded to sugar conjugates. Disulfoton reduced the proportion of conjugates and increased parent compound and unknown metabolites contents; 5-ketoclomazone content was unchanged. These results suggested that disulfoton blocked P450-mediated

clomazone metabolism and bioactivation in these R and S plants. Clomazone-resistant plants were also less susceptible to paraquat. LC-MS metabolic profiling showed significantly different profiles, before clomazone (50 µM) treatment and by 48 and 96 HAT. In summary, clomazone is converted to a more active in both R and S LWG. Both biotypes degrade clomazone similarly. However, metabolic profiling shows distinct differences between biotypes, and these may also differ in responses to photooxidative stress. We are in the process of identifying these metabolites in order to detect pathway differences between biotypes that could be related to clomazone and herbicide resistance in R LWG.

90. Can Clearfield Wheat Control *Lolium* Spp with Multiple Resistance?. Hugo Enrique Cruz-Hipólito¹, Antonia Rojano¹, Nelson Espinoza², Maria Dolores Osuna Ruíz³, Jorge Diaz², Rafael De Prado¹; ¹Universidad de Córdoba, Córdoba, Spain; ²INIA. Carillanca., Temuco, Chile; ³Finca La Orden, Badajoz, Spain

Lolium rigidum and *Lolium multiflorum* are the most injurious weed species in winter wheat world-wide. Their chemical control is currently becoming increasingly difficult as they have a cross and multiple resistance to a wide range of selective and non selective herbicides in winter wheat. At the beginning of this decade, the firm BASF presented different varieties of wheat resistant to imidazolinones (clearfield), a group of herbicides belonging to ALS-inhibitors (acetolactate synthase, EC 4.1.3.18), the first enzyme involved in the synthesis of ramified amino acids, valine, leucine and isoleucine, which are essential for the synthesis of proteins in plants. Clearfield was developed by means of classic plant improvement methods, in which there is no insertion of imidazolinone-resistant genes, so that they are not considered as being genetically modified organisms (GMO). The herbicide most used is imazamox, which is absorbed via leaf and/or root and travels through the plants. Imazamox effectively controls gramineae like *Lolium* spp, *Bromus* spp, *Phalaris* spp, *Alopecurus myosuroides*, etc, and dicotyledons such as *Amaranthus* spp, *Abutilon theophrasti*, *Chenopodium album*, etc.

The objective of this work was the use of imazamox-resistant wheat (Clearfield) in the control of five populations of *Lolium* spp. with a resistance to diclofop-methyl, iodosulfuron, imazamox and glyphosate.

The results obtained show that imazamox-resistant clearfield wheat is an excellent tool for the control of herbicide-resistant gramineae with different modes of action to the inhibitors of acetolactate synthase (ALS, EC 4.1.3.18). However, the selection of biotypes of *Lolium multiflorum* and *L. rigidum* resistant to herbicides of the sulphonylurea group, and, to a lesser degree, to imidazolinones, will create a control problem in the future.

It is of prime importance for the farmer to know about herbicide-resistant biotypes, as well as the mechanisms implicated, before using this new chemical control option. Thus, farmers should follow the recommendations made in Integrated Weed Management (IWM), in order to forecast and/or delay the appearance of herbicide-resistant biotypes.

91. Response of Somaclones of Soybean to Imazaquin Following In vitro Selection for Imazaquin Resistance. Mohammad Reza Tareghyan¹; ¹University of Birjand, Birjand, Southern Korasan, Iran

Tissue culture derived plants and their progeny show an increased level of variation in morphological and physiological parameters compared with parent plants. This somaclonal variation has been screened for increased resistance to pest, disease, salt and herbicide using in vivo and in vitro screening methods. Soybean shows a genotype dependent level of resistance to the imazaquin, one of the imidazolinone herbicides and one which acts by inhibition of the acetolactate synthase (ALS), the first enzyme common to the biosynthesis of the branched-chain amino acids, valine, leucine and isoleucine. In order to increase the selectivity of the herbicide in this crop, organogenic tissues of soybean cultivars, Century 84, Eglin, Dakir and Visir were exposed to an EC90 (2 mg a.i./L) concentration of imazaquin in vitro. Surviving individuals were allowed to set the seed (R1 progeny) and these were bulked to provide second generation (R2 progeny). The herbicide resistance was assessed in vivo using seedlings of R2 progeny exposed in the hydroponic culture at an EC50 (2.5 mg a.i./L) concentration of imazaquin for 10 days. Then the root length and the shoot dry weight measured. The herbicide resistance of plants was also assessed in vitro by exposing callus and cell suspensions initiated from leaves of parent plants and somaclone progeny in media containing imazaquin at an EC50 (1.5 mg a.i./L) concentration. Growth analysis of the R2 and parent plant seedlings showed that in the presence of imazaquin, R2 seedlings were up to 3-fold resistant in comparison with parent plant seedlings. Tissue cultures of R2 plants were also more resistant than their parent plants. Biochemical analysis of selected somaclones was not due to an alteration in the ALS enzyme. It was also shown that there was no association between herbicide inhibitory effects and synthesis of three amino acids, valine leucine and isoleucine. Therefore the increased resistance might be due either to a modification to uptake and translocation of the herbicide or to the mechanism of detoxification. However results from the in vitro selected somaclone progeny showed that there was the potential for increasing the resistance of soybean cultivars to imazaquin.

92. **An Alanine-to-Valine Mutation in Triazinone-Resistant *Chenopodium album* L.** Els Mechant¹, Tania De Marez¹, Olivier Hermann², Robert Bulcke¹; ¹Ghent University, Gent, Oost-Vlaanderen, Belgium; ²KBIVB-IRBAB, Tienen, Vlaams-Brabant, Belgium

The triazinones metamitron and metribuzin are inhibitors of photosynthesis at Photosystem (PS) II (HRAC Group C1). Metamitron is a key herbicide in European *Beta vulgaris* L. (sugar beet) whereas metribuzin is selective to a variety of crops. In *Chenopodium album* L. (fat hen), a cosmopolitan weed species, target site resistance to atrazine accompanied by target site cross resistance to triazinones has been reported previously. The resistance is due to a mutation in the *psbA* gene that is responsible for a serine264-to-glycine substitution within the QB binding site of the D1 protein. In recent years, *B. vulgaris* growers in several European countries are experiencing problems with the control of *C. album*.

Greenhouse bioassays revealed resistance to metamitron in 'suspected' *C. album* populations from Belgium, France and Sweden. All Belgian and French metamitron-resistant populations are also resistant to atrazine and metribuzin. However, the Swedish populations which are highly resistant to metamitron, are also resistant to metribuzin but sensitive to atrazine.

DNA sequence analysis of the *psbA* gene encoding the D1 protein of PS II, showed the previously known serine264-to-glycine substitution in a selection of the Belgian biotypes. In a Swedish biotype displaying the aberrant resistance profile, an other *psbA* point mutation was identified: alanine-to-valine at position 251. As this mutation has been previously reported only in unicellular green algae such as *Chlamydomonas* and as a double mutation (alanine251-to-valine and valine219-to-isoleucine) in cell cultures of *Chenopodium rubrum* L., this is the first report of a higher plant from the field with this substitution at position 251 and resistance to PS II inhibitors.

The occurrence of *C. album* biotypes with resistance to metamitron but different cross resistance profiles could raise the question which herbicide(s) did select for the resistance. In Sweden, having no history of atrazine use, the triazinones metamitron, used in *B. vulgaris*, and metribuzin, used in rotational *Solanum tuberosum* L. (potato), could have selected for resistance. In Belgium three different herbicides and/or crop rotations could have contributed to resistance development: (1) a record of continuous use of atrazine in *Zea mays* L. (maize) resulting in triazine-resistant *C. album* in the seedbank, (2) metamitron use in *B. vulgaris* and (3) metribuzin use in *S. tuberosum*.

93. **Glyphosate-Resistant Weeds in Europe: A Review.** Hugo Enrique Cruz-Hipólito¹, Christian Gauvrit², José Urbano³, Ribas Vidal⁴, Rafael De Prado¹; ¹Universidad

de Córdoba, Córdoba, Spain; ²INRA, BP 86510, Dijon, France; ³Seville University, Sevilla, Spain; ⁴Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil

Glyphosate has become the world's most widely used herbicide, with many uses in agricultural, urban and natural ecosystems. Glyphosate is also globally used for broad-spectrum weed control in cover crops in olive and citrus orchards and in vineyards, etc. Despite persistent use on the same crop fields, there are only a few reports on the evolution of a glyphosate-resistant weed population in Europe, and this review focuses precisely on that evolution.

The first case of glyphosate resistance was confirmed in five populations of *Conyza bonariensis* found in olive groves in southern Spain in 2003. The glyphosate rates required to control resistant populations were 7 to 10 times higher than those needed to control the susceptible populations. In 2007, new populations of resistant *Conyza canadensis* were found in Ecija and Marchena (Southern Spain) and in Prague-Bubny (Czech Republic). In both cases, the resistant biotypes were 14 times more tolerant to glyphosate than the susceptible ones. The recent appearance of glyphosate-resistant *Lolium rigidum* in France (2005) in vineyards, in eastern Spain (2006) in citrus orchards and *Lolium multiflorum* in southern Spain (2006) in olive groves, are of major concern. In all those cases, the *Lolium* spp were not controlled with field dose rates (2,880 g a.i./ha) of glyphosate. The evolution of glyphosate resistance becomes apparent in those agroecosystems in which the herbicide exerts a high and continuous selection pressure on weeds. However, glyphosate-resistant weeds are not yet a problem in many parts of Europe, and lessons can be learnt and actions taken to achieve glyphosate sustainability.

94. **Modeling Analysis of Herbicide Dose-Response Relationships: A New Proposal.** Daniela Neves¹, Durval Dourado-Neto¹, Saul Carvalho¹, Bianca Martins¹, Pedro Christoffoleti¹; ¹University of Sao Paulo, Piracicaba, Sao Paulo, Brazil

The use of dose-response studies has become a crucial tool to confirm suspect cases of herbicide-resistant weeds. The main models used in these studies are the logistic or log-logistic ones. However, the estimate values from the observed ones do not describe, precisely, data as a biological factor of resistance and just represent a statistical adjustment. The dynamics of herbicide resistance evolution are governed by the biology of weedy plant species, considering the genetic resistance trait, the herbicide characteristics and its use. As a result, this dose-response herbicide resistance study, parameterized for biotypes of *Lolium multiflorum* resistant to glyphosate, was used as a basis to perform a new predictive model with the proposal to explore biological factors. With the

objective of modeling the data under the form of mathematical equations of prediction, for each growth stage of the biotypes, it was developed a representative model independently of the growth stage of the plant. This model assumes the hypothesis 1) for null dose ($x = 0$), the response variable of weed control will be null ($z = 0$) and 2) for the full control variable ($z = 100$), the dose of the herbicide is infinite ($x = \infty$). This fact restricts the estimative of control values superior to 100%, which would be biologically unviable, causing an overestimate of the observed data. The experiment layout was a randomized design with eight replications and the treatments were consequence of factorial scheme with two biotypes, nine increasing doses of glyphosate and four growth stages. The dependent variable analyzed was shoot biomass, as % of untreated control, at 21 days after treatment. The first analysis done was a factorial analysis of variance followed by non-linear regression that showed a lowest error mean of square than other usual non-linear regression used for these types of studies. The variance for the untreated plants is higher than the variance for plants receiving high doses, this pattern also was reflected in this new proposal of predicting mathematic model. The estimate parameters with 95% confidence limits showed accuracy. Based on these estimate parameter we concluded that the model $z = 100 \cdot C \cdot (100 / ((1 + ((ax)^b)^c))$, where z represents the percentage of control at herbicide rate x and a, b, c are empiric parameters, provide a good biological fit to the data. The use of this new proposal does not only benefits weed scientists in terms of designing more effective studies of resistance to herbicides, but can also assist farmers, permitting them to adopt the correct management and to quantify the occurrence of resistance cases.

95. Resistance Relationship of Glyphosate Rate and *Lolium multiflorum* Growth States: A 3D Model View. Daniela Neves¹, Durval Dourado-Neto¹, Saul Carvalho¹, Bianca Martins¹, Rafael De Prado², Pedro Christoffoleti¹; ¹University of Sao Paulo, Piracicaba, Sao Paulo, Brazil; ²University of Cordoba, Cordoba, Andaluzia, Spain

Glyphosate is the most important non-selective, wide-spectrum herbicide used internationally. Evolved resistance to this herbicide has been reported in a few weed species, including *Lolium multiflorum* (Italian ryegrass). Dose-response experiments were developed with the objective of modeling the relation of susceptible (S) and resistant (R) biotype to glyphosate, independently, with two independent variables (rates of herbicide and plant growth stages), and then, accepting or rejecting the hypothesis of constancy of the LD50Resistant/Susceptible ratio among the different growth stages of the biotypes using the logistic non-linear regression. The experiment conducted was a randomized design with eight replications and the treatments were consequence of factorial scheme with two biotypes (resistant - R and susceptible - S), nine

increasing rates of glyphosate (0 to 2,304 g a.e. ha⁻¹) and four growth stages (0, 3, 7 and 11 number of tillers). The dependent variable analyzed was shoot biomass, as % of untreated control, at 21 days after treatment. The first analysis done was a factorial analysis of variance followed by non-linear regression with two independent variables. The non-linear model that provided a good description of the relationship among shoot biomass in each biotypes for doses of herbicide and growth stages, is $z = a / ((1 + ((x-b)/c)^2) * (1 + ((y-d)/c)^2))$, where z represents the shoot biomass (% of untreated control) at herbicide rate x ; y is the growth stages represented by number of tillers (Np) and a, b, c, d are empiric parameters. The parameters estimated with 95% confidence limits showed accuracy to provide a good biological fit to the data. It was observed R² values of 0.90 for R and 0.89 for S biotypes and a, b, c, d parameters of 200.23, 59.66, 323.92, 329.02 for R; 3453.03, -309.64, 72.91, 71.24 for S biotypes. For each biotype, there was a general decrease in relative shoot biomass in comparison to its respective untreated controls as glyphosate rate increased and growth stage decreased (LD50Resistant/Susceptible = $-0,0025Np^3 + 0,0704Np^2 - 0,517Np + 3,4594$; R² values of 1.0). It was observed LD50Resistant/Susceptible ratio values of 3.46, 2.47, 2.42, 2.91 for 0, 3, 7 and 11 Np, respectively. Those results represent a more effective study of resistance weed populations to herbicides, impacting in benefits for weed scientists and assist farmers to adopt correct management.

96. Effects of Landscape and Crop Management on Herbicide Resistance Evolution in *Echinochloa* spp. in California Rice Systems. Claudia Marchesi¹, Chris Greer¹, Marie Jasieniuk¹, Mick Canevary¹, Randall Mutters¹, Richard Plant¹, Albert Fischer¹; ¹UC Davis, Davis, CA, United States of America

Late watergrass (*Echinochloa phyllopogon*, LWG), early watergrass (*E. oryzoides*, EWG) and barnyardgrass (*E. crus-galli*, BYG) are the most competitive and difficult weeds to control in rice. Herbicide resistance in some of these species was confirmed in California in 1998. Resistance is the result of an evolutionary process in which preexisting mutants are allowed to proliferate under selection pressure. Selection pressure is determined by herbicide factors, weed characteristics and management factors. It is crucial to understand not only how resistance evolves but also how it spreads. Factors that shape the incidence, evolution and spread of herbicide resistance weeds can be associated with crop management and landscape properties.

Resistance of various ECH to herbicides with different modes of action has been reported in California. Further research has shown the prevalence of metabolic cross resistance in California watergrasses, which has evolved and spread differently for each species. Different studies have associated either the effects of diverse crop manage-

ment practices or the extent of gene flow with the temporal distribution of R biotypes. However, interactions between these driving factors also need to be considered. My objective is to develop an integrative study that establishes how interactions between crop management practices, landscape variables and mechanisms of resistance dispersal contribute towards defining the patterns of ECH resistance currently observed throughout the rice area in California. A downscaling approach from a regional scale using GIS will be used to investigate the complexity of the mentioned interactions.

The research involves a field survey and controlled environment studies. Geo-referenced seed samples representing populations of EWG, LWG or BYG, were taken from rice fields (U-shaped transect and problematic patches). Seed from each population along with known R and S controls are being screened for resistance against a thicarbamate, ACCase inhibitor and ALS inhibitor. Detailed field histories (herbicide use, water management and other rice cultural practices) are being collected via questionnaires. Molecular data from known R and S biotypes is available. Data will be subject to multivariate analysis to assess relationships between these variables and levels of herbicide resistance.

Preliminary data are quite interesting suggesting various levels of resistance, different for each ECH species. Establishing the relevance of management and landscape variables, and populations genetic structure will be crucial to explain such differences between species, and finally, appropriate management strategies could be suggested.

97. A Rapid Assay for Detection of ACCase-Inhibitor Resistance in Grass Weeds: *Avena sterilis*, *Lolium* spp. and *Phalaris paradoxa*. Alberto Collavo¹, Anna Frezza¹, Maurizio Sattin¹; ¹National Council of Research, Legnaro, Pafova, Italy

Detection of resistance with traditional whole plant herbicide tests is time-consuming and expensive. The objectives of the research were to develop a rapid, reliable and cheap method for detection of ACCase resistance in *Avena sterilis*, *Lolium* spp. and *Phalaris paradoxa*.

A susceptible population for each species, target site and metabolic resistant genotype, plus resistant populations of unknown mechanism, were tested in Petri dishes with concentrations discriminating susceptible from resistant populations and concentrations that mimic the field dose used in traditional whole plant herbicide tests. Herbicides used were clodinafop, pinoxaden, clethodim and sethoxydim. The approach differed with species: herbicides were diluted in agar and seedling survival was assessed for *Lolium* and *P. paradoxa*, while filter paper soaked with herbicides diluted in distilled water and the no. of seedlings with root length >5 mm was used to discriminate resistant from susceptible for *A. sterilis*. Specific experiments showed that the results of the quick test done using

commercial products and technical grades were well correlated.

Survival results obtained from Petri dish assays were compared with results from whole plant herbicide experiments using the same resistant and susceptible populations. The reliability has also been validated using other populations not included in the quick test experiments. The discriminating concentrations for *Lolium* spp. are clodinafop 1 µM, pinoxaden 0.2 µM, clethodim 0.2 µM and sethoxydim 0.1 µM; for *P. paradoxa*, clodinafop 0.1 µM, pinoxaden 0.05 µM and clethodim 0.1 µM; for *A. sterilis*, clodinafop 1 µM, pinoxaden 0.5 µM. Concentrations discriminating from weak to strong resistance in *Lolium* spp. are clodinafop 100 µM, pinoxaden >0.25 µM, clethodim >0.25 µM and sethoxydim 0.5 µM; for *P. paradoxa*, clodinafop 1 µM, pinoxaden 0.1 µM and clethodim 0.25 µM; for *A. sterilis*, clodinafop 5 µM, pinoxaden 1 µM.

The results from the quick test and the whole plant herbicide test are well correlated for pinoxaden and clodinafop, while clethodim and sethoxydim concentrations, used in the quick test experiments, well discriminate between susceptible and resistant seedlings, most likely selecting those plants with a target site resistance mechanism. The assay was revealed to be reliable with all three species in screening large numbers of samples compared to the costly and time-consuming whole plant herbicide experiment.

98. Characterization of the Biology and ALS-resistance in *Chrysanthemum coronarium* L. and *C. segetum* L. Inbar Greenspoon¹, Moshe Sibony¹, Lydia Quansah¹, Baruch Rubin¹; ¹Faculty of Agriculture, The Hebrew University of Jerusalem, Israel, Rehovot, Israel, Israel

Chrysanthemum coronarium (crown daisy) and *C. segetum* (corn marigold) are annual winter weeds, which severely infest arable crops. Misuse of acetolactate synthase (ALS) inhibitors in cereals resulted in the evolution of populations that are no longer controlled at the recommended rates. We investigated seed germination and dissemination characteristics of both species and the mechanisms involved in the ALS resistance. Both species are allogamous, with the ligulate seeds bigger and more dormant than tubular seeds. Corn marigold germinated better under light, short days and low temperatures (18°C/12°C), whereas crown daisy did not respond to photo- and thermo- period. Several biotypes of crown daisy are highly resistant (>45 folds) relative to the susceptible (S) biotype to sulfonylurea herbicides with cross-resistance to other ALS inhibitors. Corn marigold R plants survived up to 5 times the recommended rate (X) of sulfonylurea, whereas the S population hardly survived 0.5X rate. Alteration of the ALS gene was detected in crown daisy but not in corn marigold. In region 1 of R crown daisy, Pro197 was substituted to either Thr, Ser, or Arg in different

populations. In corn marigold, no mutations were found in all R plants examined indicating possible involvement of other resistance mechanism.

99. Control of Herbicide Resistant *Limncharis flava* (L.) Buchenau Using Herbicides Mixtures. Abdul Juraimi¹, Ismail Sahid², Azmi Man³, Erwan Shari⁴; ¹University of Putra Malaysia, Serdang, Selangor, Malaysia; ²Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia; ³MARDI Seberang Prai, Kepala Batas, Pulau Pinang, Malaysia; ⁴University Kebangsaan Malaysia, Bangi, Selangor, Malaysia

Limncharis flava (L.) Buchenau (Yellow bur head) is an important broadleaf weed in rice fields (Azmi 2003). This weed spreads throughout South East Asia especially in the rice crop (Azmi 2003). It has been reported resistance to 2,4-D and metsulfuron methyl in Indonesia and Malaysia respectively (Heap 2005). Herbicide mixture may help to prevent resistance problem as well as shifts in weed population which is always associated with the use of a single herbicide (Wrubel and Gressel 1994). Little study has been conducted to determine the effect of herbicide combination to control biotype resistant of *L. flava* in Malaysia. The purpose of this study was to determine the effect of bensulfuron-methyl, bentazon sodium/MCPA dimethyl, singly or in combination on resistant biotype of *L. flava*. A field experiment has been conducted in 2006 at weed experimental Plot, MARDI Stesyen, Seberang Prai, Penang, Malaysia to control herbicide resistance biotype of *Limncharis flava* (L.) Buchenau using bensulfuron-methyl and bentazon sodium/MCPA dimethyl. The 5 weeks old plants were treated with single herbicide or a combination of the two herbicides. The herbicide rates used were half of recommended rate, recommended rate and double recommended rate. The results shows that bentazon-sodium/MCPA dimethyl at the recommended (0.74 kg a.i/ha) or higher rates alone controlled biotype R of *L. flava* effectively. Bensulfuron-methyl alone at all rates did not control *L. flava*. Of all tank-mix combination treatments of bentazon sodium/MCPA dimethyl and bensulfuron-methyl, three antagonistic and six additive joint actions were observed.

100. Soil-Less Bioassays for Early Screening Resistance to Imazapyr in Sunflower (*Helianthus annuus* L.). Tatiana Vega¹, Gabriela Breccia¹, Graciela Nestares¹, Maria Mayor², Roxana Zorzoli³, Liliana Picardi³; ¹Fac. Cs. Agrarias - Universidad Nacional de Rosario, Rosario, Santa Fe, Argentina; ²Iowa State University, Ames, Iowa, United States of America; ³Universidad Nacional de Rosario, Rosario, Santa Fe, Argentina

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops worldwide. Broadleaf weeds are

known to cause considerable yield losses to sunflower production, hence, development of imidazolinone-resistant (IMI-R) cultivated sunflower represents a major step in advancing weed control in commercial hybrid production. Diagnostic tests that are rapid, accurate, cheap and that provide an indication of the likely effect of resistance on herbicide activity in the field are most useful for early selection of the herbicide resistance in sunflower breeding programs. The objective of this work was to develop a bioassay to evaluate the response of resistant, intermediate and susceptible sunflower inbred lines to imidazolinone herbicides, specifically imazapyr. Two tests were developed, in which seeds from three sunflower inbred lines differing in resistance to imidazolinones were germinated either on solid culture medium or placed in plastic pots filled with commercial perlite. The herbicide doses tested were 1.25 - 2.5 - 5 - 7.5 - 10 μ M. After 8 days of incubation under controlled conditions (25 °C with a 12-h photoperiod - 50 μ mol m⁻² s⁻¹) imazapyr resistance was assessed by visual inspection of root development. Root growth arrest was observed for the susceptible genotype for all doses of herbicide. The discriminating dose between intermediate and resistant genotypes was 10 μ M. Seedlings from the intermediate genotypes had reduced or no development of secondary root system while the resistant genotypes showed a root growth that did not differ from the control. The simple screening techniques described in the present study have proved to be useful in discriminating imidazolinone resistance levels at the seedling stage. These techniques presents potential to develop easy and efficient tools to identify IMI-R genotypes from large populations within a short period of time and also a limited space.

101. Are Non Target-Site Herbicide Resistance and Environmental Stress Tolerance Related? Albert Fischer¹, Danijela Pavlovic², Hagai Yasuor¹, Aldo Merotto, Jr³, Sava Vrbnicanin⁴, Dragana Bozic⁴; ¹University of California-Davis, Davis, California, United States of America; ²Institute for Plant Protection and Environment, Belgrade, Yugoslavia; ³Universidade Federal Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil; ⁴University of Belgrade, Belgrade, Yugoslavia

Echinochloa phyllopogon represents one of the worst herbicide resistance cases in a major crop weed and seriously compromises rice production in California. Low-level resistance to atrazine in *Chenopodium album* L. was recently documented in Serbia. Here we discuss possible commonalities between both situations: a) non target-site (NTS) mechanisms of herbicide resistance in *E. phyllopogon* from California rice fields, b) resistance to ROS (reactive oxygen species)-related herbicides in *E. phyllopogon* and *C. album*, and c) a hypothesis regarding stress tolerance and NTS resistance with new implications for herbicide-resistance management. Experimental procedures involved plant growth analysis, 14C-herbicide

uptake, whole-plant dose-response, target-site enzyme (ALS, ACCase) activity, herbicide metabolism using cytochrome-P450 (P450) inhibitors, P450 contents and activity assays, metabolic profiles and metabolomics. The spread of R *E. phyllopogon* in CA was studied using AFLP markers. Leaf pigment and chlorophyll fluorescence (Fv/Fm) measurements assessed resistance to photooxidant-generating herbicides. Resistance in *E. phyllopogon* occurs simultaneously for several thiocarbamate, ACCase and ALS inhibitors. These R biotypes also exhibit enhanced submergence tolerance, low-level clomazone resistance, and low paraquat sensitivity. Moisture stress tolerance and low atrazine sensitivity was documented in a *C. album* biotype surviving in Serbian atrazine-treated corn fields. Submergence and moisture stresses can cause photooxidation damage to plants. These multifactorial NTS herbicide resistances result from enhanced detoxification and possibly other mechanisms. Chloroplast photoprotective systems and stress-inducible detoxifying enzymes can confer cross-protection to both environmental and xenobiotic photooxidative stresses. If these complex NTS resistances result from a general up-regulation of stress tolerance responses in biotypes adapted to various environmental stresses, weed management in stressful environments should emphasize strategies to delay NTS resistance evolution. Conversely, selection for certain NTS resistance mechanisms could result in plants with increased stress tolerance and fitness levels.

102. Evaluation the Efficacy of some Different Mode of Action Herbicides for Control the Susceptible and Resistant Canarygrass (*Phalaris* spp.) Biotypes to Clodinafop-Propargyl. Javid Gherekhloo¹, Eskandar Zand², Rafael De Prado³; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan, Iran; ²Plant Protection Research Institute, Tehran, Iran; ³Universidad De Cordoba, Cordoba, Spain

To study the efficacy of some herbicides with different mode of actions to control the susceptible and resistant *P. minor*, *P. paradoxa* and *P. brachystachy* biotypes to clodinafop-propargyl, three experiments were conducted under controlled conditions in the greenhouse of Iranian Plant Protection Research Institute, Tehran. In each experiment, resistant and susceptible biotypes were sprayed separately with 19 herbicide treatments. The applied herbicides were 10 ACCase inhibitors, 6 Acetolactate Synthase (ALS) inhibitors, prosulfocarb, flamprop-M-isopropyl, isoproturon plus diflufenican. Four weeks after spraying, the aerial parts of living plants were harvested, fresh and dry weights measured and were expressed as percentage of the untreated. Results showed that the susceptible biotypes of *P. minor* were effectively controlled by clodinafop propargyl and pinoxaden while pinoxaden and cycloxydim were the best options to control the resistant biotypes of *P. minor*. Among ALS inhibitors, iodosulfuron plus mesosulfuron controlled susceptible and

resistant biotypes of *P. minor* effectively and semi-satisfactory, respectively. Iodosulfuron plus mesosulfuron and sulfosulfuron plus metsulfuron dramatically reduced the fresh weight of individual plants compare to control so that the plants were not damaging any more. Among the other herbicides, isoproturon plus diflufenican controlled the resistant and susceptible biotypes very effectively and semi-satisfactory, respectively.

103. Target Site Mutations in the Acetolactate Synthase (ALS) Gene and Single Nucleotide Polymorphism (SNP) Genotyping in ALS Inhibitor-Resistant *Kochia scoparia*. Suzanne Warwick¹, Renlin Xu¹, Connie Sauder¹, Hugh Beckie¹; ¹Agriculture and Agri-Food Canada (AAFC), Ottawa, Ontario, Canada

Kochia scoparia (L.) Schrad. [kochia], an introduced annual, is an abundant agricultural weed and is reported to have one of the highest rates of spread of alien weeds in western Canada and the United States. Recent Canadian reports indicate widespread, broad cross-resistance to acetolactate synthase (ALS)-inhibitor herbicides in over 90% of *K. scoparia* populations surveyed. The molecular basis for ALS-inhibitor resistance is unknown for Canadian populations, and was determined in this study for six susceptible (HS) and 24 resistant (HR) *K. scoparia* populations from western Canada, three from Alberta (AB), three from Manitoba (MB) and 18 from Saskatchewan (SK). HR plants survived spray application of the ALS-inhibitor herbicide thifensulfuron:tribenuron mixture in the greenhouse. Most of the HR populations were heterogeneous and contained both HR and HS individuals. The molecular basis for resistance was determined in 273 HR individuals by sequencing the ALS gene (2270 bp) and/or conducting a TaqMAN genotyping assay developed in this study using real time PCR for single nucleotide polymorphism (SNP) 1709, where a G to T substitution resulted in a Leu for Trp substitution at amino acid position 574 (Trp 574Leu mutation). A total of 16 SNPs were identified in the ALS sequences (0.7% polymorphism), 5 of which resulted in amino acid changes that confer resistance to ALS-inhibiting herbicides. The SNPs correspond to three target-site mutations: Pro197 [SNPs 565 and 566], Asp376 [SNP 1116] and Trp574 [SNPs 1708 and 1709]. The Trp574Leu mutation was predominant [189 HR plants]. The next most common mutation was the highly-variable residue Pro197 [44 HR plants] with substitution by one of nine amino acids. The least frequent were Asp376Glu [9 plants] and Trp574Arg [3 plant] substitutions. The presence of two ALS target-site mutations was found in 30 individual plants, the first report from field-selected weed populations. These include combinations Pro197 + Trp574 [23 plants] and Pro197 + Asp376 [7 plants]. Pro197, Asp376 and Trp574 mutations and both combinations were detected in individual HR plants from all three western provinces. These results

suggest multiple-founding events for HR *Kochia scoparia* populations in western Canada.

104. Differential Tolerance to Diclofop-Methyl in Three *Lolium* Species from Chile. Hugo Enrique Cruz-Hipólito¹, Daniel Gil¹, Ribas Vidal², Nelson Espinoza³, Rafael De Prado¹; ¹Universidad de Córdoba, Córdoba, Spain; ²UFGRS, Porto Alegre, Porto Alegre, Brazil; ³INIA Carillanca, Temuco, Chile

Lolium is one of the most important genera with herbicide resistance in the world. Plants from three different *Lolium* species (*Lolium perenne*, *Lolium rigidum* and *Lolium multiflorum*) originated from Chile had demonstrated different degrees of resistance. The objectives of this study are to evaluate the level of diclofop-resistance in those three species and to determine the resistance mechanism. Four experiments were conducted to reach the objectives. Petri dish seed bioassays were developed to determine EC50 values (dose that reduces 50% of the plumule of the plant). Dose-response assays using whole plants and diclofop concentrations from 0 up to 500 g ha⁻¹ to yield ED50 values (herbicide dose that reduces fresh weight to 50%). Seed germination studies using ABT (aminobenzotriazole, cytochrome P450 inhibitor), diclofop, and diclofop+ABT. ACCase enzyme bioassays (I50, herbicide concentration for 50% ACCase inhibition). Resistant biotypes were compared with each susceptible equivalent. Petri dish bioassay confirmed the resistant behavior of suspected compared to susceptible biotypes, with resistant factors (RF) of 1.5 for *L. perenne*, 2.9 for *L. rigidum* and 6.8 for *L. multiflorum*. RF in whole plant dose-response assay was 2.0 for *L. rigidum*, 6.2 for *L. perenne* and 15.4 for *L. multiflorum*. Seed germination with ABT evidenced that metabolism is not a resistance mechanism. ACCase bioassay confirmed resistance in all biotypes studied, yielding RF of 2.5 for *L. rigidum* and 6.3 for both *L. perenne* and *L. multiflorum*. These results evidenced that insensible ACCase to diclofop is the mechanism of resistance.

105. Evaluation of Resistance to Diclofop-Methyl, Clodinafop Propargyl Herbicides in *Phalaris minor* Populations from Iran. Javid Gharekhloo¹, Mohammad Rashed Mohassel¹, Mehdi Nassiri Mahallati¹, Eskandar Zand², Ali Ghanbari¹, Rafael De Prado³, Maria Osuna Ruiz⁴; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan Razavi, Iran; ²Plant Protection Research Institute, Tehran, Iran; ³Universidad de Córdoba, Córdoba, Spain; ⁴Finca La Orden, Badajoz, Spain

Diclofop-methyl and clodinafop propargyl are two Aryloxyphenoxy propionate herbicides which are commonly used post emergence to control grass weeds such as *Avena* spp and *Phalaris* spp in wheat fields of Iran. In

recent years, we received many reports about poor control of *Phalaris minor* in wheat fields by aryloxyphenoxy propionate herbicides from two provinces of Iran where these graminicides had been applied for several years. Forty-four populations of little seed canary grass, sampled from wheat fields of Fars and Golestan provinces, were studied under controlled conditions in greenhouse and laboratory to confirm resistance to ACCase herbicides. Pre-screening experiment was done in greenhouse and the seedlings were sprayed with recommended dose of diclofop methyl. From this experiment, 9 populations including 8 potentially resistant and one susceptible were selected, and a dose response experiment with 9 doses was conducted to determine the resistance factor. The populations showed different resistance levels and these results suggest that the resistance in these biotypes are may be because of different mechanisms. Selected populations were also subjected to clodinafop propargyl in a dose-response assay. Results showed three populations have cross-resistance to clodinafop propargyl. Bioassay in Petridish confirmed the results of dose-response in greenhouse. But the resistant factors were higher than greenhouse assay for all populations and the two applied herbicides.

106. ALS Resistance in Polyploid Beggarticks (*Bidens subalternans*). Fabiane Lamego¹, Nilda Burgos², Ribas Vidal¹, Marites Sales², Vinod Shivrain²; ¹Federal University of Rio Grande do Sul - UFRGS, Porto Alegre, RS, Brazil; ²University of Arkansas, Fayetteville, AR, United States of America

Herbicides that target the acetolactate synthase (ALS) enzyme are among the most used in the world. Consequently, the highest number of resistant weeds has been selected by herbicides with this mode of action. Beggarticks is one of the most important weeds in conventional soybean systems in Brazil and has been reported as resistant to ALS inhibitors. The objectives of this research were to quantify levels of beggarticks resistance to ALS inhibitors, examine cross-resistance patterns and determine the molecular basis of resistance. Seeds of resistant (R) plants were collected from soybean fields in Goias, Brazil. The susceptible (S) seeds were collected from a field that has never been sprayed with ALS herbicides, in Rio Grande do Sul, Brazil. In vivo enzyme assays were conducted at the University of Arkansas to evaluate levels of resistance to ALS inhibitors in S and R beggarticks from Brazil. Total genomic DNA was extracted from individual R and S plants using a modified CTAB protocol. Primers pairs were designed to amplify the ALS gene in three regions: region 1 (C, A and D domains); region 2: (middle region) and region 3 (B and E domains). The sequences were assembled, aligned and analyzed. The R biotype showed 166-, 436- and 516-fold resistance to imazethapyr, cloransulam and pyriithiobac herbicides, respectively, relative to the S biotype. It also showed 17-

fold resistance to chlorimuron. Except for pyriproxyfen, all other herbicides are widely used in conventional soybean fields in Brazil. Therefore, this ALS-resistant beggartick population can no longer be controlled by other ALS inhibitors. The primer pairs used to amplify the first (C, A and D domains), second and third regions (B and E domains) of the ALS gene amplified fragments of 700 bp, 550 bp, and 490 bp, respectively. *B. subalternans* harbors, possibly, three alleles of the ALS gene which agrees with the polyploid nature of this species. A guanine to thiamine mutation encoded the Trp574Leu substitution in one allele of ALS in *B. subalternans*. Substitutions of Trp574 in other species result in high levels of resistance to sulfonylureas, imidazolinones, triazolopyrimidine sulfonanilides and pyrimidinyl thiobenzoates. The resistance known to be conferred by this mutation concurred with the resistance level observed in the enzyme assay. We conclude that a modified ALS enzyme with reduced herbicide-binding properties is partly responsible for cross-resistance to ALS inhibitor herbicides in *B. subalternans* R biotype from Goias, Brazil.

107. Simple to Complex: Modelling Pollen-Mediated Gene Flow. Hugh Beckie¹, Linda Hall²; ¹Agriculture and Agri-Food Canada, Saskatoon, SK, Canada; ²University of Alberta/Alberta Agriculture & Food, Edmonton, AB, Canada

Coexistence among transgenic and non-transgenic cropping systems and identity preservation at the field level are increasingly important issues in many countries. Different types of pollen-mediated gene flow models have been released during the past decade primarily as a decision-support tool to achieve the European Union (EU) 0.9% transgenic adventitious presence threshold for food and feed. We review such models for four crops - oilseed rape (*Brassica napus* L.), maize (*Zea mays* L.), wheat (*Triticum aestivum* L.), and creeping bentgrass (*Agrostis stolonifera* L.). Their strengths, weaknesses, relevance, and utility are examined. Many empirical models simulate gene flow well, although their utility is usually restricted by datasets with limited environmental variability or spatial scale. Experimental and modelling outcrossing studies often reveal that minimal or no isolation distance is required between commercial fields of transgenic pollen donor and non-transgenic receptor to meet the EU adventitious presence threshold. Development of predictive mechanistic models and simulation of transgene flow via insects and wind across agroecosystem landscapes are still in their infancy, although recent progress is promising.

108. Response of Imidazolinone-Resistant Winter Wheat Cultivars to Imazamox Rate and Application Timing. Traci Rauch¹, Donn Thill¹, Arron Carter², Robert Zemetra¹, Jennifer Hansen¹; ¹University of Idaho, Moscow, Idaho,

United States of America; ²Washington State University, Pullman, Washington, United States of America

Imidazolinone-resistant winter wheat is grown extensively throughout the Pacific Northwest region of the USA. Imazamox herbicide is applied to imidazolinone-resistant wheat to control many troublesome grass weeds including wild oat (*Avena fatua* L.), downy brome (*Bromus tectorum* L.), Italian ryegrass (*Lolium multiflorum* Lam.), and jointed goatgrass (*Aegilops cylindrica* Host). Much research has been done to determine the optimum rate and time of imazamox application for grass weed control in imazamox-resistant wheat. However, less is known about imazamox-resistant winter wheat cultivar response to different rates and times of imazamox application. The objective of these studies was to determine the response of imazamox-resistant winter wheat cultivars to different rates and times of application of imazamox. Studies were conducted in 2003 to 2005 near Genesee and Moscow, Idaho where imazamox was applied to 1 to 3 (early timing) and 3 to 7 tiller (late timing) wheat cultivars at 45 (within the labeled rate, 1X) and 90 (twice the labeled rate, 2X) g ai/ha. Two Lambert background cultivars consistently showed significantly less visible injury and no reduction in grain yield compared to the other cultivars tested. Additional studies were conducted in 2005 to 2007 near Grangeville, Idaho to further determine the effect of imazamox application time and rate on visible crop injury and yield of several imazamox-resistant wheat cultivars. Imazamox was applied to 1 to 3 and 3 to 5 tiller wheat at 52 (1X) and 104 (2X) g ai/ha. The experimental design was a split plot with four replications, where the main plots were four winter wheat cultivars, subplots were the two application times, and sub-subplots were the two herbicide rates and an untreated control. Data were pooled across years. Visible injury was greater at the early application time (11%) compared to the later application time (4%) 40 days after treatment (DAT) but not at 60 DAT. Visible injury at 60 DAT was significantly different among cultivars. The Lambert background cultivar (99-435) had 30% less visual injury than the Brundage 96 background cultivar (02-859), an advanced line in the University of Idaho winter wheat breeding program (00-475-2), and the standard IDO587. Averaged across evaluation times, visible injury was 74% greater at the 2X rate compared to the 1X rate. The early herbicide application time produced 12 and 18% less grain than the late application time and the untreated control, respectively. Wheat seed yield decreased with increasing herbicide rate. However, wheat seed yield did not differ among cultivars, but tended to be 8% greater for 99-435 when averaged across all cultivars.

109. Mechanism of Sulfonylurea Herbicide Resistance in Broadleaf Weed, *Monochoria korsakowii*. Park Tae Seon¹, Kang Chung Kil¹, So Jae Sung¹, Park Jae Eup¹;

¹Sedundong, Kwonseon-gu, Suwon, Republic of Korea, Suwon, Kyonggi, Korea, South

This experiment was carried out to study the resistant mechanism of sulfonylurea(SU) herbicides to *Monochoria korsakowii* occurring in the rice fields of Korea. The activity of acetolactate synthase(ALS), absorption and translocation of [14C]bensulfuron-methyl, and DNA sequence of ALS genes were studied. The apparent SU resistance to *Monochoria korsakowii* was confirmed in greenhouse tests. Fresh weight accumulation(GR50) in the resistant biotype was about 5- to 64-fold higher in the presence of six SU herbicides compared to the susceptible biotype. The ALS activity isolated from the resistant biotype to herbicides tested was less sensitive than that of susceptible biotype. The concentration of herbicide required for 50% inhibition of ALS activity(I50) was 14- to 76-fold higher as compared to the susceptible biotype. No differences were observed in the rates of [14C]bensulfuron uptake and translocation. However, the DNA sequence from the resistant biotype differed from that of the susceptible biotype by single nucleotide substitution at three amino acid each in the middle region excluding the ends of ALS genes. We found three point mutations causing substitution of serine for threonine at amino acid 168, arginine for histidine at amino acid 189, and an aspartic acid for phenylalanine at amino acid 247, respectively, in the resistant biotype.

110. Has Herbicide Resistance in *Lolium rigidum* Led to Higher Weed Densities in Australian Cropping Fields? Rick Llewellyn¹, Francis D'Emden², Mechelle Owen³, Stephen Powles³; ¹CSIRO Sustainable Ecosystems, Glen Osmond, SA, Australia; ²Department of Agriculture and Food Western Australia, Esperance, WA, Australia; ³University of Western Australia, Crawley, WA, Australia

The aim of this study was to test whether herbicide resistance in the most common weed in Australian cropping, annual ryegrass (*Lolium rigidum*), has led to increased densities of this weed in Western Australian (WA) cropping fields. In doing so, we explore whether the major costs incurred by herbicide resistance are likely to be associated with higher densities affecting crop yield, or whether the major farmer response to herbicide resistance is to maintain resistant weed populations at relatively low densities.

The study focused on the most common forms of resistance and multiple resistance in the region; ryegrass resistant to ACCase- and ALS-inhibiting herbicides. A total of 523 wheat crops were visited prior to harvest across 15 agronomic areas of the central WA cropping belt in 1998 and 2003. Ryegrass density was visually assessed and, where possible, seed was collected from the population. Ryegrass was found in 91% of the wheat crops visited and sampled populations were tested in the following year

for resistance to chlorsulfuron, sulfometuron, diclofop and clethodim.

The results showed that herbicide resistant ryegrass populations were generally being as well-controlled as susceptible populations. For both resistant and susceptible populations, the most common (mode) ryegrass density at harvest time was less than 1 plant/m², with a median of 1-10 plants/ m². Ryegrass density and multiple resistance status were found to be uncorrelated using non-parametric and ordered logit regression methods. Overall, 51% of ryegrass populations used in the analyses were resistant to either sulfonylurea or diclofop or both of these herbicides. Multiple resistance (i.e. resistance to both ACCase and ALS herbicides) was observed in 40% of populations.

The results indicate that grain growers are generally maintaining a low control threshold for weed density in fields with herbicide resistant ryegrass. By adopting alternative practices to maintain resistant ryegrass at relatively low levels they are avoiding high densities of ryegrass setting seed and high costs of reduced crop yield due to weed competition. Field and model-based weed management research that allow weed populations to continue over multiple seasons at very high densities are unlikely to reflect common grower practice.

111. An Overview of Resistant Weeds to Sulfonylurea Herbicides in Korea. Park Tae Seon¹, Park Jae Eup¹, Oh Se Mun¹; ¹Sedundong, Kwonseon-gu, Suwon, Republic of Korea, Suwon, Kyonggi, Korea, South

The widespread and diverse sulfonylurea(SU) resistance problem has found in Korea, where SU herbicides such as bensulfuron-methyl and pyrazosulfuron-ethyl have been used continuously since 1989. SU- resistant weeds in 6 annual weeds, *Monochoria korsakowii*, *Monochoria vaginalis*, *Lindernia dubia*, *Scirpus juncooides*, *Rotala indica* and *Cyperus difformis*, and 2 perennial weeds, *Scirpus planiculmis* and *Sagittaria pigmaea* as of 2004 have confirmed in paddy fields in Korea. The *M. vaginalis*, *S. juncooides* and *C. difformis* of SU herbicides resistant weeds have been rapidly spreading in Korea.. These SU-resistant weeds have been mainly identified in the western and southern areas practicing extensively in flooded direct-seeded rice, but they are expanding year by year, all over Korea. The herbicide concentrations required for 50% inhibition of fresh weight (GR50) to SU herbicides resistant biotype ranged from several tens-fold to several hundreds-fold higher than those of the susceptible biotype. The resistance to SU herbicides has been usually checked by herbicide treatment to seedlings. This treatment technique is time consuming and not very practical. Therefore we have developed rapid and practical diagnosis which allow easy detection of the SU-resistant weeds within a population. In the pot experiment under flooded direct-seeded rice and infant seedling culture with machine, several herbicides having different mechanisms of action from SU herbicides,

such as carfentrazone, pyrazolate, and thiobencarb had excellent controlling effects on the resistant weeds. The SU herbicides resistant weeds survived from the rice fields treated with SU herbicide-based mixtures could effectively be controlled by soil application of butachlor + pyrazolate and pyrazosulfuron + pyrazolate + simetryne GR or foliar application of the mixtures of bentazone SL and 2,4-D SL.

112. ACCase Mutations Confer ACCase Resistance in Two *Phalaris minor* Populations from Iran. Javid Gherekhloo¹, Mohammad Rashed Mohassel¹, Mehdi Nassiri Mahallati¹, Eskandar Zand², Ali Ghanbari¹, Maria Osuna Ruiz³, Juan Ruiz-Santalla⁴, Jean Wagner⁵, Rafael De Prado⁴; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan Razavi, Iran; ²Plant Protection Research Institute, Tehran, Iran; ³Finca La Orden, Badajoz, Spain; ⁴Universidad de Cordoba, Cordoba, Spain; ⁵University of Hoenheim, Hoenheim, Germany

Aryloxyphenoxy propionate herbicides (belonging to ACCase inhibitors group) are commonly used in post emergence to control grass weeds such as *Avena* spp and *Phalaris* spp in wheat and barely fields of Iran. Aryloxyphenoxy propionate-resistant *Phalaris minor* populations have appeared in recent years and now are present in some wheat fields in two provinces of Iran where these graminicides had been applied for several years.

The biochemical and molecular basis of resistance to ACCase inhibiting herbicides of fenoxaprop and diclofop was investigated in two resistant (AR and MR4) and one susceptible (S) populations of *Phalaris minor* from Iran. In vitro enzyme assays revealed a herbicide resistant ACCase enzyme in both R populations. Extracted ACCase enzyme from the shoots of AR and MR4 populations was highly resistant to fenoxaprop (7- and 14-fold, respectively) and to diclofop (6- and 16-fold, respectively). The ACCase gene fragment covering potential mutation sites in these populations was amplified, sequenced, and compared. Two ACCase mutations (tryptophan-2027-cysteine, and aspartate-2078-Gly) were identified in AR and MR4 populations, respectively.

113. Molecular Study of Resistance to Aryloxyphenoxypropionate Herbicides in Winter Wild Oat (*Avena ludoviciana* Durieu.) Populations from Iran. Javid Gherekhloo¹, Mehdi Rastgoo², Mohammad Rashed Mohassel¹, Mehdi Nassiri Mahallati¹, Eskandar Zand³, Rafael De Prado⁴; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan Razavi, Iran; ²Zanjan University, Zanjan, Iran; ³Plant Protection Research Institute, Tehran, Iran; ⁴Universidad de Cordoba, Cordoba, Spain

To molecular study of resistance to Aryloxyphenoxypropionate herbicides in winter wild oat (*Avena ludoviciana*

Durieu.) populations, an experiment was conducted in base of dCAPS method at Biotechnology Laboratory of Ferdowsi University of Mashhad in 2006. Thirty-eight suspected populations, sampled from Ahvaz (VR), Andimeshk (NR), Shush (SOR), Shushtar (STR), Ramhormoz (ZR), Susangerd (Dashte Azadegan) (AR), and Dezful (DR) cities of Khuzestan province-Iran, were sprayed with recommended dose of clodinafop propargyl, diclofop methyl, and fenoxaprop-P ethyl herbicides, separately. Survived populations were exposed to a dose-response assay in greenhouse with the mentioned herbicides. Then the populations with high resistance factor subjected to the molecular study. dCAPS method was carried out in three steps including PCR, enzyme digestion, and gel electrophoresis. Results showed that mutation at position 1781 of ACCase enzyme resulted in a high level of resistance in 10 wild oat populations to aryloxypropionate herbicides. Substitution of isoleucine by leucine at position 1781 of acetyl CoA carboxylase is a key point mutation conferring resistance to most ACCase inhibiting herbicides in grass weeds. Other mechanisms maybe are responsible for resistance in the rest of resistant populations in this study.

114. Herbicide Resistant Crops Versus Conventional Herbicide Cropping System in 2-Year and 3-Year Winter Wheat Rotations. Joan Campbell¹, Donald Thill¹; ¹University of Idaho, Moscow, ID, United States of America

An initial 7 year experiment was established in spring 1994 near Moscow, Idaho, USA to compare the effectiveness of different combinations of weed management practices on weed control in a winter wheat-spring barley-spring pea production system. Comparisons were among three factors: 3 year versus 2 year rotation, typical seeding rate versus 130% of typical, and three herbicide rates. Another long-term experiment was superimposed over the first experiment in 2001 to evaluate the effect of continuous herbicide resistant crop (HRC) technology on weed management. Plots with the established rotations were maintained. In the second experiment, canola, winter wheat and spring wheat are direct seeded and crop varieties are imidazolinone tolerant. Crop strips are 6 by 91 m long. Half the strip (46 m) is treated with imazamox and half is treated with a standard herbicide application that is used in non-HRC systems. The experimental design is a randomized complete block, split block with four replications. Main plots are a factorial of rotation and crop and sub-plots are herbicide system. Weeds are counted before herbicide application and weed biomass is taken from three 0.5 sq m areas within each experimental unit. Crops are harvested at maturity to determine yield. This experiment will continue until resistant weed populations develop. Total weed biomass is always greater with standard herbicide applications compared to imazamox applications. Weed biomass from 2002 to 2007 averaged 7, 6, and 4 g per sq m from standard applications

and 2, 1, and 1 g per sq m from imazamox applications for canola, winter wheat, and spring wheat, respectively. In the initial experiment, weed populations were higher in the 2 year rotation compared to the 3 year rotation. However, weed biomass has been variable between the 2 year and 3 year rotations in the consecutive experiment. This likely is due to lack of tillage and annual to twice annual use of glyphosate. Although no initial weeds have developed resistance, imidazolinone tolerant hard red spring wheat planted in 2003 volunteered in canola in 2004 and was not controlled in the HRC system. This wheat again was a volunteer problem in the 2005 HRC system soft white winter wheat. Judiciously used, HRC technology will improve weed control and possibly reduce selection of herbicide resistant weeds through reduced weed density.

115. Glyphosate-Resistant Crops as a Tool for Integrated Weed Management. Baruch Rubin¹, Gil Tsuk¹, Hagai Yasuor¹, Moshe Sibony¹; ¹Faculty of Agriculture, Hebrew University of Jerusalem, Rehovot, Israel

Weed management in cotton and other irrigated row crops is well established practice, including cultivation, pre- and post-emergence herbicides. However, long-term use of these practices contributed to the high infestation with troublesome weeds (e.g., *Cyperus rotundus*) that is not effectively controlled by the current practices, causing severe yield and quality losses. The role of genetically-modified glyphosate-resistant (Roundup Ready®, RR) crops as a component of *Cyperus rotundus* management was examined using DP5415RR cotton and DK44/45RR corn. Laboratory studies have shown that glyphosate applied on the leaves prevented tuber sprouting along the 'tuber chain'. In addition, the shading imposed by cotton and corn canopies severely affects tuber production. Glyphosate efficacy was examined in field experiments after application at different timing throughout the summer season, as compared to the common local practice of using residual herbicides ('commercial treatment'). In all examined sites glyphosate treatments provided better weed control than the 'commercial treatments' with the optimal application windows (early post and later on as a directed spray). A general decline in density of all weeds without any 'shift' toward a specific species was recorded in glyphosate-treated plots. The irrigation facilitated the emergence of a large proportion of the seedbank that was controlled by the herbicide. The soil moisture enhanced tuber sprouting that combined with the suppression imposed by the shading of the crop canopy and the impact of a timely application of glyphosate, provided excellent control of *Cyperus rotundus*. We concluded that a careful and rational introduction of RR crops such as cotton and corn into the crop rotation significantly improves on the current weed management practices and may become an ecologically sustainable, cost-effective and powerful tool for troublesome weed management.

116. New Highly Resistant Grasses in Specific Summer Cropping Systems and the Value of Sustainable Weed Management. Maurizio Sattin¹, Guido Pignata¹, Laura Scarabel¹; ¹CNR, Legnaro, Padova, Italy

Herbicides are essential tools for weed management in conventional agriculture, with acetolactate synthase (ALS) and acetyl-CoA carboxylase (ACCase) inhibitors being widely used. However, agronomic practices, especially the pattern and intensity of herbicide use, as well as the biological characteristics of weeds, have a strong impact on the evolving of herbicide resistant populations. Generally, a low diversity of agronomic practices in space and time and a high genetic variability of the weeds favour the evolution of resistance. Summer cropping systems in central-northern Italy do not usually have these characteristics, but the diversity and effectiveness of chemical weed control tools is sometimes limited by pedo-climatic conditions (e.g. organic soils). In these situations, three weed species have recently evolved a few populations resistant to ACCase inhibitors (*Sorghum halepense* and *Digitaria sanguinalis*) or to ALS inhibitors (*Echinochloa crus-galli*).

There are no published reports of *E. crus-galli* resistant to ALS, although one case from Serbia is included in Heap's database. Only two cases of ACCase resistance have been reported for *D. sanguinalis*, while a few cases of *S. halepense* resistant to ACCase inhibitors have been reported from the USA and one case from Israel.

Outdoor dose-response pot experiments proved that all populations, sampled in 2005 and 2006, are highly resistant to only one herbicide mode of action, with *D. sanguinalis* (one pop. infesting a soyabean field) showing a wide cross-resistance pattern to both FOPs and DIMS, while *S. halepense* (3 pops. infesting dicot crops) proved to be highly resistant to FOPs and weakly resistant to DIMS. *E. crus-galli* (4 pops. found in maize fields) showed a wide pattern of cross resistance to ALS inhibitors.

The high resistance levels indicate that altered target enzymes may be involved. Molecular analyses confirmed that in all three resistant populations of *S. halepense* a single nucleotide substitution (ATT to AAT) had occurred in the carboxyl transferase domain of the chloroplastic ACCase gene, conferring a change from the amino acid isoleucine to asparagine (at position 2041). Molecular characterisation is underway for the other two species.

Field records and pedo-climatic conditions of the fields infested with resistant populations indicate that these situations are related to weed control exclusively or predominantly done in post-emergence, i.e. where control of these grasses mostly relies on only one herbicide mode of action.

117. Herbicide Resistance to Photosystem-II Inhibitors in *Lolium multiflorum* in Oregon: Cross-Resistance Patterns and Investigation of the Mechanism of Resistance. Alejan-

dro Perez-Jones¹, Wilson Avila¹, Carol Mallory-Smith¹;
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The first resistant weed biotype to photosystem-II (PS-II) inhibitors was identified in 1970 for a simazine resistant biotype of *Senecio vulgaris*. Today, more than sixty species have evolved resistance to PS-II inhibitors worldwide, including Italian ryegrass (*Lolium multiflorum*) in Oregon. Diuron, a PS-II inhibitor, is widely used in Oregon to control Italian ryegrass and other winter annual weeds in perennial ryegrass (*L. perenne*) and in winter wheat. However, several populations of Italian ryegrass have evolved diuron resistance due to the continuous application of this herbicide. Therefore, greenhouse and laboratory experiments were conducted in order to investigate the mechanism of diuron resistance and the cross-resistance patterns to PS-II inhibitors in Italian ryegrass. Seeds of three resistant (B, D, and F) and one susceptible (S) Italian ryegrass populations were planted in 263-mL plastic pots containing commercial potting mix. The plants were grown in the greenhouse at 25/20 C and were treated with the PS-II inhibitors diuron (0.22 to 14.34 kg ai ha⁻¹), atrazine (0.14 to 8.98 kg ai ha⁻¹), metribuzin (0.10 to 6.73 kg ai ha⁻¹), and terbacil (0.11 to 7.17 kg ai ha⁻¹) at the 2-leaf stage, using an overhead sprayer calibrated to deliver 187 L ha⁻¹. A nonionic surfactant at 0.25% was added to the herbicide treatments. Aboveground shoot biomass was determined 2 wk after herbicide treatment. Based on the dose-response experiments, it was determined that the three Italian ryegrass populations were resistant to diuron, while B and F were moderately resistant to atrazine and metribuzin. All four populations were susceptible to terbacil. DNA sequence analysis of the herbicide binding region of the chloroplast psbA gene encoding the D1 protein, the target site of PS-II inhibitors, did not reveal any point mutations. Based on these results, non-target site resistance (enhanced metabolism) seems to be responsible for diuron resistance in Italian ryegrass in Oregon.

118. High-Throughput SNP Genotyping to Identify Target Site-Based Glyphosate Resistance in *Lolium multiflorum*. Alejandro Perez-Jones¹, Wilson Avila¹, Carol Mallory-Smith¹; ¹Oregon State University, Corvallis, OR, United States of America

Glyphosate resistance in Italian ryegrass (*Lolium multiflorum*) is conferred by two different mechanisms, limited translocation (nontarget site-based) and mutation of the EPSP synthase gene (target site-based). The biochemical and/or physicochemical basis of the nontarget site-based mechanism controlling limited glyphosate translocation are not well understood. However, the molecular basis of the target site-based mechanism has been determined. Sequence analysis and kinetic data indicated that a proline 106 to serine amino acid substitution at EPSP synthase

decreased glyphosate binding and conferred glyphosate resistance in plants. This mutation results from a substitution of a cytosine residue by a thymine at position 319 at the epsps gene. In previous studies, it was determined that the Italian ryegrass population designated as SF which has moderate levels of glyphosate resistance carries this mutation. In order to screen numerous populations for target site-based glyphosate resistance in Italian ryegrass, three different high-throughput SNP genotyping methods, Acycloprime™ II, Amplifluor®, and TaqMan®, were evaluated. These three methods rely on different principles for allele discrimination. Because Italian ryegrass is an out-crossing species, the target site mutation associated with glyphosate resistance is likely to segregate. Plants of the population SF were grown in the greenhouse. Genomic DNA from 96 plants was extracted and then the plants were treated with glyphosate (0.58 kg ae ha⁻¹) at the 4-leaf stage. Plants were scored as susceptible (dead), partially resistant (alive but stunted), or resistant (alive with no symptoms) three weeks after herbicide treatment. The three SNP genotyping methods were conducted according to the manufacturers' instructions. All three methods successfully differentiated between the homozygous resistant and homozygous susceptible individuals, and the genotyping of each individual correlated with the phenotype, dead and alive with no symptoms, respectively. However, the determination of the heterozygous individuals and the correlation with the individuals that were alive but stunted was inconsistent. The implementation of any of these SNP genotyping methods would allow the detection of target site-based glyphosate resistance, or other types of target site-based herbicide resistance, when numerous populations need to be screened; however, the availability of resources and equipment will determine which method can be used.

119. Herbicide Resistance Action Committee (HRAC) – Its Role in the Management of Weed Resistance. Les Glasgow¹, Harvey Glick², Michelle Starke², Marvin Schultz³; ¹Syngenta Crop Protection Inc, Greensboro, North Carolina, United States of America; ²Monsanto, St Louis, Missouri, United States of America; ³Dow AgroSciences, Indianapolis, Indiana, United States of America

Herbicides are an integral part of efficient food production. The loss of effective control with herbicides through the development of weed resistance could have a significant impact on crop management, food prices and food availability. Thus, herbicide resistance is an issue that affects all stakeholders in agriculture.

The first case of herbicide resistance was reported in 1964. Since then there has been a significant increase in the number of cases reported, with reports of new herbicide resistant biotypes each year.

The Herbicide Resistance Action Committee (HRAC) was formed in September 1989, with membership comprised of technical representatives of herbicide-producing companies. Its mission is to facilitate effective management of herbicide resistance by fostering understanding, cooperation and communication between industry, government and farmers.

HRAC goals include:

-Promotion of a mutually agreeable and responsible approach for the proper use of herbicides as part of an integrated weed management (IWM) strategy, and support of its implementation through practical guidelines.

-Support of, and participation in, research to increase our understanding and scientific knowledge of the causes, mitigation and economics of herbicide resistance management.

-Communication of the causes and consequences of herbicide resistance.

-Promotion of active collaboration between public and private researchers, especially in problem identification and development of agreed management strategies.

-Facilitation of discussion of proper product stewardship among industry representatives.

HRAC provides a forum for development of consistent stewardship goals and best management practice (BMP) recommendations around herbicide resistant weeds through educational materials, such as brochures and presentations, to be used by all stakeholders and to ensure transparency of scientific findings on resistance. Recent discussions have centered on establishing best weed management principles to minimize the potential for the development of herbicide resistant weeds.

HRAC maintains a website (HRACGLOBAL.com) which provides information about weed resistance and its management, and continues funding of the International Survey of Herbicide Resistant Weeds (WeedScience.com) website which displays up to date, worldwide information on herbicide resistant biotypes. HRAC, through its industry membership, also encourages the funding of basic research on herbicide resistance.

The agricultural community (farmers, industry, academia, government) is working together to provide effective solutions for weed resistance and to provide farmers with a range of management tools to effectively deal with this issue on their farms.

120. Accumulation of Shikimate in Glyphosate-Tolerant and -Susceptible Maize and Soybean. Danijela Pavlovic¹, Charlie Reinhardt², Nicolette Taylor², Sava Vrbnicanin³, Albert Fischer⁴; ¹Institute for Plant Protection and Environment, Belgrade, Yugoslavia; ²University of Pretoria, Pretoria, South Africa; ³University of Belgrade, Belgrade, Yugoslavia; ⁴University of California-Davis, Davis, California, United States of America

Glyphosate-tolerant crops are progressively spreading worldwide. This technology appeared based on the 'one-shot' herbicide concept, but its long-term practical use was marred by the growing problem of weed resistance. Glyphosate resistance has been proven in thirteen weed species around the world. Other negative outcomes of glyphosate-tolerant crops and repeated glyphosate use are gene flow to related species, shift of weed species naturally resistant to glyphosate, herbicide drift and off-target movement, resistant volunteer crops, and spread of resistant weeds from non-arable lands. The purpose of our research was to establish a rapid, effective and reliable technique allowing to differentiate between glyphosate-tolerant (T) and -susceptible (S) crops that could also be used for detecting resistance to glyphosate in weeds and serve as diagnostic tool in cases of suspected glyphosate injury to non-target crops. Thus we measured chlorophyll levels using SPAD readings and methanol extraction and determined amounts of shikimate accumulation in glyphosate-treated and untreated crop plants. Plants were assayed 2, 4, and 6 days after treatment with 1 kg a.e. ha⁻¹ glyphosate. Minimum and maximum shikimate concentrations in non-treated plants of both crops ranged from 0 to 641 µg g⁻¹ fresh weight in the 2-6-day period following treatment and were, as expected, significantly lower than in glyphosate-treated plants. Shikimate concentrations in treated T maize (0-533 µg g⁻¹) were lower than in T soybean (0-1071 µg g⁻¹). The amount of shikimate in S crops ranged from 0-959 µg g⁻¹ in maize and from 0-6431 µg g⁻¹ in soybean. Shikimate increase was greater and more prolonged in S than in T plants; thus while the latter soon recovered, the former did not. Differences in chlorophyll contents were not significantly correlated with shikimate levels. Thus measuring shikimate accumulation was the most reliable rapid technique for identifying glyphosate-R crops and weed plants and would be also useful for establishing the involvement of glyphosate in cases of herbicide injury to non-target crops.

121. Penoxsulam Faces Metabolic Resistance in California's Late Watergrass [*Echinochloa phyllopogon* (Stapf) Koss.] Hagai Yasuor¹, Maria Osuna¹, Aida Ortiz², Albert Fischer¹; ¹University of California, Davis, Davis, California, United States of America; ²Universidad Central de Venezuela, Maracay, Venezuela

Echinochloa phyllopogon is a major weed of California rice that has evolved multiple-herbicide resistance. Cross-resistance to penoxsulam was evaluated in a resistant (R) population collected in a rice field. Ratios (R/S) of the R to S GR50 values of about 5 were observed in whole-plant and seedling dose-response assays. Adding malathion (P450 inhibitor) enhanced herbicide phytotoxicity to R plants, while pre-treatment with thiobencarb (P450 substrate) antagonized penoxsulam. HPLC assays with 14C-penoxsulam showed higher clomazone metabolism in R

plants; malathion inhibited penoxsulam metabolism and accumulation of parent compound in R plants was similar to S plants treated with penoxsulam alone. ALS activity assays were similar for R and S plants. These results suggest *E. phyllopon* resistance to penoxsulam is due to P450-mediated enhanced metabolism and not due to reduced ALS sensitivity.

122. Field Evidence of Multiple Glyphosate Resistance Mechanisms in *Amaranthus palmeri*. Kenneth Smith¹, Jason Norsworthy¹, Robert Scott¹, Nilda Burgos¹; ¹University of Arkansas, Monticello, AR, United States of America

The first reported case of evolved weed resistance to glyphosate was *Lolium rigidum* (rigid ryegrass) in Australia. *Conyza canadensis* (horseweed) was the first major weed species confirmed to be glyphosate-resistant in the USA in 2000. Since, there have been 11 additional species confirmed glyphosate-resistant worldwide and 7 additional species in the USA. Southern U.S. agriculture is heavily dependent upon glyphosate for weed control in genetically altered glyphosate-resistant crops. This is especially prevalent in Arkansas, USA, with 99% of all cotton and soybean and 75% of all corn planted in the state being glyphosate tolerant. Heavy reliance on glyphosate for in crop weed control since the late 1990's has allowed evolution of glyphosate-resistant *A. palmeri* in Arkansas. Field and greenhouse experiments have identified two very distinct responses to glyphosate. Although phenotypically similar, each is considered a distinct biotype.

Biotype 1 demonstrates a lower level of resistance and when treated with field doses of glyphosate shows varying levels of symptoms as chlorosis, necrosis, and stunting. The apical bud is often destroyed, but regrowth occurs from lower axillary buds. The F2 and F3 generations continue to segregate exhibiting varying levels of susceptibility and resistance. Although segregating, antidotal evidence suggests the succeeding generations have some individuals with higher tolerance than their parents, implying a gradual movement toward resistance. Since succeeding generations continue to segregate, the population of escapes is scattered over a large area of the field with no definite pattern. Multiple applications and higher glyphosate rates improves control of this biotype. This biotype is widespread throughout Arkansas cotton and soybean cropping area.

Biotype 2 has been found in less than 10 fields throughout the state, but when found is localized in areas usually smaller than 150 m². The plant population in the infested area is as high as 100 plants/m². This pattern suggests that all plants in the infested area are offspring from a single parent plant. Each plant in the infested area demonstrates greater than 8X resistance. This biotype exhibits little or no symptomology when treated with doses as high as 8X normal field rates. The F1 generation from

this biotype does not segregate and each offspring is as resistant as the parent. Different mechanisms of resistance have exhibited varying responses in other species. It is hypothesized that these two very distinct responses to glyphosate are likely the result of two different mechanisms for resistance between the two biotypes found in Arkansas cropping systems.

123. Prickly Lettuce Resistance to 2,4-D. Ian Burke¹, Dilpreet Singh¹, Joseph Yenish¹; ¹Washington State University, Pullman, WA, Canada

Prickly lettuce (*Lactuca serriola* L.) has become a widespread and troublesome weed in the PNW. It occurs in all rainfall zones and is difficult to control largely due to ALS resistance but also due to increased tolerance to 2,4-D and glyphosate. In wheat fields near to Pullman, WA, several individual plants within a prickly lettuce population were observed to survive two separate broadcast applications of a glyphosate plus 2,4-D in mixture (0.84 kg ae/ha each). Other broadleaf weed species and most prickly lettuce plants within the treated area were effectively controlled. Consequently, seed were collected from the surviving plants to determine the level of resistance to 2,4-D. The objectives of this study were to identify to the determine response of putatively resistant prickly lettuce biotypes to increasing rates of 2,4-D and to investigate the mechanism of resistance. In dose response experiments, the GR₅₀ for susceptible prickly lettuce was 8 and 9 times less than the field-collected biotype and its progeny, respectively. The resistant prickly lettuce biotype was found to be 27-fold more resistant to 2,4-D than the susceptible biotype based on regrowth of the resistant biotype. The resistant prickly lettuce biotype is cross-resistant to MCPA and dicamba, but not to aminopyralid, clopyralid, or fluroxypr. To determine the mechanism of resistance, absorption and translocation studies using ¹⁴C-2,4-D were conducted on the suspected 2,4-D resistant biotype and a known susceptible biotype. At 96 HAT, resistant and susceptible biotypes absorbed 33.8 and 42.7% of applied ¹⁴C-2,4-D respectively and out of the total herbicide absorbed, 74.5 and 70.1 % remained within the treated leaves of resistant and susceptible biotypes, respectively. At 96 HAT, the total amount of radioactivity translocated from the treated leaf to different plant parts was similar in both biotypes (25.5 and 29.9% for resistant and susceptible biotypes, respectively). However, 25% less 2,4-D was translocated to the crown of resistant biotype compared to susceptible biotype. Re-growth of resistant prickly lettuce biotypes commonly occurs from apical or lateral meristems located in the crown. Reduced herbicide translocation to the crown in resistant biotypes could be, in part, a mechanism for 2,4-D resistance in prickly lettuce.

124. Glyphosate Resistant Crops and Evolved Glyphosate Resistant Weeds – the Need for Stewardship. Micheal Owen¹; ¹Iowa State University, Ames, IA, United States of America

Agriculture imparts selection pressure on weed communities that inevitably result in weed population shifts. However, the adoption of glyphosate resistant crops (GRCs) does not impart selection pressure on the weed community directly. However, the management systems used in GRCs will affect selection pressure on the weed community due to conservation tillage, recurrent use of glyphosate, and the limited number of alternate herbicides used to control weeds. It has been interesting to follow the predictions of how quickly weed shifts (accounting for both evolved resistance and natural tolerance) would develop. Resistance to glyphosate in isolated common waterhemp (*Amaranthus tuberculatus*) plants was observed 2 years after the commercialization of GR soybean (1998) and in horseweed (*Conyza canadensis*), glyphosate resistance was widely distributed 3 years after grower adoption of GR soybean. Worldwide, there are numerous reports of evolved glyphosate resistance weed biotypes and weed population shifts. A number of weeds have been described as having inherent tolerance to glyphosate and these weeds have become more prevalent in global agroecosystems. These weeds, first and foremost, demonstrate exceptional ecological adaptation to the prevailing agroecosystem, and thus have become significant economic problems. The key consideration in managing these weed problems, whether resistant to glyphosate or tolerant to glyphosate, is diversification of weed management tactics by following the principles of integrated weed management. Unfortunately, growers do not perceive the existence of problems until after they exist at population densities that may preclude resolution to the problem. Grower perceptions are that GR crop systems and the use of glyphosate has provided an important and consistent opportunity to manage weed problems, and while they may be aware of the possibility of weeds within these GR crop systems evolving resistance to glyphosate exists resulting in weed population shifts, they tend to ignore this reality and presume that new technology will soon be available. Recent grower surveys support this supposition and it reinforces the need to establish robust tactics to provide stewardship to GRC systems and glyphosate. The importance of glyphosate stewardship was universally accepted at the National Glyphosate Stewardship Forum II - A Call to Action. However, implementation of glyphosate stewardship programs has not occurred and it is imperative that agriculture takes appropriate action.

125. Characterizing Glyphosate-Resistant Weeds. Robert Sammons¹, Stephen Schrader¹, Keith Kretzmer¹, Erin Hall¹, Elizabeth Ostrander¹, Bill Duncan¹; ¹Monsanto, St. Louis, Missouri, United States of America

The number of glyphosate resistant weeds continues to increase with 13 species reported globally. Knowing which resistance mechanisms to look for would allow us to examine suspected weeds before a resistant population is well established. There are three principal resistant mechanisms to consider. Target site mutations where in the herbicide binding site an amino acid has mutated preventing the herbicide from being effective. Secondly, herbicide resistance by metabolism in the plant and rendering the herbicide ineffective. Finally, there are cases of resistance that are best characterized by exclusion where the herbicide is kept from the target site whether by active sequestration or by passive distribution. The design of simple biochemical tests to characterize the principal resistance mechanism allows a classification and comparison of the known glyphosate-resistant weeds.

The first step is to determine the unit toxicity of glyphosate to determine if the weed is resistant. The unit activity of glyphosate (G) is defined by the shikimate (Sh) to glyphosate ratio (Sh/G). Comparing the Sh/G values for mobilized glyphosate in putative resistant (R) and sensitive (S) plants definitively confirms a resistance mechanism is present. A simple translocation experiment with ¹⁴C glyphosate and an HPLC determination of shikimate allows the Sh/G comparison. Once resistance is clearly present then an EPSPS assay is done to determine the sensitivity to glyphosate for R and S EPSPS. A simple extraction procedure was developed to stabilize the EPSPS and a continuous phosphate release assay was adapted to determine, by initial rate kinetics, the relative inhibition by glyphosate. In this way target site resistance can be implicated or not directly. The metabolism of glyphosate then can be done using ¹⁴C glyphosate and leaf discs incubated to allow the formation of aminomethylphosphonate, the standard plant derived metabolite of glyphosate. This can be determined by HPLC which also monitors the formation of unknown compounds. These three tests then together can identify whether the known mechanisms for glyphosate resistance are present.

Data comparing *Lolium rigidum*, *Lolium multiflorum*, *Eleusine indica*, *Plantago lanceolata*, *Amaranthus palmeri*, *Amaranthus rudis*, *Conyza canadensis* and *Sorghum halepense* will be presented. To date target site resistance and exclusion of glyphosate are implicated. Because these resistance mechanisms can be additive and more than one mechanism can be present, correlating the resistance mechanism to the magnitude of resistance is a more difficult task.

126. Strategies for Enhancing the Efficacy of *Microsphaeraopsis amaranthi* as a Bioherbicide to Control Weedy *Amaranthus* spp. Daljit Singh¹, Yasser Shabana², David Doll³, David Smith⁴, Loretta Ortiz-Ribbing⁴, Gordon Roskamp⁵, Steven Hallett¹; ¹Purdue University, West Lafayette, Indiana, United States of America; ²University

of Florida, Gainesville, Florida, United States of America; ³University of California, Davis, California, United States of America; ⁴University of Illinois, Urbana-Champaign, Illinois, United States of America; ⁵Western Illinois University, Macomb, Illinois, United States of America

Weeds in the genus *Amaranthus* are troublesome in agronomic and horticultural crops in many parts of the world. *Microsphaeropsis amaranthi* is a candidate bioherbicide for the control of weedy *Amaranthus* spp because it has restricted host range, is easily grown in culture and can cause damaging infections. However, the fungus needs improvement in terms of virulence enhancement and reliable field performance. Also, its restricted host range decreases its utility in situations where complex communities of weeds require management. We conducted a sequence of experiments to address the virulence enhancement of the fungus and its potential to be integrated into weed management systems. Production was improved by finding a medium upon which the virulence of conidia was higher. Sterilized corn stubble was found to produce virulent, thick walled conidia which germinated and caused infection earlier than those produced on other media. Experiments were conducted on delivery methods and it was observed that foliar applications could be improved by the selection of a spraying system delivering an appropriate spray droplet distribution. Application with a hollow cone at high pressure produced more stem infections, as did preemergence granular applications. In greenhouse experiments, when glyphosate and conidia of *M. amaranthi* were sprayed onto common waterhemp seedlings, the herbicide predisposed plants to infection by *M. amaranthi*. To confirm this interaction in field conditions, experiments were conducted at West Lafayette, Indiana and Macomb, Illinois, during 2007 in Roundup Ready soybean fields infested with natural stands of common waterhemp and redroot pigweed (*Amaranthus retroflexus* L.). At both the locations, a synergistic interaction was found between *M. amaranthi* and glyphosate resulting in enhanced disease severity and weed control. Field experiments were also conducted during 2006 and 2007 on tomatoes to evaluate the potential of *M. amaranthi* in horticulture production system. Multiple applications of the bioherbicide caused high disease severity and resulted in good weed control and higher tomato yield. *Microsphaeropsis amaranthi* continues to show promise as a candidate bioherbicide as evident by good weed control under optimum growing conditions. Its failure in sub-optimal conditions, however, shows that significant improvements still need to be made. These experiments demonstrate that there is potential for the enhancement of the efficacy of *M. amaranthi* and for the integration of the bioherbicide into production systems.

127. A Biological Control Program for Common Tansy (*Tanacetum vulgare*) in Canada and the United States. Alec

McClay¹, Monika Chandler², André Gassmann³, Gitta Grosskopf³, Urs Schaffner³, John Gaskin⁴; ¹McClay Ecoscience, Sherwood Park, Alberta, Canada; ²Minnesota Department of Agriculture, St. Paul, MN, United States of America; ³CABI Switzerland Centre, Delémont, Switzerland; ⁴USDA-ARS Northern Plains Agricultural Research Laboratory, Sidney, MT, United States of America

Common tansy (*Tanacetum vulgare* L., Asteraceae) is an aromatic herbaceous perennial native to Europe, which was introduced into North America as a culinary and medicinal herb. Now widely naturalized in pastures, roadsides, waste places, and riparian areas across Canada and the northern USA, tansy is also spreading in forested areas. It contains several compounds toxic to humans and livestock, such as α -thujone. Tansy reduces the productivity of pastures, displaces native vegetation in natural areas, and can be a problem in regeneration of logged areas. It is listed as a noxious weed in several states and provinces. Common tansy is a good target for biological control, as it is a perennial plant growing in stable habitats, and has few native North American congeners. A biological control program for common tansy is being funded and coordinated by a Canadian-US consortium led by the Alberta Invasive Plants Council and the Minnesota Department of Agriculture. CABI Switzerland Centre is identifying and testing potential agents for efficacy and host specificity, including the stem-mining weevil *Microplontus millefolii*, the leaf-feeding beetle *Cassida stigmatica*, the rhizome-mining moths *Isophrictis striatella* and *Dichrorampha* spp., and the stem, rosette and flower head-galling gall midge *Rhopalomyia tanaceticola*. Several of these species are now in culture at CABI, and preliminary host specificity testing is under way. A test plant list has been developed and is under review by the Canadian Biological Control Review Committee and the US Technical Advisory Group.

128. Field Efficacy of *Exserohilum prolatum* for Biological Control of Itchgrass. Hala Alloub¹, Abdul Shukur Juraimi², Juga Kadir³; ¹University of Gezira, Medani, Gezira, Sudan; ²University Putra Malaysi, Serdang, Selangor, Malaysia; ³University Putra Malaysia, Serdang, Selangor, Malaysia

Itchgrass is a serious weed causing severe yield losses in annual and perennial crops in South East Asia. *Exserohilum prolatum* isolated from diseased itchgrass plants has shown effectiveness in controlling the weed in glasshouse conditions. This study is undertaken to evaluate the efficacy of *E. prolatum* in controlling itchgrass under field conditions. The effect of three concentrations of *E. prolatum* formulated in 0.01% Tween 20 and 2% palm oil and a control on itchgrass was tested in field under natural conditions in a non-crop situation, by applying the conidia of the fungus at three rates in single, double or triple applications. The findings indicate application

frequency and inoculum concentration greatly influenced Itchgrass control. Three applications had scientifically higher percent control compared to double and single applications and within the three frequencies of application, 2 x 10⁹ conidia/ml obtained increased disease severity followed by 2 x 10⁸ then 2 x 10⁷ conidia/ml compared to the untreated check. The study demonstrated that *E. prolatum* effectively controlled itchgrass under field conditions.

129. Biological Control of Lippia (*Phyla canescens*): Native Range Surveys for Rust and other Plant Pathogens. María Guadalupe Traversa¹, Freda Anderson¹, Mirta Kiehr¹, Rolf Delhey¹, Mic Julien¹; ¹National University of the South, Bahía Blanca, Buenos Aires, Argentina

Lippia (*Phyla canescens*, Verbenaceae) is native to South America and is invasive in Australia and elsewhere. To identify candidates for the biological control of this weed in Australia, surveys for fungal pathogens of lippia and the related *P. reptans* have been carried out throughout their ranges in Argentina from December 2005 until now. The only rust described before on *P. canescens* is the micro-cyclic *Uromyces lippiae* Speg., now synonymized with *Puccinia lantanae* Farl. We re-discovered this rust at two sites in the Argentinean north-west, but on *P. reptans* rather than on *P. canescens*. This fungus could be experimentally transmitted to both, *P. canescens* and *P. reptans*. In the field and the laboratory, *P. lantanae* is able to produce serious damage to *P. reptans* where occasionally a semisystemic infection occurred. *Cercospora* cf. *lippiae* and three *Colletotrichum* spp., were also found associated with *P. canescens* and *P. reptans* throughout much of its natural range, causing leaf spots and stem cankers. Additional information on biology and host specificity is required to propose any of these fungi as biological control candidates.

130. Augmentative Biological Control of *Parthenium hysterophorus* L. using *Zygotrogramma bicolorata* Pallister in Central India. Sushil Kumar¹; ¹National Research Centre for Weed Science, Jabalpur, Madhya Pradesh, India

Augmentative biological control involves one to several release of natural enemy in an attempt to suppress and maintain a pest population at a sub-economic density. Augmentation is basically an outcome of an unsuccessful or partially successful effort to establish a natural enemy as in the case of the Mexican beetle, *Zygotrogramma bicolorata*, a potential biocontrol agent of *Parthenium hysterophorus*. Many times, under field condition the population buildup of the beetles is slow as compared to the increase in parthenium density. Under such circumstances, augmentation of lab or net house reared beetles during lean season or at the onset of monsoon when beetle

population in nature remains low may be highly profitable to establish the population quickly.

For augmentation purpose, 12 sites each of approximately 2500 square meters infested with dense parthenium were selected. Augmentation was done by the release of either adults or grubs in each site. Initially adults or grubs were released at the rate of 3000 per hectare followed by another 1500 adults or grubs per hectare at an interval of 7 and 14 days after initial augmentation. No beetles were released in the control sites. Population upsurge of the beetles was monitored by counting the number of eggs, grubs and adults randomly from 25 plants at every 15 days till 60 days or 100% damage caused to the weed stand. Damage on parthenium patch by the beetles was noted in percentage by visual ranking.

As a result of augmentation of adult beetles, 6.7% defoliation was caused by the 15th day of beetles release. After 30 and 45 days, 53.3 and 83.3% defoliation to parthenium stand was observed, respectively. Initially, defoliation in the grubs released sites was higher than the adult released sites but later on it was higher in the adults released sites. The grubs caused 53.3, 86.7 and 99.5% defoliation by the 15th, 30th and 45th day, respectively.

Though grub augmentation caused better damage to parthenium patch, population increase was better in the adult augmented sites. By the 15th day of initial augmentation, population of the beetles was 8.8 eggs, 5.2 grubs and 2.3 adults per plant in the adult augmented sites while 0.3 eggs, 2.0 grubs and 0.9 adults per plant were observed in larval augmented sites. By the 30th day, there were 14.0 egg, 13.7 grubs and 4.1 adults per plant in the adult augmented sites while there were 11.1 eggs, 8.3 grubs and 3.7 adult per plant in larval augmented sites. By the 45th day there were 4.6 eggs, 8.8 grubs and 2.6 adults per plant while no adult beetle population was observed in the larval augmented sites due to complete defoliation followed by browning of parthenium stand. Complete defoliation was observed at the adult augmented sites only after 60 days.

In the control sites, no population was observed from June to mid August. The parthenium height increased from an average of 45 cm to 180 cm while in the adult augmented sites plant height increased from 45 cm to 72 cm and from 48 to 60 cm in larval augmented sites.

131. Biological Control of *Solanum viarum* (Solanaceae) in the USA: Current Status and Perspectives. Julio Medal¹, Yorley Bustamante¹, William Overholt¹, Philip Stansly¹, Amy Roda², Kennett Hibbard³, Steven Hight⁴, Rodrigo Diaz¹, Divina Amalin¹, James Cuda¹; ¹University of Florida, Gainesville, Florida, United States of America; ²USDA-APHIS, Kendall, Florida, United States of America; ³FLDACS-DPI, Fort Pierce, Florida, United States of America; ⁴USDA-ARS, Tallahassee, Florida, United States of America

Solanum viarum Dunal (Solanaceae) is a perennial prickly bush, native to South America that has been spreading throughout southeastern United States since it was found in Florida in 1988. This non-native plant has invaded at least 400,000 hectares of grasslands, agricultural crops, and conservation areas in at least seven states. The rapid spread in the United States can be partially attributed to the large seed production per plant, effective seed dispersal by cattle and wildlife that feed on fruits, and introduction of the plant to the new area without its natural enemies (herbivorous & pathogens) that keep weeds population in low numbers in the area of origin. Management practices for *S. viarum* are mostly based on herbicides/ mowing which only provide a temporary solution and are relatively expensive. A biological control project was started in 1997 by the University of Florida in collaboration with Brazilian and Argentinean researchers. The first biological control agent approved for field release in 2003 was the leaf beetle *Gratiana boliviana* (Spaeth) (Coleoptera: Chrysomelidae). Currently, more than 120,000 beetles have been released in Florida, Georgia, Alabama, South Carolina, and Texas. Evaluation of the feeding effects of the beetles on *S. viarum* plants and changes in the number of beetles on the plants have been made since 2003 in at least 5 of the release sites. The beetles got established in almost all the release sites. Beetle dispersal is a function of plant availability ranging from 1 to 15 km/year. Defoliation by *G. boliviana* have been decreasing fruit formation and reducing population number of *S. viarum*. Field releases and post-release monitoring continue through 2008.

132. Allelopathy of Saffron – A Biocontrol of *Phalaris minor*. Ali Reza Astaraei¹; ¹College of Agriculture-Ferdowsi University of Mashhad, Mashhad, Khorasan Razavi, Iran

Weeds can inhibit the growth and yield of many agronomic plants by releasing compounds that are phytotoxic (i.e., allelopathic), and the phenomenon of allelopathy can be used as bio weed control. *Phalaris arundinacea* reduces growth, causes twisted roots, inhibits root development, and kills the roots of test plants, but has less effect on seed germination. Many species of medicinal plants have pronounced allelopathic effects as well. We evaluated allelopathic effect of saffron (*Crocus sativus* L.) in a germination bioassay using *Phalaris minor* Retz (Poaceae). Water extracts of leaf, corm, and soil attached to corm (SAC) were tested as the main sources of allelopathy. Water extracts of these sources at five concentrations (0, 0.5, 1, 3, and 5%) were used in a 3 x 5 factorial arrangement with three replicates. Fresh weight of plumule and radicle of *P. minor* were reduced significantly by 47% and 49.9%, respectively, when treated with the water extract of SAC compared to water extracts of leaf and corm treatments. Both plumule and

radicle lengths showed significant reduction in both water extracts of leaf and corm extracts. Water extract at 3% and 5% concentrations reduced germination by 27% and 55% compared to control, Plumule and radicle fresh weights were reduced at 0.5% water extract by 51 and 50%, respectively, when compared to their controls. Plumule and radicle lengths were reduced significantly at 0.5% (39%) and 1% (44%) concentrations, respectively, compared to their control There was a significant source by concentration interaction for all germination traits. Leaf water extract of all concentrations had more negative effects on plumule and radicle lengths compared to water extracts of corm and SAC.

133. Comparison of Nutritional Effects on Sporulation, Desiccation Tolerance and Virulence of Two Isolates of *Fusarium Oxysporum* in Order to Introduce an Effective Biocontrol Agent of *Orobanche aegyptiaca*. Mitra Ghotbi¹, Mansoor Montazeri², Majid Amini Dehghi³, Marjan Ghotbi¹, Jafar Kambouzia⁴; ¹University of Shahed, Tehran/Tehran, College of Agronomy/Shahed University-Tehran, Iran; ²Plant & Pathology Research Center, Tehran/Tehran/Velenjak, Institute of Weed Science/Research Center of Plant Pest, Iran; ³Shahed University, Tehran/Tehran, College of Agronomy/Shahed University, Tehran, Iran; ⁴University of Shahid Beheshti(Tehran), Tehran/Tehran, Department of Environmental Science/University of Shahid, Iran

Two isolates of *Fusarium oxysporum* were compared under the same condition. In semi-defined liquid medium with C: N ratio of 15:1 which pH ranged between 5 to 8, isolate Iran-506 preferred pH of 7 to 7/5 and pH of 6/5 to 7/15 was preferably chosen by isolate-502 in ratios of 2, 5 and 7% of glycerol in semi-defined liquid medium with C:N ratio of 15:1 and pH of 6/5, The highest sporulation of isolate 502 belonged to 2 and 5% of glycerol containing media, but adding glycerol had no significant effect on Sporulation of isolate 506. Glycerol had negative influence on spore germination rate of both isolate and during 4 weeks decreased desiccation tolerance and germination rate of both isolates spores. It proved that isolate 506 as more efficient in managing *Orobanche aegyptiaca* than isolate 502 and therefore it was introduced an effective isolate for producing mycoherbicide.

134. Comparison the Effects of Cover Crop Monoculture with Polyculture on Weed Control and Yield of Tomato. Batoul Samedani¹; ¹Iranian Research Institute of Plant Protection, Tehran, Iran

Planting mixture of cover crops can optimize the benefits of their use. Therefore, in a field experiment the effects of cover crop monoculture and polyculture on weed control in tomato were investigated at the Varamin

Research Station from 2003-2005. The experiment had a split plot design in a complete randomized block form with three replications. Supplemental weed control were considered as the main factor with two levels (weeding and weedy) and different mixture of rye and hairy vetch (100% rye, 25% rye + 75% hairy vetch, 17.5% rye + 82.5% hairy vetch, 10% rye + 90% hairy vetch and 100% hairy vetch) were placed in subplots. For comparison three control treatments (weeding, weedy and metribuzin herbicide) were placed in the two sides of the experiment. Biomass of rye and cover crop mixtures were higher than hairy vetch monoculture. Cover crop mixture reduced weed density and biomass compared to vetch monoculture in the first year, but in the second year weed control of all cover crops treatments was similar. Fruit yield in both years were similar in the hairy vetch and rye monoculture and all mixtures but was lower in the rye monoculture in the first year. Tomato grown in the cover crops without weeding yielded lower than the corresponding treatments with weeding. Cover crops with increasing number of fruit on plant increased tomato yield.

135. Allelopathic Potential Effects of Russian Knapweed (*Acroptilon repens*) on Germination and Plumule Growth Characteristics of Wild Barley (*Hordeum spontaneum*). Mohammad Reza Roosta Nejad¹, Forough Abbasi¹, Reza Ghorbani², Mohammad Bazoobandi¹; ¹Islamic Azad University of Mashhad, Mashad, Khorasan, Iran; ²Ferdowsi University of Mashhad, Mashad, Khorasan, Iran

In order to determine the allelopathic effects of Russian knapweed on wild barley, a bioassay study was conducted. The experiment was based on completely randomized design, with 4 replications. The studied factors were Russian knapweed parts (shoot or root), and concentration of plant extracts (0, 15, 25, 30, 35, 40, 45, 50, 75 and 100 percent). Results showed that the allelopathic effects of Russian knapweed on wild barley were very significant. Plumule and radicle length, germination rate, percentage and germination rate were significantly reduced. This reduction was higher in shoot compared to roots of Russian knapweed

136. Investigation of Allelopathy Effects of Shepherd's Purse (*Capsella bursa-pastoris*) Extract on Germination of Alfalfa (*Medicago sativa*), Wheat (*Triticum aestivum*) and Canola (*Brassica napus*). Mohammad Reza Roosta Nejad¹, Seid Mohsen Nabavi Kalat¹, Mohammad Bazubandi², Mostafa Shafe¹; ¹Islamic Azad University of Mashhad, Mashad, Khorasan, Iran; ²Khorasan Agricultural & Natural Resources Research Center, Mashad, Khorasan, Iran

In order to study the allelopathy effects of shepherd's purse on germination indices and primary growth of three

crops (alfalfa, wheat and canola) an experiment was conducted during 2006 at Islamic Azad University of Mashhad. The experiment designed as a Completely Randomized Design with three replications. Treatments were consisted of, 0, 25, 50, 75, and 100 concentrations of foliar extract. Results indicated that the extract effect on length of seedling, percent and rate germination and coefficient's rate in three crops were significant. Whole studied parameters decreased with increasing extract concentration extract increased. Highest allelochemical inhibition obtained in canola and lowest obtained in alfalfa.

137. Need for Combined Integrated Management of Aquatic Weeds by Augmentation of Biocontrol Agents. Puja Ray¹, Akhilesh Pandey², Sushil Kumar¹; ¹National Research Centre for Weed Science, Jabalpur, Madhya Pradesh, India; ²R.D. University, Jabalpur, Madhya Pradesh, India

Invasion of aquatic weeds render water bodies useless for human use other than causing severe damage to aquatic ecosystem by displacing native vegetation, oxygen depletion and eutrophication of the water bodies. Biological control of a weed is a result of interspecific competition and herbivory. These actions result in reduction in biomass, growth, reproduction and competitive fitness of the weed species and under several cases result in dominance of some other noxious weed in the area.

Water hyacinth (*Eichhornia crassipes*) and alligator weed (*Alternanthera philoxeroides*) of South American origin are the two major invasive, free floating, weeds in most of the water bodies in Central India. With the importing of the two of the most successful biocontrol agents of water hyacinth, the weevils, *Neochetina bruchi* and *N. eichhorniae* in 1982, remarkable work has been undertaken in various parts of the country for biological control of water hyacinth with mixed results.

In an anticipation of lodging a successful biological control of water hyacinth, augmentative release of *N. bruchi* and *N. eichhorniae* was implemented. Since May 2003, the weevils were released in five water bodies under severe water hyacinth infestation at an interval of 4 months, at the rate of 3000 weevils/ha of weed stand. Within a span of 1.5 years establishment and population buildup of the weevils was clearly visible by the extensive damage caused by the weevils to the weed resulting in damaged and reduced weed density. By the end of 2 years (May 2005), clear water surface with hardly 10% of water hyacinth mats in scanty patches, could be observed as compared to that present before weevil augmentation in all the water bodies under observation. With this observation the study was considered successful and further observations and release of the weevils were seized for more than a year.

Later in the October, 2006 it was observed that four out of 5 water bodies were covered to about 40 to 70% of water surface area by the alligator weed. While in one of the ponds cultivation of *Trapa natans* was done by the local inhabitants to be used as edible fruit and manual cleaning of weeds resulted in weed free water body. In absence of any potential biocontrol agent of the alligator weed in the area, the management of the weed appeared to be a mountainous job. Periodical survey of the water bodies infested with alligator weed brought into light few polyphagous insect species including *Hymenia recurvalis*, *Spodoptera litura* and an unidentified leaf binder causing appreciable damage to the weed. Other than these, a monophagous turtle beetle, *Cassida* sp. nr *enervis* Boh was also found to be causing good damage to the weed.

With further planning and evaluation, some exotic and potential control agents of alligator weed needs to be brought into the area for the management of weed. Also combined integrated management program of the two weeds, water hyacinth and alligator weed with their respective control agents needs to be brought into action simultaneously to obtain a weed free aquatic environment.

138. Phyto-toxic Effect of Foliar Leachates and Extracts of Selected Plants Species on the Germination and Seedling Growth of *Parthenium hysterophorus* L. G Satsangi¹; ¹Dayalbagh Educational Institute, Dayalbagh, Agra, Uttar Pradesh, India

Parthenium hysterophorus L. has drawn considerable attention of scientists as a grave health hazard causing several allergic diseases to human beings. It is a most prominent noxious weed inhibiting the growth and productivity of associated plants due to release and accumulation of phytotoxins from its decomposing biomass and root exudates in soil. All parts contain trichomes sesquiterpene, phenolic inhibitors. By considering its ill effects, the present study was carried out to explore the phytotoxic response of extracts and leachates of selected plants (three herbs and three shrubs) upon germination and seedling growth of *Parthenium hysterophorus* L. For observing the effect of selected plant species, the foliar treatment doses were prepared by following the methodology of Oudhia and Tripathi (2000), in which crushed (extracts) and uncrushed (leachates) leaves of the selected plants were soaked in distilled water in ratio of 1:10, 1:15, 1:20, 1:25 for 24 hrs. Twenty *Parthenium* weed seeds were soaked in the prepared extracts for 24 hrs. and transferred into petri plates lined with the Whatman's filter paper number 1. Seeds soaked in distilled water were treated as water control. Observations were recorded after 15 days of soaking. It was observed that extracts were found more effective than leachates and the degree of inhibition was directly proportional to the increasing concentration of the treatment. Among herbs *Amaranthus viridis*, *Chenopodium album*, *Achyranthus aspera* and in shrubs *Artimisia annua*,

Lantana camara, *Tagetes erecta* were found effective in inhibiting the germination and vegetative growth of the test weed. Therefore, these plants can be used to control the noxious weed specially at its initial phenophase. A bold program should be launched to train the people to come forward for eliminating *Parthenium hysterophorus* L., to acquaint them about weeds ill effects upon their lives. An Integrated Weed Management approach should be followed as an ideal control process for this weed.

139. Comparison of Two Liquid Media in Increasing Virulence and Desiccation Tolerance of Two Isolates of *Fusarium oxysporum* for Biocontrol of Broom Rape (*Orobanche* spp). Mitra Ghotbi¹, Majid Ghotbi¹, Mansoor Montazeri², Marjan Ghotbi¹, Jafar Kambouzia³; ¹University of Shahed, Tehran/Tehran, College of Agronomy/Shahed University, Tehran, Iran; ²Plant Pest & Pathology, Tehran/Tehran, Department of Weed Science, Iran; ³University of Shahid Beheshti(Tehran), Tehran/Tehran, Department of Environmental Science/University of Shahid Be, Iran

Parasitic plants, including *Orobanche* Spp. cause divesting damage to crops world wide. *Fusarium oxysporum* is a highly parasitic fungus which is utilized as a potential biocontrol agent against *Orobanche* Spp (broom rape). The recent study was conducted to evaluate the nutritional effects of two media on sporulation, virulence, and desiccation tolerance of two isolates of *Fusarium oxysporum* in order to control *Orobanche aegyptiaca*. Two isolates of this mycoherbicide were grown respectively in liquid semi-defined (SM) medium and Richard solution (RS) (0 and 5 % glycerol, pH: 6.5). Both isolates (Iran-502 and -506) yielded higher spores in SM medium (C/N, 15/1). The addition of glycerol had significant effect on sporulation rate in RS but not in SM. Comparison between 4 given media (SD vs. RS using two doses of glycerol) only in the case of long run, the addition of glycerol decreased germination rate. SD was better than RS for sporulation rate, spore germination rate and desiccation tolerance. The most successful treatments in order to control *O. aegyptiaca*, was isolates in SD and RS without glycerol and it has been shown that under the same condition Iran-506 was more efficient in sporulation, desiccation tolerance and virulence ability than Iran-502.

140. Host-Range and Factors Enhancing the Virulence and Desiccation Tolerance of *Fusarium oxysporum* as Promising Biocontrol Agent of *Orobanche aegyptiaca*. Majid Amini Dehghi¹, Mitra Ghotbi¹, Marjan Ghotbi¹, Mansour Montazeri¹, Jafar Kambouzia¹; ¹University of Shahed, Tehran, Department of Agronomy, Shahed University, Tehran, Iran

In 2004, a few pathogenic isolates of *Fusarium oxysporum* were obtained from *Orobancha aegyptiaca* in tomato fields in Iran which were heavily infested to this parasitic weed. In preliminary tests, among 18 isolates, the virulence of an isolate (coded isolate-506) on *O. aegyptiaca* was more severe than the others. In this research the host range and factors enhancing conidiation and virulence of this isolate were studied. To determine the host range, in glasshouse experiment, stem puncture and soil-applied inoculation at 5×10^6 conidia/ml, induced no symptom on tomato, soybean, red bean, chick pea, canola, sugar beet, sunflower, tobacco, cucumber, cucurbit, maize, wheat, barley, cotton, rape seed, alfalfa and clover. In a liquid semi-defined culture medium with a C: N ratio of 15:1, the highest conidia was obtained at pH 6.5 and 7.5, after 6 days incubation on a rotary shaker at 21°C. Adding glycerol into the medium had no positive effect on enhancing conidiation and germination percentage of the conidia. Soil applied conidia obtained from semi-defined medium with a C: N ratio 15:1 or Richards solution without glycerol resulted in 100% control of *O. aegyptiaca*.

141. Antifungal Properties of Water Hyacinth. Ayyathurai Eswaran¹, Balasubramanian Elavarasi¹, Vaikundaperumal Jaiganesh¹, M.S. Sangeetha¹; ¹Faculty of Agriculture, Annamalai University, Annamalainagar, Tamil Nadu, India

The plant (weed) species like *Eichhornia crassipes* is the most problematic weed in Asia (Holm, 1977) and is abundantly available in the country. The exploitation of antifungal properties from the weed would form indirect mode of management through weed utility and eco-friendly disease management strategy. In the light of the above, screening of different plant products as source of antifungal principle against *Alternaria alternata* under in vitro and in vivo conditions were taken up. Thirteen plant species belonging to twelve different families were taken for evaluating their antifungal properties. After screening against the pathogen, five plant species viz., *E. crassipes* (Mart.), *Nerium indicum* Mill., *Lawsonia inermis* L., *Datura metal*, *Cassia fistula* L. at five and ten per cent concentrations were taken for further studies. Carbendazim (Bavistin 50 WP) at 0.1% concentration was used for comparing with plant products. The cold water (Manju Lataupadhyaya and Gupta, 1990) and hot water extracts (Jagannathan and Narashiman, 1988) and crude extraction of acetone and ether petroleum extracts of the weed species were prepared and used against the leaf blight pathogen *A.alternata* by following poisoned food technique method. Green house and field experiments were carried out at Faculty of Agriculture, Annamalai University. Green house and also field experiments consisted of 7 treatments Viz., T1-*Eichhornia crassipes* (Mart.), T2-*Lawsonia inermis* L., T3-*Cassia fistula* L.,T4-*Nerium indicum*

L.,T5- Bavistin 0.25 per cent, T6-Inoculatedcontrol,T7-Uninoculated control. Certified seeds of K 1 were collected from Regional Research Station, Kovilpatti, Tamil Nadu, India and used. The Pectinolytic enzymatic changes of Polygalacturonase (PG) and Polygalacturonase transeliminase (PGTE) were determined the technique by Mahadevan and Sridhar, (1996). Among the extracts of the test products, hot water extracts *E. crassipes* @ 10 per cent conc. recorded the maximum inhibition on the mycelial growth (21.4 mm) of *A. alternata* when compared to other extracts of various plant species tested. Among all treatments the hot water extract of *E. crassipes* at 10 per cent conc. recorded maximum reduction of PDI at 60 DAP with 86.77 per cent reduction over control followed by *Lawsonia inermis* (72.00%) and *Cassia fistula* (50.84%). The results showed that the yield characters are increased in all treatments when compared with control. *Eichhornia crassipes* recorded maximum number of pod per plant (40), fruit length (9.2 cm) and fruit weight (4.52 g fruit-1). *Nerium indicum* was the least effective and recorded the minimum yield parameters. The hot water extract *E. crassipes* showed maximum inhibition of PG and PGTE activity when compared to other treatments. With the regard of the cellulolytic enzymatic changes, hot water extracts of *E. crassipes* recorded minimum C1 enzyme and Cx production. The plant products, viz., hot water extracts of *E. crassipes* have the potential to suppress *A. alternata*, causing leaf blight in chillies.

142. Isolation, Cultivation and Pathogenesis Studies of a Biological Control Agent for Wild Oats. Liang Cheng¹, Qingyun Guo¹, Youhai Wei¹, Liangzhi Guo¹, Cunyue Xin¹, Hua Weng¹; ¹Qinghai Academy of Agriculture & Forestry, Xining, Qinghai, China (Peoples Republic of)

The natural infected wild oat were discovered and collected in the wheat field of Xining, Qinghai province. The pathogen was isolated and identified, and the cultural characteristics, safety test and pathogenic factors were also studied. The wild oat leaves in vivo test method was performed. The results showed that the pathogen is *Drechslera avenacea* (Curtis ex Cooke) Shoem. The colonies of this fungus are grey to black, with coarse, radiating mycelium forming characteristic large milky white to grayish turfs in PDA medium, and producing no or a few conidia in PDA. More than 70% pathogenic efficiency of wild oat was obtained when cultural duration were 7days, dew period 72h,and dew temperatures 17-20° in the greenhouse. The pathogenesis experiments showed that this fungus only wild oats, not wheat, rapeseed, broad bean and pea. It was indicated that the strain could be used as potential mycoherbicide against wild oat in crops.

143. Biological Control of Broomrape (*Orobancha cernua*) Seed Germination Utilizing an Indigenous Actinomycete

Isolate in Jordan. Khalid Hameed¹, Ismail Saadoun¹, Qutaibeh Ababneh¹, Sereen Bataineh¹, Chester Foy²; ¹Jordan University of Science and Technology, Irbid, Jordan; ²VPI&SU, Blacksburg, Virginia, United States of America

Rationale or justification for the research: - Soil microorganisms have diverse effects toward growing plants. Some are recognized as growth promoting organisms and others are phytotoxic. An indigenous *Streptomyces* isolate from soil in Jordan, now designated as (R9) was discovered to have phytotoxic activity against seed germination of some weeds.

Objectives: - The intent was to evaluate the indigenous *Streptomyces* isolate from soil in Jordan (R9) for its potential activity against *Orobanche cernua* seed germination under laboratory conditions.

A brief description of methods used: - Cell-free culture filtrate (1liter) of R9 on glucose peptone molasses (GPM) shaken broth culture incubated for 7 days at 28°C was used either lyophilized or liquid concentrate. Sterile distilled water and GPM broth were used as controls. Preconditioned *O. cernua* seeds were uniformly spread on the surface of water agar plates and irrigated with 1 ml of either lentil (*Lens esculenta*) root exudates or GR-24 (0.2 g/l) as germination stimuli several hours before treatment. R9 extracts (250 µl) were transferred in wells (10 mm in diameter) cut in the center of each plate. Plates were incubated in a humid incubator at 25°C for 3 days then percent seed germination was calculated around wells using a dissecting microscope at 45 X.

Results:- Results showed 0% *O. cernua* seed germination for the R9 culture filtrates in contrast to 31.3 to 50% and 2.3 to 8% seed germination in the water and GMP controls, respectively, in twice repeated experiments.

Conclusions:- Hence R9 may be considered as a potential source for bio-herbicides to control Orobanche.

144. Integrated Management of *Cyperus rotundus* L. in Rice Based Cropping System. Madhavan Nadar Lavanya¹, Ramanathan Kathiresan²; ¹M.Sc Agriculture, Chidambaram, Tamilnadu, India; ²Annamalai University, Chidambaram, Tamilnadu, India

The worlds most troublesome perennial weed *Cyperus rotundus* L, widely perceived as an upland weed, has been observed to occur frequently in transplanted lowland rice, in the tail end of Cauvery river delta region of Tamilnadu State in India. An integrated management programme with main emphasis on biological or cultural strategies is being evolved through field experiments, to tackle this perennial weed. Off-season land management practices comprising 1) Off-season ploughing during summer months 2) Glyphosate spray during off-season summer months 3) Allowing pigs for three days in the puddled rice field prior to final land preparation were compared with an

untreated fallow as main treatments. The sub treatments of the experiment in split plot design comprised weed management practices during the rice cropping period that included twice hand weeded, pre-emergence oxyfluorfen 0.25 kg/ha with and without a hand weeding supplement, incorporation of the husk of *Tamarindus indica* L @ 10 t/ha with and without a hand weeding supplement and an untreated control. These treatments were replicated thrice, with individual plot size of 20m². Allowing pigs in the puddled field reduced the weed infestation in general and purple nut sedge in particular in the rice field by virtue of burrowing the field and eating the tubers by the pigs. Further in corporation of tamarind husk in rice fields also showed inhibition of weed seed/tuber germination and establishment. Both these biological approaches synergistically interacted imparting most efficient weed control and enhanced rice grain yield. This integrated biological control reduced the nut sedge population by 80.2 per cent and total weed counts by 59.7 per cent in transplanted rice. Laboratory studies showed that husk of tamarind possessed higher allelopathic inhibitory activity over tubers of *C.rotundus* compared to the bark, leaves and pulp of tamarind.

145. Biocontrol of Sprangletop [*Leptochloa chinensis* (L.) Nees] by White Leafhopper (*Balclutha saltuella* Baum) in Rice Fields. Chanya Maneechote¹; ¹Department of Agriculture, Ministry of Agriculture and Co-operatives, Chatuchak, Bangkok, Thailand

Sprangletop (*Leptochloa chinensis* L. Nees) is a noxious grass weeds in the direct wet-seeded rice in Thailand. It could reduce rice yield by 20-100% depending on percent of infestation. To control this species, herbicides have been continuously applied resulting in the development of resistance to ACCase-inhibiting herbicides. In 2003, white planthopper (*Balclutha saltuella* Kirschbaum) (Homoptera: Cicadellidae) was firstly reported to be a potent insect for biocontrol of sprangletop (*L. chinensis* L. Nees) in Thailand. It abundantly appeared on sprangletop plants at the flowering-seed formation stages. It attacked only sprangletop panicles and potentially caused seed sterility. Prior to use as a biocontrol method of sprangletop, data on biology, ecology, crop selectivity, host plants, potential of weed damage, response to insecticides and possible vector of rice ragged stunt virus (RRSV) of white leafhopper was required. Random survey of 128 rice fields in 15 provinces in central and lower north of Thailand showed that white leafhoppers were abundantly found in the fields where the density of sprangletop was high, $r = 0.823^{**}$. The number of lady beetles and long-jawed spiders were positively correlated with the number of white leafhopper. Laboratory studies showed that its life cycle was 20-24 days and it was very specific on this grass species without damage on four rice varieties or other weed species except crabgrass (*Digitaria sanguinalis* L. Scop.). In

addition, 40 adults reduced seed formation of sprangletop by 60%. RRSV was unlikely to be transmitted by this insect as no symptom of RRSV disease was appeared in a sensitive rice variety, Taichung Native 1. All six insecticides (i.e. buprofezin 10% WP, isoprocarb 50% WP, fenobucarb 50% EC, ethofenprox 10% EC, carbosulfan 20% EC, imidacloprid 10% SL) killing brown planthoppers were also effective on this species. Hence, white leafhoppers may be a potential insect for controlling the infestation of sprangletop in the rice fields due to its selectivity on sprangletop and depletion of its seed bank in soil.

146. Trichoderma is a Promising Bio-Agent for Controlling Orobanche in Tomato. Barakat Abu Irmaileh¹; ¹Faculty of Agriculture, University of Jordan, Amman, Jordan

Controlling broomrape species in many crops has been continuing for the past decades with only limited success. Fumigants such as methyl bromide and herbicides are the only direct control practices. However, their application requires specific technology that is beyond the capability and affordability of many farmers around the world. In addition, chemicals are not totally safe to the environment.

Biological agents such as insects or fungi were among the available methods for research and development. In this paper, the efficiency of *Trichoderma* spp. to control *Orobanche aegyptiaca/ramosa* on tomato was investigated in greenhouse experiments. In one experiment, five treatments were laid in a completely randomized design. *Trichoderma harzianum* MUCL 38044, was suspended in water to give 2.4 X 10,000,000 conidia /ml. The treatments were: *Orobanche*-infested pots treated with either 2.4 X 10,000,000 conidia /ml or 1.2 X 10,000,000 conidia /ml, at 10 ml / tomato pot at time of planting, non-infested pots treated or untreated with the fungus, and a check of *Orobanche*-infested pots that are not treated with the fungus. Each treatment was replicated twenty times; i.e. twenty pots per treatment. When *Orobanche* shoots appeared in the check treatment, the dry weights of tomato shoot and root and *Orobanche* shoots as well as the number of attachments were recorded. The results indicated that *Orobanche* shoot dry weights and number of attachments were reduced to less than 30% as compared to their values in the check treatment. Tomato shoot and dry weights were also improved in the *Trichoderma* treated pots.

In other experiments, *Trichoderma viridi* (ATCC 29726) was tested for their ability to control *Orobanche* on tomato. The results showed that *Trichoderma viridi* can reduce infestation, but *Trichoderma harzianum* was more effective.

147. Primary Study of Phylogenetic Diversity of Bacteria in Rice Field Soil by 16S rDNA Analysis. Jianping Zhang¹,

Liuqing Yu¹; ¹China National Rice Research Institute, Hangzhou, Zhejiang, China (Peoples Republic of)

Understanding the diversity in the soil microbial communities helps to find some valuable hints for exploring beneficial bacteria and chemicals which might provide potentials for weed biological control in the field. For this objective, a 16S ribosomal DNA (16S rDNA) clone library from a paddy rice field soil of Zhongwei in China Ningxia, where pesticides were never used by native farmer but weed such as *Echinochloa crus-galli* grew naturally, was established by PCR using bacterial universal primers 27F and 1492R-DA total of 200 clones were screened by amplified 16S rDNA restriction analysis (ARDRA) using fourbase-specific restriction enzymes MspI. 74 restriction fragment length polymorphism (RFLP) types, constituting 23.1% of the total clone libraries, were detected and sequenced. Comparative sequence analysis of these clones found all sequences had more than 85% similarity to that of 16S rDNA sequences retrieved from the DNA databases and 37.8% sequences was the most similar to that of uncultured bacterium in GenBank. The phylogenetic analysis found that the sequenced clones fell into six major lineages of the domain bacteria-Proteobacteria, Acidobacteria-Actinobacteria, Chloroflexi-Bacteroidetes and Planctomycetes. Among them, members of the Proteobacteria as the dominant group, which amounts to 37.8%, including Alphaproteobacteria(35.7%), Gammaproteobacteria 32.1%, Deltaproteobacteria 17.9% and Betaproteobacteria 14.3%, followed by Acidobacteria, Actinobacteria, Bacteroidetes CChloroflexi and Planctomycetes division with 16.2%, 12.2%, 10.8%, 10.8%, 8.1%, respectively. In addition, Firmicutes, Gemmatimonadetes, and Verrucomicrobia were found to be less represented. The results of phylogenetic analysis revealed extensive microbial diversity and the potential availability of special microbial resources in the rice soil of China Ningxia.

148. Biocontrol Control of Wild Oats by Puccinia coronata f. sp. Avenae in Mazandaran, Iran. Abdolreza Foroutan¹, Aidin Foroutan²; ¹Agricultural & Natural Resources Research Center Of Mazandaran - Iran, Sari, Mazandaran, Iran; ²Faculty of Agricultural Sciences of Mazandaran, University, Sari, Mazandaran, Iran

Wild oat (*Avenae fatua*) is a major weed of wheat field in Mazandaran province, Iran. Crown rust of Wild oats caused by *Puccinia coronata* f.sp. avenae, is an endemic disease in the province. A survey was carried out in 1993-1994 growing seasons, and samples were collected from different commercial wheat fields including Behshahr, Neka, Ghaemshahr and Sari in Mazandaran, Iran. Strain 26 of the causal agent with a potential control agent and a short latent period was selected from a wheat field of Neka. A field trial was conducted in 2001-02 at Bay-kola

research station (Neka area) with three replicates. Wild oat seeds were grown in a six row plots, each 1.5 m long with 25cm between rows. Each set containing plot treated with crown rust, control plot (without artificial inoculation), and plot treated with propiconazol fungicide for comparing the differences among treatments. The results indicated that disease was established from artificial inoculations ten days earlier than the onset of disease from natural infections. Analysis of yield showed that biomass and seed number of wild oat were significantly lower in inoculated plots than in control and fungicide-treated plots.

149. Etiology of Premature Ripening of Wild Oat in Mazandaran. Abdolreza Foroutan¹, Naser Jafari², Aidin Foroutan³; ¹Agricultural & Natural Resources Research Center Of Mazandaran - Iran, Sari, Mazandaran, Iran; ²Mazandaran University, Babolsar, Iran, Sari, Mazandaran, Iran; ³Faculty of Agricultural Sciences of Mazandaran, University, Sari, Mazandaran, Iran

Wild oat (*Avena fatua*) is a weed in wheat fields. During 2004-2005 crop seasons, wild oat with premature ripening plants was observed in some locations in the province. Infected plants have dark elliptical lesions, were confined to the lower stems. The lesions resembled to eyespot disease, but with dark-coloured acervuli. The samples were collected from the margins of wheat field in Behshahr, Neka (Mazandaran province). The specimens were plated on PDA. Pathogenicity test was done by spraying of spore suspension which had been earned from the purified cultures on PDA at 1x 10⁶ spores/ml, on seedlings of pod grown wild oat in chamber with over 90% relative humidity and about 20°C. After four days resulted in disease expression as chlorotic lesions on leaves. The lesions then turned to necrosis, and finally leaf defoliation occurred. Colonies on PDA were gray with numerous conidia, which grew on hyaline and cylindrical phialides. Phialides were measured as 5.2-7.8 x 12-18 µm. Conidia were sickle shape and 3.7-4.5 x 22-28.5 µm. The identified characters the fungus was according to the characters of *Colletotrichum graminicola* in references. This is the first report the disease on wild oat in Mazandaran province.

150. Damping off of Rye plants in Mazandaran. Abdolreza Foroutan¹, Aidin Foroutan², Mehraban Oladi¹; ¹Agricultural & Natural Resources Research Center Of Mazandaran - Iran, Sari, Mazandaran, Iran; ²Faculty of Agricultural Sciences of Mazandaran, University, Sari, Mazandaran, Iran

Rye is a weed in some wheat fields in Mazandaran province of Iran. Damping off of rye plants was observed in Ghrakheil Research station of Mazandaran province (Iran) in 2003. Samples were taken from the plants

showing root and crown rot and tissue darkening. In order to isolate the disease agent (s), infected parts of plants after surface sterilization with 1% sodium hypochlorite were plated on PDA. Fungal colonies grew from tissue, and subsequently were purified on WA. Pathogenicity test was done by spraying of spore suspension on seedlings of pod grown rye at 2 x 10⁵ and 1x 10⁶ spores/ml respecting to *F. solani* and *c. graminicola*. In the case of *R. solani*, the propagated isolate (on autoclaved sorghum seeds) was incorporate with the pre-sterilized potted soil at first, then seeds of rye plant were sown in the inoculated pots. The inoculated rye seedlings were kept in chamber with over 90% relative humidity and about 20-25°C. Diseases expression were recorded after one to three weeks, and the same fungi were re-isolated on PDA. On the bases morphology and cultural characters, the isolates were identified as *Fusarium solani*, *Colletotrichum graminicola* and *Rhizoctonia solani*. This is the first report of damping off of rye plants in Mazandaran.

151. Effect of Crown Rust in Reducing the Populations of Wild Oats of Wheat Fields in Mazandaran, Iran. Abdolreza Foroutan¹, Esmail Yasari²; ¹Agricultural & Natural Resources Research Center Of Mazandaran - Iran, Sari, Mazandaran, Iran; ²Payam Nour University, Sari, Mazandaran, Iran

Wild Oat (*Avena fatua*) is a major weed of wheat field in Mazandaran province, Iran. Crown rust of Wild Oats caused by *Puccinia coronata* f.sp. *avenae*, is an endemic disease in the province. A field trial was carried out from 2004 to 2006 in two commercial fields of Neka and Gaemshahar with natural infestation by Wild oat. The fields were inoculated with the multiplied of mixed strains of the causal agent which collected and preserved in previous crop season. The results indicated that disease was established from artificial inoculations in three years. Analysis of yields showed that biomass and seed number of wild oat were significantly lower ($P < 0.05$) in 2006 than 2004 and 2005. This research showed that, with augmentation over several years, crown rust may be effective in reducing populations of wild oats in Mazandaran wheat fields.

152. Rhizoctonia Associated with Sheath Rot of *Phyllostachy nigra* in Mazandaran. Aidin Foroutan¹, Abdolreza Foroutan²; ¹Faculty of Agricultural Sciences of Mazandaran, University, Sari, Mazandaran, Iran; ²Agricultural & Natural Resources Research Center of Mazandaran, Sari, Mazandaran, Iran

Phyllostachy nigra is a volunteer plant and weed in some fields in Mazandaran province (Iran). During 2004-2005 crop seasons, plants with elliptical, light brown areas limited by thin, dark brown border on leaf sheaths were

observed in some regions in the Province. Lesions occurred up to 40 cm high on stem in some locations. Mycelia strands spread across the central portion of the lesion, frequently developed into dark brown. Sclerotium like bodies were arranged in a loose network. Samples of infected plants were collected, washed and cultured on PDA medium. The isolates were purified by hyphal tip method on WA. White mycelia grew on medium. The colonies turned to brown and darker during the periods of time. Hyphal with 6-12 µm wide and right angle branches were grown on PDA. Based on morphological features and morphometric characters the causal agent was identified as *Rhizoctonia solani* Kuhn. This is the first report of sheath rot disease on *Phyllostachy nigra* in Mazandaran province.

153. Evaluation of *Bipolaris sorokiniana* for the Control of *Echinochloa crus-galli* (L.) Beauv. and its Safety to Crops. Liu Yu¹, Rui Geng¹; ¹China National Rice Research Institute, Hangzhou, Zhejiang Province, China (Peoples Republic of)

Barnyardgrass (*Echinochloa crus-galli* L. Beauv) is one of the most troublesome weeds in the world, which has caused the resistance to some chemical herbicides. However, biological control had more advantage in avoiding the negative influence of chemicals. The objective of this study was to evaluate the activity of a new strain *Bipolaris sorokiniana* for barnyardgrass control in rice and its safety to major crops in South of China.

Methods: *B. sorokiniana* was isolated from natural diseased barnyardgrass plants collected in Kunming, Yunnan Province, China. The potential of this strain as mycoherbicides for barnyardgrass control was further investigation. The culture filtrate of *B. sorokiniana* prepared after cultivation in PDB growth media. Bioassay method was accepted which test the inhibition activity to barnyardgrass root and shoot after treated with the culture filtrate in the laboratory. Effects of barnyardgrass control were observed after treated with the mycelium turbid liquid at different rate, and the response of crops on the strain was recorded in the greenhouse condition.

Results: The results of bioassay in the growth inhibition ratio of barnyardgrass root and bud showed that the culture filtrate from the strain at 5 days after fermentation had excellent inhibition activity to the weed. The treatment of culture filtrate gave higher activity than the treatment of 10² dilution. The barnyardgrass root was much more susceptible to the strain than bud, with the root growth inhibition ratio of 95.78% and the bud growth inhibition ratio of 82.13%. Under laboratory condition, the results from the detached leaf bioassay suggested that the initial symptoms of the disease, brownish irregular spots with chlorotic halo around them, started developing at 2nd day after post treatment. There was marked damage at the 4th day. 100% disease incidence of the detached leaves occurred at the 5th day. Under greenhouse conditions,

the results from whole plant bioassay suggested that disease symptoms were apparent at the 3th day the death of plants occurred on the 7th day and 82.67% mortality of the plants occurred at 21st day. What's more, crop tolerance test showed that *B. sorokiniana* was safe to major crops.

Conclusion: *B. sorokiniana* gave the excellent inhibition ratio of barnyardgrass root and plant mortality which indicated that the culture filtrate and mycelium of the strain has high activity for the weed control. *B. sorokiniana* did not injure the major crops like rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), rape (*Brassica napus* L.), maize (*Zea mays* L.) and some vegetables. As a strain of bio-fungus, *B. sorokiniana* has good application prospects.

154. Microbial Management of Weeds In India : Current Status. Sadaf Qureshi¹, Akhilesh Pandey¹; ¹R.D. University, Jabalpur, M.P., India

The designation of a plant species as a weed is rarely unanimous and substantial disagreement often arises. A plant may be a weed to one person but the same plant may be useful to another. Chemical pesticides have been proved to be excellent tools in today's crop protection technology, but sometimes cause formidable problems. Even with proper use, chemicals may be hazardous indirectly in various ways, namely toxicity of residuals, injury to non target crops and endangered species, development of resistance and resurgence at more serious levels. Significant health and environmental hazards have risen at specific non-agricultural sites as our requirement for synthetic chemical pesticides increased. As a result of outcries against the tragedies, the discovery and development of alternatives to chemical pesticide is an essential agenda for agricultural scientists faced with the daunting task of protecting crops and livestock on a large scale over a wide range and ever shifting spectrum of agricultural pests. Biological control of weeds with microorganisms have provided an effective and eco-friendly management for many weed problems. Several microorganisms or their secondary metabolites have been patented and successfully commercialized. *Parthenium hysterophorus* L., an aggressive, herbaceous weed adversely affects crop production, animal husbandry and biodiversity. Being a pernicious and dreaded weed it can reduce yield by 40% in agricultural crops and upto 90% in forage production in grassland, henceforth, its management becomes of paramount importance. As conventional, traditional strategies have aborted due to several reasons, exploitation of secondary metabolites i.e. biorationals of both pathogenic and non-pathogenic fungi has attracted the attention of scientists worldwide. Phoma is a well-known phytopathogen responsible for inciting many diseases in plants. Various species and strains of the fungus are known to synthesize an array of phytotoxic secondary metabolites. Herbicidal potential of CFCF (Cell Free Culture Filtrate) of Phoma

sp FGCC#54 against *Parthenium* was evaluated by employing seedling and detached leaf bioassays. Maximum phytotoxicity was obtained from 21 days old fermented broth of 100% concentration. Significant reduction in biological content i.e. photosynthetic pigment and protein contents was observed. Phytotoxic damage such as severe wilting, chlorosis, necrosis and complete collapse of the entire parts of the weed were also noticed due to CFCE application. Biorationals from *Phoma herbarum* could be used as herbicides for the management of the obnoxious weed *Parthenium*. But before application the phytotoxins have to be formulated to enhance their absorption and translocation within the foliar tissues. Herbicidal potential of test strain, cultivated on extract of several agro wastes (5) was evaluated by shoot cut, seedling and detached leaf bioassays. Thus, the main aim of this paper is to highlight the herbicidal efficacy of the biorationals of *Phoma* as novel and lucrative sources of potential herbicides for the management of the problematic weed, *Parthenium hysterophorus*.

155. On Isolation, Purification of *Exserohilum monoceras* Phytotoxin and Its Application as a Potential Microbial-Product Herbicide. Yong Chen¹; ¹South China Agricultural University, Guangzhou, Guangdong, China (Peoples Republic of)

E. monoceras is a natural pathogen to *Echinochloa crus-galli*, one of the worst weeds in the world. Its spores can well control *E. crus-galli* in field. In this study, the strain X27 of *E. monoceras* was chosen. Its isolation, purification were preliminarily studied and its potential as microbial-product herbicide was preliminarily evaluated.

The crude phytotoxin was extracted from mycelia and fermentation broth with different organic solvent in file, including petroleum ether, ethylacetate, and methanol, and purified with six times silica gel column chromatography, combining bioassay. The bioassay on seed germination, that detect radical and seedling growth inhibitory rate with filter paper method (FPM). The phytotoxin activity to 22 kind plant species, such as crops, vegetables and weeds were tested by FPM and spot-spraying method. For 4-leaf stage *E. indica* and 2-leaf stage *E. crus-galli*, chlorophyll content, superoxide dismutase content, malondialdehyde content and Relative electrical conductivity of leaves were also tested with Ultraviolet spectrophotometric method, NBT method, TBA method, and electromagnetic induction conductometer method respectively.

When the polarity of eluting solvent was between petroleum ether: ethylacetate = 1:2, and petroleum ether: ethylacetate = 1:1, the toxin in eluting solvent was most active, and the medicine effect increased approximate 200 times.

The crude toxin had different degree of activity to the 22 kind plant species, especially to *Triticum aestivum*, *Lycopersicon esculentum*, *Eleusine indica* and *Amaranthus*

retroflexus. The radicle and seedling growth inhibitory rate were all beyond 90%. When tested with spot-spraying method, *E. indica*, *E. crus-galli*, *A. retroflexus*, *Digitaria sanguinalis*, and *Bidens bipinnata* were all sensitive to the crude toxin, especially 4-leaf stage *E. indica* and two-leaf stage *E. crus-galli*.

On the 7th day after spraying 5000ppm crude toxin with 0.4% Tween 20, chlorophyll content decreased, not significantly comparing to that of comparison, but SOD and MDA content, relative electrical conductivity were significantly higher than that of comparison. But on the 15th day, the 4 indexes of leaves in treatments and comparisons were not different remarkably.

The crude toxin of *E. monoceras* had broad-spectrum herbicidal activity, and through purification, its activity would increase greatly.

156. Host-Specific *Colletotrichum* for Control of Field Dodder (*Cuscuta campestris*). Mou-Yen Chiang¹, YC Hsieh¹, FY Lin¹; ¹Taiwan Agricultural Chemicals and Toxic Substances RI, Wufeng, Taichung, Taiwan

Cuscuta campestris is the most important parasitic plant in Taiwan, widely distributed in lowland areas and capable of parasitizing many herbaceous hosts. Currently, this weed is most troublesome for lawn, groundcovering and ornamental plants of less intensively managed habitats. Seriously infected areas often have to be renovated because unsightly view and impossible to control with traditional methods such as chemicals and hand weeding. A *Colletotrichum* sp. was isolated from diseased dodder in central Taiwan. A series of tests and investigations were conducted to evaluate the potential of developing this fungal pathogen as a bioherbicide for control of *C. campestris*. This *Colletotrichum* fungus is most closely related with *C. acutatum* based on sequence analysis of ITS of ten *Colletotrichum* species. Host range tests indicate that this fungus is very specific, congenic Japanese dodder (*C. japonica*) and 30 other plants were not affected. Inundated spray with conidia suspension of 1×10⁶ spores/ml frequently resulted in severe necrosis of dodder in 10-15 days. Field tests at multiple sites indicated 2-3 application produced more than 95% control of established *C. campestris* in moderately-to-heavily affected areas. Other studies on dew requirement, spore production and environmental persistency also indicate that this fungus is a good candidate to be developed to bioherbicide. Small market demand is likely the major constraint for further commercial development of this biocontrol agent in Taiwan.

157. Fungal Plant Pathogens to Red Sprangletop (*Leptochloa chinensis*) as Potential Biocontrol Agents in Japan. Ken-ichi Yamaguchi¹, Maiko Mutsunobu¹, Takao Tsukiboshi²; ¹Minami Kyushu University, Takanabe-cho,

Miyazaki, Japan; ²National Institute of Livestock and Grassland Science, Nasu-shiobara, Tochigi, Japan

Red sprangletop (*L. chinensis*) has become a serious weedy grass not only in South-east Asian countries such as Vietnam but also in Japan. This weed is adapted to moist and swampy so that it is troublesome around paddy field, especially in direct-seeded rice. Also it can be found in soybean converted from paddy, and even in transplanted rice in Kyushu district, the southern part of Japan. Fungi including *Bipolaris*, *Exserohilum*, *Drechslera* and *Curvularia* species were isolated from naturally infected Red sprangletop in south Kyushu. Two different types of *Exserohilum* showed apparent pathogenicity to Red sprangletop seedlings when inoculated with mycelia and then kept with high humidity inside a plastic bag. To evaluate the potential of these *Exserohilum* species for bioherbicides, conidia of each *Exserohilum*, produced on V-8 juice agar under black light blue irradiation, were sprayed on several weeds and crops including some cultivars of rice and soybean. *E. micropus*, identified based on both morphological characteristics of its forming conidia and sequences of its 18S rDNA, caused severe disease symptom only on Red sprangletop and then killed. On the other hand *E. rostratum* (*Setosphaeria rostrata* in teleomorph) caused leaf spots not only on Red sprangletop but also on some non-target plants. These results suggested *E. micropus* is expected to have more potential as a biocontrol agent against Red sprangletop better than *E. rostratum*.

158. Exploration of Genetic Variability of Plant Pathogens to Improve Biocontrol of Perennial Thistles. Alexander Berestetskiy¹, Svetlana Kashina¹, Irina Bilder¹; ¹All-Russian Institute of Plant Protection, Pushkin, Saint-Petersburg, Russia

Perennial thistles as *Cirsium arvense* (Canada thistle) and *Sonchus arvensis* (perennial sow-thistle) are troublesome weeds through temperate regions in Europe and North America. Their eradication is difficult without the use of high rates of chemical herbicides. Several fungal pathogens were identified by our group to develop a bioherbicide(s) against the perennial thistles. The culture collection of these fungi (*Phoma exigua* var. *exigua*, *Septoria cirsii* and *Stagonospora cirsii*) was established. The main goal of the research was to evaluate variability in the biocontrol fungi and prospects for further selection of high aggressive strains. Morphology, aggressiveness and molecular markers (AFLP, ITS sequences) were explored to differentiate strains of the weed pathogens. The most variable fungus was found to be *Stag. cirsii*. It is possibly due to teleomorph stage, which can be produced by the fungus both in vivo and in vitro. Several strains of *Stag. cirsii* that significantly were more aggressive than a standard one were found. Perfect stages for *P. exigua*

var. *exigua* and *S. cirsii* are still unknown. Generally, strains of *Stag. cirsii* were more aggressive than strains of *S. cirsii* and *P. exigua*. The last fungus was low aggressive and instable. So searching new strains of this species is not promising. Whereas *S. cirsii* was demonstrated some potential to find stronger biocontrol strains than standard ones. The next step of our research is evaluation of selected strains of *Stag. cirsii* and *S. cirsii* on clones (ecotypes) of the thistles of different geographical origin in order to find pathogens aggressive to the most of the clones.

159. *Microsphaeropsis amaranthi* as a Bioherbicide for the Control of Weedy *Amaranthus* spp: Infection Process and Virulence Enhancement. Daljit Singh¹, Yasser Shabana², Steven Hallett¹; ¹Purdue University, West Lafayette, Indiana, United States of America; ²University of Florida, Gainesville, Florida, United States of America

Microsphaeropsis amaranthi is a host specific fungal pathogen of *Amaranthus* spp and is virulent against a number of weed species in Amaranthaceae. The fungus was grown on a range of different media, and it was observed that the conidia produced on corn stubble were larger, and had a thicker cell wall, compared to the conidia produced on other media. When sprayed onto the waterhemp seedlings the conidia produced on corn stubble were also the most virulent, and killed plants within 48 hr. The infection process of *M. amaranthi* was studied on detached waterhemp leaves inoculated with suspension of conidia produced on either solid V-8 medium or corn stubble. The conidia produced on corn stubble were superior to those produced on V-8 in number of ways. At 4 hours after inoculation, it was observed that conidia produced on corn stubble germinated earlier, and the percent germination was twice as those produce on V-8 medium. The germ tube elongation was also greater in conidia produced on corn stubble at 4 hours after inoculation. The fungus grown on corn stubble was also seen to produce thick hyphae earlier during the initiation of pycnidium. Thus overall the fungus invaded the cells earlier and colonized the host tissues rapidly as compared to fungus grown on V-8 juice agar. *Microsphaeropsis amaranthi* is highly effective against common waterhemp under favorable conditions, but often fails to perform under sub-optimal conditions. The primary requirement for the bioherbicide to be effective is the availability of free moisture for germination and penetration. Thus virulent conidia such as produced on corn stubble can enhance the disease development, and be effective in environments where the moisture availability is for shorter duration.

160. Fungi Associated with Root and Crown Rots of Bermuda Grass in Mazandaran. Esmaeil Yasari¹, Aidin Foroutan²; ¹Payame Noor University, Sari, Mazandaran, Iran; ²Mazandaran University, Sari, Mazandaran, Iran

Bermuda grass (*Cynodon dactylon*) is a volunteer plant and as a major weed in crop fields and orchard gardens in Mazandaran province (Iran). Diseased plants of *Cynodon dactylon* were observed in a citrus garden in Sari in 2003. Samples were taken from the plants showing root and crown rot and tissue darkening. In order to isolate the fungi, infected parts of plants after surface sterilization with 1% sodium hypochlorite were plated on PDA. Fungal colonies grew from tissue, and subsequently were purified on WA. Koch postulation was done either by spraying of spore suspension on seedlings of pod grown of Bermuda grass plant at 1×10^6 spores/ml, or planting of Bermuda grass seeds on pre-inoculated of potted soil. In this case, the propagated isolate (on autoclaved sorghum seeds) was incorporate with the pre-sterilized potted soil at first, and then seeds were sown in the inoculated pods. The inoculated pods were kept in chamber with over 90% relative humidity and about 20-25 °C. On the basis of morphological and cultural characters, the isolates were identified as *Gaeumannomyces graminii*, *Fusarium solani*, *Colletotrichum graminicola* and *Rhizoctonia solani*. Diseases expression was recorded after one week to three months, and the same fungi were re-isolated on PDA except *Gaeumannomyces graminii*. Pathogenicity test of the *Gaeumannomyces graminii* was not approved. This is the first report of the above mentioned fungi on Bermuda grass plants in Mazandaran, Iran.

161. Scale-Up and Formulation of *Mycoleptodiscus terrestris*: A Biological Control Agent of *Hydrilla verticillata*. Christopher Dunlap¹, Mark Jackson¹; ¹USDA NCAUR, Peoria, IL, United States of America

Rationale: The invasive weed, *Hydrilla verticillata* is one of the most challenging aquatic weeds in the United States of America. Its ability to rapidly spread and alter the properties of the watershed make it a difficult management problem. It is currently managed with chemical herbicides and mechanical methods. Increasingly, herbicide resistance and public environmental concerns have increased the need for non-synthetic control options. *Mycoleptodiscus terrestris* is a natural plant pathogen of *Hydrilla verticillata* and has been shown to be effective in controlling the weed in aquarium and field assays. The development of *M. terrestris* into a commercially viable bioherbicide requires developing methods to produce, formulate and disperse infective propagules. Our current research addresses these problems at the pilot plant scale. Objective: Develop methods and procedures to produce pilot plant quantities of *M. terrestris*. Evaluate methods of drying and particle size reduction of propagules of *M. terrestris*. Identify critical process variables that may be used as quality control indicators.

Experimental methods: Biomass was produced using Braun 100 L fermentors and harvested with a rotary drum vacuum filter. Particle size reduction was performed with a

vacuum assisted conical mill. Final product drying was achieved with air-drying or with a fluidized-bed dryer. Extraction and chemical composition of the propagules was accomplished with standard analytical methods.

Results: Methods and handling parameters have been developed to produce uniform sized particles, which are amenable to the drying process. The drying process has been optimized to provide stabile propagules with a long shelf-life. In addition, analysis of the chemical composition of the microsclerotia suggests the membrane stabilizers, trehalose and mannitol, are important to its drying tolerance. Conclusions: Our research has shown *Mycoleptodiscus terrestris* is amenable to pilot plant scale production. Methods and handling parameters for working with the biomass are now established. Future research will be directed at formulation issues, which impact efficacy and shelf-life.

162. Surveys on Alligator Weed (*Alternanthera philoxeroides*) in Argentina and Bolivia: Rust and other Fungal Pathogens as Possible Biological Control Agents. María Guadalupe Traversa¹, Alejandro Sosa¹, Mirta Kiehr¹, Rolf Delhey¹, Mic Julien¹; ¹National University of the South, Bahía Blanca, Buenos Aires, Argentina

Alligator weed (*Alternanthera philoxeroides*, Amaranthaceae) is an evergreen species native of South America. It is an invasive plant in Australia, USA, China and other countries. To identify possible candidates for the biological control of this plant, surveys of fungal pathogens were carried out in Argentina (November 2004 to May 2005) and Bolivia (August 2007). In Argentina, many sites were explored and several pathogens have been found in Buenos Aires, in the northwest and northeast provinces. *Colletotrichum orbiculare*, *Colletotrichum* cf. *capsici* and *Fusarium* sp. have been found associated with stem lesions and leaf spots; *Albugo bliti* (on *A. philoxeroides* and *A. aquatica*), *Phoma* sp. and *Phomopsis* sp. have also been identified. *Uredo pacensis* Lindq. is a rust described in 1957 on *A. philoxeroides* in the yungas formation near La Paz, Bolivia. We rediscovered and collected this rust at several sites near Coroico, La Paz Province. Cinnamon-coloured uredinia were found on leaves. The very thick apical wall of the urediniospores identifies our collections as similar to the original *U. pacensis*. A high incidence in and an important impact on the host populations were observed. Our field surveys will concentrate on some places of northwest of Argentina where the environmental conditions are similar to the sub-tropical Bolivian yungas. Finding the rust in Argentina would facilitate further studies on its biology, specificity and impact. Future research should consider surveys for other pathogens in different regions and seasons in Argentina.

163. **The Potential for Biological Control of *Lippia*, *Phyla canescens*.** Mic Julien¹, Alejandro Sosa², Guadalupe Traversa³, Mohammad Fatemi⁴, Eduardo Greizerstein⁵; ¹CSIRO Entomology, Clapiers, Languedoc, France; ²US-DA, Hurlingham, Buenos Aires, Argentina; ³Universidad Nacional del Sur, Bahia Blanca, Buenos Aires, Argentina; ⁴University of New England, Armidale, New South Wales, Australia; ⁵University of Buenos Aires, Buenos Aires, Federal District, Argentina

Lippia, *Phyla canescens* (Verbenaceae), is a low-growing herbaceous plant from South America. It was introduced into Australia as an ornamental and now infests over 5 million hectares of grazing (mostly floodplains) and riparian land. It continues to spread and causes losses to the cattle industry exceeding \$2.3 million annually. *Lippia* can be managed with cultivation, however, cultivation is not appropriate in many situations and habitats. Similarly, management with herbicides is neither affordable, nor practical in many locations and not permitted along waterways.

In 2005 a number of projects were initiated to improve our potential to control this weed. Surveys for potential biological control agents in Argentina (native range) have identified 20 insect and about 15 fungi natural enemies. These are being prioritized and studies are underway on the high priority species to develop rearing or culturing methods and to understand their biologies. Preliminary host range testing of the first insects is anticipated soon and a proposal to assess a rust is being prepared.

The taxonomy and distribution of *lippia* and related species is uncertain and therefore their distributions are also unclear. Collections in South America, Australia and France (where it is also invasive) and molecular genetic analyses are determining where *lippia* occurs and the relationships between native and invasive range populations. This may help pinpoint the centres or origin of the invasive material and so help focus surveys for potential agents. Collections of other *Phyla* species, especially *P. nodiflora*, are being made with the intention of sorting out the relationship between *lippia* and *P. nodiflora*. This is important because these two *Phyla* species only are reported from Australia and there is doubt that *P. nodiflora* is also exotic to Australia. Knowing this status will help determine the level of host specificity required for potential biological control agents for *lippia*.

Analyses of pollen and root tip cells from *lippia* collected from the three countries is determining ploidy levels and the presence of hybridisation.

Studies are also focusing on the biology, physiology and ecology of *lippia* to determine if there are key factors in its environment and/or life cycle that might be exploited through biological control or integrated management.

The overall aim of these projects is to develop better management strategies for *lippia* that compliment grazing strategies already in practice, to reduce dependence on herbicides and to provide control measures where none are

currently available or practices, that is, in riparian and forested areas, and public and conservation lands.

164. **Weed Biological Control in Organic Agriculture; Case Study: Effect of Nitrogen Fertility on Biocontrol of *Chenopodium album* by *Ascochyta caulina*.** Reza Ghorbani¹; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan, Iran

Organic and ecological agriculture has increased in popularity in recent years mainly due to concerns about the safety of chemical pesticides in the environment and a desire for a more sustainable production system and healthier food. One of the most important principles for making a farm more sustainable is reducing the use of synthetic agrochemicals and replacing non-renewable petrochemical resources by biologically based renewable inputs. Biological control strategies are seriously recommended by organic agriculture and in integrated pest management (IPM) systems. Biocontrol tactics that are usable in organic agriculture include conservation, classical and biopesticide approaches. In conservation strategies, protection of predators, parasitoids and antagonistic pathogens of pests are recommended. Application of microorganisms is allowed while application of transgenic microorganisms is prohibited. Plant nutrient supply is one of the main issues in organic agriculture as susceptibility to pathogens is undoubtedly affected by plant nutrition. In greenhouse experiments, replicated groups of common lambsquarters plants raised with different N supplies were sprayed with various isolates and concentrations of *Ascochyta caulina*, three weeks after planting. Disease development was positively related to increasing plant tissue nitrogen and also to increasing spore concentration. Fungal spore concentration also had a positive effect on plant tissue nitrogen percentage. Nutrient pools in organically farmed soils similar to conventionally managed soils could be essential for successful application of biocontrol strategies in weed management.

165. **Does Vacuum-Packaging Atmosphere Enhance Shelf-Life of Striga-Mycoherbicide Products Containing *Fusarium oxysporum* f.sp. *Strigae* During Storage?** Abuelgasim Elzein¹, Juergen Kroschel², Paul Marley³, Georg Cadisch¹; ¹University of Hohenheim, Stuttgart, BW, Germany; ²International Potato Center (CIP), Lima, Peru; ³Ahmadu Bello University, Zaria, Nigeria

For practical use after formulation, biocontrol products must be packaged in such a way as to maintain the products in suitable shelf-stable state for storage, distribution and application in the agricultural market. In this study, the effect of vacuum packaging atmosphere for prolongation of the shelf-life and facilitation of handling of *Striga* mycoherbicide products (Pesta granules and seed

treatment made with chlamydospores of *Fusarium oxysporum* f. sp. strigae strains (Foxy 2, PSM197) was studied at two temperature regimes (4°C and 22±3°C) throughout one year of storage. The storage under vacuum packaging atmosphere, an oxygen deficient environment, did not enhance the shelf-life of Striga mycoherbicide products (Pesta granules and seed treatment) regardless of the type of inoculum used (Foxy2, PSM197 and their mixture), the co-incorporated amendments [urea into Pesta and co-delivered fungicides (Ridomil Gold®, Apron XL®) on coated sorghum seeds], and coating material (Arabic gum AG, SUEB binder SB) and storage temperature regimes (4°C and 22±3°C) after 12 months of storage. Instead, in some cases, negative effects were encountered that storing under vacuum packaging atmosphere reduced the half-life times (t_{0.5}) of Foxy2, PSM197 and their mixture into Pesta formulation by 3.3, 10.2, and 2.4 months under room temperature, as well as it has shortened the t_{0.5} of Foxy2-SB-coated seeds to a half from 11 to 5.6 months when stored at 4°C. All Striga mycoherbicide products combinations retained a significantly higher shelf-life when stored at 4°C than at 22±3°C irrespective of the storage atmospheres. The insignificance of vacuum packaging atmosphere for enhancing the shelf-life of Striga mycoherbicide products reflects the stability and tolerability of the formulated fungal propagules chlamydospores to withstand environmental extremes and thus their handling and distribution through the ordinary (normal) packaging channels in Africa would be harmless and feasible as well.

166. The Role of Invasive Weeds in the Epidemiology of Plant Viruses in Hungary. Joseph Horvath¹, Gabriella Kazinczi¹, Andras Takacs¹; ¹University of Pannonia, Keszthely, Zala, Hungary

Ten percent of the neophytes (71 species) are considered as invasive alien species in Hungary. Most plant invaders are harmful to ecological balance of biotic communities and nature conservation areas, to rare and protected plant species, and to biological diversity. Some invasive weeds can cause human health problems and may reduce crop yields. Their indirect harmful effect as alternative hosts of plant pests and pathogens may also be important. In the last three years, the natural virus infection of invasive alien plants were surveyed in Hungary. Mechanical inoculations and vector transmissions were also made under glasshouse conditions. It can be said that some perennials (*Phytolacca americana*, *Asclepias syriaca*, *Cyperus esculentus*) may play an important role in the overwintering of some economically important viruses like Tobacco mosaic virus, Alfalfa mosaic virus, Cucumber mosaic virus and Brome streak mosaic virus. *Ambrosia artemisiifolia*, the most harmful and widespread invasive weed in Hungary and Europe, was resistant to mechanical inoculation with a large number of viruses. In spite of this, 3% of the field samples were positive for Cucumber mosaic virus. This suggests

that vector transmission of viruses under field conditions is more effective than mechanical transmission. This was confirmed by transmission tests with thrips as well.

167. Classical Biological Control of Invasive Aquatic Plants: Alligator Weed and Cabomba. Shon Schooler¹, Mic Julien¹; ¹CSIRO Entomology, Brisbane, Queensland, Australia

Invasive aquatic plants have diverse social, economic and environmental impacts and associated high costs of control. These plants are difficult to control because standard chemical and physical control methods are not effective, or in some cases, may exacerbate the problem. Fortunately, classical biological control has proven successful in managing many invasive aquatic plants, such as salvinia (*Salvinia molesta*) and water hyacinth (*Eichornia crassipes*), across much of their introduced range. We are currently searching for safe and effective agents for two other serious worldwide plant invaders; alligator weed (*Alternanthera philoxeroides*) and cabomba (*Cabomba caroliniana*). Biological control of alligator weed has been effective in controlling large floating mats in aquatic systems. We are seeking additional biological control agents for terrestrial and cooler areas. Several promising agents, a beetle (*Disonycha argentinensis*) and a thrips (*Amynothrips andersoni*), were not host specific and are therefore not safe for release in Australia. We are currently testing a tip-galling fly (*Clinodiplosis alternantherae*) and are beginning the testing of a flea beetle (*Systema nitentula*) and a leaf mining fly (*Ophiomyia* spp). In contrast to floating and emergent weeds, biological control of submerged aquatic plants has not yet been proven successful. We have identified three potential biological control agents for cabomba. These include a stem boring weevil (*Hydrotimetes natans*) and two pyralid moths (*Parapoinx* spp and *Paracles* spp). We have begun testing the host specificity of the weevil in quarantine. Comparing these two species highlights the difficulties involved in biological control research. Alligator weed has many natural enemies in its native range, but also has many native congeneric species in the introduced range, which limits the choice of agents to those exhibiting very high host specificity. Submerged plant species tend to have fewer natural enemies, but also have fewer closely related species in the introduced range and the potential biological control agents tend to be more host specific.

168. Use of Organic Mulch as an Alternative to the Plastic Mulch-Methyl Bromide System for Suppressing Purple and Yellow Nutsedges in Tomato Production. Yasser Shabana¹, Raghavan Charudattan¹, Ayman Abou Tabl¹, Waldmar Klassen¹, Erin Roskopf², Pablo Morales-Payan³; ¹University of Florida, Gainesville, Florida, United States of America; ²USDA-ARS, Fort Pierce, Florida, United

States of America; ³University of Puerto Rico, Mayaguez, Puerto Rico

Cyperus rotundus and *C. esculentus* (purple and yellow nutsedges, respectively) are among the most serious weed problems in many cropping systems in Florida and other parts of the world. They have been reported to cause yield losses of 20-89% in various horticultural crops. Production systems based on plastic mulch and methyl bromide soil fumigation are used for nutsedge suppression in many conventional vegetable cropping systems. When methyl bromide has been totally phased out, the losses due to nutsedges are expected to increase in conventional horticultural crops. Organic production will continue to suffer due to a lack of effective weed control measures. Thus, 10 organic hays (shoot straw of bahiagrass, cogongrass, cowpea, millet, nutsedge, sorghum Sudangrass, sunnhemp, rye, corn, and sugarcane bagasse), four green mulches (cowpea, millet, sorghum Sudangrass, and sunnhemp), and two plastic mulches (black and IRT) were tested for their efficacy in suppressing purple and yellow nutsedge growth in a raised bed tomato (cv. Tygress) field. The beds were fumigated with methyl bromide prior to treatment establishment and a randomized complete block design was used with four replications. Tomato seedlings were transplanted in a single row in all plots at a rate of six tomato seedlings per plot with 18 in plant spacing. The following day, nutsedge tubers were seeded, with yellow and purple nutsedge tubers seeded alternately at 1 in depth and 3 in space in two lines parallel to tomato rows (one line on each side with 2 in spacing from tomatoes). Only the plot of weed-free control treatment in each block was not seeded with nutsedge. After seeding the nutsedge tubers, the hays and green or plastic mulches were spread in each plot. The black plastic mulch consistently reduced nutsedge emergence and growth more than the organic mulches and the IRT plastic mulch. All green organic mulches, except the green sunnhemp, were more suppressive to nutsedge emergence and growth than hay mulches. Among the organic mulches, the greatest suppressive effect on nutsedge was found when using green sorghum, green millet, and cogongrass hay followed by green cowpea and bahiagrass hay. Sugarcane bagasse, corn hay, green sunnhemp, and yellow nutsedge hay provided the least nutsedge suppression. Although cogongrass hay did not enhance the total yield, it influenced the proportion of larger fruits. The highest yield of extra large tomatoes per plant was obtained when cogongrass hay was used as mulch. However, the use of black plastic increased the total yield and the proportion of larger fruit.

169. Developmental Studies of *Myrothecium verrucaria* (IMI 361690) as a Bioherbicide. Robert Hoagland¹, Clyde Boyette¹, Mark Weaver¹, Kevin Vaughn¹, Kenneth Stetina¹; ¹USDA-ARS, Stoneville, Mississippi, United States of America

Numerous pathogens have been discovered that have bioherbicidal potential to control a large variety of weeds. One recently explored bioherbicidal fungus is *Myrothecium verrucaria* (MV; strain IMI 361690) that was first isolated from the weed, sicklepod. In our laboratory, we are presently developing this MV strain as a bioherbicide for kudzu and other invasive and hard-to-control weeds. Kudzu is our initial primary target for MV as a bioherbicide since it is a poorly controlled exotic invasive weed, and is also a host for Asian soybean rust. Early in our studies we noted that MV produced mycotoxins (macrocyclic trichothecenes), and this factor has impeded its acceptance and approval for registration by EPA. Over the past few years, we have examined various aspects to advance the utility and acceptability of this fungus as a commercial product. Thus far we have discovered that: a) MV is generally weakly pathogenic, but is highly efficacious against several weeds when combined with the surfactant Silwet L-77; b) MV can control diverse dicotyledonous weeds (kudzu, hemp sesbania, redvine, trumpet creeper, morning-glories, purslanes, pigweeds, etc.); c) MV interacts additively and synergistically with the herbicide glyphosate to provide more efficacious weed control; d) MV produces several trichothecenes, and we have developed methodologies (HPLC and ELISA) to detect and quantify these mycotoxins in MV cultures, extracts, and in plant tissues treated with MV formulations; and e) production of these undesirable mycotoxins can be mitigated by using mycelial formulations grown in sub-merged culture, formulations of washed spores, or by modifying nutritional components whilst high bioherbicidal activity is maintained. We are currently investigating the bioherbicidal activity of various chemically-induced mutants of MV, the role of hydrolytic enzymes in MV pathogenicity, the ultra-structural effects of MV action on kudzu and other weed tissues, and the use of biomarkers in order to monitor the infection process, over-wintering, and ecological impacts of MV applications in the environment. Advances in the understanding of bioherbicidal mechanisms of action and the elimination of mycotoxins in MV formulations will help promote this fungus as a safe and effective bioherbicide product.

170. Mycoherbicidal Control of *Marsilea minuta* - a Weed of Rice Crop. Rukhsana Bajwa¹, Nusrat Rabbani¹; ¹University of the Punjab, Lahore, Punjab, Pakistan

Weed scientists are facing new challenges, particularly emergence of weed resistance to herbicides and herbicide residue in food and environment. These have provided the impetus to evaluate alternative methods of weed control, which are environmental friendly. One of these alternatives is to use various indigenous plant pathogenic fungi for their potential to be used as biological agents for weed management. The present study was designed to evaluate the mycoherbicidal potential of *Drechslera hawaiiensis* for

the management of *Marsilea minuta*, one of the problematic weeds of rice.

Optimization of nutritional and climatic requirements of *D. hawaiiensis* on different growth media under varying temperature, humidity, pH and photoperiod revealed the suitability of potato dextrose agar (PDA) as most suitable medium for growth and sporulation of the fungus under 12 hour photoperiod and 25 C. Efficacy of the fungal pathogens against the target weed was evaluated both under controlled as well as under prevailing environmental conditions. Under controlled set of environmental conditions highest disease incidence, disease severity and biomass reduction of the target weed was observed under 24 and 36 hr dew period at 25 and 30 C with conidial concentration of 109 ml⁻¹. Under prevailing environmental conditions, maximum control of weed was recorded during the month of November. For host specificity evaluation of the fungal candidate agent, was sprayed on economically important crops of the season viz. maize, rice and sunflower. All the test crops showed immunity to the pathogen indicating that the selected pathogen was host specific. In order to enhance the mycoherbicidal efficacy of the fungal candidate agent, different formulations were tried both under controlled as well as under natural environmental conditions. Under controlled laboratory trials, 106 conidia ml⁻¹ in 20% canola oil emulsion at 35 C and 36 hr dew period provided significant control of *Marsilea*. This most effective mycoherbicidal formulation was evaluated under field conditions by spraying on *Marsilea* growing in rice field. The control of target weed resulted in increase in yield of rice varieties 385-B Super Basmati by 28.8 and 18.6%, respectively. Mass production of the candidate agent on different substrates revealed the suitability of wheat straw amended with chickpea for maximum production of conidia. The present study concludes that *D. hawaiiensis* can be used as a mycoherbicide as 20% canola oil formulation at 35 C and 36 hr dew period.

171. Application of Rice Allelopathy to Reduced Rate of Herbicide. Yiqing Guo¹, Donghyun Shin, Kilung Kim; ¹Yunnan Academy of Agricultural Sciences, Kunming, Yunnan Province, China (Peoples Republic of)

Pot experiment and herbicide bioassay were conducted to compare the barnyardgrass suppression by 3 rice viz. cv. Kouketsumochi (allelopathic), cv. Dongjinbyeo (non-allelopathic) and cv. K21 (newly bred potent allelopathic). The consequence of applying less herbicide, a mixture of butachlor and bensulfuron-methyl, to these cultivars was also evaluated. The results showed that the weed suppression potential varied among the three rice cultivars. Kouketsumochi was the most allelopathic rice cultivar; K21 was in the middle of them, while Dongjinbyeo was the least one. The allelopathic effect of Koukishumuchi, K21 and Dongjinbyeo on barnyardgrass height was about 45%,

31% and 20%, while on barnyardgrass plant weight was about 35%, 30% and 20%, respectively. These effects were converted into herbicide rate according to the equation of toxicity regression. For the inhibition of plant height and weight, the value of Kouketsumochi is 10.6mg/L and 8.4 mg/L, K21 6.3 mg/L and 6.9 mg/L, and Dongjinbyeo 3.7 mg/L and 4.0 mg/L respectively. By comparing the value of LD50 under condition without rice?Cherbicide has been reduced around 20-50%; Under condition with rice growth, for Kouketsumochi and K21, herbicide rates can be reduced about 30% and 20% than Dongjinbyeo. The results suggested that rice cultivars with allelopathic potential can reduce herbicide application for weed management, and thus promote a more ecofriendly rice cropping system.

172. A Tale of Three Didders for the Biocontrol of *Mikania micrantha* in Hong Kong. Paul But¹, Yujia Hu¹, Lee-Man Chu¹, Jin-Hei Wan¹, Ting-Kwok Woo¹; ¹Chinese University of Hong Kong, Shatin, Hong Kong, China (Peoples Republic of)

Mikania micrantha is the most noxious weed in Hong Kong. Three species of didders, namely *Cuscuta australis*, *C. campestris* and *C. japonica*, are found to preferentially parasitize on *Mikania*. The first two didders, however, exert only localized impact against *Mikania*. *Cuscuta japonica*, on the other hand, tends to molest *Mikania* much more aggressively.

173. Application of Fresh Vegetative Cuttings of Didders for the Biocontrol of *Mikania micrantha*. Paul But¹, Yujia Hu¹, Lee-Man Chu¹, Jin-Hei Wan¹, Ting-Kwok Woo¹; ¹Chinese University of Hong Kong, Shatin, Hong Kong, China (Peoples Republic of)

Three species of didders, including *Cuscuta australis*, *C. campestris* and *C. japonica*, are found parasitizing on *Mikania micrantha*. Dodder seeds, however, are not good agents for application for the control of *Mikania*, because of unpredictable seed dormancy. Fresh cuttings of the three didders, if inserted in a small bag of water, can survive for more than four days and continue to spread and search for *Mikania* nearby.

174. Survey of Indigenous Fungi Isolated in South Kyushu, Japan, for Biocontrol Agents against Japanese Knotweed (*Fallopia japonica*). Yuujirou Nakamura¹, Ken-ichi Yamaguchi¹; ¹Minami Kyushu University, Takanahe-cho, Miyazaki, Japan

Japanese knotweed (*F. japonica*) is a rhizomatous perennial weed belonging to the Polygonaceae. This troublesome weed has been reported from much of

mainland Europe, many states in the USA and Canada, also New Zealand and Australia. Japanese knotweed was introduced from Japan to the West as an ornamental in the mid-nineteenth century. This plant increases in area very rapidly and soon forms monoculture stand, one present at a site. We tried to find biocontrol agents against Japanese knotweed in south Kyushu, the southern part of Japan. Plenty of fungi were isolated from naturally infected Japanese knotweed in Kagoshima Pref., Kumamoto Pref., and Miyazaki pref. There were 67 fungal groups based on their morphological characteristics on potato dextrose agar medium. Five fungal groups showed apparent pathogenicity during the primary screening using leaves of Japanese knotweed as an ex-plant. Only one kind of the fungal isolates, not identified yet, was not pathogenic against several crops including water pepper belonging to the Polygonaceae, cucumber, sweet pepper, and grasses. Our results showed there might be possible candidates for the biocontrol agent against Japanese knotweed in the fungal isolate showing stem rot. We identify the fungus isolated in the mountain area of Miyazaki pref., and need to conduct several experiments in the fields.

175. Selection of Potential Biological Weed Control Insects of *Rumex obtusifolius*. Park Jaeup¹; ¹National Institute of Agricultural Science and Technology, Seoul, Korea, South

In order to develop effective biological control of *Rumex obtusifolius* in pastures, potential agents have been selected. *Gastrophysa atrocyanea* and *Ostrinia palustralis memnialis* were finally selected as agents, and their basic ecological characteristics and weeding efficacy were tested. *Gastrophysa atrocyanea* of chrysomelidae damaged the leaf blade, stem, seed in plant part of *Rumex obtusifolius*. *Ostrinia palustralis memnialis* of Pyralidae damaged the stem, root in plant part of *Rumex obtusifolius*. Non-choice test showed that the two species finally selected were suitable candidates for the biological control of *R. obtusifolius* since they showed host specificity on major 38 test crops and plants (chenopodiaceae, caryophyllaceae, cruciferae, rosaceae, leguminosae, umbelliferae, labiatae, convovulaceae, solanaceae, cucurbitaceae, compositae, gramineae, liliaceae). Both laboratory and field experiments on weeding efficacy resulted in positive potential of biological control success on *R. obtusifolius* by application of insect agents in practice. *Rumex obtusifolius* by treatment of 10 adult female and 20 male *Gastrophysa atrocyanea* per plant were 98% controlled in the greenhouse. Especially *Rumex obtusifolius* in pasture with a treatment of *Gastrophysa atrocyanea* and *Ostrinia palustralis memnialis* were 100% controlled.

176. Volunteer Weed Seeds in Brassica Production Systems. Yantai Gan¹, S.S. Malhi², S.A. Brandt³, Neil Harker⁴, Cal McDonald¹; ¹Agriculture and Agri-Food

Canada, SPARC, Swift Current, Saskatchewan, Canada; ²Agriculture and Agri-Food Canada, Melfort, Saskatchewan, Canada; ³Agriculture and Agri-Food Canada, Scott, Saskatchewan, Canada; ⁴Agriculture and Agri-Food Canada, Lacombe, Alberta, Canada

Organic farmers are increasingly interested in putting Brassica species in their production systems, but seeds shattered from the crop at maturity often cause significant volunteer weed problems in following years. We conducted a study to determine the difference among five canola/mustard species in the degree of seed-shattering and the response of shattering to two harvest practices; swathing versus straight-combining. *Sinapis alba* yellow mustard 'AC Base', *Brassica juncea* canola 'Amulet', *Brassica juncea* mustard 'Cutlass', *Brassica rapa* canola 'Hysyn', and *Brassica napus* canola 'InVigor 2663' were grown at Star City, Scott, and Swift Current, Saskatchewan, Canada, from 2004 to 2006. Catch trays were placed between crop-rows during maturity to catch shattering seeds. Seed yield was highest for napus canola, 2146 kg ha⁻¹, followed by juncea mustard, 1971 kg ha⁻¹, and juncea and rapa canola, 1850 kg ha⁻¹, while alba mustard yielded the lowest at 1547 kg ha⁻¹. On average, oilseed crops shattered 647, 1261, and 2123 seeds m², respectively, at low-, moderate-, and high-shattering environmental sites. The total shattered seeds accounted for 1.0, 3.3, and 5.2% of the total seed yield at low-, moderate-, and high-shattering environmental sites, respectively. Among species/cultivars, juncea mustard shattered the highest number of seeds at 3452 seeds m², and alba mustard the lowest at 543 seeds m². There was no difference between the remaining three species (average of 1240 seeds m²). Shattered seeds were from both shed pods and prematurely open pods on the stem. Shattering was significantly affected by harvest management practices adopted in the study. Swathing led to 13% more seeds shattered for juncea canola and juncea mustard, and 7% more for rapa canola than straight-combine practice, while napus canola did not show a difference in seed shattering between the two harvest practices. This study suggests that a large number of Brassica volunteers could be expected following these crops, especially in fields of juncea mustard. Furthermore, swathing these species is likely to lead to higher volunteer weed population potential than straight-combining. Actual volunteer densities in following years will be greatly dependent on fall tillage practices, fall moisture conditions and over-wintering losses due to low temperatures, desiccation, and seed predators. Selection of shattering resistant species and the use of straight combining may reduce risks of volunteer weeds in organic farming systems.

177. Evaluation of Cowpea Genotypes for Use as a Weed Suppressing Cover Crop. Howard Harrison¹, Richard

Fery¹, Judy Thies¹; ¹USDA-ARS, Charleston, SC, United States of America

Cowpeas (*Vigna unguiculata*) were used extensively for a cover crop and green manure source prior to the onset of modern agricultural practices. They are desirable as a cover crop, because they are tolerant of hot dry conditions, grow vigorously and compete well against weeds, and provide nitrogen for rotational crops. Most of the old forage varieties are no longer available; however one variety, Iron Clay is widely available. Modern varieties of *V. unguiculata* are known as southernpeas, and most of these have a compact growth habit and are determinate. Thus, they are inferior to the forage varieties for use as a cover crop. This study was conducted to identify forage cowpea genotypes that are superior for use as a weed suppressing cover crop. A preliminary screening experiment was conducted to evaluate 47 cowpea genotypes for use as a weed suppressing cover crop. Of these, 11 were selected for further testing on the basis of vigorous growth and weed suppressing ability. In a field experiment repeated over four years, the selected genotypes were not different from the leading cover crop cultivar 'Iron Clay' in biomass production. Vigor ratings, vine growth ratings and canopy widths of some genotypes exceeded those of 'Iron Clay' Vigor ratings and canopy measurements were efficient selection criteria that could be useful for breeding cover crop cowpea cultivars. All except one selection were highly resistant to southern root knot nematode [*Meloidogyne incognita*], and the selections varied in seed size, photoperiod, and response to foliar diseases. Several selections are superior to Iron Clay due to their more rapid early growth and shorter photoperiod which enables them to remain vegetative later in the growing season.

178. Sudangrass Suppression of Canada Thistle. John Masiunas¹, Abram Bicksler¹; ¹University of Illinois, Urbana, IL, United States of America

Canada thistle is becoming a major problem on organic farms. Our objective was to determine if a Sudangrass cover crop can suppress Canada thistle. In 2006, field studies were conducted on organic farms and the University of Illinois Cruse Research Farm using established patches of Canada thistle. Prior to planting cover crops, we tilled to kill emerged thistle, slice the upper roots into small pieces, and prepare the seedbed for planting cover crops. The cover crop treatments were no cover crop (weedy fallow), buckwheat, Sudangrass, and Sudangrass + cowpea. The cover crop treatments were mowed either none, one or two times. Cowpea could not compete with Sudangrass and most cover crop plants in the mix were Sudangrass. Even without treatment, the number of Canada thistle shoots declined over the growing season. Cover crops and mowing acted independently to reduce thistle patches. At 3 months after planting cover crops,

thistle was 21 and 3% of initial numbers in the buckwheat and Sudangrass (alone or with cowpea), respectively. At 3 months, mowing once reduced thistle more than mowing twice. Two mowings further damaged growing points of thistle but made other weeds and cover crops less competitive and triggered emergence of new thistle shoots. In 2007, at the Cruse Research Farm we determined if previous year treatments affected Canada thistle patches. The field was intensely tilled and we planted organic food-grade soybeans. In soybeans, the areas formerly with Sudangrass or Sudangrass + cowpea had Canada thistle populations approximately 2% of those the previous spring. Canada thistle shoots emerging in these areas were stunted and not competitive with the soybeans. Areas mown once had fewer thistle shoots than areas mown twice. Mowing and buckwheat only suppressed thistle for a single growing season. Sudangrass rapidly grows, tilling extensively, forms a tall dense canopy, tolerates mowing, quickly regrows, and forms thick mulch.

179. Weed Flora of Indian Spinach (*Basella alba* L) in an Enriched Humid Tropical Environment. Muphtha Smith¹, Emmanuel Ayenigbara²; ¹The Federal University of Technology, Akure, Ondo, Nigeria; ²Ministry of Agriculture, Akure, Ondo, Nigeria

Soil amendment with fertiliser materials facilitates the growth of both crop and weed. Weed density, occurrence, relative importance value (RIV) and diversity (Shannon's H) in enriched *Basella alba* were evaluated during the late (1997) and early (1998) seasons in southwestern Nigeria. The treatments viz. no treatment (CON), 400 kg/ha NPK 20-10-10 (NPK), 2 t/ha poultry manure (PM), cow dung (CD), goat manure (GM) or green manure (GrM) were arranged in a randomised complete block design using three replications. Weeds were sampled at 3 and 6 weeks after sowing (WAS) *B.alba*. Initial weed density was higher in organic manure than in NPK and CON, and in the late than in the season. GM consistently gave the highest weed density while GrM and PM gave the lowest in the late and early seasons, respectively. Weed occurrence was highest in GrM and NPK in the late and early seasons, respectively. PM and GM gave the lowest weed occurrence in the late season and GrM in the early season. RIV was highest in GrM in the late season and GM in the early season. CD consistently gave the highest H but GrM and PM gave the lowest H in the late and early season, respectively. The most important weeds were *Panicum maximum*, *Euphorbia heterophylla* and *Paspalum orbiculare* in the late crop, and *P.orbiculare*, *E.hetrophylla*, *Digitaria horizontalis* and *C.mucunoides* in the early crop. Differences in ecological weed growth indicate potential differences in weed interference, crop growth and yield response to soil enrichment.

180. Use of Weed for Soil Productivity Maintenance. Awodun Adeyeye Adeyemi¹; ¹University Of Technology Akure, Ondo State, Nigeria

The paper discusses the role of weeds in the maintenance of productivity of available soils in West Africa. It is found that weeds, living or dead, are effective in soil conservation, and weed fallow is useful for rejuvenating soil physical, chemical and biological status. A surface layer of weed residues, roots and mulch ensures reduction of runoff, nutrient leaching and soil temperature, while it supplies organic matter and plant nutrient.

Ash derived from burnt weeds is also effective as fertilizer for crops. Such as coffee, maize and vegetables. Weed mulch is highly effective in increasing yield crops such as vegetables, groundnut, maize cassava and yam. The use of weed residue starts to provide solution to the fertility problems of soils in West Africa

181. Legumes as Living Mulches for Weed Control in Corn (*Zea mays* L.). G Mohammadi¹; ¹Razi University, Kermanshah, Iran

Weeds are serious constraint to increased production in corn and reduce grain yield and economic returns. Corn producers in Iran are highly dependent on herbicide application and cultivation as weed management tools. These practices can increase costs and soil erosion, pose a threat to the environment and may promote the development of herbicide resistance. An alternative to herbicides and cultivation is the use of living mulches between the crop rows. However, living mulches differ in their ability to establish well in an interseeding situation and compete with weeds.

This study was conducted to evaluate the six species of leguminous living mulches for weed control in corn and subsequently the selection of the most appropriate living mulch species.

The experiment was carried out in 2006 at the Agricultural Research Farm of Razi University, Kermanshah, Iran. The experimental design was a randomized complete block with four replications. The corn was planted on 18 May 2006. The treatments consisted of six leguminous living mulches (Persian clover *Trifolium resupinatum* L., white clover *Trifolium repens* L., berseem clover *Trifolium alexandrinum* L., hairy vetch *Vicia villosa* L., alfalfa *Medicago sativa* L. and black alfalfa *Medicago lupulina* L.) and two controls (weeded and un-weeded for all of the growing season). The living mulches were hand broadcast over the plots at the recommended seeding rates when corn plants were approximately 15 cm tall. At tasselling stage the weed dry weight was determined by harvesting the weeds at ground level in three random 0.5*0.5 m quadrats in each plot. At maturity, the corn ears located 2m from the three center rows of each plot were harvested, then grain yield was obtained.

Corn in the weed free condition had a higher average grain yield than all treatments. Although, there was no significant difference between this treatment and corn interseeded with hairy vetch. Weedy condition for all of the growing season led to 48.2% grain yield reduction as compared with weed free control. Among the interseeded treatments, the lowest corn grain yield was obtained from the plots interseeded with alfalfa that was 41.3% more than that obtained from the full season weedy condition.

Interseeding of corn with living mulches significantly reduced the weed dry weight produced. The reductions varied from 80.5 to 60.1% for plots interseeded with hairy vetch and black alfalfa, respectively as compared with full season weedy condition. There was a significant and negative correlation between weed dry weight and corn grain yield ($r = -0.85$).

The results indicated that the interseeded living mulches significantly improved the corn grain yield and reduced the weed dry weight produced as compared with full season weedy condition. Among the interseeded treatments, the highest corn grain yield and the lowest weed dry weight were obtained from the plots interseeded with hairy vetch indicating the suitability of this legume as a living mulch for the corn production systems.

182. Relative Effect of Weed Mulch Types on Soil Properties and Yield of Yam in Southwest Nigeria. Awodun Adeyeye Adeyemi¹; ¹University Of Technology, Akure, Ondo State, Nigeria

In order to identify suitable weed mulch material for yam cultivation in Southwestern Nigeria, mulches of Mexican sunflower, siam weed, elephant grass and guinea grass were compared and to their effect on soil physical and chemical properties and tuber yield of yam. There was a control treatment and the mulches were applied at 10tha-1. Experiments was carried out at two locations in Southwest Nigeria.

The experimental sandy loam soils were marginal in N. mulching increased soil moisture content. The mulches significantly increased exchangeable soil K. Mexican sunflower and siam weed significantly influenced soil physical properties. Relative to the control, all mulches increased yam establishment and tuber weight significantly ($P > 0.05$). Except for guinea grass much, all the mulches also increased tubers length significantly. Mexican sunflower and siam weed increased tuber weight by 57%, while guinea grass and elephant grass mulch increased it by 29%. Considering all soil and plant parameters, Mexican sunflower and siam weed were most effective as mulch for yam.

183. Effect of Planting Date, Weed Control Time and Method on Weed Population and Biomass in Organic Cumin. Reza Ghorbani¹, Alireza Koocheki¹, Maryam

Jahani¹, A. Hosseini¹, Ali Mohammad-abadi¹; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan, Iran

A field experiment was carried out in order to evaluate the effect of planting date, method and date of weed control on weed density and biomass in the experimental research field, Faculty of Agriculture, during 2006. Treatments included planting date (30 December, 20 January and 30 February), weeding date (first true leaf, start of branching and beginning of flowering stages) and weed control methods (hand weeding, fire treatment and control). The results showed that there were significant differences in weed density between different weed control methods. There were also differences in weed population between dates of weed control, as the lowest weed density was observed in treatment of flowering stage. Weed biomass was significantly different between treatments of date and methods of weed control. Hand weeding at beginning of flowering stage caused lowest weed dry weight.

184. Companion Barley for *Orobanche crenata* Control in Organic Broad Bean. Mustapha Haidar¹, Chadi Gharib¹; ¹American University of Beirut, Beirut, Lebanon

A greenhouse study was conducted to evaluate the efficacy of barley as a companion crop for *Orobanche crenata* control in organic broad bean. Barley was planted at 0, 1, 2, and 3 weeks either before or after sowing bean and at different ratios (0, 1, 2, 3 and 4 barley plants/pot) using one plant/pot for bean. Results indicated that significant reduction in *Orobanche* shoot number compared to the control (bean with *Orobanche*) occurred 120 days after planting when barley was planted 2 or 3 weeks before bean regardless of bean to barley ratio. Significant reduction in *Orobanche* dry weight occurred for all ratios when barley was planted with or before bean. Results indicate that planting barley in conjunction with broad bean appears to be an effective and feasible method against *Orobanche* in organic bean production.

185. *Fusarium oxysporum* - an Antagonist of the Holo-Parasitic Weed *Orobanche ramosa*. Eva Kohlschmid¹, Joachim Sauerborn¹, Dorette Müller-Stöver²; ¹University of Hohenheim, Stuttgart, Baden-Württemberg, Germany; ²University of Copenhagen, Copenhagen, Denmark

Broomrapes (*Orobanche* spp.) are obligate root parasites that cause serious damage to a wide range of economically important crops in temperate as well as subtropical and tropical regions. As holoparasites, they deprive their host plants of water, assimilates and nutrients, which are transferred directly via a specific contact organ, the haustorium.

Orobanche ramosa (branched broomrape) occurs in Europe, North Africa, as well as in the Middle East and

has recently been introduced to South Australia and Chile. It has a broad host range that includes members of the families Asteraceae, Solanaceae, Cannabaceae, and Brassicaceae. Under the changing agro-climatic conditions of western Europe, *O. ramosa* infests at a progressing rate host crops such as *Solanum lycopersicum* (tomato), *Cannabis sativa* (hemp), *Nicotiana tabacum* (tobacco) and to an increasing degree *Brassica napus* (oilseed rape) in France. Since there is no single method providing both effective and economically feasible control, management strategies should focus on reducing the soil seed bank and interfering with the parasite's early development stages.

An isolate of *Fusarium oxysporum* (FOG) was gained from diseased tubercles of an *O. ramosa* population from Germany. This isolate effectively reduced incidence of the parasitic weed on *Solanum lycopersicum* and *Nicotiana tabacum* under controlled environmental conditions.

The aim of our study was to test the impact of FOG on *O. ramosa* parasitising tobacco under field conditions. We investigated (i) the effect of different granular formulations of the fungus on *O. ramosa*; (ii) the development of the fungal population in the soil; (iii) the control efficacy of a combination of the biocontrol agent with the systemic resistance inducer BTH (benzo (1,2,3) thiadiazole-7-carbothioic acid S-methylester).

Large amounts of fungal propagules were produced in a bench-top fermenter. The obtained inoculum was then incorporated into 'Pesta' granules or sodium alginate pellets. Field trials were carried out at a research station in southern Germany in 2006 and 2007. In 2006, the combination of FOG, applied in-furrow, with a soil-drench of BTH was compared to the sole application of FOG. In 2007, different formulations of the fungal inoculum were tested using in-furrow application: 'Pesta' granules, alginate pellets, and Pesta plus alginates.

FOG reduced number and dry matter of *Orobanche* shoots by up to 50% in both seasons. In the second year, the combination of Pesta granules and alginate pellets was most effective. No further reduction could be observed when the biocontrol agent was combined with the resistance inducer BTH.

The results reveal the potential of FOG for *O. ramosa* control. Since the applied formulation affected the efficacy of the biocontrol agent, it may be worthwhile to test how the delivery system can be changed in order to achieve increased disease development in the field.

186. Discovery of *Merremia tridentata* subsp. *angustifolia* as a Wild Host of *Striga gesnerioides* in the Republic of Benin: A Benefit of Farmer Field School. Gualbert Gbèhounou¹, Guy Apollinaire Mensah¹; ¹Institut National des Recherches Agricoles du Bénin (INRAB), Porto-Novo, Département de l'Ouémé, Benin

A training of trainers course on farmer field school was organized in Bénin in the framework of the sub regional

project 'TCP/RAF/3008A' designed by FAO and six national agricultural research institutes of Bénin, Burkina-Faso, Niger, Mali, Senegal and Togo to promote durable integrated management of *Striga*. Host ranges of *S. hermonthica* and *S. gesnerioides* were considered an important issue for the training. Thus, a field visit was organized for participants to clarify whether groundnut was really a host of *S. gesnerioides* in the Bohicon region, in Bénin, as often reported by extension agents. During the field visit, the situation quite confusing was clarified in situ. An unsuspected host was discovered: *Merremia tridentata* (L.) Hallier F. [subsp. *angustifolia* (Jacq.) Ooststr.] from the Convolvulaceae family. *S. gesnerioides* plants thrive on this wild host, produce capsules and normal seeds. It is likely that the *S. gesnerioides* strain parasitizing *M. tridentata* subsp. *angustifolia* is the same parasitizing cowpea in this village where *S. gesnerioides* is a major biotic constraint. Rotating cowpea with groundnut, or any non host, in *S. gesnerioides* infested areas may not be enough if care is not taken to get rid of alternate hosts. To the knowledge of the authors *Merremia tridentata* subsp. *angustifolia* as a host of *S. gesnerioides* was not reported in Bénin before.

187. Importance of Germination Patterns and Herbicide Application for the Control of Swamp Dodder, *Cuscuta gronovii*, in Massachusetts Cranberry Production. Hilary Sandler¹; ¹UMass Cranberry Station, East Wareham, MA, United States of America

Dodder (*Cuscuta gronovii*) is a serious weed pest in commercial cranberry (*Vaccinium macrocarpon*) that is typically controlled with preemergence herbicides, such as pronamide (Kerb). Successful management is tied to timing the application of the herbicide to recently germinated seedlings, however the germination patterns of dodder had not been previously described in cranberry. In addition, growers occasionally reported inconsistent control when using applications of pronamide. Field and laboratory studies were conducted to examine germination patterns and herbicide management.

Utilizing a system of simulated bogs constructed in plastic containers, the germination patterns of MA dodder seed have been monitored in the field for 10 years. Unscarified dodder seed was gently incorporated into the top layer. Each year, containers were monitored to determine the date of first seedling emergence as well as daily emergence throughout the season. No additional seed was added to the containers for the duration of the study. The highest germination percentage occurred from seeds that were most recently deposited into the seedbank (Year 1); subsequent generations had declining germination percentages. Germination data indicated a definitive peak in the first year following inoculation of the containers. Peaks were noted in subsequent years, but at much lower numbers than in Year 1. Over the course of

this 10-year study, the peak germination period was delayed relative to the first year, occurring later each year.

Laboratory studies evaluated timing of herbicide application, seedling germination, and herbicide rate. One hundred scarified dodder seeds were placed into large trays filled with sand either before or after application of pronamide at various rates. Germination rates and seedling injury were evaluated for at least 14 days. Data indicated that the herbicide must be present several days prior to seedling emergence for greatest efficacy.

The viability of dodder seeds is very long-lived and overlapping generations of dodder seed exist in an infested farm field. The delay of peak germination from resident populations in the seedbank extends the potential germination period of dodder. Since most herbicides targeting dodder can only be efficacious for a specific window of time, a portion of the population may be able to escape preemergence control and cause infestations in the vine canopy. The limitations of herbicide efficacy and complicated dodder biology support the need for an integrated management approach for dodder management.

188. GR24 Induces Germination through Distinct Metabolic Changes in *Orobancha minor* Seeds. Benesh Joseph¹, Atsushi Okazawa¹, Kanokwan Jumtee¹, Eichiro Fukusaki¹, Koichi Yoneyama², Yasutomo Takeuchi², Akio Kobayashi¹; ¹Osaka University, Suita, Osaka, Japan; ²Utsunomia University, Utsunomia, Tochigi, Japan

Parasitic plants have evolved to have an additional regulation for seed germination at the level of absolute requirement for host derived germination stimulants. GR24 is a synthetic analogue of germination stimulant for many parasitic plants including members of the genus *Orobancha*. The mechanism through which the GR24 induces seed germination is unknown. Metabolic profiling with GC-TOF/MS following GR24 stimulation revealed that significant metabolic changes begin 24 hrs later GR24 stimulation. Among 50 known and 15 unknown metabolites detected, two compounds allantoin and gentianose were selected for further analysis. Allantoin is an intermediate of purine oxidation, metabolized to urea and ammonium. Gentianose is a trisaccharide, which is so far reported only in storage roots of the members of the family Gentianaceae. Both allantoin and gentianose decreased nearly 10 times within the first two days after GR24 stimulation. Exogenous allantoin at 10 mM increased seed germination by 50%. Acetohydroxamic acid (AHA), an inhibitor of allantoinase (and urease), totally inhibited germination at 1 mM. Exogenous allantoin, urea and ammonium reversed AHA inhibition. Phenylphosphoramidate (PPD), a specific inhibitor of urease also inhibited germination at 1 mM. PPD inhibition was not reversed by arginine (urea can be generated either from allantoin or from arginine only), indicating allantoin as the source for essential urea during early germination.

Allantoin accumulated about 2.5 times during conditioning. Allopurinol is an inhibitor of xanthine oxidase, an enzyme of purine oxidation pathway leading to allantoin. Application of allopurinol during both conditioning and germination decreased germination by 50%, indicating that allantoin accumulation during conditioning and its subsequent mobilization following GR24 stimulation is essential for *O. minor* germination. Allantoin and gentianose accumulates only in seeds, but neither in haustorium, shoot or flower. *O. minor* partial allantoinase sequence was cloned using degenerate PCR for further analysis.

189. Disinfection of Broomrape Seeds on Agricultural Equipment with Didecyl Dimethyl Ammonium Bromide.

Yaakov Goldwasser¹, Shaul Graph², Abraham Gamliel³; ¹The Hebrew University of Jerusalem, Rehovot, Israel; ²Extension Service, Ministry of Agriculture, Kiryat Shmona, Israel; ³ARO, The Volcani Center, Bet Dagan, Israel

The tiny and plentiful seeds of *Orobancha* spp. easily disperse by wind, water animals and human beings. A common way of seed spread is their adherence to agricultural equipment including produce containers. Contaminated equipment that is transported from infested fields to non-infested fields is a significant source for new infestations. A common sight is heavy infestations originating from spots where containers have been placed in previous growing seasons. The aim of this study was to identify effective sanitary measures for disinfection of agricultural equipment and specifically tomato containers. In earlier screening studies quaternary salts including Didecyl Dimethyl Ammonium Bromide (DDAB) were found effective in *Orobancha* spp. seed disinfection. DDAB is a twin long chain quaternary ammonium disinfectant with a wide activity spectrum proven to be effective against bacterial, viral & fungal pathogens of both veterinary and human importance. In Petri dish experiments, soaking of *O. aegyptiaca* seeds in 0.1% DDAB for 5 minutes achieved complete *O. aegyptiaca* seed kill. In laboratory spray table studies, *O. aegyptiaca* seeds placed in sealed mesh tea bags were completely controlled by application of 1 % DDAB, while at 0.2% DDAB 86% were controlled and at 0.02% DDAB 57% were controlled. In a commercial disinfecting facility prototype, 0.5 % DDAB achieved complete control of *O. aegyptiaca* seeds placed in sealed mesh tea bags on walls and the floor of tomato containers. Further studies are needed to improve the spraying coverage and conditions of the disinfecting facility in order to increase the efficacy and reduce the application rates of DDAB.

190. Effect of Soil Solarization, A Nonchemical Method, on the Control of Egyptian Broomrape (*Orobancha aegyptiaca*) and Yield Improvement in Greenhouse Grown Cucumber.

Zoheir Ashrafi¹, Hassan Alizadeh¹, Sedigheh Sadeghi¹; ¹University of Tehran, Karaj, Tehran, Iran

Parasitic weeds of *Orobancha* spp. cause serious damage to several crops in Europe, the Mediterranean region, Central Asia, the Arabian Peninsula and some African countries. Solarization entails covering wet soil with transparent polyethylene sheets during the hot season. This serves to trap solar energy, thereby, heating the soil sufficiently to destroy soil pests and microbes. The temperature increase achieved is primarily the result of the elimination of evaporation, but is also partially because of the greenhouse effect created. Soil solarization has proven to be among the most effective methods of broomrape control in open field crops. The effect of soil solarization on germination and viability of buried Egyptian broomrape seeds was also examined. Cucumber cultivation in the Mediterranean region is susceptible to infestation by the parasitic weed Egyptian broomrape (*Orobancha aegyptiaca*), and severe yield losses can result. The effectiveness of solarization, a soil disinfection technique that uses passive solar heating, to control the incidence of broomrape under greenhouse conditions was studied over two growing seasons. Solarization substantially increased the soil temperature in both seasons and at both depths. The highest recorded absolute maximum temperatures at 5 cm depth in mulched soil were 54.4 and 56.2 °C in the first and second seasons, respectively, where it was 42.3 and 46.5 °C in bare soil. Solarization was accomplished by the application of clear polyethylene sheets to moist soil for 50 to 65 d during the hot season. The treatment increased maximum soil temperature by around 15 C, and at 5 cm below the soil surface, a temperature of more than 45 C was reached for 34 to 60 d, whereas this temperature was not reached at all in the first season and not for 20 d (second season) in unmulched soil. Egyptian broomrape was completely controlled by soil solarization because the treatment did not allow the development and emergence of shoots, underground haustoria, or tubercles on the cucumber roots. In contrast, in nonsolarized soil, Egyptian broomrape shoots had emerged by 45 DAP (first season) and 56 DAP (second season), and by 86 DAP (95 DAP), there were as many as 43 (52) shoots per cucumber plant. Plant growth and fruit yield were consistently and significantly higher in solarized soil than in nonsolarized soil. In mid-April, when the cucumber plant reached its maximum size, soil solarization increased fresh leaf and stem weight per plant. Fruit yield in solarized and nonsolarized plots was similar at the first harvest (106 DAP and 114 DAP), whereas starting with the second harvest, the yield rate of plants grown in solarized soil was significantly higher than for plants grown in nonsolarized soil. In solarized soil, no broomrape shoots emerged, and neither haustoria's nor underground tubercles of the parasite were found on cucumber roots. The treatment killed about 95% of buried viable seed, and induced secondary dormancy in the remaining 5%. In nonsolarized plots, broomrape shoots were present at a high density, decreasing plant growth and fruit production. Fruit yield was 133 to 258% higher in the solarized as

compared with the nonsolarized treatment. Based on these results, we suggest that soil solarization, which precludes chemical contamination and is suitable for organic farming, is an appropriate technology where the risk of egyptian broomrape infestation is high. Under such weather conditions [Iran(Hashtgerd)], soil solarization proved to be an excellent method for complete control of egyptian broomrape infestation. In addition, solarization was able to consistently improve cucumber yield under greenhouse conditions, where egyptian broomrape is particularly destructive. Without solarization treatment, egyptian broomrape consistently decreased fruit yield. Soil solarization provided total control of Egyptian broomrape because shoot emergence from treated soil was completely inhibited, and no haustoria or underground tubercles were found on the cucumber roots at the end of the crop cycle.

191. Parasitic Weeds of the Orobanchaceae Family and their Natural Hosts in Jordan. Jamal Qasem¹; ¹University of Jordan, Amman, Jordan

A field survey carried out during the period from 2003 to 2007 revealed the presence of 7 species of Orobanche, and two species of Cistanche in Jordan. Orobanche species were found parasitizing 86 plant species belong to 24 botanical families of different growth habit, habitat and economic value, and ranged from common wild herbs to fruit and forest trees. Cistanche attacked 19 species of 6 families. Most attacked species by Orobanche were belong to Compositae (20 species), Solanaceae (11 species), Leguminosae (9 species), Umbelliferae (7 species), Cruciferae (7 species), Cucurbitaceae (4 species), Labiatae (4 species) and Rosaceae (4 species), Other families were represented by 1 to 3 species. Most Cistanche hosts belong to the Chenopodiaceae (7 species) and Leguminosae (3 species). The intensity of parasite infection on different hosts and the severity of infestation were also recorded. Certain plant species served as hosts for more than one parasitic species while many are first time reported for both genera; including *Amygdalus communis*, *Olea europaea* and *Quercus coccefera* parasitized by *Orobanche palaestina*, *A. communis*, *O. europaea*, *Prunus armeniaca* and *Prunus persica* by *Orobanche cernua*, *Olea europaea* and *A. communis* by *Orobanche schultzei*, *Punica granatum*, *Alhagi maurorum*, *Centaurea postii*, *Prosopis farcta* by *Cistanche tubulosa*, and *Achillea* sp., *Anabasis syriaca*, *Haloxylon persicum*, *Haloxylon salicornicum*, *Suaeda* spp. and *Zilla spinosa* by *Cistanche salsa*. Certain Orobanche species were totally destructive to the cultivated field crops. Results indicated the high potential of these parasites to spread and attack new plant species, while the threat they impose to agriculture in Jordan remain existing in absence of poor weed management and farmers training.

192. Host and Habitat Specificity of the Cuscuta species in Hungary. Kornél Baráth¹, János Csiky¹; ¹University of Pécs, Pécs, Baranya, Hungary

Hitherto seven *Cuscuta* species (*C. lupuliformis* Krock., *C. australis* R.Br., *C. campestris* Yuncker, *C. epilinum* Weihe, *C. europaea* L., *C. approximata* Bab., *C. epithymum* (L.) Nath.) have been recorded in Hungary. Some of them cause severe damage to agriculture, while others never or very rarely parasitize cultivated plants. The question of the host and/or habitat specificity of the *Cuscuta* species appears often in the international literature.

We investigated the structure of the plant community in the habitats of dodders according to the methods of Braun-Blanquet school. Altogether 90 syntaxonomical relevés were taken in 2x2m to 5x5m size. Beside that we examined the number and susceptibility of host plants, measured the length, the height, and the stem diameter of the different *Cuscuta* species. Syntaxonomical relevés were analyzed with CÖNOSTAT and SYNTAX for Windows. The relationship between the morphological features and the habitat characteristics of dodders was tested by statistical methods.

Compiling the host spectra of the different *Cuscuta* species based on herbaria, literature and our own observations we revealed that these plants parasitize at least 18 % of the Hungarian flora. The habitats of the dodders are strongly different. *C. campestris* occurs in great quantities on the edge of roads and agricultural fields as well as along the banks of irrigation channels. *C. europaea* can be found along streams and wet ditches. *C. australis* is a rare plant in swamps and fens, while *C. lupuliformis* occurs in floodplains. We revealed ambivalence in the case of the habitat of *C. epithymum* agg. *Cuscuta epithymum* ssp. *epithymum* is widespread in mesophilous meadows and pastures, while ssp. *kotschy* prefers drier rocky grasslands. *C. approximata* is known only at one location in acidophilous oakwoods. However, *C. epilinum* has probably extinct due to the shrinkage of flax field and strict seed-testing in Hungary.

193. Mistletoes (Viscum cruciatum Siebr. ex Boiss. and Loranthus acaciae Zucc) and their Hosts in Jordan. Jamal Qasem¹; ¹University of Jordan, Amman, Jordan

A field survey was conducted during the period from 2001 to 2007 to study the mistletoes, distribution and host range in Jordan. Results showed the occurrence of *Loranthus acaciae* Zucc and *Viscum cruciatum* Siebr. ex Boiss. in different regions of the country. *L. acaciae* was found parasitizing 24 plant species belong to 11 plant families of different growth habit, habitat and economic value, and ranged from wild shrubs to fruit and forest trees. *V. cruciatum* attacked 14 plant species of similar growth habit from 8 families. The most infected family by *L. acaciae* was Leguminosae (10 species), and by *V.*

cruciatum was Rosaceae (6 species). The intensity of infection by both parasites was severe and cause death to host plants in many cases. A massive vegetative growth of the parasites was found on most hosts in different locations. Host species for *L. acaciae* include; *Acacia arabica*, *Acacia asak*, *Acacia cyanophylla*, *Acacia farnesiana*, *Capparis spinosa*, *Casuarina equisetifolia*, *Ceratonia siliqua*, *Ficus carica*, *Juglans regia*, *Melia azadarichta*, *Nerium oleander*, *Parkinsonia aculeata*, *Pistacia atlantica*, *Pistacia vera*, *Poinciana gilliesii*, *Prosopis chilensis*, *Prosopis farcta*, *Punica granatum*, *Retama raetam*, *Rhus tripartita*, *Salix alba*, *Tamarix pentandra*, *Zizyphus jujuba*, *Zizyphus lotus* and *Zizyphus spina-christi*. Infected species by *V. cruciatum* were *Amygdalus communis*, *Calictome villosa*, *C. spinosa*, *Crataegus azarolus*, *Crataegus monogyna*, *Olea europaea*, *Pistacia lentiscus*, *Prunus armeniaca*, *Prunus domestica*, *Prunus cerasifera*, *P. granatum*, *Rhamnus palaestina*, *R. raetam* and *S. alba*. Most hosts of both parasites are reported for the first time. Of the cultivated species, *A. communis*, *F. carica*, *P. granatum* and *O. europaea* were severely attacked. *P. granatum*, *R. raetam*, and *S. alba* were attacked by both parasites but variations in their growth were observed on any of these hosts. Results indicated the high potential of *L. acaciae* and *V. cruciatum* to spread and attack new plant species, and the threat that both impose to fruit and forest trees in absence of control measures and lack of agriculture extension and farmers' experience.

194. *Erwinia carotovora* as a Stimulant Agent for *Orobancha aegyptiaca*. Sirous Hasannejad¹, Hasan Mohamad Alizade¹, Soheila Porheidar Ghafarbi²; ¹University of Tehran, Karaj, Tehran, Iran; ²University of Birjand, Birjand, Khorasan Jonobi, Iran

Egyptian broomrape (*Orobancha aegyptiaca* Pers.) is an achlorophyllous, phanerogamic holoparasite that attacks the roots of many dicotyledonous crops in Iran, like many other countries. Bacterium

E. carotovora isolated from diseased *Orobancha* underground stages. In this research, *O. aegyptiaca* seeds sown in vials containing soil, then different concentrations of *E. carotovora* suspension (1×10⁷, 1×10⁸, 1×10⁹, and 1×10¹⁰ CFU) and distilled water (as a control) were incubated in vials soil. These vials were incubated at 25 C in the dark for 2, 8, and 16 week. After these periods, *O. aegyptiaca* seeds were moved from vials and put on Petri dishes and seed germination was investigated. Using GR60 (1 ppm of this compound), germination stimulant, seed germination was test. Results showed that *E. carotovora* significantly increased *O. aegyptiaca* seed germination. Two week after incubation (WAI) of the bacterium *E. carotovora* suspensions, maximum seed germination was observed, so that 74%, 86%, 83%, and 83% seed germination was obtained in 1×10⁷, 1×10⁸, 1×10⁹, and 1×10¹⁰ CFU, respectively) compare with controls (65% and 0 seed germination in 1

ppm of GR60 and distilled water, respectively). Eight WAI, minimum seed germination was obtained (12%, 9%, 7%, and 4% seed germination in 1×10⁷, 1×10⁸, 1×10⁹, and 1×10¹⁰ CFU, respectively). Sixteen WAI, as well as eight WAI, seed germination was decreased. Reduce seed germination in 8 and 16 WAI of *E. carotovora* suspensions due to highly seed germination in the primary weeks. In this study, we observed that this agent was very effective at stimulating *O. aegyptiaca* seed germination and suicidal of these germinated seeds in absence of host plants. Application of *E. carotovora* could be an effective control method to be combined to other control measures in an integrated weed management (IWM) programs.

195. Evaluation of *Erwinia carotovora* and Three Isolates of *Fusarium oxysporum* as Biological Control Agents of Egyptian Broomrape (*Orobancha aegyptiaca*). Sirous Hasannejad¹, Hasan Mohamad Alizade¹, Soheila Porheidar Ghafarbi²; ¹University of Tehran, Karaj, Tehran, Iran; ²University of Birjand, Birjand, Khorasan Jonobi, Iran

Broomrapes are achlorophyllous holoparasites of many economically important dicotyledonous crops. As weeds, they cause reductions in crop yield, adversely affect crop quality, and result in loss of cultivated land due to reduced crop alternatives. During extensive surveys in fields, heavily infested by *Orobancha aegyptiaca* parasitizing tomato (*Lycopersicon esculentum*) plants in Iran, *Erwinia carotovora* and three isolates of *Fusarium oxysporum* (Foxy1, Foxy2, and Foxy3) found on diseased, juvenile, emerging *O. aegyptiaca* tubercles and flower stalks. All isolates were tested in pot trials in a greenhouse with tomato as the host plant. Results showed that *F. oxysporum* isolates (1×10⁶/spore) infected and degradation of *O. aegyptiaca* dormant seeds and seed germ tubes, and *E. carotovora* (1×10⁹ CFU) causes suicide germination. Therefore in the present study we observed that these biological agents strongly reduced the number and weight of emerging broomrape shoots and tubercles attached to the host roots (around 100%). No reduction in seed germination or foliage development of tomato could be observed and inoculation with

F. oxysporum isolates and *E. carotovora* increased seed germination, shoot height and the total biomass of tomato. Application of these biological agents to soil containing Egyptian broomrape seeds provided full protection to the tomato plants, and could be part of an integrated control approach to reduce the seed bank in heavily infested fields.

196. Biological Control of *Striga hermonthica* by the use of *Polygala varifolia* on Maize in Burkina Faso. Oumar Ouedraogo¹; ¹INERA, Fada N'Gourma, Gourma, Burkina Faso

Control of *Striga hermonthica* is always a crucial problem for agriculture in many countries of West Africa. Burkina Faso located in the heart of Africa in the Sahelian zone is not an exemption to this assessment. Many works to control Striga have been realized and are still in diffusion. It emerges from surveys in the country that farmers do have local knowledge in weed management, especially *S. hermonthica*. Between the set of local knowledge, we were interested in the use of weed: *Polygala rarifolia* to control *S. hermonthica* on maize production. This practice is held and used by a woman producer who is known as the originator by the Support Program for Local Development in the East (ADELE), program funded by the Swiss government. The main objective of the research is to study the biological effectiveness of *P. rarifolia* in order to identify its means of action and to propose to farmers a low cost biological system of Striga management. The methodology used is that of growing in vitro, developed by Lane et al., (1991), adapted for weeds by Ouédraogo, (1995), Ouédraogo et al., (2000); cultivation in pots in open air and on farm. The results obtained in vitro growing confirm again that the germination of Striga seeds inducted by Polygala is not infesting it, later after the younger germinations die which is corresponding to the means of action of trap crop of Striga. The test in pot growing reveals that Polygala reduces the germination of Striga for 27%, on farm *P. rarifolia* associated to maize gives a best grain yield than the association of beans (*Vigna unguiculata*) and maize. The cropping system proposed is the sowing of Polygala in the same hole in alternated manner or the seedbed of Polygala between two lines of maize. The practice of the method can be considered in Burkina Faso at large scale because it is affordable for resource poor farmers. The production of *P. rarifolia* is easy and can be encouraged because the grains are used for cooking meals.

197. Phanerogamic Parasite on Fruit Crops of Kerala. Girija Vijayaraghavan¹, Chirathadam Abraham¹; ¹Kerala Agricultural University, Thrissur, Kerala, India

The state of Kerala situated, in the humid tropics is the home land of commercially important tree crops and spices. The major fruit crops of the region are Mango, Sapota, Jack fruit, Cashew, Anona, Jamuns etc. The major threat to these fruit crops are the semi parasitic weeds belonging to the family Loranthaceae and Viscaceae. A study was undertaken to find out the major species of the phanerogamic parasites attacking the commercially important tree crops and fruit trees of the region. The mode of attachment of the parasite on the host plant was also studied. Surveys were conducted in all the major districts of the state. The mode of attachment of the parasite was studied using microtome sectioning. An initial survey of the region has shown that among the tree species Mango is the most vulnerable crop. Nearly 60-70 % of the trees

except those in well kept orchards are infected by the parasite. The major parasitic species found on mango is *Helicanthus elastica* and *Dendrophoe falcata*. *Microsolan* is mainly seen on Jack fruit.

Studies show that the mode of attachment of species on the host plant is different. Hence while devising control measures for the species these factors should be taken into consideration.

198. Dodder (*Cuscuta pentagona*) Control in Processing Tomato (*Lycopersicon esculentum*). Tom Lanini¹; ¹University of California, Davis, Davis, California, United States of America

Dodder is a stem parasite that attacks a wide range of crops, including tomato. Dodder extracts nutrients and water from the host plant, resulting in reduced growth and yield. Dense infestations of dodder often result in total crop loss. Generally, growers control dodder in tomatoes by removing the infected host plant, which results in yield loss, but prevents further spread, and seed production. The objectives of this research were to examine dodder germination and attachment behavior, tomato varieties for potential resistance, and herbicides for pre- or post-attachment control. Fluctuations in soil moisture and temperature near the soil surface may initiate dormancy breaking of buried dodder seed. Temperatures during the spring and early summer months are ideal for dodder emergence. However, dodder emergence in field trials was observed to cease in early to mid May, despite temperatures in the optimum range for germination and emergence. Thus, a way to avoid major dodder infestations is to plant after the mid-May. Generally transplanted tomatoes are used for late planting; in greenhouse studies, tomato size influenced the success of dodder attachment, with larger tomatoes being the most resistant to dodder attachment. Removal by hand crews, of the tomatoes with dodder attached, remains a viable option, when infestations are small. Hand removal is often done when dodder is first detected to prevent spread and seed production. In a trial area, farm workers were observed to remove dodder approximately 90% of the time. The remaining 10% was generally missed, because it was too small to be easily detected. Plants with attached dodder do not need to be removed from the field unless they have viable seed. Dodder can reattach to a new host if left in close proximity to living tomato plants, but if the plants are moved 15cm or more from the remaining tomato plants, the dodder will not be able to reach a new host. In greenhouse and field tests of potential dodder resistant tomato varieties, H9492, H9553, H9992, CDX 233, H1100, H9888, H9997, and SVR 024 2 0665 were all resistant to dodder attack. Dodder generally attached to these varieties, but would fail to form adequate haustoria attachments and would either dry up and die or grow very slowly, failing to reach maturity. Herbicides have also been evaluated for pre-or

post-attachment control. Sulfentrazone at 170 g/ha or flufenacet at 675 g/ha applied preemergence resulted in over 95% reduction in dodder emergence. Pendimethalin applied preemergence at 1125 g/ha resulted in 80% less dodder emergence. Rimsulfuron or halosulfuron applied postemergence resulted in increased branching of the dodder and some suppression of growth, but normal dodder growth resumed within 3 weeks after application. Thus, dodder can be managed in tomatoes by avoiding the peak germination period, using transplants, use of a resistant variety, and/or preemergence treatment with pendimethalin, sulfentrazone or flufenacet.

199. Effects of Some Medicinal Plant Extracts on *Orobanche cernua* Seed Germination. Sirous Hasannejad¹, Saber Mirzaii²; ¹University of Tehran, Karaj, Tehran, Iran; ²Agricultural Institute of Karaj, Karaj, Tehran, Iran

Orobanche cernua is a nonphotosynthesizing root holoparasitic angiosperm that heavily parasitizes on several crop plants, such as sunflower, tomato in Iran and many other countries in the world. In laboratory studies, *O. cernua* seeds exhibited a high germination rate (approximately 85%) in 1 ppm of GR60 (stimulated compound), therefore in all treatments, GR60 was used as stimulated compound. The aim of this study was to examine the effects of different concentrations (1.25:100, 2.5:100, 3.75:100, and 5:100/w.v) of some of medicinal plants such as walnut (*Juglans regia*), oleand (*Nerium oleander*), eucalyptus (*Eucalyptus globules*), juniper (*Juniperus communis*), and pine (*Pinus sylvestris*) extracts on *O. cernua* seed germination. Distilled water was used as a control treatment in this research. Results showed that these plants had allelopathic effects on *O. cernua* seeds, so that seed germination reduced and germ tubes became brownish and stopped elongation. By increasing of extract concentrations, in all of these plants, seed germination rate was reduced, from 64.75% in 1.25:100/w.v to 21.25% in 5:100/w.v of walnut extract, 63% in 1.25:100/w.v to 26.75% in 5:100/w.v of oleand extract, 63% in 1.25:100/w.v to 39.5% in 5:100/w.v of eucalyptus extract, 69% in 1.25:100/w.v to 37% in 5:100/w.v of juniper extract, and 69.25% in 1.25:100/w.v to 47.25% in 5:100/w.v of pine extract. Natural compounds as medicinal plants extracts by reducing seed germination, stopped germ tube elongation, and prevention of haustorium penetration in the host plant roots could be very useful in the management of parasitic plants.

200. Parasitic Flowering Plants in Turkish Flora. Ahmet Uludag¹, Yildiz Nemli²; ¹Ministry of Agriculture and Rural Affairs, Alsancak, Izmir, Turkey; ²Ege University, Bornova, Izmir, Turkey

Turkey has a very rich flora, over 9000 plant species, because three phytogeographical regions, the Euro-Siberian, Mediterranean, and Irano-Turanian regions, exist. There is a diverse flora of parasitic flowering plants as well. The aim of the presentation is to review economically important and endemic parasitic plants of Turkey. Parasitic species from Cuscutaceae, Loranthaceae, Orobanchaceae, Rafflesiaceae, Santalaceae, Scrophulariaceae families have been recorded in flora of Turkey. Orobanche has 35 species in Turkey and the most economically important genus out of four genera of Orobanchaceae, which are Cistanche, Necranthus, Phelypaea and Orobanche that are root holoparasites. *Orobanche ramosa* L. and *Orobanche aegyptiaca* Pers. are problems in tomato and tobacco fields, *Orobanche crenata* Forsk. in faba bean. *O. aegyptiaca* and *O. ramosa* have been in lentil fields generally as mixed populations. The latest race of *Orobanche cumana* Wallr., race H, has been determined in sunflowers in Turkey. Three species of Orobanche in Turkey are endemic: *O. armena* Tzvelev, *O. hodrantha* Beck, and *O. sideana* Gilli. *Necranthus orobanchoides* Gilli is another endemic species from Orobanchaceae family. Three *Cuscuta* species, which are shoot holoparasites, are important in agricultural crops out of 15 species and there is an endemic species, *Cuscuta obtusata* Trabut. *Cuscuta campestris* Yuncker infests about 40 plants including many crop species such as tobacco, onion, pepper, and alfalfa in Turkey. *Cuscuta* approximate Bab. has been found together with *C. campestris* in alfalfa. It infests tobacco, tomato, and pepper as well. *Cuscuta monogyna* Vahl. is determined on grapevine. *Viscum album* L., *Loranthus europaeus* Jacq., and *Arceuthobium oxycedri* (DC) Bieb. are species from Loranthaceae family that is a family of shoot hemiparasites. *V. album* has three subspecies attacking different tree species/genera. *L. europaeus* lives especially on Fagaceae plants. It is determined on Quercus, Crataegus, and Castana trees. *A. oxycedri* is found on *Juniperus* spp. *Melampyrum arvense* L. from Scrophulariaceae family, hemiparasites, attaches roots. *M. arvense* var. *arvense* infests in wheat in the Inner West Anatolia while *M. arvense* var. *elatius*, an endemic species, is seen in the East Blacksea Region. *Pedicularis*, *Rhynchospora*, and *Euphrasia* exist from Scrophulariaceae, *Euphrasia minima* Jacq. ex DC., *Rhynchospora odontophylla* Burbidge et Richardson and *Pedicularis olympica* Boiss. are endemic species. *Cytinus hypocistis* L. and *Pilostyles haussknechtii* Boiss. are from Rafflesiaceae family, which are holoparasites. Three genera, Thesium, Comandra and Osyris, are recorded from Santalaceae. *T. aureum* Jaub & Spach., *T. oreogetum* Hethredge, *T. scabriflorum* Davis, and *T. bertiamii* Aznar are endemic species.

201. The Influence of Sowing Date and *Striga hemonthica* on the Yield of Different Varieties of Sorghum (*Sorghum bicolor*). Friday Ekeleme¹, Alpha Kamara¹, Lucky Omoi-

gui¹, David Chikoye¹; ¹International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State, Nigeria

Striga hemonthica is a serious biotic constraint to sorghum production in the dry savannas of sub-Saharan Africa. In West Africa about 94% of sorghum fields were estimated to be infested by *S. hemonthica*. Crop cultivars have been proposed as a means of reducing losses due to Striga. Two improved sorghum varieties (ICSV 111 and ICS 400) obtained from ICRISAT and two local checks (KSV8: improved and ANUGIWA: landrace) were evaluated at different sowing dates under natural infestation with *S. hemonthica* in 2005 and 2006 in Nzuda and Damboa, northeast Nigeria. The trial was conducted in a split plot design with four sowing dates (July 7, July 14, July 21 and July 28) as main plot and four sorghum varieties as subplot treatments. The number of emerged Striga plant was 3.7 times higher in 2005 than in 2006. The number of emerged Striga was twice higher in early sowing than when sowing was delayed for 21 or 28 days. ICSV 111 and ICS 400 had 25-110% fewer Striga shoots than KSV8 and ANUGIWA. Despite a higher Striga infestation, early sowing did not give significant higher yields compared to late sowing. Although Striga infestation was significantly more on KSV8 it yielded higher than the other varieties except ICSV 111 which had the highest grain yield. The landrace produced 51% less grain than the average grain yield of the improved varieties. Sowing date by variety interaction was significant. KSV8 and ANUGIWA produced significantly more grains when sown in the first week of July while the yields of ICSV 111 and ICS 400 increased substantially when sown on the fourth week of July. Farmers in the zone would maximize sorghum yield if improved sorghum varieties are planted at the appropriate date.

202. Evaluating the Possibility of Chemical Control of Broomrape. Somayeh Foruzesh¹, Hassan Alizadeh¹, Mohammad Baghestani², Hamid Mashhadi¹; ¹University of Tehran, Karaj, Tehran, Iran; ²Weed Research Institute, Tehran, Iran

Considered as an industrial plant, tomato is one of the most important agricultural vegetables. Among constraints to the production of this crop is the interference resulting from the presence of weeds, in particular, the parasitic broomrape where no effective method has been warranted for its control. In 2005-2006, greenhouse and in situ experiments were conducted to evaluate the possibility of selective, chemical control of broomrape (*Orobanche aegyptiaca* L.) in tomato crop. Both greenhouse and in situ experiments were arranged as a complete randomized blocks design with 19 herbicide treatments replicated 4 times in which there were 4 observations per replication. Treatments included application of chlorsulfuron at 7.5 g a.i./ha (either applied soil incorporated (PPI) or through

irrigation water (HERB)), glyphosate at 20.5, 30.75, 41 and 61.5 g a.i./ha, rimsulfuron at 2.5, 5, 7.5, 15 and 30 g a.i./ha, sulfosulfuron at 25, 50 and 100 g a.i./ha and trifluralin at 960 or 1200 g a.i./ha PPI and 1200 g a.i./ha HERB. Broomrape infested and non-infested pots (and plots under in situ condition) were also considered as controls. Under greenhouse condition, tomato yields obtained by sulfosulfuron at 50 and 100 g a.i./ha, and rimsulfuron at 7.5 and 30 g a.i./ha were the highest and did not vary with the non-infested check. Nursery (in situ) results also indicated that sulfosulfuron at 50, 100 g a.i./ha and glyphosate at 5, 7.5 g a.i./ha had the highest fruit weight. Chlorsulfuron at 7.5 g a.i./ha, sulfosulfuron at 50, 100 g a.i./ha and 61.5 g a.i./ha caused the maximum reduction in broomrape shoot weight in greenhouse experiment. Chlorsulfuron at 1.5 g a.i./ha applied through irrigation water, trifluralin at 1200 g a.i./ha and glyphosate at 61.5 g a.i./ha effectively reduced underground broomrape biomass production. According to the results of nursery, rimsulfuron at 15 g a.i./ha, glyphosate at 30.75 and 61.5 g a.i./ha and sulfosulfuron at 100 g a.i./ha effectively controlled broomrape in terms of shoot weight. Broomrape underground biomass was highly reduced when sulfosulfuron applied at 2.5, 15 or glyphosate at 30.75, 41 and 61.5 g a.i./ha.

203. New Options for Biocontrol of Parasitic Weeds of the Genera *Orobanche* and *Cuscuta*. Nadjia Zermane¹, Nadjia Zermane¹; ¹National Institute of Agronomy El-Harrach, Algiers, Algeria

Orobanche crenata Forsk. (crenate broomrape) and *Cuscuta campestris* Yuncker (field dodder) are the most widespread parasitic weeds in cropping systems in North Africa where they inflict severe damage to a wide range of vegetable, pulse, ornamental and industrial crops. Over the past few years, innovative biocontrol methods against these parasitic weeds were studied. Soil and rhizosphere bacteria were evaluated for their potential use as biocontrol agents for both parasites under controlled conditions. Bacteria from the faba bean-*Orobanche* root environment were screened to detect effective isolates for *Orobanche* control. In pot experiments, *Pseudomonas fluorescens* strain Bf7-9 significantly reduced *Orobanche* emergence and dry weight by 64% and 39%, respectively, compared with non-inoculated controls and positively influenced faba bean growth. Significant increase in faba bean dry biomass (53%), number of branching (150%) and number of flowers (433%) as well as advanced flowering and fruiting stages were recorded over the *Orobanche*-infested control. Selected Plant Growth Promoting Rhizobacterial strains exhibited the ability to promote *Orobanche* seed germination. In germination tests using a microtiter plate system and a water agar medium supplemented with lentil root exudates, up to a 43% increase of *O. crenata* seed germination was obtained after treatment with *Ralstonia*

pickettii strain Bzc76 over the non-inoculated control. The effect of soil bacteria on *C. campestris* seed germination and growth was also investigated. The main objective was to select bacterial isolates that inhibited *Cuscuta* seed germination and growth. Of 55 isolates assayed, 25 significantly reduced (25 to 46%) the length of *Cuscuta* seedlings compared with the non-inoculated control. Soil drenching with the most promising isolate CT2.2 of *Microbacterium* sp. resulted in a 59% reduction of seedling emergence. However, the bacterium showed no inhibitory effect on *Cuscuta* seed germination. A range of water soluble plant extracts was evaluated for activity against *O. crenata* and *C. campestris*. Various extracts applied to seeds of either species inhibited or stimulated seed germination. The most noticeable reductions of *Orobancha* seed germination were obtained with extracts from *Allium sativum* and *Lavandula stoechas* (100% and 91% reduction, respectively). Other extracts that also had an inhibitory effect on *Orobancha* seed germination were those of *Thymus fontanesii* (75% reduction), *Cuminum cyminum* (74%), *Datura stramonium* (69%), *Artemisia herba-alba* (64%), *Eucalyptus citriodora* (62%), *Oxalis pes-caprae* (58%), leaves of *Citrus lemon* (55%), peel of *C. sinensis* and *C. lemon* (55% and 46%, respectively), *Inula viscosa* (53%), *C. aurantium* (48%) and *Ricinus communis* (45%). Conversely, only extracts from *Inula viscosa* and leaves of *Citrus lemon* showed inhibiting effect on seed germination of *C. campestris* (74% and 26% reduction, respectively). Extracts from *Ricinus communis* and peels of *C. lemon* showed, on the other hand, a stimulating effect on *Cuscuta* seed germination.

204. Can Invasive Plants have an Impact on Croatian Agriculture? Edita Stefanic¹, Ivan Stefanic², Sanda Rasic¹; ¹Faculty of Agriculture Osijek, Osijek, Osijek-baranja county, Croatia; ²Technology Development Centre Ltd., Osijek, Osijek-baranja county, Croatia

Among many invasive plant species introduced to the Republic of Croatia, special attention should be paid to those having an adverse effect or representing a threat to agricultural production. Controlling such weeds poses a special dilemma because, up to the time a weed infestation is identified, it has often spread to such an extent that control is extremely difficult and expensive. Moreover, invasive species cause losses in biodiversity, change the weed communities, influence on considerable yield losses and represent a public health problem (ragweed pollen allergy).

Weed surveys were conducted between 2005-2007 on Northeastern Croatian arable lands to gather information on the biology, ecology, invasiveness and management of selected species. A field data from approximately 450 vegetation study plots across the investigated territory were used to determine the Invasiveness Rank of exotic plant species.

With this information a multivariate analysis was performed in order to identify a invasiveness pattern of dominant alien species.

There are several species recorded in investigated agricultural areas that are increasing in their range and frequency. The vast population of: *Abutilon theophrasti* Medic (velvetleaf), *Ambrosia artemisiifolia* L. (short ragweed), *Conyza canadensis* L. (horseweed), *Datura stramonium* L. (jimsonweed), *Erigeron annuus* (L.) Pers. (annual fleabane), *Galinsoga parviflora* Cav. (smallflower galinsoga) is especially troubling.

The extent of their infestation is being monitored in order to measure the direction and rate of change in the size of the colony. In awareness of the serious consequences and high cost of suppression if these invasive non-native species spread, strategies of chemical and non-chemical control are being discussed.

Only prevention, national and international contracts and laws as well as integrated methods (including agro-technical, mechanical, chemical and biological ones) can give satisfactory results.

205. Plant Community Response to Disturbance in the Presence of the Non-Native, *Linaria vulgaris* (Yellow Toadflax). Erik Lehnhoff¹, Lisa Rew¹, Bruce Maxwell¹; ¹Montana State University, Bozeman, MT, United States of America

Disturbance, both anthropogenic and natural, is a powerful force that shapes plant communities. Disturbance can also lead to the invasion of these communities by non-native species. Herbicides are often used to control the undesirable non-native species, and this control method may in turn alter the extant plant community. We sought to understand how soil disturbance (removing vegetation and homogenizing the upper 7 cm of soil by digging and sifting the soil), vegetation clipping (clipping all vegetation to ground level), fire (burning of all vegetation with propane torch), and chemical weed control (Picloram - Tordon K applied at 0.56 kg ai/ha) affected plant communities in southwestern Montana. These disturbances were applied to diverse plant communities with existing patches of *Linaria vulgaris* (yellow toadflax) in four different environments - Clearcut, Riparian, Wildfire burned forest and Meadow - in spring 2004 using 0.25-m² plots. Species counts and percent cover were assessed in all plots in the spring of each year from 2005 through 2007 and compared with pre-disturbance assessments (2004). Species richness, relative species abundance (dominance) and Simpson's diversity index were compiled. Treatments generally reduced species richness and diversity in the first year. Species richness and diversity recovered to pre-disturbance levels by 2007 after burning, clipping and digging in plots at the Meadow and Riparian sites, while these metrics remained depressed at the Clearcut and Wildfire sites. Digging resulted in a shift

from native species dominated communities to *L. vulgaris* dominated ones on all sites except the Meadow. Species dominance was not altered by burning and clipping at any site. Applying herbicide to the vegetation suppressed richness throughout the study period at the Clearcut, Riparian and Wildfire sites, although the values were increasing toward pre-disturbance levels by the third year. Herbicide application at these sites also resulted in a change to *L. vulgaris* dominance, as the herbicide removed competing forbs, but did not completely kill the target species. At the Meadow site, which contained the non-native species *Poa pratensis* (Kentucky bluegrass), richness and diversity remained very low after herbicide application, and the mixed grass/forb community changed to a grass monoculture while *L. vulgaris* was controlled. The results indicated that plant community response to disturbance was very site and disturbance specific. Furthermore, the effectiveness of herbicide as a control measure for non-native species was also site specific, with herbicide resulting in unintended consequences at some sites.

206. A Functional Niche Promotes an Invasion in a Biodiversity Hotspot. Irfan Rashid¹, Manzoor Shah¹, Zafar Reshi¹, B Wafai¹; ¹University of Kashmir, Srinagar, Jammu and Kashmir, India

Historically, the principal approach in community ecology has been to evaluate how different factors (e.g., abiotic stress, competition for resources, herbivory and mutualism etc.) separately influence population dynamics or community structure. However, modern population and community ecology is perched to move beyond lists of community-structuring factors to a predictive framework for where, when, and how multiple factors may work, both individually and in combination, to structure communities. Species invasions, a principal component of global change that can cause habitat degradation, extinction of native flora and fauna and inflict grave monetary costs, often change relatively diverse communities into near monocultures and hence warrant modern community ecology approach to understand the success of alien species in their non-native ranges. Thus our central aim in the present investigation was to address the consequences of losses and gains of biotic interactions in respect of demographic success of an alien invasive plant species. Using case study of *Anthemis cotula* L., a highly invasive species in the Kashmir Himalayan biodiversity hotspot, we examined influence of the most common above ground (herbivore) and belowground (arbuscular mycorrhizal fungi) co-associates, in non-native range, of this species on its performance. Results reveal that the species exploits the new niche to benefit from its novel associates in the invaded region for successful invasion. Thus, highlighting the importance of belowground and aboveground associations in alien plant invasions, the study brings out need

for comprehensive multifactor interaction analyses while dealing with plant invasions.

207. Integrated Strategies for *Imperata cylindrica* Management. Greg MacDonald¹, Jason Ferrell¹, Brent Sellers¹, Kenneth Langeland¹; ¹University of Florida, Gainesville, Florida, United States of America

Imperata cylindrica, cogongrass, is a serious weed problem throughout the southeastern United States. This perennial grass reproduces via seeds and rhizomes, and is extremely persistent due to an extensive rhizome system. Cogongrass is a problem along roadsides, pine (*Pinus* spp.) plantations, and natural areas. This species is also becoming extremely problematic in pasture and native rangeland settings. Studies were conducted to control cogongrass in these types of settings utilizing an integrated approach including tillage, herbicides, fertility inputs, and overseeding with desirable forage. The first study was conducted in an area with greater than 90% cogongrass infestation. Several factors were evaluated including, tillage (disking or plowing), herbicides (imazapyr or glyphosate), fertilizer inputs and seeding rate (*Paspalum notatum*). The herbicides glyphosate or imazapyr were applied in the fall months, followed by tillage, overseeding and fertility inputs (1100 kg-ai/kg lime + 110 kg-ai/ha nitrogen or nitrogen alone) the following spring. The second study was conducted in an area with 30-60% cogongrass infestation within an established *P. notatum* pasture. In this study, the herbicides imazapyr, glyphosate, fluazifop or imazapic were applied in the fall months, followed by fertility and overseeding the following spring. Tillage was not employed in this study. The third study was performed on native rangeland. Herbicides were applied during spring, summer or winter months to isolated patches of cogongrass. In the first and second studies, evaluations of cogongrass control and *P. notatum* density were performed. In the third study, cogongrass control and recolonization of desirable native species was recorded.

In study one, >90% cogongrass control was achieved with imazapyr herbicide at 1.1 kg-ai/ha, regardless of tillage operation. However, only the glyphosate followed by the plowing tillage regime resulted in >90% control. Overseeding rates of *P. notatum* and fertility inputs had little impact on *P. notatum* levels. In the second study, imazapyr selectively controlled cogongrass with minimal *P. notatum* injury at rates of 0.26 kg-ai/ha. However, selectivity could not be achieved with glyphosate, as both species were severely affected. Imazapic or fluazifop did not severely injury *P. notatum*, both also did not provide acceptable cogongrass control. Once again, fertility and overseeding had little impact on *P. notatum* levels. In the third study, imazapyr and glyphosate at rates of 0.26, 0.56 or 0.78, 1.6 kg-ai/ha, respectively, provided good cogongrass control. Once again, fluazifop and imazapic did not

provide acceptable control of cogongrass. However, all treatments, regardless of cogongrass control, did not result in significant recolonization of desirable native species. This could be attributed to the lack of seed inputs, wind-borne or seedbank, or the lack of appropriate conditions for seedling germination and establishment. Collectively, these studies indicate the potential for selective cogongrass control within *P. notatum* and further demonstrate the need for an integrated approach, including chemical, mechanical and cultural control methods. These studies also suggest recolonization, either through native species recruitment or purposely introduced species, are necessary for long-term management of *Imperata cylindrica*.

208. *Echinochloa oryzicola* (Barnyardgrass): A New Emerging Threat to Paddy Fields of Iran. Bijan Yaghoubi¹, ¹Ali Abobakr; ¹Rice Research Institute of Iran, Rasht, Guilan, Iran

In paddy crop, certain species of the annual barnyardgrass (*Echinochloa* spp.) show plant morphological traits quite close to the rice plant. Over the years the farmers controlling *Echinochloa* species through hand weeding have easily controlled the grass species i.e. *Echinochloa crus-galli* that are distinctively different in appearance to the rice crop. However, certain species of *Echinochloa* similar in appearance to rice plant remained in the fields and their populations are now being felt as a major weed threat and are difficult to be distinguished or weeded because of convergent morphology and phenology. Based on our recent observations over the last three years in farmers field pertaining to herbicide resistance of barnyardgrass lead us to identify a new weed uncommon to this region i.e. *Echinochloa oryzicola* that mimic the appearance of the rice plant especially at its vegetative phase. This weed resembles the rice plant for its nodal colour, tillering ability, tillering angle, boot shape, leaf colour and angle. Its early germination in nursery and being transplanted instead of rice seedling in the main reason for its population built-up. It has been reported that the herbicide tolerance of this species is higher than the *Echinochloa crus-galli* allowing it to get selected in the fields. Probably the dosage of herbicide should be increased to suppress this weed. However, over the years the herbicides have indirectly selected this weed due to its increased tolerance and its phenology close to rice plant has avoided the hand weeders. *E. oryzicola* (*E. oryzicola*) is also called as 'Rice barnyardgrass' which is the most serious weed in California rice fields. *E. oryzicola* is now emerging weed species escaping the hand weeding and chemical weed control in rice fields of Iran. *Echinochloa oryzicola* is resistant to flooded paddy fields and its seeds rarely shatter that allows them to get harvested and scattered along with rice crop. This situation may pose a real threat for rice production, especially in the northern provinces of Iran where hand weeding and flooding still plays a main role in

IWM of rice fields. *E. oryzicola* has been reported to become resistant to higher doses of many herbicides in other rice growing regions in the world. However, this is the first report of *E. oryzicola* prevalence in rice fields of Iran and we are contemplating a proper IWM strategy.

209. Parthenium Management by Allelopathic Grasses. Arshad Javaid¹; ¹University of the Punjab, Lahore, Punjab, Pakistan

Parthenium weed [*Parthenium hysterophorus* L.] is rapidly spreading in many parts of the world including Pakistan. Some herbicides are effective against this weed. In recent years, the use of chemicals has increased consumer's concern and their use is becoming more restrictive due to carcinogenic effects, residual toxicity problems, environmental pollution, occurrence of microbial resistance and high inputs. Increasing public concern on these issues requires alternative disease management systems, which are less pesticide dependent or based on naturally occurring compounds. The present study was carried out to assess the herbicidal potential of aqueous extracts of five allelopathic grasses viz. *Imperata cylindrica*, *Desmostachya bipinnata*, *Dicanthium annulatum*, *Cenchrus pennisetiformis* and *Sorghum halepense* against parthenium.

Field surveys were carried out to investigate the distribution of parthenium at localities with and without infestation of allelopathic grasses *I. cylindrica* and *D. bipinnata*. Data regarding frequency and density of parthenium at localities with and without these allelopathic grasses were recorded. In a laboratory bioassay, aqueous extracts of five aforementioned allelopathic grasses were obtained by soaking 25 g crushed root and shoot materials in 100 ml distilled water for 36 hours at 25 °C and filtered. Further dilutions of 20, 15, 10 and 5% w/v were prepared by adding appropriate quantity of water to the 25% w/v stock solution. Seeds of parthenium were sown on a filter paper seedbed in sterilized Petri dishes, moistened with aqueous root and shoot extracts of the test allelopathic grasses. The plates were incubated at 25 °C for 7 days. Germination, root and shoot length, and seedling fresh biomass was recorded at the end of the experiment. Data were analyzed statistically by applying Duncan's Multiple Range Test.

Field surveys revealed that the allelopathic grasses *I. cylindrica* and *D. bipinnata* restrict the spread of parthenium. The frequency and density of parthenium in herb zone (without allelopathic grasses) was 80% and 40, which were reduced to 30% and 5, and 20% and 3, at *D. bipinnata* and *I. cylindrica* dominating zones, respectively. Aqueous extract bioassays showed that aqueous root and shoot extracts of all the five test grass species markedly suppressed the germination and seedling growth of parthenium. Extracts of *D. bipinnata* and *C. pennisetiformis* were proved more inhibitory to parthenium than rest

of the test grasses. A 20% shoot extract of these grasses completely arrested the germination and seedling growth of parthenium. The present study concludes that the aqueous extracts of allelopathic grasses are highly effective against germination and growth of parthenium.

210. The Biology of Invasive Alien Plants in Canada: A Series of Review Papers. Suzanne Warwick¹, Stephen Darbyshire¹; ¹Agriculture and Agri-Food Canada (AAFC), Ottawa, Ontario, Canada

Presently an estimated 1-2 new alien plant species are becoming established in Canada each year and this rate is expected to increase. These new pests are generally poorly known and their weedy potential unrecognized. In this poster, we highlight a series, The Biology of Invasive Alien Plants in Canada, initiated in 2003 in the Canadian Journal of Plant Science. It serves as a companion series to the long-running Biology of Canadian Weeds which appears in the same journal. The series of peer-review contributions is designed to review the biology of recently introduced plant species that pose a demonstrable economic or environmental risk in Canada. As well as summarizing current knowledge, contributions to the series serves as alerts of emerging problems, emphasizing aspects of identification, occurrence, economic and environmental impact, effective control methods and future prognosis. The series will also engender research to fill important gaps in our knowledge. Eight species accounts have been published to date and nine more are in preparation. Our display will provide information on all published accounts, a list of accounts in preparation and a list of species for which accounts are needed. Plant species covered in the series must occur in Canada, but contributing authors need not. Authors from outside of Canada with special knowledge of Canadian weed species are encouraged to register to write accounts. For more information on the series, submission process and instructions to authors, see the Canadian Weed Science Society web site (http://www.cwss-scm.ca/Biology_of_weeds/invasive.htm) or contact the associate editor at warwick-s@agr.gc.ca for a pdf file.

211. Invasive Plant Management from Cradle to Grave: Managing Decomposition of the Annual *Impatiens glandulifera*. David Clements¹, Le Zhou¹, Paul Brown¹; ¹Trinity Western University, Langley, BC, Canada

Well-known impacts of invasive plants include competing with other plants, causing harm to livestock, and acting as alternative hosts for other pests. Most of these impacts stem from vigorous capabilities for reproduction and growth but plants may also produce negative impacts beyond their lifecycle. The litter from dead plants may yield harmful effects or, alternatively, the lack of litter may

create problems. The latter is apparently the case for *Impatiens glandulifera* (Himalayan balsam); as an annual that infests riparian areas, its rapid decomposition leads to increased potential for soil erosion in such environments. Rapid spread of *I. glandulifera* in riparian areas has occurred in many areas of Europe and North America, but attempts to measure its impact have focused on reproduction and competitive ability. Our study in southwestern British Columbia quantified the impact of the seasonal decomposition of *I. glandulifera* on plant communities. We also attempted to quantify the presence of naphthaquinones in the tissues of *I. glandulifera* through different life cycle stages. This was to examine the role of naphthaquinones in decomposition rates, since their presence is known to slow decomposition. We observed a rapid decline in the % cover of *I. glandulifera* in riparian habitats observed in the Salmon River watershed in Langley, BC. Naphthaquinones were present in *I. glandulifera* and their potential decline as plants die and begin to decompose illustrate threats posed to bank stability due to rapid decomposition. Recent studies in Europe have questioned assumptions that *I. glandulifera* significantly reduces diversity and native plant abundance. However, impacts other than direct competition such as alteration of the soil environment by invasive species like *I. glandulifera* may help justify extensive management efforts such as the eradication programs for *I. glandulifera* underway in various areas of southwestern British Columbia.

212. Effects of Abiotic and Biotic Factors on the Occurrence and Establishment of Non-Indigenous Plant Species. Fred Pollnac¹, Tim Seipel¹, Charles Repath, Lisa Rew¹; ¹Montana State University, Bozeman, Montana, United States of America

Roadways are known vectors for dispersal of non-indigenous plant species (NIS) and several studies have shown that NIS tend to be more abundant along roadsides than in interior habitats. Knowledge of the relative roles that abiotic and biotic factors play in this phenomenon would facilitate the creation NIS population spread models and would aid in prioritization of control efforts. We hypothesize that NIS abundance along the roadside will decrease with increased elevation. We also hypothesize that NIS emergence will decrease as distance from road increases. Two studies were initiated in the Greater Yellowstone Ecosystem to investigate these hypotheses. In each study, 100 m transects were established perpendicular to surveyed roadways. The first study examined the effects of an elevation gradient (1,800 m - 3,300 m) on NIS abundance on three roads. The second study examined the effects of native species cover and distance from a roadway on NIS cover and surrogate NIS emergence. Data were analyzed using generalized linear models. NIS abundance decreased with increased elevation ($p < 0.05$) and distance from the road ($p < 0.001$) in the first study. Similarly, NIS

abundance decreased with distance from road ($p < 0.001$) and also with increasing native cover ($p < 0.001$) at the second site. Despite equal planting densities, surrogate NIS emergence decreased with distance from road during the fall ($p < 0.01$), but there was no significant trend for the spring. The combined results of these studies lend support to previously observed patterns of NIS abundance declining away from roadways. The observed decline of roadside NIS abundance with increased elevation in the first study, and the observed decline of surrogate NIS emergence away from a road suggests that abiotic factors play an important role in the establishment of NIS, and highlights the need for additional studies concentrating on the effects of environment on NIS establishment.

213. Can a Historical Analysis of the Spread of *Ambrosia artemisiifolia* Explain its Actual Success in France? Bruno Chauvel¹, Fabrice Dessaint¹; ¹INRA, Dijon, Burgundy, France

Introduction. Common ragweed (*Ambrosia artemisiifolia* L.) is one of the plants recently described as invasive weed in France. Although botanical literature describes the introduction of the species at the end of the nineteenth century, very limited biological and ecological information on this species is available in France. Here, historical analysis is used to assess whether or not the habitat preferences of this plant have shifted through time.

Material and methods. Herbarium specimens stored in herbaria in France and in bordering countries and data contained in ancient botanical communications were used to reconstruct the spread of common ragweed. All data found since 1863 (sampling year, location, habitat, population size, introduction pathways) were incorporated into a data base. Specific indication as 'new plant' was used to determine the timing of the introduction of the species into a new area.

Results. Ancient data indicated that this species has been first introduced in France as contaminants of agricultural products (red clover, maize, potatoes) in various independent geographical points and at various times and more recently with birdseed food. Its introduction and spread were also facilitated by material transport during the First World War. Introduction of common ragweed was not always successful and in some locations, the species disappeared or survived only with very low populations. During the first half of the 20th century, *A. artemisiifolia* was always described as a weed but was also found on communication lines (road, railways) or waste areas. Riverbanks were the only natural habitats invaded by this species. During the last 50 years, lines of communication became the main habitat of the species, but it was still present in fields. Since 1970, the expansion of sunflower crop and the more recent suppression of different herbicides for environmental reasons, have strongly contributed to the development of the species.

Conclusion. All data analysed indicated that the key factors in the introduction of *A. artemisiifolia* in France were anthropogenic. The spread of the species over France showed no clear front because new localities separated by large distances were colonized simultaneously. Dispersal vectors often remained unknown. The success of *A. artemisiifolia* could be explained by the existence of empty ecological niches in the French flora where few native species are competitive. Despite the lack of an effective mechanism of seed dispersion, the difficulties in controlling human activities (agriculture, road maintenance) will certainly continue to contribute to an increase in the abundance and distribution of *A. artemisiifolia*.

214. Invasive Alien Weeds in Hainan Island of China*. Zhi Wei Fan¹, Yi De Shen¹, Ying Lu¹, Li Zhen Liu¹; ¹Chinese Academy of Tropical Agricultural Sciences, Danzhou, Hainan, China (Peoples Republic of)

There are invasive alien weeds of 141 species, belonging to 104 genera and 35 families in Hainan Island, South China at present after investigation. The families with more species are Leguminosae (31 species, 19 genera), Compositae (19 species, 16 genera), Gramineae (17 species, 12 genera), Amaranthaceae (12 species, 5 genera), Euphorbiaceae (10 species, 5 genera), Solanaceae (7 species, 5 genera) and Labiatae (4 species, 2 genera); 61.2% of them are native to America and the most of them are originated to Tropical America.

The worst invasive alien weeds in Hainan Island are *Eupatorium odoratum*, *Eupatorium catarium*, *Ageratum conyzoides*, *Conyza canadensis*, *Parthenium hysterophorus*, *Amaranthus spinosus*, *Borreria latifolia*, *Mimosa invisa* var. *invisa*, *Eichhornia crassipes*, *Echinochloa crusgalli*, *Eleusine indica*, *Panicum repens*, *Rhynchelytrum repens* and *Cyperus rotundus*. The main invasive alien weeds in Hainan Island are *Alternanthera philoxeroides*, *Synedrella nodiflora*, *Bidens pilosa*, *Crassocephalum crepidioides*, *Tithonia diversifolia*, *Wedelia trilobata*, *Amaranthus viridis*, *Celosia argentea*, *Gomphrena celosioides*, *Chenopodium ambrosioides*, *Euphorbia hirta*, *Stachytarpheta jamaicensis*, *Lantana camara*, *Cassia tora*, *Cassia occidentalis*, *Sorghum halepense*, etc. Quarantine and surveillance must be attached importance to those worst invasive alien weeds, such as *Eupatorium adenophorum*, *Solidago canadensis*, *Ambrosia artemisiifolia*, *Galium aparine*, *Spartina alterniflora*, *Lolium temulentum* and *Scirpus planiculmis*, etc., which have not discovered into Hainan Island. However, these weeds have caused a great harm and economic loss in other provinces of China and the world.

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215. Characterizing Invasion of *Linaria dalmatica* at a Population and Metapopulation Scale. Tyler Brummer¹, Bruce Maxwell¹, Lisa Rew¹; ¹Montana State University, Bozeman, MT, United States of America

Understanding the pattern and rate of non-indigenous species invasion are important for prioritizing populations for management. Ages of individual *Linaria dalmatica* plants across patches and among patches were determined using herb-chronology methods. Age patterns were used to identify plant spread as phalanx, guerrilla, or infiltration. Reconstructing an invasion using age structure allowed for calculations of relative rates of colonization. Individual plant roots were collected and mapped along two axes, 1 meter in width, of an established patch of *L. dalmatica* in Yellowstone National Park, USA. Satellite patches were also mapped and roots collected. The roots were cross-sectioned with a rotary microtome, dyed with phloroglucinol/HCl, and the annual growth rings identified for each root. Spatial locations of each root were recorded. The age frequency distribution of the main patch was positively skewed with a mean age of 3.54 years and a median age of 3 years. Ages ranged from 1 to 10 years old. Spatial analyses of the age and density structure showed that the patch can be best characterized as infiltration invasion which can be described as micro-invasions coalescing into a patch. The distribution of young plants between older plants on each of the axes was also indicative of this pattern of spread. There were significant ($p = 0.0472$) linear density aggregations along the long axis of the patch. Repeating patterns in the cross-sectional age distributions were seen at a scale of 3.0 meters using a Three-Term Local Quadrat Variance test of mean age along both axes also supporting infiltration as the spread pattern. The satellite population age distributions were analyzed to assess the rate of spread into the surrounding area. An individual based population dynamics spatial automaton model was used to evaluate the role of demographic and dispersal processes on the age structure within the population as well as the creation of new satellite populations.

216. Joint-pine (*Ephedra alata* Decne), an Invasive Weed and A Real Threat to Certain Forest and Fruit Trees in Jordan. Jamal Qasem¹; ¹University of Jordan, Amman, Jordan

Ephedra alata Decne is a woody perennial shrub belong to the Ephedraceae and mainly distributed in the subtropical and Mediterranean regions in Jordan. A field survey of *E. alata* was carried out to study plant species attacked and smothered by growth of this invasive weed in the central and northern parts of Jordan during the period of 2006-2007. The study showed that 29 species of fruit and forest trees belong to 19 plant families suffered from this species. Growth of the attacked species was greatly

reduced by the heavy and massive growth of *E. alata* formed by their vegetative parts. In addition to its possible competition effect with host plants for water and nutrients, its massive growth may completely prevent light from reaching host species, reduce or completely prevent photosynthesis, smother growth, prevent development and under heavy and massive vegetative growth of *E. alata* host plant may be completely suppressed and die. However, *E. alata* doesn't climb or attack any plant species in its vicinity indicating that it adopts a host preference strategy and as also judged from the differences in the mass of vegetative growth it attained on different hosts. Fruit trees attacked and mostly destroyed by *E. alata* were *Amygdalus communis* L., *Ficus carica* L., *Olea europaea* L., *Opuntia ficus-indica* (L.) Miller, *Punica granatum* L., and *Vitis vinifera* L. The forestry species suffered and found supporting *E. alata* growth were *Ceratonia siliqua* L., *Crataegus azarolus* L., *Crataegus monogyna* Jacq., *Cupressus sempervirens* L., *Pinus halepensis* Mill., *Pistacia atlantica* Desf., *Pistacia palaestina* Boiss., *Quercus coccifera* L., *Quercus infectoria* Olivier, *Retama raetam* (Forsk.) Webb & Berth., *Rhamnus palaestina* Boiss., *Rhus tripartita* L., and *Zizyphus spini-christi* L. Ornamental species severely attacked and greatly reduced in growth including *Hedera helix* L., *Jasminum grandiflorum* L. and *Nerium oleander* L. Results indicated that *E. alata* is an invasive weedy species in certain parts of Jordan, it is highly competitive for light and can completely smother host species supporting its growth.

217. Overview of Current South African Invasive Alien Plant Species Research. Andrew Wannenburg¹; ¹Department of Water Affairs & Forestry, Cape Town, Western Cape, South Africa

Success in bridging the traditional divide between basic and applied research resulted in the 1995 establishment of one of the world's largest programmes dealing with invasive alien plant species control, South Africa's Working for Water (WfW) Programme. Through research, WfW aims to expand the basis of knowledge needed to make sound management decisions, by conducting research that will deliver vital data and information on which to base such decisions, and by developing frameworks for the integration of knowledge into management. WfW currently invests 4.5% of its US\$57 million annual budget in research; of which 71% is spent on biological control, 21% on monitoring & evaluation and 5% on prioritization, research.

Biological control research is aimed at the development and evaluation of biocontrol agents against thirty-nine terrestrial and five aquatic invasive alien plant species, making South Africa the third most active country in the biological control of invasive alien plant species after the USA and Australia.

Monitoring and evaluation research is focused on the development of a cost-effective, objective, statistically sound and repeatable invasive alien plant species distribution monitoring system. Support is also provided for an update of the Southern African Plant Invaders Atlas (SAPIA). Backing is also provided for conducting studies on species that can be successfully quantified by means of remote sensing and the development of a minimum set of indicators to underpin the implementation of a monitoring and evaluation programme within WfW.

Prioritization research is directed towards assessing the water consumption for areas cleared by WfW and making comparisons between species in these areas. Also covered, is the selection and pair-wise comparisons of appropriate criteria for the ranking of invasive alien species and the areas in which they occur, through expert workshops.

218. Distribution of *Ambrosia artemisiifolia* (Common Ragweed), an Allergenic Weed, in an Urban and Rural Setting of Eastern Canada. Marie-Josée Simard¹, Diane Lyse Benoit¹; ¹Agriculture and Agri-Food Canada, Québec, Canada

Ambrosia artemisiifolia L. is the most prevalent allergenic weed in North America. Although native to the New World, it has spread to new areas and it is an invasive exotic species on other continents. Where the species is abundant (e.g. eastern Canada), its pollen is responsible for most cases (>70%) of late summer/fall allergic rhinitis (hay fever). Therefore, Québec provincial health authorities have initiated a four year mobilization project in order to monitor the health effects of *Ambrosia a.* control in a selected area. Two locations were selected: 1) Salaberry-de-Valleyfield (45.25 N; 74.13 W), located near Montréal, and 2) Saint-Jean-sur-Richelieu (45.30 N; 73.26 W). The latter location is a control area where no *Ambrosia a.* control is done. At both locations, 220 residents that suffer from allergic rhinitis fill a questionnaire during the *Ambrosia a.* flowering period, and airborne pollen is monitored. An assessment of the distribution and abundance of *Ambrosia a.* in the urban and rural surroundings of both locations was also necessary. The urban survey consisted of a visual estimation of *Ambrosia a.* density along all roadsides in the Salaberry-de-Valleyfield area and weed density evaluations in different urban settings at both locations. The agricultural survey was done by evaluating *Ambrosia a.* density in field borders, field centers and field entries on roads. 43 *Zea mays* (corn) and 21 *Glycine max* (soybean) fields were surveyed in the Salaberry-de-Valleyfield area. Roads and fields were surveyed in July-August 2007. *Ambrosia a.* was less abundant in residential areas than in other urban settings. *Ambrosia a.* was more abundant in field entries on roads ($93.31 \text{ m}^{-2} \pm 6.99(\text{STE})$) than in fields or field borders which had similar densities ($2.91 \text{ m}^{-2} \pm 1.73$ and $1.99 \text{ m}^{-2} \pm 2.25$ respectively). *Ambrosia a.* was more abundant in fields under conventional than reduced

tillage ($p < 0.001$). The species was also more abundant in transgenic than conventional corn fields but less abundant in transgenic than conventional soybean ($p < 0.001$). These differences can be explained by lower herbicide selectivity (conventional soybean) and higher herbicide persistence (conventional corn). As previous observations suggested, roadsides are important refuges for *Ambrosia a.* and the species is associated with soil disturbance.

219. Effect of *Datura stramonium* Aqueous, Ethanolic and Methanolic Extracts on *Trichophyton rubrum*. Jamal Hashemi¹, Masood Hashemi², Pooran Hosainjani, Issa Gholampoor²; ¹Tehran University/Medical Sciences, Tehran, Iran; ²Islamic Azad University, Tonekabon, Guilan, Iran

Introduction:

The drug effects of *Datura Stramonium* under title of weed are verified. In about the antimicrobial effects of *Datura stramonium* are not clear and there are not many researches done on it.

Method:

In this research with gel diffusion; plate count and Broth Dilution method; MIC and MFC determine test antifungal effects of seed and leaves Aqueous, Ethanolic and Methanolic Extracts of *Datura Stramonium* on *Trichophyton rubrum* growing have been studied.

Results:

It showed that *Trichophyton rubrum* is not able to grow in S.D.A agar medium contains 10% of the seed and leaves of *Datura stramonium* extracts. Leaf methanolic extract with MIC=1.56 mg/ml, Leaf ethanolic extract with MIC=3.125 mg/ml, Leaf aquatic extract with MIC=25 mg/ml, seed aquatic extract with MIC=3.125 mg/ml, seed methanolic extract with MIC=6.25 mg/ml and seed ethanolic extract with MIC=3.125 mg/ml inhibited *Trichophyton rubrum* growth.

Conclusions:

Datura stramonium extract inhibit the growth of *Trichophyton rubrum* in, in vitro condition

220. Georgia's Comprehensive State-Wide Program on *Imperata cylindrica* Detection and Control. David Moorhead¹, Charles Barger¹, James Johnson², Carey Minteer¹; ¹University of Georgia, Tifton, GA, United States of America; ²Georgia Forestry Commission, Athens, GA, United States of America

Since its accidental introduction at Grand Bay, Alabama USA in 1912, *Imperata cylindrica* (L.) Beauv. has become wide-spread in the states of Alabama, Florida and Mississippi. This exotic grass poses serious problems to landowners and land managers as it supplants native vegetation, hinders forest and native plant regeneration, and produces hazardous buildups of highly flammable

fuel. In the aforementioned states, there are more than 400,000 hectares of *I. cylindrica* infestations. And while there are varying control program efforts underway in these states, eradication is unlikely and *I. cylindrica* will remain a persistent and serious management issue. In contrast, limited infestations of *I. cylindrica* occur in the state of Georgia. In the spring of 2008, there were ninety-nine documented infestations totaling approximately 25 hectares in twenty-one counties within the state. A comprehensive state-wide effort has been initiated to locate, map and eradicate infestations in Georgia. The program was initiated following the setup of a Cogongrass Task Force comprised of representatives from The University of Georgia, Georgia Forestry Commission, Georgia Department of Agriculture, USDA Forest Service, USDA APHIS, PPQ and other land management/conservation organizations. With funding from the USDA Forest Service and leadership by the Georgia Forestry Commission an aggressive educational, detection, control and research program was initiated. Since 2005, there have been over 400 direct contact programs reaching in excess of 16,000 landowners, foresters, other natural resource managers, timber harvesters, highway maintenance workers, hunters, and the general public. As a result of the direct program efforts and supporting web and printed publications, *I. cylindrica* has gone from a little-known problem species to one that land managers and others are actively looking for and treating.

The following protocol is initiated once a suspected infestation is reported to the Forestry Commission, Extension office or to other cooperators: the infestation is confirmed by an on-site inspection by GFC or APHIS personnel; ownership is determined and landowner contacted informing them of the find; treatment is initiated following landowner consent by APHIS or Georgia Forestry Commission (the Commission enters into a five-year contract with the owner to treat, free of charge, until the population is eradicated); current treatments involve spring application of glyphosate to suppress flowering, followed by fall treatments of imazapyr and with annual follow-up evaluation and retreatment (to increase the control effectiveness, herbicide screenings involving various formulations of imazapyr, glyphosate and surfactants have been established to evaluate level of *I. cylindrica* control, regrowth and changes in root biomass); all infestation locations, descriptions and treatments are cataloged in the University of Georgia's Bugwood Network Early Detection, Distribution and Mapping System (EDDMapS). An update of current program efforts, degree of control and results of herbicide trails will be presented.

221. Invasive Plants and the Nursery Industry in Australia. Robert Chin¹; ¹Nursery & Garden Industry Victoria, Wantirna South, Victoria, Australia

In Australia, we have about 2780 weeds. Of these, about 1 830 are introduced garden plants that have become feral and invaded farming land and natural areas including National Parks. So, over 65% of Australia's introduced weeds have started out as garden plants. These 'garden thugs' are costing millions of dollars annually to control on farms and in bushland and other natural areas. Not only do they consume large amounts of resources in the agriculture and horticulture sectors, they are also having devastating impacts on our environment. The Nursery Industry is an important player in the area of invasive plants. They have sold many of these invasive plants and are now actively working in a variety of ways to reduce the impact of invasive plants on Australia's environment.

2.Objectives: This paper outlines some of the work that the Nursery & Garden Industry in Australia is doing to minimise the impact of invasive plants on the Australian environment.

3.Description of work done: There are a variety of ways in which the industry is fighting the impact of invasive plants. This is primarily done through working with governments and other stakeholders to educate industry and the community on the impact of invasive plants. These include:

- a.A range of education programs aimed at growers, retailers and the gardening public
- b.Workshops for the above
- c.Publications in a range of industry and gardening magazines, newsletters, websites and a range of other media
- d.Working with local, state and federal governments and other relevant stakeholders in a positive and co-operative manner
- e.Joint displays at community and national gardening shows and displays
- f.A national community and education program 'Grow Me Instead' which is an unprecedented jointly funded program between the industry and government.

4.Other significant areas of interest relating to Invasive Plants and the nursery industry:

- a.Many of Australia's worst invasive plants are not those sold by the nursery industry but were recommended or introduced by Farmers, Governments etc
- b.Many of Australia's worst invasive plants were introduced by mistake as litter, pollutants etc
- c.Many invasive plants were sold in Australia by the nursery industry before they were even considered to be weedy. Australia is a harsh environment and when we were settled just over 200 years ago people planted anything that they could get to grow

d.As an industry and as a gardening public we suffer from the challenge of having three levels of government regulating or being involved with weeds in Australia. There is also a range of other highly motivated stakeholders such as Landcare Groups, local environmental groups, lobby groups and all of these add to the challenges faced

e. List this as one of the biggest challenges there are? Create many lists of plants? Some declared or legislated but many that are not. Federal lists, quarantine lists, local lists, state lists (Australia has eight (8) states and territories), Alert lists and many others. As an industry it is difficult to keep up with all of these lists and know which ones we should be taking notice of.

f. The challenge for the Nursery & Garden Industry faces a fundamental conflict that between making money from growing and selling plants and reducing the number of invasive plants. Gardening consumers are looking for plants that are easy to grow and keep alive. The desirable characteristics of good plants are also the ones that give them their invasive tendencies.

5. Results: This is a long term project on many different levels. Some outcomes are immediate and concrete outcomes are achieved. Many of the programs are longer term. It is reasonable to say that there has been a significant change in the attitude of industry to invasive plants and an overall reduction in the amount of invasive plants grown and sold.

6. Conclusions: The nursery industry is doing some very positive and groundbreaking work to minimise the impact of invasive plants. It has been responsible for many of the invasive plants in Australia but not for all of them. For too long we have been blamed for all of the invasive plants and this is not right. Other issues we face in this area are the plethora of 'Weed lists'. What is a weed? The environment versus our industries livelihood and who pays? We are actively working with governments and other major stakeholders at a national, state and local level and it appears to be working. There is still much work left to do though.

Caveat: this presentation would not be based on specific scientific research that has been done but more a collection of works done by the Australian nursery industry in the area of invasive plants over a period of time. The format supplied for submission of the abstract is not ideally suited for a presentation like this. I have done my best.

222. Effects of Fire on Seed Germination Potential of *Mimosa invisa*. Emmanuel Aigbokhan¹, Kevin Ilobun¹; ¹University of Benin, Benin City, Edo State, Nigeria

The invasive weed *Mimosa invisa* (Mimosaceae) has become widespread in parts of southern Nigeria. Its vigorous rate of spread and success as an invasive plant may be attributable to its successful germination. A common practice among subsistent farmers whose farms are infested with *M. invisa* is to burn the weed at the beginning of the dry harmattan season. In this study, the effects of burning and light conditions were tested on the incidence of germination of *Mimosa invisa* seeds. Laboratory germination tests in ten replicates were conducted on Mimosa seeds harvested prior to and after burning treatment (designated as unburned and burned respective-

ly) with a sub-treatment effect light and dark was evaluated. Results indicate that seeds exposed to burning germinated more (27%) than unburned seeds (25.8%). Less seeds germinated in the presence of light (18.7%) than under dark conditions (21%). It was apparent that burning and absence of light enhanced *Mimosa invisa* seed germination and these conditions may accentuate higher levels on *M. invisa* infestations where they occur.

223. *Solanum eleagnifolium*, a Serious Threat for the Greek Agroecosystems. Eleni Kotoula-Syka¹; ¹Democritus University of Thrace, Thessaloniki, Greece

In Greece, especially in Thessaloniki and Chalkidiki counties (Northern Greece) almost all fields with arable and horticultural crops, such as cotton, tomatoes, peppers, eggplants, olive orchards, vineyards, pastures, rangeland as well as forest openings, waste places and roadsides have been infested by *Solanum eleagnifolium*. This troublesome weed is a perennial herb, with creeping roots and prickles on the stems. Foliage and berries contain variable amounts of several glycoalkaloids and can be toxic when ingested by livestock or people. Mature berries of this weed also contain high levels of solanine and solanosine, which are toxic to livestock. Large infestations can reduce harvest yields and the carrying capacities of pastures by competing with desirable plants of nutrients and soil moisture. *S. eleagnifolium* appears to have allelopathic properties especially in cotton fields. Plants develop colonies from extensive systems of creeping horizontal and deep vertical roots, both of which produce new shoots. Colonies of *S. eleagnifolium* are difficult to control or eliminate by mechanical methods neither by biological means because there are no currently registered biocontrol agents for use on this plant. On the other hand, few phloem-mobile herbicides such as glyphosate, dicamba, 2,4-D, and triclopyr that have been tested for this purpose, were quite effective against the weed. However, being non-selective to most irrigated summer-crops, limits their use in cultivated annual crops. The combination of this weed growth characteristics and the safe use of these herbicides should be considered when designing management practices.

224. The EWRS Invasive Plants Working Group. Christian Bohren¹; ¹Agroscope ACW in Changins, Nyon, Switzerland

We are a working group of the European Weed Research Society (EWRS) with presently 121 members of 29 countries. This working group focuses on invasive alien plant species and environmental weeds in Europe.

We aim at bringing together scientists from scattered invasive plants community as well as practitioners concerned and affected by those plants. It is one of our main objectives to promote discussion and joint experi-

mentation on possibilities to control invasive alien plant species and environmental weeds.

The EWRS Working Group Invasive Plants will develop an international and interdisciplinary platform dedicated to monitor, study, warn and advise on the management of invasive plant species in Europe. This mission will be achieved through the integration of existing and/or execution of especially designed research taking into account agronomic, environmental, health and economic aspects of plant invasion.

Main Topics of the Working group are:

Identifying key research and control technology needs and encouraging their execution, including collaborative programmes;

Organizing meetings, symposia and conferences, and including the topic in existing meetings;

Supporting communication and information exchange between agricultural and environmental researchers, between scientists and professionals, between individuals and organizations, between national and international organizations;

Encouraging and assisting education and training on invasive plants (control, horticultural and environmental aspects) for institutions, students, professionals (interdisciplinary) and general public.

There is no formal membership of this working group, rather it is an informal grouping of people interested in invasive plants and environmental weeds? these constitute the members. Everyone is welcome to contribute to practical concerted research and to attend the working group meetings and other conferences. Apart from the web site (<http://www.ewrs.org/IW/membership.asp>), communication to the membership between meetings is via e-mail. This has been largely used to solicit opinion on the direction of the group, where and when meetings should be held, and to give advance details of meetings.

You do not have to be a member of the EWRS to participate in the working group, although EWRS members receive discounts to attend the working group meetings and in the past, post-graduate members have been able to apply for travel subsidies to these meetings. When you join the WG, you will eventually be encouraged to become a member of the EWRS. If you would like to join the Working Group please contact the coordinator Mr. Christian Bohren, e-mail: christian.Bohren@acw.admin.ch

225. *Cyperus Esculentus* (Yellow Nutsedge) a New Invasive Weed to Irrigated Crops in Israel. Tuvia Yaacoby¹; ¹Ministry of Agriculture and Rural Development, Bet - Dagan, Israel

Invasive alien species (IAS) are considered among the most dangerous threats to biodiversity of native species as well as a major task for their control. International Ag-products trade and tourism increase the spread of invasive

species, allowing them to overcome natural geographic barriers. The lack of effective regulatory rules on grain's import for food industry or animal feed leads to enormous burden on crop management, as well as on other human enterprises and health. *Cyperus esculentus* (yellow nutsedge), is one of the most aggressive perennial noxious weed throughout the world. *C. esculentus* was recently found in the northern Negev, a semi arid part of the country, and a major vegetables growing area. The introduction of *C. esculentus* to Israel occurred several years ago, probably via import of grains for oil production or for animal feed from USA. The most troublesome weed in summer crops of Israel is purple nutsedge (*C. rotundus*) a native to the Mediterranean, Irano-Turanian and Tropical region, that under the local conditions propagates vegetatively only. The ability to re-propagate by underground tubers only, limits its dissemination without the use of agro-machinery equipments. Unlike purple nutsedge, yellow nutsedge found in Israel produces tubers and seeds, allows this invader to spread very fast from infested area to its neighbor fields. The intensive farming methods in these farms, along with the limited number of selective herbicides in such crops resulted in a very high infestation that eliminated certain cash crops from the area. Hence, yellow nutsedge infestation caused a shift from late winter to early spring crops such as cabbage, onion, fennel and radish to arable crops such maize, wheat or watermelons where the weed could be controlled. In order to allow farmers to use the land for high-income crops, the Plant Protection and Inspection Services (PPIS), Ministry of Agriculture, initiated an eradication program by encouraging farmers to control the weed in these arable crops for 3 to 5 years. The farmers will be compensated for the income losses and to cover for the more effective chemicals. The program is planned to reach continuous and efficient control of *C. esculentus* and to prevent its establishment in other fields.

226. *Heracleum sosnowskyi* Manden - the Invasive Alien Species in Poland. Krystyna Miklaszewska¹; ¹Institute of Plant Protection, Poznań, Wielkopolskie, Poland

Heracleum sosnowskyi was introduced to Poland as a cultivated plant in the year 1958. It was promoted as a cultivated fodder and a nectar plant.

This project was abandoned in a very short time (the flavour of meat and milk from the animals to which it was fed were affected).

From that time on the *Heracleum sosnowskyi* is out of human control and has spread across unmanaged land areas and near ditches. It is a very expansive species which invaded weedy places, road margins and natural plant communities as well.

Heracleum sosnowskyi is causing to a reduction in local plant biodiversity. It is also very dangerous for humans and causes skin and mucous membrane burns, particularly

dangerous for children. The plant exudes a clear watery sap, which contains several photosensitizing furanocoumarins. In contact with human skin and with combination with ultraviolet radiation, these compounds cause burnings of the skin. The phototoxic reaction can be activated by ultraviolet radiation 15 minutes after contact. Several furanocoumarins have also been reported to be carcinogenic.

Heracleum sosnowskyi Manden. for the first time was described by Mandenova in 1944.

They grow up to 4-5 m tall. Stems are usually 5-10 cm in diameter and are often purple spotted or continuously purple. Leaves of mature plants are divided to a varying extent into three approximately equal parts. Leaves can grow up 3 m in length. More than 80,000 flowers can occur on a single plant. In central Europe plants flower from June to end of July and seeds are released from late August to October. One plant bear about 20,000 seeds, but individual plants with over 100,000 seeds have been reported. The reproductive potential of the plant is enormous.

Several main modes of seed dispersal are known. Some are human assisted and some are natural.

Heracleum sosnowskyi can reach high densities in abandoned grasslands and ruderal habitats, leading to a strong decline in the species richness of these habitats.

To prevent high *H.sosnowskyi* infestation, the combination of control methods (mechanical and chemical) can be more efficient that using a single method.

227. Management Concerns Regarding Old World Climbing Fern (*Lygodium microphyllum*). Jeffrey Hutchinson¹, Kenneth Langeland¹; ¹University of Florida, Gainesville, Florida, United States of America

Old World climbing fern (OWCF; *Lygodium microphyllum* {Cav.} R. Br.) has been documented in Florida for < 50 years, but is considered one of the most highly invasive plants in natural areas. OWCF has spread rapidly across the south Florida landscape due to wind-blown spores invading mesic and hydric wetlands, including the Florida Everglades. Current coverage of the fern is > 48,000 ha and the fern is spreading north into central Florida. Control of OWCF is expensive and labor intensive as the fern often occurs in isolated areas only accessible by helicopter. Management of the fern is difficult and control of OWCF can only be obtained with frequent monitoring and repeated herbicide treatment. We found that translocation of glyphosate, metsulfuron methyl, and triclopyr in OWCF is limited with no translocation horizontally along rhizomes, explaining why managers often report re-growth several months following herbicide treatment of OWCF. Based on greenhouse studies, we found that OWCF can produce > 800 rachis sprouts from a single plant and > 4400 new sporophytes per m². Growth rates from re-sprouts on

rhizomes and new sporophytes can be 3.8 and 1.9 m / year, respectively, under greenhouse conditions. The development of fertile leaflets begins at 3-4 months and spores can remain viable for at least seven years. Germination rates of OWCF can be as high as 96%. For effective management of OWCF, complete coverage with herbicide of all rachis sprouts and pinnae must be obtained. Due to the overlapping, indeterminate growth pattern of OWCF, complete control of large infestations of OWCF with one herbicide application is nearly impossible. Long-term monitoring and follow-up herbicide applications will be required in established populations of OWCF due limited herbicide translocation, re-sprouts from rhizomes, quick development of fertile leaflets, excessive spore production, high spore germination rates, high densities of new sporophytes, fast growth rates, and long spore viability.

228. Control of *Lantana camara* in Grazed Pastures. Jason Ferrell¹, Greg MacDonald¹, Brent Sellers¹; ¹University of Florida, Gainesville, FL, United States of America

Lantana camara is a common weed in central Florida cattle pastures. Current literature on control of *Lantana camara* is contradictory or provides insufficient information to develop an effective control strategy. Therefore, an experiment was initiated in October 2006 to develop an effective control program for *Lantana camara* in warm season pasture production. Experiments were designed to address the impact of herbicide and application timing. Herbicide treatments included aminopyralid (0.1 kg/ha), fluroxypyr (0.5 kg/ha), aminopyralid & fluroxypyr (0.1 & 0.5 kg/ha). These herbicide treatments were applied either once (10/18/06) or twice (10/18/06 and 5/14/07) to determine the influence of repeat applications on *Lantana camara* control. These herbicides were applied broadcast at 280 l/ha to plants that were well established, approximately 130 cm in height, and actively blooming. Previous research conducted in Florida has shown that triclopyr-ester is ineffective on *Lantana camara* and was excluded from this study. Herbicides applied one time in October, regardless of treatment, did not exceed 20% control 1 year after application. *Lantana camara* in plots receiving fluroxypyr were completely defoliated within 1 month of application, but resprouting was common in all plots within 6 months of the application. Conversely, sequential applications of fluroxypyr and aminopyralid & fluroxypyr resulted in 80 and 95% control, respectively, at 6 months after the sequential application. Aminopyralid alone did not provide greater than 10% control with either single or sequential applications.

Another experiment was conducted to determine if basal treatments (herbicides applied in an oil carrier directed to the stem base) would be an effective individual plant treatment. Triclopyr-ester (Remedy Ultra 20% v/v), triclopyr-ester & fluroxypyr (Pasturegard 50% v/v), triclopyr-ester + aminopyralid (Remedy Ultra 20% +

Milestone 1% v/v), and imazapyr (Chopper 3% v/v) were applied. Triclopyr-ester alone was found to provide poor and inconsistent control. In general, triclopyr-ester provided approximately 50% control when applied as a basal treatment. Conversely, all other herbicides provide between 93 and 100% control at 6 months after treatment.

These data indicate that at least two broadcast applications are required to control *Lantana camara*. Additionally, fluroxypyr provides a significant level of *Lantana camara* control alone, but the addition of aminopyralid with fluroxypyr improves control. Additionally, fluroxypyr and aminopyralid are safe on a wide variety of pasture grasses. For individual plant basal treatments, triclopyr-ester is ineffective. However, fluroxypyr or imazapyr containing products have been shown to provide significant *Lantana camara* control.

229. Chemical, Mechanical and Combined Control of Common Ragweed. Christian Bohren¹, Georges Mermillod², Nicolas Delabays²; ¹Agroscope ACW, Nyon, VD, Switzerland; ²Agroscope ACW in Changins, Nyon, VD, Switzerland

Ambrosia artemisiifolia L. (Ambrosia, common ragweed) is a summer annual herbaceous plant that is native to temperate North America. It multiplies through seed grains only. It is considered an invasive species in Europe. Its harmful pollen causes human health problems such as allergies and asthma. Control methods, which include the prevention of seed production and the reduction of pollen production, must be developed. The ruderal character of Ambrosia, its high multiplication rate comparable with the rate of *Chenopodium album* L. and the ability to develop side branches after insufficient control are some important factors making Ambrosia control challenging.

Two different approaches to successful control are considered: control methods in agriculture, and disrupting life cycle of plants growing in ruderal areas; both with the aim to slow down Ambrosia-distribution. Herbicide efficacy was tested in field trials in several years. The herbicides were applied in normal dose at application time for the crop according to the label. The efficacy of some active substances was clearly influenced by the plant stage during application. The viability of seeds was tested in these trials. Control measures generally reduced seed viability. A clear reduction of viability was observed after the application of the herbicide florasulam.

Combined field trials including a cut and a herbicide treatment were conducted during two years. With regard to Ambrosia control along roadsides, railway tracks or in fragile habitats like nature reserves or along water lines, the influence on viability of grains of one herbicide treatment often in combination with a cut was investigated. A combination of early cut and late florasulam application resulted in a good reduction of viability. Other herbicides may have a comparable effect on viability; we

continue our trial series and hope other institutes will adopt this approach for Ambrosia control.

A successful control includes in minimum the prevention of viable seed production. This is necessary to restrict the Ambrosia distribution in Europe and to improve finally the quality of human health in already infested areas. We advocate strongly a European approach in a well-structured interdisciplinary programme for future successful Ambrosia control.

230. The Problem with Grubby Footwear at International Borders: a New Zealand Case Study of Golfers. Tracy Payne¹, Toni White¹, Mark McNeill¹; ¹AgResearch Ltd, Hamilton, Waikato, New Zealand

Due to New Zealand's geographical isolation, the country is free from many of the pests, weeds and diseases that are problematic in agricultural, horticultural, silvicultural and natural environments elsewhere in the world. To help protect the country from incursions by new pest, weed and diseases, biosecurity officers check and, if necessary, clean travellers footwear as they enter the country. Footwear worn outdoors in unpaved areas can collect and carry contaminants such as soil and leaf matter. If contaminated footwear is not detected at the border, it can pose a significant biosecurity risk by providing an entry pathway for unwanted pests and diseases associated with soil and leaf matter. Research elsewhere has identified a diversity of hazards on a range of footwear types including spiked or sprigged footwear, such as that used by golfers. This research examined the experiences of golfers returning to New Zealand after playing golf overseas both in terms of their risk awareness and of their biosecurity experiences at the New Zealand border. A face-to-face questionnaire was used to ask Golfers about their experiences. Preliminary findings suggest that golfers awareness of the biosecurity risks from dirty footwear is relatively low and this may influence their response to biosecurity issues when travelling. This work was funded by New Zealand's Foundation for Research, Science & Technology through contract CO2X0501, the Better Border Biosecurity (B3) programme (www.b3nz.org).

231. Quantifying Non-Indigenous Plant Impacts in Natural Areas to Aid with Management Prioritization. Tanya Skurski¹, Bruce Maxwell¹, Lisa Rew¹; ¹Montana State University, Bozeman, Montana, United States of America

While significant progress has been made in generalizing the patterns of spread of non-indigenous plant species (NIS), less attention has been given to quantifying impacts of NIS. It is common for NIS abundance to be equated to impact. Impacts, however, are a function, of their biological attributes, site-specific environmental conditions, and the composition of the extant plant community,

not merely NIS presence. Presuming that all NIS affect the same degree of impact and that these impacts will be consistent across a varied landscape may result in inappropriate weed management approaches. The goal of this research was to assess NIS impacts at multiple scales using a variety of response variables and ultimately use modeling to predict where NIS were having the greatest impact. The final goal was to relate this information to management optimization. We conducted in-situ experiments on two NIS of concern in western USA: *Centaurea stoebe* and *Bromus tectorum*. Plots were established at three sites representing a range of communities and disturbance histories typical of southwestern Montana. Three treatments were randomly applied to ¼ m² plots: (1) manual removal of *C. stoebe* or *B. tectorum*, (2) ground disturbance to mimic disturbance created in NIS removal plots, and (3) control. Each treatment was crossed factorially with plot position (inside, outside, and on the edge of NIS patches). Each treatment-position combination was replicated three times at each site. Impacts were measured as changes in plant species richness, diversity, and biomass over time. Analysis of baseline data shows that, within sites, mean species richness did not differ significantly among inside, edge, or outside plots. However, there was greater species evenness (diversity) in the outside and edge plots compared with the interior plots. After taking target-NIS abundance out of the analysis, we found a higher ratio of exotic to native species in plots inside NIS patches than on the edge or outside. This suggests plot location in relation to a weed population is a determinant of species composition, and therefore may be a factor in the degree of NIS impact. We found a negative relationship between species richness and *B. tectorum* density ($p < 0.001$). Finally, analysis of temporal variability in species richness and abundance suggests that relatively minor responses to treatments are detectable at multiple scales.

232. Fruit Description, Seed Germination, and Soil Seed Bank Characterization for Beach Vitex (*Vitex rotundifolia*): An Invasive Coastal Plant. Jeanne Briggs¹, Ted Whitwell¹, Matthew Cousins¹; ¹Clemson University, Clemson, SC, United States of America

Vitex rotundifolia (beach vitex) is native to the Pacific Rim where it is a dominant species on coastal sand dunes. It was introduced to the Southeastern United States in the mid-1980s and has become invasive on primary and secondary sand dune systems. Its extensive and rampant growth competes with, and eventually excludes, native grass and broadleaf species and also creates nesting and hatchling problems for endangered sea turtles. The non-fibrous root system does not trap sand effectively allowing beach erosion. Beach vitex primarily spreads through the production of long running stems that readily root at nodes. Many resources have been dedicated to the removal

of this plant. As a companion to these removal efforts, it has become important that the fruits, seed germination characteristics, and seed banks of this plant be characterized to understand the potential ability of beach vitex to recover in areas where it has been removed. Fruit characterization studies found that drupes were approximately 50 mg in weight, 6.5 mm in diameter and averaged 1.29-1.54 seeds per drupe in collection lots from 2003 through 2005. On average, 75-80% of drupes contained viable seeds from all sampling years. Germination studies indicated that seeds germinated best when subjected to stratification at 10 °C for 8 weeks. Dormancy mechanisms appear to be a combination of physical barriers and inhibiting compounds. This indicates that the majority of seeds should meet the requirements for satisfaction of dormancy in the dunes. A substantial soil seed bank was found to exist at vegetated and non-vegetated sites which were sampled over consecutive years. Viable seeds were present in appreciable numbers even two seasons after vegetation removal.

233. Presentation of *Ambrosia artemisiifolia*. Christian Bohren¹; ¹Agroscope ACW in Changins, Nyon, VD, Switzerland

Name: *Ambrosia artemisiifolia* Linnaeus

Synonyms: *A. elatior* Linnaeus, *A. elata* Salisbury, *A. panicolata* Michaux

Taxonomic position: Angiosperms, Asteraceae

Bayer computer code: AMBEL

Hosts: *A. artemisiifolia* can infest practically all field crops, meadows, pastures, orchards and vineyards, and also rangeland. However, it is commonest along waterways, roads, railways and in wasteland. It intrudes in its region of origin (Northern America) almost everywhere in disturbed soils.

Biology: *A. artemisiifolia* is an annual weed, reproducing by seeds. One plant may develop 3,000-30,000 seeds. Seeds remain viable in soil up to 40 years. On heavily infested plots, the population density can reach >1,000 plants per m². Seeds germinate in all types of disturbed soil, but best in warm and well aerated soil. Ambrosia is a wind-pollinating member of the Asteraceae family.

Morphology: Ambrosia is 5-180 cm tall. The stem is densely hairy, upright, angular and well branched. It superficially resembles the common European weed *Artemisia vulgaris*. The leaves are short stalked, hairy, twice pinnatifid, giving the plant an open, feathery appearance. Upper leaves may be not partitioned. Leaves grow in opposite directions in younger stages of the plant life, whereas leaves in older stages grow in alternate directions. The root is vertical, reaching to a depth of 4 m. The inflorescence is compound, with male and female capitula separate. The yellow 5-25-flowered male capitula are borne in conspicuous long spikes at the tips of the shoots. The female capitula are 1-flowered, borne in

inconspicuous clusters of 2-3 in the axils of the leaves or of the male inflorescence. The fruit is formed of a single seed remaining within the receptacle of the capitulum; it is obovate, 2-5 mm, with 1 large spine at the tip and 5 small spines around it.

Menace to human health: *A. artemisiifolia* is an introduced exotic pest for Europe. It is a serious weed mainly because of its menace to human health and prolific seed production. In many parts of western Europe Ambrosia is introduced into urban areas mainly by bird seed grain. Once established seeds will be transported by building and excavation material. Its pollen is distributed often in densely populated areas, causing primarily hay fever and asthma. Ambrosia is controlled by many herbicides in agriculture, but once established in an area, this weed can build up large populations on wasteland, and along roadways and waterways. The ruderal character of Ambrosia, its high multiplication rate, various restrictions for herbicide use, and the ability to regenerate after insufficient control are some factors making control of this pest challenging.

234. Reproductive Ecology of Invasive Weed - *Euphorbia geniculata* Ortega. Mohd Araf¹, Irshad Hamal¹; ¹Department, University of Jammu, India, Jammu, Kashmir, India

Euphorbia geniculata an invasive weed of tropical and subtropical regions produces four generations per year thus leading to higher regeneration which poses major threat to the local flora. The understanding of reproductive strategy of weeds is crucial for management and control technique which is lacking in case of *E. geniculata*.

In India, the species occurs along the disturbed sites, waste lands as well as a weed of cotton, maize and some other crops. The species is an annual herb which reaches a height upto 156 cm. The seeds germination commences during June and flowering extends upto November however seeds are dispersed from September onwards. The species is characterized by cyathium, an inflorescence of many reduced male flowers and single female flower enclosed by a hypanthium like involucre which is provided with glands. The cyathia are aggregated terminally in umbel like structures. Plant is andromonoecious and male cyathia blooms earlier so pollen is available prior to female phase in the hermaphrodite cyathia, the later being protogynous. The species is self compatible and ants (*Camponotus compressus*) are the only reliable pollinators contributing to the reproductive success. Seeds are the progenitors of next generation and for successful establishment plants have adopted various means of dispersal. Members of the family Euphorbiaceae have adapted to a variety of dispersal modes but autochory by explosion of ballistic fruits is prevalent at the genus level. The ballistic dispersal of seeds helps in maximizing primary dispersal as seeds are ecarunculate, less attractive to ants, thus this mode of dispersal is advanta-

geous for invasive weed at least to extend its patch size in the absence of specialized adaptations for other modes of dispersal. Seeds are dispersed explosively upto a distance of 6 m. Seeds are primarily not dormant and able to germinate immediately after release.

In conclusion, *Euphorbia geniculata* is a functionally andromonoecious taxa with added advantage of entomophilous pollination and explosive dispersal, high seed viability as well as germination provides adaptability for successful invasion and establishment to the species as a weed.

235. The Success Story of the Hluhluwe – iMfolozi Park’s Invasive Alien Species Programme: a Role Model on which KwaZulu-Natal’s Protected Areas Invasive Alien Species Clearing is being Based. Colette Terblanche¹, Krissie Clark¹, Wayne Lotter²; ¹Ezemvelo KZN Wildlife, Pietermaritzburg, KwaZulu-Natal, South Africa; ²Game Rangers Association of Africa, Songea, Ruvuma, Tanzania

The Hluhluwe-iMfolozi Park (HiP) is the oldest proclaimed game park in South Africa, and has been instrumental in saving the white rhino (*Ceratotherium simum*) from extinction. Over the years HiP has become invaded with invasive alien plants. By 2003 more than 70% of the park was seriously infested, posing the greatest threat to the biodiversity of the park. Control programmes have been ongoing since the first invasions, yet the funding and programmes to curb the spread have always been inadequate to stop invasion. In 2003 a large scale clearing operation was established, with poverty relief funds aimed at using labour intensive methods. Dangerous game, difficult terrain, the size of the operation, and prioritization of clearing made this programme a difficult undertaking. Five years later HiP has become a success story. This has been due to adequate funding which has been sufficient to allow the rate of control to exceed the rate of spread, a clearly defined prioritization schedule, regular mapping surveys, an emerging weeds plan, ongoing safety and clearing standards training for the more than 500 workers in-field at any time, and support from all levels of management. Currently the infestation reduction is estimated at over 90% and close to 50% of the park is under maintenance. Once the spread of invasive alien plants had been curbed inside the park, the next step was to engage with the neighbouring landowners and communities to ensure re-infestation into HiP was minimized. This was done through engaging with the local district municipalities who are mandated to control invasive species infestations inside the district. A forum was established inviting all role players responsible for clearing invasive alien plants within the municipal boundaries. All existing clearing programmes were then mapped. The aim is now to find common areas of priority and then for programmes to synergize efforts to source additional funding and place focus on these areas in order to create a larger area which

is under control of invasive alien plant spread. The forum is also focusing on sharing expertise (best practices, mapping and implementation) and ensuring that the public is informed regarding the clearing initiative and ensuring ongoing education. Developing a clearing plan for an area with many different government departments, individual landowners, communities as well as industries is a first in South Africa. The approach taken with the HiP Invasive Alien Species Programme is serving as the leading example for managing to curb the spread inside the park, as well as the efforts to control infestation along the boundaries. Clearing programmes in all Protected Areas across the KwaZulu-Natal province are now being based on similar systems.

236. Clonal Spread of Invasive *Ludwigia* Species in Freshwater Wetlands of California. Miki Okada¹, Brenda Grewell¹, Marie Jasieniuk¹; ¹University of California, Davis, Davis, CA, United States of America

Determining the reproductive mode contributing to dispersal within and between populations of invasive species is essential to understand the ecological and evolutionary processes underlying invasions and to guide management strategies. *Ludwigia hexapetala* and *L. grandiflora* are emergent aquatic species that have recently and aggressively invaded freshwater wetlands of California. We assessed the relative role of sexual versus asexual reproduction in 27 populations of *L. hexapetala* from two watersheds, and five populations of *L. grandiflora* from another watershed, of California using AFLP markers. We also analyzed an invasive population from the state of Washington that originated as an ornamental release in 1956, for comparison. Of the total 794 *L. hexapetala* ramets analyzed from California, 95% represented a single genet. Only this genet was detected in 20 populations whereas two genets were detected in five populations, three in one population, and nine in the remaining population analyzed. The single genet detected in the population from Washington was identical to the predominant genet identified in California. Of the total 150 *L. grandiflora* ramets analyzed, only one genet was detected in the five populations sampled from the San Diego River basin. Based on the lack of genotypic variation observed in the majority of populations studied of the two species, our results strongly suggest that invasive spread, both within and between populations, and between watersheds, is almost exclusively asexual and clonal. The results indicate that management of the spread of invasive *L. hexapetala* and *L. grandiflora* should focus on reducing vegetative growth and dispersal of vegetative fragments. The genotypic uniformity of invasive populations also suggests that biological control of invasive *L. hexapetala* and *L. grandiflora* could be successful.

237. Endemic Plants Became Local Weeds in Cuba. Pável Rodríguez Vázquez¹; ¹Jardín Botánico de Cienfuegos, Granja Agropecuaria Pepito Tey, Cienfuegos, Cuba

In order to prevent and identify potential danger, it is important to determine potential new weeds in our island. We achieve this analysis of some wild endemic dominant plants, normally not considered as 'weeds'. We searched the botanical literature for 'dominants' on Vegetal Classes and

Orders, looked for wild endemic species that became dominants; and compared them with species reported as agricultural weeds. For the species obtained we applied habitat analysis, and spinescence, distribution, taxonomy of genera, growth habits, foliar size, and texture. Besides, we exchanged information on invasive plants with some field specialists. As a result, some endemic plants became invasive, and dominants on vegetation: *Polygala omissa*, herb, dominant on 1984 distribution Center-Occidental, wet lands, flooded.

The pancuban tree, *Thespesia cubensis*, dominant on 2002. We consider also the *Pinus cubensis* and *P. aestrensis*, dominants and potential weeds.

Cuban endemic plants are more than 3500, most of them herbs. The Red List has 1500, so we could analyze if the rest (2000 species) could be potential weeds. On Orders and Alliances, are 105 spp, 27 Classes and 54 Orders. On weeds lists only 44 endemics, 11% of all weeds. They have to be taken into account for an early prevention. The habitats changes, land management, erosion, fragmentation, heating, fires, and other factors could cause expansion of endemic flora, even more when it is characterized as being xerophytic, drought tolerant, and from poor soils.

238. Ragweed (*Ambrosia artemisiifolia*) - the Greatest Weed Problem in Europe. Tamas Komives¹, Peter Reisinger², Eva Lehoczy³; ¹Plant Protection Institute, Budapest, Hungary; ²University of West Hungary, Mosonmagyaróvár, Hungary; ³Pannon University, Keszthely, Hungary

The main cause of allergy and pollen asthma in North America and Central Europe is pollen from ragweed (*Ambrosia*) a widespread genus in the Asteraceae. In Europe short or common ragweed (*Ambrosia artemisiifolia*, L.) is prevalent with highest weed densities in the Carpathian basin: Croatia, Hungary, and Serbia. Despite continuous efforts by the Hungarian government during the last ten years to eradicate ragweed, levels of its pollen in the air did not diminish. Ragweed infestation is heaviest in sunflower (*Helianthus annuus* L., the third most important crop in Hungary) fields, producing the overwhelming majority of allergenic pollen in the air (in the end of the summer pollen counts reach 1000 grains m⁻³) even in urban areas. In the presentation we show the

current situation in Hungary, the most recent measures, and the strategic program we developed for controlling ragweed and suppressing its pollen production.

239. **Invasive Plant Management in British Columbia.**

Becky Brown¹, David Ralph, Linda Wilson; ¹Government of British Columbia, Victoria, British Columbia, Canada

Rationale/Justification.

Invasive plant management in British Columbia (BC) is a complex, multi-jurisdictional issue involving stakeholders at all levels. High socio-economic and environmental impacts to the province require a long-term, cost-effective, coordinated invasive plant management system that deals effectively with governance, funding, early detection and rapid response, inventory and treatment. Ninety-four percent of the land base in BC is public, placing significant responsibility on the provincial government to fulfill the primary invasive plant management mandates of the province.

Objectives.

Provincial invasive plant program objectives include: 1) Preventing introduction of new, potentially invasive species; 2) Applying an early detection and rapid response approach to address new species; 3) Reducing spread to new areas within BC; 4) Facilitating identification and analysis of impacts; 5) Addressing established infestations through integrated, cost-effective management; 6) Strengthening research, education, training, and legislative capacity for sustainable management; 7) Encouraging development of strategic and working-level management plans between stakeholders at all levels; and, 8) Strengthening cross-agency relationships for ongoing management.

Methods.

The BC Ministry of Agriculture and Lands Invasive Plant Management Program coordinates provincial government management activities and funding through the Inter-Ministry Invasive Plant Working Group and the Invasive Plant Council of BC. The provincial program supports establishment and operation of regional invasive plant management programs by providing annual grants and strategic technical advice.

The BC Weed Control Act places duty on all land occupiers (public and private) to control listed noxious weeds. Provincial program staff provide technical, diagnostic and legislative expertise; public education; project coordination; and, facilitation and mediation services to all levels of government, First Nations, industries, utilities and non-government organizations.

BC is ecologically and jurisdictionally diverse, requiring regionally specific management to coordinate numerous interests. A Canadian leader in invasive plant management, BC boasts a complex network of experienced specialists working to increase public awareness, prevent new introductions, contain infestations, develop innova-

tive management strategies, and improve overall management throughout the province.

Results/Conclusion.

BC spends six million dollars on invasive plant management annually. BC's industry, provincial, federal and continental partnerships are enabled through a complex network of coordinating bodies supported by the BC Inter-Ministry Invasive Plant Working Group and the Invasive Plant Council of BC. Initiatives such as the regional invasive plant committees, Invasive Alien Plant Program database and mapping application; early detection and rapid response framework; economic analysis; and, risk assessment model collectively form a comprehensive, strategic and effective provincial program.

240. **Vineyard Weed Management Practices Influence Soil Microbial Communities and Nitrogen Retention.**

Kerri Steenwerth¹, Kelley Belina¹; ¹USDA Agricultural Research Service, Davis, CA, United States of America

Cultivation can affect soil characteristics that are important for soil nitrogen (N) dynamics (e.g., soil organic matter content, labile carbon pools, bulk density). Thus, we hypothesized that soil N dynamics and efflux of nitrous oxide (N₂O), a greenhouse gas, would differ between weed management practices that used either chemical control or cultivation. We tested the effects of two weed management practices (i.e., cultivation and herbicide) on soil N dynamics and microbial communities during a fertigation event.

The experiment was conducted at a Chardonnay vineyard (clone 5) planted on Teleki 5C rootstock in Greenfield, Monterey Co., CA. In the cultivated treatment ('Cultivation'), the Clemens® vineyard cultivator was used to mechanically till the vineyard rows as needed during the season (i.e. 4-6x). In the herbicide treatment ('Herbicide'), simazine (2.0 lbs a.i./A) + oxyfluorfen (1.5 lbs a.i./A) was applied in the winter. In summer, post emergence applications of 2% glyphosate + 0.25% oxyfluorfen were applied as needed. These treatments had been established and repeated annually four years prior to the current study. Thus, the current study occurred during the treatments' fifth year. The soil type was Elder loam with gravelly substratum (Coarse-loamy, mixed, superactive, thermic Cumulic Haploxeroll). Soil texture among all depths and treatments was approximately 60% sand, 25% silt, and 15% clay. Soil characteristics (i.e., cation exchange capacity, soil pH, exchangeable cations, bulk density, total N) varied with depth, but few differences occurred between the 'Cultivation' and 'Herbicide' treatments. During fertigation (32kg N ha⁻¹: UN32 is 32% N, composed of 44.3% NH₄NO₃ and 35.3% urea), nitrous oxide (N₂O-N) efflux was greater in 'Herbicide' than 'Cultivation'. At its greatest efflux rate, which occurred one day after fertigation, N₂O efflux from 'Herbicide' was approximately 4.3 µg N₂O-N m⁻² s⁻¹ while it was about 2

$\mu\text{g N}_2\text{O-N m}^{-2} \text{ s}^{-1}$ in 'Cultivation'. Nitrous oxide efflux decreased thereafter, reaching pre-irrigation values ten days after fertigation in both treatments. When anionic resin bags that had been installed at 1m depth in November 2005 were removed one year later, soil nitrate concentrations under the emitters were 1300-fold greater in the 'Herbicide' than 'Cultivation'. This, in combination with the reduced $\text{N}_2\text{O-N}$ efflux, suggests that 'Cultivation' had increased soil N retention than 'Herbicide'. Preliminary estimates suggest that approximately 4-10% of the total N added to the vineyard soil during the growing season was captured by the resin in 'Herbicide'. These preliminary findings suggest that weed management practices had impacts on N_2O efflux as well as soil N retention. Microbial community composition also differed between weed management practices and shifted in response to the fertigation event in both weed management treatments.

241. Molecular Basis for Metabolic Responses of Nitrogen-fixing Cyanobacteria to Monosulfuron. Jianying Shen¹, Antonio DiTommaso², Jun Wu¹, Guoping Wu¹; ¹Shanghai Jiaotong University, Shanghai, China (Peoples Republic of); ²Cornell University, Ithaca, New York, United States of America

Nitrogen-fixing cyanobacteria are common and important bacteria because they enhance the soil's fertility by converting atmospheric nitrogen to nutrient nitrogen. However, they are very sensitive to herbicides. Many common beneficial algae are now absent from the countryside due to overuses of herbicides. Sulfonylureas are popular herbicides often used in crop and non-crop systems. Molecular analyses were performed to characterize the ALS gene produced by three non-target nitrogen-fixing cyanobacteria (*Anabaena flos-aquae* Breb., *Anabaena azollae* Strasb, and *Anabaena azotica* Ley) when they were exposed to monosulfuron, a new sulfonylurea herbicide. Under the laboratory test conditions of exposure for 6 days, the growth and protein synthesis of 3 algae were stimulated when monosulfuron was present at a low concentration of 0.03-0.3 nmol/L. Monosulfuron exhibited had an inhibitory effect when it was present at a higher concentration of 30-300 nmol/L; the amino acid production in cells was clearly inhibited by monosulfuron except *A. azotica* at 0.003-0.3 nmol/L. Application of monosulfuron at 3-300 nmol/L substantially inhibited in vitro ALS (Acetolactate Synthase) activity; the inhibition index I50 for *A. flos-aquae*, *A. azollae*, and *A. azotica* was 3.3, 65.2, and 101.3 nmol/L, respectively. By contrast, the extractable ALS activity was not affected by monosulfuron at a higher concentration of 30-300 nmol/L except for *A. flos-aquae*. The most sensitive species to this herbicide was *A. flos-aquae*, followed by *A. azollae* and *A. azotica*. Molecular analyses showed that the ALS gene of *A. azollae* and *A. azotica* differed in only one amino acid

residue, e.g., substitution of a Ala63 in *A. azollae* by a Thr68 in *A. azotica*; the genomic DNA of *A. flos-aquae* differed with *A. azollae* and *A. azotica* in 44 and 45 amino acid residues, respectively. Such original findings support the view that the toxic effects of monosulfuron on the three nitrogen-fixing cyanobacteria were results of its interference with protein metabolism by inhibition of branch-chain amino acid biosynthesis and ALS activity and that the different metabolic responses of the cyanobacteria were due to different genomic DNA of ALS target sites.

242. Risk Analysis of Herbicide Water Contamination in the Field Conditions of a Flooded Rice Irrigation System. Luiz Foloni¹, Antonio Oliveira¹, Jose Filho¹, Pedro Christoffoleti¹; ¹University of Campinas, Campinas, Sao Paulo, Brazil

The cultivation of rice crop in Brazil using the flooding irrigation system may cause environmental impacts due to the use of agricultural products, including fertilizers, insecticides, herbicides and fungicides, that area diluted directly in the water flood. Therefore, it is essential that the impacts of these pesticides and fertilizers should be adequately evaluated, by using indicators that allow evaluate the activity in water, since the dispersion of these products may represent potential pollution. That may compromises the water quality, and causes damages to the ecosystems and human health, especially when used inadequately. This research was developed in the field conditions in order to investigate the herbicide clomazone (2-(2-chlorophenyl) metyl-4.4-dimethyl-3-isoxazolidinone) in the rice crop using an irrigation flooded rice system in constant flux. In this irrigation system the herbicide application may represent a high risk to the environment and to human health. In Brazil the need of monitoring the pesticides in the environment has been a constant worry, however the researches are very initial, mainly by difficulties of setting this kind of research at field conditions and high costs of the laboratorial analysis of pesticide residues. It was analyzed the herbicide dispersion in the water matrix. The herbicide clomazone presented a great movement in the water matrix. The herbicide presented low residual persistence in the water matrix, and no residue was recovered after 106 days of application.

243. Comparative Rates of Metabolism of Atrazine, Propazine, Ametryn and Metribuzin, In 19 Soils with Different Histories of Triazine Use.. Dale Shaner¹, Brien Henry¹, Michael Poteet², Curtis Rainbolt³, Brad Hanson¹, Jason Krutz¹; ¹USDA-ARS, Fort Collins, CO, United States of America; ²Hawaii Agriculture Research Center, Aiea, HI, United States of America; ³University of Florida, Belle Glade, FL, United States of America

Atrazine is a soil-applied herbicide that is used for controlling many broadleaf and certain grass weeds in corn, grain sorghum, sugarcane and orchards. Continuous use of atrazine can select for soil microorganisms that rapidly metabolize the herbicide. Research in Colorado and Mississippi showed that atrazine has a half life of three to seven days in fields with a history of atrazine use, which leads to a loss of weed control. However, there are other triazines besides atrazine that are used in these crops for weed control including simazine, propazine, ametryn and metribuzin. This research was conducted to determine if soils that contain microorganisms that can rapidly metabolize atrazine will also metabolize other triazine herbicides. A laboratory assay was conducted on 19 soils with different histories of triazine use from California, Colorado, Florida, Hawaii and Mississippi. The herbicides tested were atrazine, propazine, ametryn and metribuzin. Atrazine, propazine and ametryn are symmetrical triazines with alkyl substitutions at the 2 and 4 positions and a chlorine or methyl-thio substitution at the 6 position whereas metribuzin is an asymmetrical triazine. Soils were treated with approximately 1 mg of each herbicide per 1 kg of soil. The herbicides were extracted by water at 0, 1, 2, 4, 7, 14, 21, 28 and 35 days after treatment and analyzed by HPLC. The rates of degradation ranged from 0.8d to 13.9d, 1.4d to 18.9d, 0.6d to 17.8d, and 4.0d to 17.2 d for atrazine, propazine, ametryn and metribuzin, respectively. The half life of atrazine in these soils was highly correlated to the triazine use history: the longer the history of triazine use, the shorter the half life. The average half life of the herbicides across all soils was atrazine = ametryn < propazine << metribuzin. The rates of degradation of atrazine, propazine and ametryn were highly correlated ($P < 0.001$), whereas there was no correlation between metribuzin degradation and the rate of degradation of the other triazines. The results suggest that the soil microorganisms that have been selected through continuous use of atrazine (or simazine) can metabolize a range of symmetrical triazines with alkyl substitutions but not an asymmetrical triazine.

244. Effect of pH on the Dissipation Behaviour of Clodinafop Propargyl in Soil and Water. Hemanta Banerjee¹, M Paramasivam¹, D Banerjee¹, T Banerjee¹, S Roy¹; ¹Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, India

The oxyphenoxy acid ester herbicide Clodinafop-propargyl [prop-2-ynyl (R)-2-[4-(5-chloro-3-fluoropyridin-2-yl)oxy] phenoxy] propionate], is used as postemergence control of annual grasses in cereals @ 30-60 g/ha. This herbicide degrades in soil and water environment rapidly to acid metabolite in neutral and alkaline medium and has high mobility in soil which in turn may contaminate the ground water. Therefore, understanding the factors governing the dissipation behavior of Clodinafop-prop-

argyl is important to predict where this herbicide can be most beneficially employed. Thus, the present study aimed to examine the effect of pH (soil and water) on the rates of dissipation processes and the products formed under aerobic condition. Experiments were conducted in the laboratory with soil having (pH 4.85, 6.67 and 9.4) and water (pH 4.0, 7.0 and 9.2) samples. Two concentration levels (1 & 2 ppm) of analytical clodinafop-propargyl (supplied by M/S Cheminova India Ltd., Mumbai) were fortified and drawn periodically along with untreated control samples. The residue analysis method of clodinafop-propargyl ester in water and soil involves extraction with ethylacetate and redissolved in MeOH for HPLC analysis with UV/VIS detector (RP C-18 column) at λ_{max} 235 nm, using MeOH : water (9:1) as mobile phase. For acid residue analysis, extraction with ethylacetate, concentrated, dissolved in 0.1N KOH, reflux, neutralized, partitioned against ethylacetate and redissolved in MeOH for HPLC analysis. The pH dependent hydrolysis of the ester linkage to form acid metabolite was the primary transformation process. Degradation followed 1st order reaction kinetics and the DT50 values at pH 4.0, 7.0 and 9.2 were calculated as 4.61 days, 5.8 and 1.25 hour respectively, showing negative correlation with pH. Thus, it may be concluded that clodinafop-propargyl may be applied in acidic field condition to achieve the proper bio-efficacy. In alkaline and neutral medium, the acid metabolite may pose a threat to ground water contamination.

245. Assessment of the Contribution of Ricehull Burning to Weed Management in Vegetable Production and Soil Fertility. Clarita Aganon¹, Orlando Ramos²; ¹Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines; ²Local Government of San Jose City, San Jose City, Nueva Ecija, Philippines

Rationale and Justification for the Research

The Philippines has a 3.5 M ha of rice lands producing an average of three tons paddy ha⁻¹ crop with two crops per year. At an average milling recovery of 70%, the Philippines generates 14.7 M tons of ricehull per year considering an average of two croppings/year. Ricehulls used to be a menace to the environment ten years ago, however, with the increasing income from vegetable production particularly from onion, brassica and solanaceous increasing utilization of ricehulls occurred.

Ricehulls which are disposed indiscriminately along the roads and highways have been an in-demand commodity for the last ten years in vegetable production. The material are bought from rice millers by the farmers to be used in their vegetable production. Sad to say, the ricehulls are dumped into fields intended for either onion, pechay and eggplant production and are burned a month before intended planting. The Philippines, in its clean air act

prohibits burning because of its air polluting effect. However, farmers cannot be stopped in their practices.

We tried to document farmers' practices and replicate it under experimental conditions in order to provide scientific explanations related to environmental, economic and socio-economic implications of the current practice.

Objectives

1. Assess the effect of the rate of application of ricehulls and the subsequent burning to weed population;

2. Determine the contribution of burned ricehulls to soil fertility and production cost in vegetable farming

Methodology

Two separate studies were conducted to document and evaluate farmers practice of ricehull application and the subsequent burning in their farms.

The first study was conducted in 2004 where 15 farmers in San Leonardo Nueva Ecija, Philippines who are growing vegetables throughout the year were the respondents. A guide questionnaire was formulated consisting of questions on the number of years they are adopting the practice, rate of application, number of days from burning to land preparation, frequency of application (whether yearly or every other year), the source of material and the cost of ricehulls per hectare, the reasons for application and subsequent burning and awareness on Clean Air Act of the Philippines..

Based on the responses derived from the survey, a field experiment was conducted in the experiment station of the Central Luzon State University using in Randomized Complete Block Designs with treatments replicated four times. Rate of ricehulls and fertilizer application were combined in four treatments. Plots without ricehull burning but treated with fertilizers were provided for comparison. After harvest of pechay, the same area was utilized in January 2005, a week after the harvest of the first crop. For both croppings weed density, organic matter and exchangeable potassium was determined and analyzed.

Results

Vegetable farmers apply 30 to 45 cm thick of ricehulls in their vegetable farms either once a year or every other year depending on available fam capital. The cost per truckload is US\$ 10. It requires 100 truck loads per hectare to attain a 30 cm thickness of ricehull in the field. The ricehull is burned for about two weeks and then cooled for a month before land preparation. On a hectare basis farmers spend about US\$ 1000 every one to two years.

Weed density were significantly reduced with burning of ricehulls both during the first and second croppings. The reduction in the weed density improved with increasing rate of ricehulls application but not with fertilizer. On the first crop of pechay, burning of applied 74 t ha⁻¹ ricehulls reduced the weed density by 173% while that of burned 147 t ha⁻¹ ricehulls reduced the weed density by 650%. During the second crop, weed density was reduced by 108 and 733% on plots where 74 and 147 t ha⁻¹ of ricehulls respectively were applied and burned. Clearly, ricehulls the

weed control effect of ricehull burning in the vegetable area lasted until the second crop of pechay. In fact, there was no increase in weed density from the first to the second crop or within the three-month period which indicates that burning have killed significant amount of weed seeds, thus the low density. The observable weed density decreased the weeding cost compared to the control plot. The result also suggests the mulching effect of the burned ricehulls.

Conclusion

Burning of ricehulls not only resulted to decreased weed density resulting to decrease cost of herbicide expenses and labor cost in weeding in vegetable farming but likewise in improving soil fertility through increases in organic matter content of the soil and exchangeable potassium. It also serve as a form of soil sterilization. The practice therefore presents a trade-off between the clean air act issue and the use of pesticides.

246. Effect of Soil Texture and Temperature on Atrazine Degradation. Ebrahim Izadi¹, Ebrahim Izadi Darbandi¹, Mohammad Hassan Rashed Mohassel¹, Mehdi Nassiri Mohallati¹, Amir Lakzian¹, Karin Müller²; ¹Ferdowsi University, Mashhad, Khorassan Razavi, Iran; ²Ruakura Research Center, Hamilton, New Zealand

In order to study the effects of soil texture and temperature on atrazine degradation, a laboratory degradation experiment was carried out as a factorial arrangement. Experimental factors were two soil textures (Sandy loam, Silty clay), three temperatures (10, 20 and 30°C) and four incubation periods (0, 20, 40 and 60 days) in a completely randomized design with three replications. Results showed that soil texture and temperature had significant effects on the degradation rates of atrazine. Highest and lowest degradation rates occurred in the sandy loam soil (30°C) and the silty clay soil (10°C) with degradation rate coefficients of 0.0077 and 0.001, respectively. The half-life of atrazine in the silty clay was lower than that in the sandy loam. At 10, 20 and 30°C atrazine's half-life was 693, 364.5, 138.6 and 277.2, 157.5, 90 days in the sandy loam and the silty clay, respectively. It seems that atrazine persistence is lower in clay soils and temperate areas.

247. Bioassay of Imazethapyr Herbicide Residual Quantity in the Soil. Yuanju Huang¹; ¹Heilongjiang Academy of Agricultural Sciences, Harbin, Heilongjiang, China (Peoples Republic of)

Imazethapyr is a wide-spectrum herbicide. Now it is mostly applied in Heilongjiang soybean production. But it brought severe problems in crops production in next season due to its high residue. The experiment was carried out in the field of the Institute of Plant Protection of Heilongjiang Academy of Agricultural Sciences in 2003.

We selected a field where imazethapyr is not applied and the soil is black with a middle texture, the content of organic matter is 2.81%, pH 6.75. We use corn as indicator plant for bioassay. Fresh weight of corn roots assayed Imazethapyr residual kinetics quantity in the soil. The herbicide is 5% Pursuit SL (imazethapyr. Hydrojet nozzles were used for herbicide spraying, with a delivery rate 300L/ha with 75g.ai/ha - 150 g.ai/ha and control. The standard curve setting used the method of plant cultivation in soil. Results have shown this method to be highly sensitive, and the lowest limit of imazethapyr detection reaches 5µg/kg. Imazethapyr decomposed quickly in the initial stages and after then decomposition was slow. The initial imazethapyr concentration has no significant influence on the decomposition speed. So the imazethapyr residual quantity increases with the increasing application rate. This result had a direct relation with the climate conditions of Heilongjiang province. The samples of imazethapyr residual quantity detection is a part of bioactivity in the soil. Therefore, the bioassay method is of more practical value in agricultural production than assaying using sensitive equipments to test imazethapyr residual quantity in soil.

248. Leaching of MCPA in Soil: Effect of Organoclay based Formulations and of Soil Organic Amendment. Lucia Cox¹, Rafael Celis¹, Alegria Cabrera¹, Carmen Trigo¹, Maria Herminos¹, Juan Cornejo¹; ¹CSIC, Sevilla, Spain

MCPA (4-chloro-2-methylphenoxyacetic acid) is an acidic herbicide widely used in olive crops in Spain. Due to its anionic form at natural soil pH, high risk of leaching and ground water contamination is expected. The aim of this work was to study the effect of herbicide application as MCPA-organoclay based formulations and the amendment of soil with an organic residue on leaching of MCPA in a sandy soil. For this purpose, batch sorption and column leaching studies were performed. The organoclays used to prepare the clay-based formulation of MCPA were obtained by treating Wyoming montmorillonite (SWy-2) and Arizona montmorillonite (SAz-1) with an amount of organic cation (hexadecyltrimethylammonium) equal to 100% of the CEC of the clay mineral. The organic residue used in this study was a solid waste from olive oil production, which is generated in great amounts in Spain (4 000 000 Mg/year). This residue has the following properties: pH 5.8, 93.2 % organic matter, 25 000 µg g⁻¹ dissolved organic carbon, and C/N = 18.3. Soil was amended with the organic residue at the rate of 10 % (w/w). Sorption and leaching studies with the sandy soil indicated that organoclay based formulations of MCPA greatly reduced the leaching of the herbicide as compared to the use of a conventional formulation containing the herbicide in an immediately available form. The increase in soil organic matter upon amendment with the organic

waste also resulted in greater sorption and reduced leaching of MCPA through the soil columns.

249. Soil Persistence and Bioavailability of Fluometuron under Rye and Balansa Clover Cover Crops in Cotton Production. Martin Locke¹, Robert Zablotowicz², R. Wade Steinriede¹, Krishna Reddy²; ¹Water Quality & Ecology Research Unit, Oxford, MS, United States of America; ²Southern Weed Science Research Unit, Stoneville, MS, United States of America

The phenylurea herbicide fluometuron is applied pre-emergence in cotton (*Gossypium hirsutum* L.) production in the Southeastern US and has been reported in surface water in regions where it is widely used. Conservation management practices such as reduced tillage and cover crops have been recommended to mitigate herbicide loss associated with leaching and runoff. Therefore, a five year field study was conducted to assess the implications of tillage (no-tillage or reduced tillage) and cover crops [rye (*Secale cereale*), balansa clover (*Trifolium michelianum* ssp. *balansae*), or none] on fluometuron persistence in crop residues and several soil depths (0 to 2, 2 to 5 and 5 to 15 cm). Soil sampled over approximately 8 wks following application was extracted with either methanol or water to determine extractable and bioavailable fluometuron concentrations. Fluometuron and a metabolite desmethyl-fluometuron were analyzed via HPLC.

Relatively high levels of fluometuron were intercepted by plant residues (100 to > 300 mg / kg), with less than 10% of this amount remaining in residues 14 d after application. However, considering the mass of residues in cover crop treatments (4113, 4356, and 1739 kg / ha for clover, rye, and none, respectively), only 50% of the fluometuron found in no cover crop soil was initially observed in cover crop soils.

Generally levels of fluometuron observed in the upper 2 cm of clover soils were < 50% of that in no cover soils for the first 21 d after application, while results from rye soils were mixed. No consistent trend in leaching in relation to cover crop management or tillage was observed. Following one to two wks after treatment, levels of the metabolite accumulated to levels as high as 0.8 mg / kg and its relative ratio to the parent exceeded 1.0 or greater. During the initial week after fluometuron application, water extractable residues represented ~ 65% of the methanol extractable residues, while after 14 days < 20% of the methanol extractable fluometuron was recovered by water extraction, indicating rapid decrease in bioavailability for either weed control or vulnerability to microbial degradation as represented by a dual phase degradation kinetics.

Results indicate that concentrations of fluometuron are significantly affected by cover crop residue, and that balansa clover can accelerate dissipation in surface soil. However, retention of fluometuron in plant residues and

accelerated degradation may lower amounts of fluometuron available for weed control.

250. Analysis and Evaluation of Plants Grown in an Area Contaminated with Industrial Waste. Sergio Jesus¹, Gerson Romao¹, Roberto Arevalo², Peres Waldemar³, Aline Coscione⁴, Monica Rossi¹, Neusa Nogueira¹; ¹University of Sao Paulo, Piracicaba, Sao Paulo, Brazil; ²Polo Regional Centro Sul - APTA/IAC, Piracicaba, Sao Paulo, Brazil; ³Government of Sao Paulo State, Piracicaba, Sao Paulo, Brazil; ⁴Agronomic Institute of Campinas, Campinas, Sao Paulo, Brazil

The residues from the use of industrialized products in regions of unplanned urban growth contribute to the contamination of soils and waters. The irregular disposal of such residues in potentially agricultural areas may induce to extensive contamination of immeasurable rates [1]. The aim of this work is to establish a protocol of analyses for native plants grown in an area of past industrial waste discharge. The species CHRPO - *Chloris polydactyla* (L.) Sw and BRADC - *Brachiaria decumbens* were chosen for this study. The contaminants in epigeal body and morphological alterations of these plants were evaluated under optical microscopy (MO), energy-dispersive spectrometry (EDS) attached to scanning electron microscopy (SEM) and inductively couple plasma spectroscopy (ICP-AES). Samples of phyllodium and flower stem were fixed using para-formaldehyde 4% for ten days in 4 °C, dehydrated in two series of metylcelosolve, ethanol, propanol and butanol and pre-leaked in butanol. After, the samples were immersed in media of histo-resine for four days. After this, samples were blocked in histo-resine with hardener. The histological cuts were contrasted with blue toluidine 2% in borax solution 1% and then the laminas were observed in optical microscopy. To the analysis of concentration of metals, phyllodium and flower stem, the samples were washed, dried and kept in an oven at 70 °C with ventilation. After ten days the material were smashed and analyzed by EDS. Also, 500 g of each sample were weighed adding 2,0 mL of H₂O₂ 30 % and 3,0 mL of concentrated HNO₃. The digestion was done following EPA 3051 method. After the extracts had cooled off they were filtered in quantitative paper filter volume 25 mL with de-ionized water and analyzed by ICP-AES. The analyses by EDS indicated the presence of Al, Pb, Cu, Mo, Ni, Zn contaminants, among others (Table 1). The analyses through ICP-AES corroborated this results besides the other elements identified. Also, with MO were observed expressive alterations in both of these plants species as discontinuous tissue of epidermal tissue, deep injuries reaching peridermal tissue and collenchyme, greater incidence intercellular voids and irregular medulla and central cavity. This poll of techniques showed covets since allowed the identification of the contaminants and the extent of alterations caused by pollution in the plants

evaluated in this study. Although EDS does not have a limit of detection comparable of ICP-AES, its versatile and feasibility suggest that this technique should be used in exploratory evaluation before the application of more sophisticated techniques which demands complex sample preparation. The MO is a technique of low cost and the routine is easily adaptable to field or laboratory analysis with considerable results in these studies.

251. The Residual Activities of Imazapyr and Glyphosate on Dormant *Pennisetum setaceum* (Forssk.) Chiov (Fountain Grass), under Arid Conditions within a Tropical High-Elevation Landscape in Hawaii. James Leary¹, Creighton Litton¹, Joe DeFrank¹; ¹University of Hawaii at Manoa, Honolulu, HI, United States of America

The US Army Pohakuloa Training Area (PTA) encompasses 44,045 ha within an elevation range between 1400-2800 m, located in the saddle between Mauna Kea and Mauna Loa volcanoes on the Big Island of Hawaii, USA. This location is known for its arid conditions with low precipitation, strong desiccating winds and high solar radiation. Major infestations of *Pennisetum setaceum* (Forssk.) Chiov. (fountain grass) exist within PTA. This invasive C4 species is extremely drought tolerant and fire-adapted, creating hazardous fuel loads that interfere with military training exercises at PTA and compete with other native vegetation. Fountain grass is dormant for much of the year with foliar regeneration stimulated by seasonal rainfall events. Herbicide suppression of fountain grass is an important component to the PTA fire management strategy, but has traditionally been limited to finite windows of opportunity when the grass is actively growing. In April 2007, replicated herbicide applications were made to a dormant stand of fountain grass within PTA (1734 m ele.) using imazapyr (0.45 kg ae/ha) and glyphosate (1.0 kg ae/ha) in different combinations with non-ionic surfactant, modified vegetable oil and an inverted emulsion. Precipitation was only 0.2 cm for April, and accumulated precipitation from April-Aug 2007 was only 3.0 cm with no observable growth or herbicide effects during this period. Accumulated precipitation during Sept-Dec 2007 increased to 23.4 cm with grass regeneration and herbicide effects finally observed in November at 29 weeks after treatment (WAT). Digital image analyses of the treatment plots were used to distinguish pixels representing living and dead vegetation. At 29 WAT, the live pixel density in the imazapyr treatment was significantly lower than in the glyphosate treatment (P = 0.0017), at 0.5% and 6.3%, respectively. Regeneration within many of the glyphosate treatments was indistinguishable from the surrounding untreated areas. We will continue to monitor this experiment through May 2008 to determine the longevity of the different imazapyr treatments. Our initial results show long-term activity of imazapyr, which could be associated with both the residual and systemic

properties of this chemical. Imazapyr herbicide could become an effective tool in the PTA fire management plan by greatly expanding the time frame for effective herbicide applications, thereby giving greater flexibility in the decision-making process to mitigate fire risks.

252. Leaching of Flazasulfuron and Flumioxazin in Two Brazilian Soils. Robert Deuber¹, Waldinei Pastre¹, Andressa Giusti¹; ¹Instituto Agronomico de Campinas, Campinas, Sao Paulo, Brazil

Flazasulfuron is recommended for sugarcane and flumioxazin for soybean and other leguminous crops in Brazil. Due to the importance of these crops the herbicides may be widely used and there is a need to know their behavior in the cultivated soils. In order to study the leaching of these compounds, an experiment was carried out in greenhouse with two soils: a sandy loam Typic Hapludox (LVd) with 22 g.dm⁻³ of o.m. and a clay Rhodic Eutrudox (LRe) with 13 g.dm⁻³ of o.m. (both important soils in the State of São Paulo). Flazasulfuron was applied at 50 and 100 g.ha⁻¹ and flumioxazin at 50 g.ha⁻¹. The soils were put in 50 cm high plastic columns, with 10 cm diameter. The herbicides were applied with a CO₂ sprayer over the surface of the columns. Rains of 50 and 100 mm were dripped over the surface with perforated cans in amounts of 10 mm each time. Each treatment had four replicates. After this, the columns were cut longitudinally in halves and *Cucumis sativus* and *Avena sativa* were sown all along as test-plants. Evaluations of herbicide symptoms were done at 7, 11, 14 and 23 days after sowing, measuring the extent of damaged plants along the columns. Only *C.sativus* showed sensibility to the herbicides. Flazasulfuron at 50 g, in LRe, leached to 6,5 cm with 50 mm of rain and to 10 cm with 100 mm. In the LVd soil, it reached 3,6 cm with 50 mm and 1,1 cm with 100 mm. At 100 g, in LRe it leached 6,2 cm with 50 mm and 10,5 cm with 100 mm. In the LVd it reached no more than 2,0 cm with both rains. Flumioxazin showed very little leaching in both soils, being the symptoms detected in no more than 2,7 cm in the LRe and 2,0 cm in the LVd. Differences in leaching were not directly related to the different solubilities, considering that flumioxazin is highly soluble in water and flazasulfuron presents low solubility. The differences observed between the soils are due mainly to the o.m. content. Both herbicides showed little leaching in general. Symptoms of the herbicides were detected in the bottom of the columns, showing that some amount was leached through the entire height of soil. No detection was observed in the middle of the columns leading to the conclusion that in this part the herbicides were much diluted. The concentration of the leached herbicides was low in any part of the soil, since no detection occurred with *A. sativa*.

253. Long Term Studies on the Residual Fate of a New Herbicide: Penoxsulam in Rice Field under West Bengal Climatic Condition. Anjan Bhattacharyya¹, Sukhendu Pramanik¹, A Roy²; ¹Bidhan Chandra Krishi Viswavidyalaya(BCKV), West Bengal, India; ²Dow AgroScience India Pvt. Ltd, Kolkata, West Bengal, India

Penoxsulam (2-(2,2-difluoroethoxy)-N-(5,8-dimethoxy), [1,2,4] triazole, [1,5-C] pyrimidin, 2-yl]-6-(trifluoromethyl) benzenesulfonamide), a triazolopyrimidine sulfonamide group of herbicide, is used as a selective post emergence product to control important grass, broadleaf and sedge weeds in transplanted, dry seeded rice. It has outstanding effect on all Echinochloa (ECHSS) grasses, the major weed pest in rice around the world and major broad-leaf and sedge weeds when applied between the two-leaf and mid-tillering stage of rice. The present study was undertaken to find out the harvest residues of penoxsulam in paddy grain, husk and straw and to find out the dissipation pattern in water, soil and plant since there was no report regarding these under West Bengal agro-climatic conditions. Penoxsulam 24%SC was supplied by M/s Dow AgroScience India Pvt Ltd and was applied in the paddy field at recommended, double recommended doses in three replicates. This study was conducted at the University Research Farm, Kalyani, BCKV, during the year 2005-07 (Kharif 2005, Boro 2006, Kharif 2006, Boro 2006-07 and Kharif 2007). For dissipation study, paddy water, soil & plant samples were collected at different days interval from each treatment plot replication wise along with control plot. Soil cropped with paddy, straw, grain and husk samples were collected at harvest. Water sample was extracted with dichloromethane subsequently evaporated to dryness and final volume was made up with HPLC grade methanol. Penoxsulam residue from soil samples was extracted with acetonitrile: water (8: 2, v/v) by shaking in a mechanical shaker. The extract concentrated and partitioned with dichloromethane. The dichloromethane layer was concentrated and reconstituted with HPLC grade methanol and finally analysed by HPLC. Plant, grain, husk and straw samples were extracted with acetonitrile: water (7:3, v/v). The extract was concentrated and partitioned with dichloromethane. The concentrated dichloromethane layer was chromatographed over silica gel. The acetonitrile fraction was collected and concentrated and reconstituted with methanol for HPLC analysis. HPLC (JASCO-JAPAN; Model: UV-1575) equipped with Chemito 5000 data processor coupled with UV-VIS detector was used for quantification of penoxsulam in different substrate. The other HPLC parameters were as follows: (Column = Thermo Hypersil (250mm x 4.6mm) 5 μ Hypersil® ODS; λ max = 230 nm; Mobile phase = 100% Methanol; Flow rate = 1 ml/min; Retention time = 2.25 min; Limit of Quantification (LOQ) = 0.1 ppm; Limit of Detection (LOD) = 0.05 ppm). The study revealed that the dissipation of penoxsulam in field water, field soil was followed first order kinetics irrespective of doses and

season. The half-life values were calculated in the range 1.13 to 3.10 days for water and 9.26 to 27.12 days for soil irrespective of the treatment and season. No residue was detected in soil samples as well as in grain, husk and straw samples at harvest for all doses. The present study revealed that the rice grain may safely be consumed without any hazards.

254. Glyphosate Effects on Symbiotic Relationships, Nitrogen Assimilation and Seed Composition in Glyphosate-Resistant Soybean. Robert Zablotowicz¹, Nacer Bellaloui¹, Krishna Reddy¹, Craig Abel¹; ¹USDA Agricultural Research Service, Stoneville, Mississippi, United States of America

Previous research has demonstrated that glyphosate can affect nitrogen fixation and/or nitrogen assimilation in soybean. The objective of this present study was to investigate the effects of glyphosate (GLY) at 1.12 and 3.36 kg ae ha⁻¹ on symbiotic relationships, nitrogen metabolism, and seed composition in GLY-resistant (GR) soybean. Results from a 2-yr field trial, conducted in 2006 and 2007, showed that there was little or no effect of GLY on nitrogen fixation as measured by acetylene reduction assay and delta 15N natural abundance. However, there were significant effects of GLY on nitrogen assimilation, as measured by in vivo nitrate reductase activity (NRA) in leaves, roots, and nodules, especially at the higher GLY rate applied at early growth stage. Application of GLY at 1.12 kg ha⁻¹ rate had no effect on mycorrhizae, but infection was reduced by ~ 50% by the higher GLY rate. Temporal changes in 15N abundance or nitrogen content of leaves treated with the higher GLY rate supported the NRA data. Seed protein content was significantly higher (10.3%) in soybean treated with the higher GLY rate compared to untreated. Inversely, total oil and linolenic acid was lower at the higher GLY rate, and oleic acid was greatest in treated soybean. GLY had no significant effect on soybean yield or saturated fatty acids (palmitic and stearic) content of seed at both rates. These results suggest that nitrate assimilation in soybean was more affected than nitrogen fixation under higher rate of GLY. The inhibition of NRA may be due to the absence of substrate (nitrate) in leaves and roots or a temporary inhibition of de novo synthesis of the nitrate reductase enzyme. Higher protein and oleic acid and lower linolenic acid in treated plants may be due to altered carbon and nitrogen metabolism from the higher GLY rate.

255. Atrazine-Degrading Bacteria Isolated from a Mississippi Delta Soils Expressing the Potential for Accelerated Atrazine Degradation. Robert Zablotowicz¹, Cesare Accinelli², L. Jason Krutz¹, Krishna Reddy¹; ¹USDA Agricul-

tural Research Service, Stoneville, Mississippi, United States of America; ²University of Bologna, Bologna, Italy

The ability for accelerated atrazine degradation has been reported in many Mississippi Delta soils following exposure even a single atrazine application on many sites in recent years. These adapted soils maintain populations of 1000 to > 100,000 atrazine degraders / g soil. Using enrichment techniques, ten atrazine-degrading bacteria capable of using atrazine as sole carbon and nitrogen source were isolated from a Dundee silt loam soil following five years of continuous atrazine exposure. These bacterial isolates were characterized for s-triazine substrate range using radiological assays for atrazine and simazine and liquid chromatography methods for cyanazine. Bacterial DNA was isolated and amplified for the presence of atrazine degrading genes (atzA, atzB, atzC and trzN) using PCR and the sequences of cloned fragments were further characterized. Based on radiological assays, all bacterial isolates metabolized atrazine as a sole carbon and nitrogen source, and also were able to rapidly metabolize other triazines such as simazine and cyanazine. However, only seven of these bacteria were capable of mineralizing the s-triazine ring in atrazine and simazine. The other three non-mineralizing strains accumulated a highly polar metabolite with a retention time similar to cyanuric acid. All ten triazine degraders contained the trzN chlorohydrolase and atzB and atzC amidohydrolases. The Mississippi Delta soils had a long-term history of exposure to cyanazine as this herbicide was historically used in cotton (*Gossypium hirsutum* L.) production. Although many of the isolates have not been classified taxonomically, some isolates have been identified as *Variovorax* and *Pseudomonas*-like based on 16s sequences. Therefore, the evolution of a s-triazine degrading population based on trzN instead of atzA as the initial dehalogenating gene product is logical considering the preexposure to cyanazine and the wider substrate range of trzN chlorohydrolase.

256. Persistence of Metsulfuron-Methyl Residues in Wheat Crop and Soil. Shobha Sondhia¹, Anil Dixit¹; ¹National Research Centre for Weed Science, Jabalpur, M.P., India

Possible bioaccumulation of herbicide in crop produce may cause ailing effect on animal and human. Thus it becomes essential to evaluate these chemicals in the soil and crop produce at harvest. Thus persistence of metsulfuron-methyl was evaluated in soil and crop produce at four application doses. Metsulfuron-methyl is a post-emergence herbicide. It is highly active to control broad-leaf in cereals, pasture and plantation crops. Metsulfuron-methyl was applied at 3, 4, 5, and 8 g a.i. ha⁻¹ rates, after 30 days after sowing of wheat as post-emergence herbicide in rabi 2006. Soil samples treated with metsulfuron-methyl were collected after 30 and 60 days

after herbicide application and at harvest along with control. Wheat grains and straw were sampled at harvest and analyzed for residues by High Performance Liquid Chromatography (HPLC) using photo diode array detector at 220 nm. At harvest the residue level of metsulfuron-methyl in soil was found below the detection limit at 3-5 g a.i./ha application rates and 0.002 µg g⁻¹ at 8 g a.i./ha respectively. Residues of metsulfuron-methyl were detected below the detection limit (<0.001 µg g⁻¹) in wheat grains at 3-5 g a.i./ha rates. However, 0.002 µg g⁻¹ residues were detected in wheat straw at 6 and 8 g a.i./ha application rates. It can be concluded that metsulfuron-methyl application at 3-4 g a.i./ha can be safely applied to the wheat crop as post-emergence herbicide.

257. Degradation of Fluroxypyr-MHE in the Soil of an Oil Palm Plantation in Malaysia. Halimah Muhamad¹, Tan Yew Ai¹, Ismail Sahid²; ¹Malaysian Palm Oil Board, Kajang, Selangor, Malaysia; ²Universiti Kebangsaan Malaysia, Kajang, Selangor, Malaysia

Leaching of fluroxypyr in an oil palm agroecosystem was conducted in an oil palm plantation in Sepang, Selangor. This oil palm estate is situated in the central portion of the state of Selangor in Peninsular Malaysia at an altitude of 70 m to 100 m above sea level. The study plot covered 6 hectares, and consisted of 9 subplots of 0.66 hectare each. The 9 subplots received three treatments namely; the manufacturer's recommended dosage (T1), double the manufacturer's recommended dosage (T2) and the control (T3) without herbicide treatment. Each treatment was done in triplicate and each subplot was separated by a 2 m buffer zone. The herbicide fluroxypyr-MHE (Starane® 200 EC; Dow Elanco Ltd) was applied as an aqueous spray using a knapsack sprayer at a spraying volume of 250 L/ha. The herbicide was applied at the manufacturer's recommended and double the recommended manufacturer's dosage, 72.05 g a.i./ha and 144.10 g a.i./ha, respectively. The control plot was not treated with herbicide. Soil samples were collected at different depths (viz. 0?10, 10?20, 20?30, 30?40 and 40?50 cm) at the following intervals; 1(before treatment), 1, 3, 7, 14, 30 and 60 days after treatment.

The recovery of fluroxypyr-MHE in soil, analyzed by the HPLC equipped with DAD was determined by analyzing the soil samples spiked with fluroxypyr-MHE standard solution at four different levels viz. 4, 10, 25 and 50 µg/g. The recovery and relative standard deviation of fluroxypyr-MHE ranged from 80% to 96% and 3.0% to 6.7%, respectively. The results obtained were good and reproducible with higher recovery and used for determination of fluroxypyr-MHE in soil from the field trial. Meanwhile the recoveries and relative standard deviations of fluroxypyr in soil samples spiked at levels of 1, 5, 10, 25 or 50 µg/kg were 91 ± 8.0, 94 ± 6.8, 93 ± 6.2, 90 ± 6.5 and 103 ± 9.0%, respectively.

Fluroxypyr-MHE was observed at all depths (0-50 cm), although the highest concentrations were detected in the uppermost layer one day after treatment. Fluroxypyr-MHE degraded to fluroxypyr one day after treatment at 20-50 cm and 10-50 cm depths when applied at the recommended and double the recommended dosages, respectively. While fluroxypyr-MHE was only detected one day after treatment, fluroxypyr was detected in the soil up to 7 and 14 days after treatment when applied at the recommended and double the recommended dosages, respectively.

258. Search of Plant Resources and its Characteristics of Growth and Development for Reduction of Soil Erosion at Growth Chamber and Field Condition. Chung Kang¹, Tae Park¹, Kwang Kim¹, Young Jang¹, Jung Lee¹; ¹Rural Development Administration, Suwon, Kyunggido, Korea, South

In Korea, we have a localized torrential downpour on July to September, every year because of monsoon climate. In addition, most of the upland are located on slopes. Heavy rainfall, when it occurs, causes heavy soil erosion in most of the upland in Korea. Simultaneously, soil erosion tends to contribute to the problem of water contamination and nutrition runoff (N, P) in rivers and lakes. In order to decrease this problem, we recommended the cultivation of *Secale cereale* L. However, this plant is harvested in May, so it cannot help with the situation of heavy rainfall. We need new plant or weed resources to reduce soil erosion at upland inclination for summer cultivation of chinese cabbage. Chinese cabbage is a very important vegetable to make Kimchi in Korea. A series of experiments were conducted to investigate the search of weed or plant resources and its characteristics of growth and development for reduction of soil erosion at growth chamber and field condition. We investigated growth and development of 4 plant resources by temperatures under growth chamber conditions in 2006, and 2007. In order to examine the effect of reductive soil erosion by seeding volume of Guwin #2, *Avena sativa* and *Secale cereale* under lysimeter condition (17% inclination). Also we compared biomass (weed occurring) between open field and covered plants. Among the tested 4 plant resources under growth chamber, higher length was found in Guyin #2, #1, *Avena sativa*, and *Secale cereale*, in that order. The higher the air temperature, the higher plant length, the shorter heading date. While Guyin #2, #1 and *Avena sativa* reduced heading date at higher temperature, but little or no influence was found in *Secale cereale* treated with higher temperature. Higher biomass was shown in Guyin #1, #2, *Avena sativa*, and *Secale cereale*, in that order. The higher the seeding volume, the higher biomass, the lower weed emerging under lysimeter. Among the tested plants, the most effective plant resource was Guyin #2 for reduction of soil erosion under lysimeter condition. The lower region

above sea level had little difference in weed production among grass, broadleaf weeds etc., whereas higher region (400m above sea level) had many broadleaf weeds.

259. Dissipation and Lixiviation of Penoxsulam and Molinate under Paddy Rice Conditions. Claudio Alister¹, Patricio Gómez¹, Sandra Rojas¹, Lorena Cabezas¹, Marcelo Kogan¹; ¹Universidad de Viña del Mar, Viña del Mar, Valparaiso, Chile

Herbicides applied to flooded rice crop (paddy rice) present a high risk to result as superficial water contaminants. In Chile, does not exist any information related to environmental herbicide dynamics in rice production. During seasons 2007 and 2008 two studies were established with the aims of studying the dynamics of penoxsulam and molinate under paddy rice environment. The first one was performed under field conditions, in experimental paddy rice plots in Parral, VII Region. The second study corresponded to a column experiment. Previous to establish the experimental paddy rice plots, seven undisturbed soil columns were extracted using PVC tubes (0.2 m-diameter; 1-m height) with a 0.6 m-soil height and transported to the experimental area at CIAA facilities. In both studies, penoxsulam (50.4 g/ha) and molinate (4,482 g/ha), were apply into the water, after rice seeding (12 cm water level was kept during the whole study period). Water samples were collected from the plots at application time, 1, 2, 4, 6 hours and 2, 4, 8, 16, 32 and 72 days after herbicide applications. In the case of undisturbed soil column study, soil solution samples were collected at 20 cm of soil depth to determine herbicides lixiviation. Results from water samples were fitted to a first order degradation kinetic. Penoxsulam and molinate half life values were 1.82 ± 0.27 and 1.23 ± 0.19 days respectively, under paddy rice plot conditions. However under soil column conditions half lives were 16.63 ± 2.96 and 5.39 ± 0.78 days for penoxsulam and molinate respectively. A significant inverse relation was found between temperature and half life values. An increase of 1°C in water temperature average during the first 5 days after herbicide application produced a 15 days reduction on penoxsulam half life. In the case of molinate water temperature was least important and it was determined a reduction of 4 days on its half life for 1°C degree water temperature average increase. In relation to soil movement neither penoxsulam nor molinate were detected in soil solution at 20 cm depth. These preliminary results indicated that keeping the water not leaving the paddies for only 5 days after its application into the water, as recommended, could have two consequences: 1) flooding water from the paddies could carry relatively high amount of herbicides, depending on temperature and 2) herbicide efficacy could be diminished. (Supported by Research Founding FONDECYT 1070069).

260. Effect of Interaction of Herbicide and Organic Inputs of Varying Resource Quality on Soil Organic Matter and Crop Yield in a Tropical Dryland Agroecosystem. Pratibha Singh¹, Nandita Ghoshal¹; ¹Banaras Hindu University, Varanasi, Uttar Pradesh, India

Weeds are of major concern in tropical drylands as they compete for major resources with crop plants. Application of herbicide (HC) has been considered as an effective measure for weed control, however concerns have been raised over long-term sustainability of crop productivity due to their use. Dryland soils are characterized by low crop productivity due to limitation in available nutrients and soil moisture. Application of exogenous organic inputs has been recommended for amelioration of soil fertility and conservation of soil moisture. These inputs when added with HC can alter the effectiveness of herbicides which in turn could have important implications on dynamics of soil organic matter (SOM), and thus on long term soil fertility. Soil microbial biomass (SMB) representing the active pool of SOM has been recognised as a reliable index of soil fertility. Studies on the impact of soil amendments in combination with HC on SMB and crop yield are limited in agroecosystems. We evaluated the effect of the application of HC in combination with various soil amendments having contrasting resource quality on SMB and crop yield under the *Oryza sativa* var. NDR-97 (rice)- *Hordeum vulgare* var. Lakhan (barley)- summer fallow crop sequence in a tropical dryland agroecosystem. In this two year study (2005-2007), the seven treatments (having equivalent amount of Nitrogen) studied were: (1) Control (no input; CO), (2) Recommended dose of HC, (3) HC + Chemical fertilizer (CF), (4) HC + Farmyard manure (C:N 31.5; FYM), (5) HC + *Sesbania aculeate* (C:N 15.6; SS), (6) HC + Wheat straw (C:N 89; WS) and (7) HC + 50% CF + 50% FYM (FP). During the two annual cycles SMB was estimated 14 times at seedling, grain-forming and maturity stages of rice and barley crops and at summer fallow by using Chloroform fumigation extraction method. Addition of exogenous soil amendments showed marked variations in levels of SMB throughout the two annual cycles. Single application of HC decreased the level of SMB compared to CO, however, combined application of HC showed a distinct increase in the levels of SMB carbon (C). Throughout the study period higher levels of SMB was accumulated in HC+FP (92% increase over CO), HC+SS (+84%) and HC+FYM (+65%) treatments. Total grain yield (rice + barley) was comparable in CO and HC treated plots, however combined treatments of HC showed enhanced grain yield. Total grain yield were higher in HC +FP (70% increase over CO), HC+CF (+62%), HC+SS (+51%) and HC+FYM (+45%) plots. Variability in total grain yield was found to be regulated by the variations in the mean levels of SMBC ($r = 0.79$, $n = 14$, $df = 12$). It is concluded that the reduction in level of SOM (represented in terms of SMBC) due to

single application of HC could be negated by addition of exogenous organic inputs. Such weed management practices may help in designing 'eco-technologies' which can improve and sustain fertility and productivity in soils of tropical drylands.

261. How to Manage *Eichhornia crassipes*? Pest Risk Analysis, Climatic Prediction and Management Strategies in European and Mediterranean Countries. Sarah Brunel¹; ¹EPPO/OEPP, Paris, France

Eichhornia crassipes (Pontederiaceae) is an aquatic plant originating from South America. It is extensively traded for ornamental and aquarium purposes. It is naturalized and often found to be invasive in tropical and subtropical regions. Because its distribution is still very limited in European and Mediterranean countries (recorded in Spain, Portugal, Corsica and Israel), this plant can be considered a new emerging invader in Europe.

As a matter of fact, the European and Mediterranean Plant Protection Organization organizes on 2008-06-2/4 a workshop on the *Eichhornia crassipes* so that to draft national guidelines for the management of the species. A pest risk analysis will also be elaborated and presented to member countries for recommendation. A climatic prediction will be undertaken as well with the software CLIMEX, integrating a climate change scenario. These tools as well as the concrete results for this species will be presented.

262. Not all Colonizing Species (Weeds) are Bad all the Time. Nimal Chandrasena¹; ¹Ecowise Environmental Pty Ltd, Penrith, NSW, Australia

The literature in a number of fields provides evidence that many colonising taxa, called 'weeds' by most people, may form worthy resources in diverse areas of human interest. These include their traditional uses as food, for both humans and animals, and continued use as therapeutic plants. There is considerable interest at present in obtaining pharmaceuticals from many taxa occupying disturbed habitats. Other major areas of significant interest include the use of the colonising strengths of several species in the remediation of water and terrestrial environments that have been damaged by human activities. Among some outstanding prospects are the potential to use aquatic species, such as Water Hyacinth [*Eichhornia crassipes* (Mart.) Solms] in pollution removal, and the use of some strong colonisers in wastewater treatment systems, or in the rehabilitation of riparian zones of watercourses and rivers. The Common Reed [*Phragmites australis* (Cav.) Trin. ex Steud.] and Cattails (*Typha* spp.) are examples of such taxa. Globally, there is considerable interest in using the large biomass produced by these species in a variety of

beneficial ways, including as raw materials for a range of products and as bio-fuels of the future.

In addition, there are many opportunities for using colonising plants in phyto-remediation, to scavenge soil pollutants. Furthermore, the awareness of the role of weeds as part of biological diversity is increasing, and there is continuing interest in creating more sustainable farming systems, in which colonising species are appreciated. There are also significant opportunities to further exploit chemical warfare between plants (allelopathic phenomena) in beneficial ways. These include the discovery of new bioactive chemicals and the use of allelopathic plant residues within low input agricultural systems. Many colonising plants are useful in providing such benefits.

The conflict between humans and weeds will continue, so long as humans modify ecosystems. However, a fresh look at the potential of 'co-existing' with weeds and using them as resources is overdue, given the many possibilities demonstrated. In many cases, the focus is on managing problematic species in specific situations, rather than on their utilization. However, if land managers can be led to appreciate the extraordinary strengths of the colonising taxa, this will allow a better integration of these species into our economies. Improved understanding of the causes of biological invasions should help to reduce the current confusion and negative attitudes towards invasive species. This Paper discusses the above viewpoints, and provides examples to illustrate that not all weedy taxa are bad all the time, just because they may interfere, under certain circumstances, with human interests.

263. Characteristics of *Polygonum cuspidatum*: An Invasive Species. Prasanta C. Bhowmik¹; ¹University of Massachusetts, Amherst, MA, United States of America

Polygonum cuspidatum Sieb. & Zucc. (Japanese knotweed) is an invasive, herbaceous perennial. This species, a native of South-East Asia, was introduced to Europe in 1825 as an ornamental hedge and it was subsequently introduced to the United States by late nineteenth century. Because of its tenuous growth habit it escaped from cultivation, and is currently one of the serious weeds in 36 states of the United States. *Polygonum cuspidatum* colonizes a wide variety of habitats such as wetlands, waste places, along roadways, and other disturbed sites. It spreads quickly to form dense monoculture stands by crowding out all other native vegetation, and greatly alter the natural ecosystem. It can grow over 300 cm in height. Stems are hollow, smooth, stout and are swollen at the nodes. Leaves are normally about 15 cm long by 7 to 10 cm wide, broadly ovate with pointed tips. Flowers are greenish white and on a branched panicle. Plants are strictly dioecious, and except from its native habitat, the occurrence of male plants is very rare. Populations rely solely on vegetative regeneration of rhizomes for propagation. An extensive rhizome system may spread up to

about 6 m laterally and to a depth of 180 to 210 cm. New shoots appear in early spring from underground rhizomes (as deep as 1 m) after over-wintering. Established plants flower in late August or early September. Plants senesce after reproduction and the above ground parts are killed by the first frost. Established *Polygonum* populations are extremely persistent, and are difficult to control. High regenerative capacity of the stem and rhizome fragments makes mechanical control more difficult and limited control strategies are currently available.

264. Biochemical Adaptation of Purple Nutsedge to Flooding: Sugar Metabolism and Enzyme Activities in Upland and Lowland Ecotypes. Aurora Baltazar¹, Jennifer Pena-Fronteras², Mizpah Villalobos³, Florinia Merca¹, Abdelbagi Ismail⁴, David Johnson⁴; ¹University of the Philippines Los Banos, Los Banos, Laguna, Philippines; ²University of the Philippines Mindanao, Davao City, Philippines; ³Central Philippine University, Iloilo City, Iloilo, Philippines; ⁴International Rice Research Institute, Los Banos, Laguna, Philippines

Cyperus rotundus (purple nutsedge) is becoming a dominant weed in flooded rice in the Philippines where the crop is grown in rotation with vegetables. In the past, purple nutsedge was known primarily as an upland weed, but over the last 35 years, its populations in flooded rice have increased from occasional (1970) to 20 plants per sq m (1990) to 50 plants per sq m (2000). Farmers may spend up to \$400 per ha to control this weed during the vegetable cropping season. Purple nutsedge appears to have evolved some adaptive mechanism to survive an oxygen-deficient environment during early establishment, which may be due to a switch from aerobic respiration to glycolysis and ethanol fermentation. Laboratory studies were conducted to determine the basis for its adaptation to flooded soil by comparing upland and lowland ecotypes with respect to: 1) morphology, 2) soluble sugar content, starch content, and amylase activity in tubers before and during germination, and 3) activities of the key enzymes of ethanol fermentation, alcohol dehydrogenase (ADH) and pyruvate decarboxylase (PDC) in roots during the first 24 to 48 h of germination. Seven-day old upland and lowland purple nutsedge plants grown from tubers in the greenhouse were subjected to hypoxia for 24-48 h and tubers and roots were analyzed for sugar and starch content, amylase, ADH and PDC activities. Plant and tuber height and weight were also recorded. Results showed that the lowland ecotype is taller than the upland ecotype, and its tubers, where carbohydrates are stored, are twice bigger than those of upland plants. Before and during germination, carbohydrate content of lowland tubers are twice that of upland tubers and stored largely as soluble sugars while those in upland tubers are stored as starch. Lowland tubers also had higher amylase activity than upland tubers, enabling greater breakdown of starch into soluble sugars for further

metabolism under anaerobiosis. At 24 h following germination, ADH and PDC activities increased in both lowland and upland plants. However, at 48 h after germination, ADH and PDC activities in the upland plants continued to increase while activities of these enzymes in the lowland plants decreased. Our data suggest that tolerance of lowland purple nutsedge to flooding is due to its high carbohydrate content, high amylase activity and high levels of soluble sugars in the tubers. This is coupled with down-regulation of its ADH and PDC activities during germination to reduce its utilization of carbohydrate reserves, thus prevent depletion of substrates to avoid starvation, injury, and death under prolonged flooding.

265. The Invasive *Buddleja davidii* (Butterfly Bush): History, Ecology and Management. Nita Tallent-Halsell¹; ¹US EPA, Las Vegas, Nevada, United States of America

Buddleja davidii Franchet (Synonym. *Buddleia davidii*; common name Butterfly bush) is a perennial, semi-deciduous shrub or small multi-stemmed tree that is resident in gardens and disturbed areas in temperate locations worldwide. Since its introduction to the United Kingdom from central and western China in the late 1800's it has become a popular component in horticulture, but is also considered problematic because of its ability to rapidly colonize and dominate disturbed areas. There is concern that it has potential negative and irreversible impacts on agricultural and wild lands. Around the globe, native and non-indigenous *Buddleja* are opportunists that are able to tolerate a wide range of physical conditions. *Buddleja* is highly prolific (producing millions of wind- and water-dispersed seeds per plant) and vegetatively expansive (stem and root fragments readily develop roots). It has a rapid growth rate, high specific leaf area, and high foliar N and P levels relative to native woody shrub species; all of these attributes increase its photosynthetic efficiency and competitive capabilities. *Buddleja* has an arbuscular mycorrhizal association and thus, is an efficient phosphorus accumulator. The species displays a high degree of phenotypic plasticity and consequently has been able to expand beyond the environmental limits of native *Buddleja* species. It has a low susceptibility to disease and herbivory. Although a successful colonist, whether *Buddleja* alters successional trajectories over the long term is undetermined. The ecological, horticultural, and economic impacts of *Buddleja* must be determined in order for best management practices to be implemented. The primary goal of this presentation is to synthesize what is known about *Buddleja* so that ecologists, horticulturalists, land managers and others can understand the impacts related to the continued presence of *Buddleja* in gardens and natural landscapes. I also address methods by which to manage *Buddleja* and discuss the ecological and social repercussions of various management strategies and

policies implemented to protect or remove Buddleja. Although this work was reviewed by the USEPA and approved for publication, it may not necessarily reflect official Agency policy.

266. Seedbank Dynamics and Depletion of *Commelina benghalensis* L. (Benghal Dayflower). Michael Burton¹, Theodore Webster², Alan York¹; ¹North Carolina State University, Raleigh, NC, United States of America; ²USDA, Tifton, GA, United States of America

Commelina benghalensis L. (Benghal dayflower) is listed as a USA federal noxious weed because of multiple herbicide tolerances (including glyphosate) and the potential for continuous germination and competition with crops, especially cotton and peanut. Rapid increase in the distribution of this species in the Southeastern USA has resulted in quarantines by state regulatory agencies and local eradication attempts. Some have suggested that *C. benghalensis* might be locally eradicated through seedbank depletion (i.e. destroying emerged plants before they reproduce) over a period of several years. Data to support such speculation is lacking. Consequently, seedbank longevity experiments were initiated in 2004 and 2005 in North Carolina (NC) and Georgia (GA), USA. Seeds (75 small and 25 large aerial seeds) from a NC Benghal dayflower population were mixed with screened native soil and sewn into plastic mesh bags. Sufficient bags were buried at 20 cm depth (at the bottom of the plow layer) to allow exhumation of four replicate bags every six months for several years. The experiment was replicated in NC by a parallel experiment (separate start year) in 2005 using seed from a GA population, and a similar experiment was initiated in 2005 in Tifton, GA, using seed from the same NC and GA seedlots. A separate set of experiments examining the survival of *C. benghalensis* seeds subjected to shallow burial (0 to 5 cm) was also initiated in NC. Treatments included annual and frequent cultivation and the presence/absence of a crop. Preliminary results of the deep burial experiments indicate that seed demise has occurred more rapidly in GA than in NC. After two years of deep burial, both NC and GA seed lots declined linearly to about 30% viability when buried in GA. However, the same seedlots had only declined to about 50% viability after 3 years of burial in NC. Frequent cultivation in the shallow burial experiment was the only treatment that stimulated germination/emergence of *C. benghalensis* in shallow depths with little apparent effect of crop presence until the 2007 drought year. While the early and rapid demise of the seedbank suggests rapid depletion might be possible, there are yet insufficient data to determine whether the linear trend will eventually transition to an exponential decay model. Difficulties in breaking dormancy for germination tests and difficulties with tetrazolium chloride staining continue to complicate interpretation of results.

267. Weedy Rice Germination as Affected by Overwinter Temperatures and Water Conditions. Aldo Ferrero¹, Silvia Fogliatto¹, Marco Milan¹, Francesco Vidotto¹; ¹Agroselviter, Università di Torino, Grugliasco, To, Italy

Weedy rice (*Oryza sativa* L.) is one of the major weed issues in rice production worldwide. A large number of weedy rice populations have dormant seeds that do not germinate until the next spring.

Overwinter flooding of rice fields may promote weed seed depletion by attracting waterbirds and favoring suicidal germination during autumn. Information on dynamics of weedy rice seed dormancy during overwinter flooding can be usefully exploited for a rational control of the weed. The objectives of the study were to investigate the effect of temperature and water on seed germination and to assess the depletion of viable seeds present on soil surface after overwinter flooding.

The study was conducted in 2005-2008 with laboratory and field trials. In the laboratory trial, seeds of two weedy rice populations (awned and awnless), collected in the field, were maintained at constant -20 °C, +5 °C, +25 °C, or at field conditions. At each temperature regime, the seeds were stored either dry or immersed in water. Amounts of seeds were tested for germinability every 2 weeks up to about 200 days.

The field trial was carried out at two locations in Northwestern Italy. At each site, 3 paddy fields of at least 3 ha each were overwintered either in dry conditions, continuously flooded for up to 3 years or for up to 4 years. After harvesting and at the end of winter flooding, soil cores (12 cm diameter, 2-4 cm depth) were taken in different areas from each field and weedy rice seeds present on core top were counted.

Constant temperatures of seed storage resulted in variable germination patterns with no consistent correlations with populations and watering conditions. In simulated field conditions, both populations showed a consistent trend to lose dormancy during storage, especially in the case of storage in water. After 150 days of storage, germinability ranged from 78% (dry) to 90% (water) in the awnless population and from 26% (dry) to 85% (water) in the awned one. A fast increase of germinability was observed in all conditions starting from about 180 GDD (min. 8°C, max. 25°C).

In the field study, the weedy rice infestation recorded before seed dispersal averaged from 10.8 to 23.5 plants/m² at the two sites, and seed rain ranged from about 960 to 2100 seeds/m². Overwinter flooding always resulted in a reduction of the number of seeds on soil surface greater than 90%. In fields kept dry overwinter, a reduction ranging from 25 to 28% of the seed rain was also observed. The results obtained in laboratory conditions may in part explain those achieved in the field, as flooding may induce a significant number of seeds to germinate, thus exposing the seedlings to the rigors of winter.

268. Weed Species in Paddy Rice Soils in Chile and their Response to Sulfonylurea Herbicides. Rodrigo Figueroa¹, Marcelo Kogan¹, Marlene Gebauer¹, Albert Fischer²; ¹Pontificia Universidad Católica de Chile, Santiago, Metropolitan Region, Chile; ²University of California, Davis, California, United States of America

Rice crop is the only cropping alternative for more than 1,500 farmers (<15 ha in average) located in poorly drained soils where several weed species can affect yields with losses up to 60%. Available information on weed community composition, relative importance of species and effectiveness of sulfonylurea herbicide is rare and obsolete. The aim of this research was to rank the weed species commonly found, by determining weed emergence from soil samples taken through the rice area and also, to determine sulfonylurea herbicides effectiveness through herbicide dose-response curves.

Soil cores from 23 and 35 locations were collected in 2005 and 2006, respectively, from rice fields located between Linares (35°43'S, 71°49'W) and San Carlos (36°22'S, 71°57'W) counties. Seedlings emergence was evaluated under continuously flooded conditions. Relative importance parameters were determined for each species identified as the sum of relative frequency plus relative density. Data analysis indicated that the most important species were *Cyperus difformis* (CYPDI), followed by *Echinochloa crus-galli* (ECHCG) or *Schoenoplectus mucronatus* (SCPMU) and last by *Alisma plantago* (ALSPA). According to these results, cluster analysis of species relative importance was conducted, being possible to identify four groups of locations, from which soil cores were taken in 2007 and subjected to different sulfonylurea herbicides rates. Dose response curves were obtained for ALSPA, CYPDI and SCPMU applied with bensulfuron-methyl, metsulfuron-methyl and penoxulam at rates of 0, x/4, x/2, x, 2x, 4x, 8x and 16x (with x=72, 5 and 41 g ai/ha, respectively). At commercial rate, penoxulam was the most effective herbicide on all three species, being CYPDI the most susceptible one. Metsulfuron-methyl was more effective than bensulfuron-methyl (x), controlling some of the CYPDI ecotypes. It is concluded that between rice locations sampled, most ALSPA ecotypes were resistance to bensulfuron and metsulfuron, as well as some CYPDI ecotypes (Funding provided by FONDECYT, project #1050807).

269. Weed Rice (*Oryza sativa* f. *spontanea*) in Thailand. Chanya Maneechote¹, Benjavan Rerkasem², Sansanee Jamjod²; ¹Ministry of Agriculture and Co-operatives, Chatuchak, Bangkok, Thailand; ²Chaing Mai University, Moeng, Chiang Mai, Thailand

To date, weedy rice (*Oryza sativa* f. *spontanea*) has been documented as a serious weed in direct-seeded rice cultivation, in the Central and Lower North of Thailand.

Rice yield loss due to weedy rice infestation ranged from 10-100% depending on the level of infestation. During 2002-2007, several methods had been developed in close collaboration with three farmers in Khao Sam Sib Harb village, Tamaka district, Kanchanaburi province. The results showed that one fallow with flooding followed with clean seeds and hand pulling of young weedy rice plants greatly reduced density of weedy rice from 287 ± 24 to 24 ± 2 panicles/m² in the following season and rice yield was recovered. Other two farmers, who continued growing rice, made weedy rice infestation under control within four years. In addition, DNA analysis indicated that the management of weedy rice by using clean seeds and intensive topping off panicles required at least three consecutive years prior to using as source of clean seeds. Technologies of weedy rice control were later transferred to members of the village since 2004 resulting in the reduction of weedy rice infestation from 700 to 237 rai. In conclusion, use of clean seed is the most crucial step in the integrated control and very cost effective. However, other components of control (e.g. one fallow, eradication prior to sowing, hand pulling, removal of weedy rice panicles etc.) are also needed to obtain successful results.

270. Environmental Impact of the Adoption of Imidazolinone-Resistant Rice in Contrasting Production Systems of Latin America. Néstor Saldain¹, Fernando Pérez de Vida², Pedro Blanco², Fabían Capdeville², Andrés Lavecchia², Victoria Bonnacarrere², Raúl Bermudez², Julio Méndez², Claudia Marchesi², Aída Ortiz³, Cástor Zambrano³, Catalina Ramis³, José Lazo³, Marjorie Cásares³, Thaura Ghneim⁴, Álvaro Anzalone⁵, Zaida Lentini⁶, Luis Ávila⁷, Aldo Merotto⁸, Albert Fischer⁹, David Gealy¹⁰, Martín Piriz¹¹, Artides Leal¹²; ¹Instituto Nacional de Investigación Agropecuaria, Treinta y Tres, Uruguay; ²Instituto Nacional de Investigación Agropecuaria, Treinta y Tres, Uruguay; ³Universidad Central de Venezuela, Maracay, Aragua, Venezuela; ⁴Instituto Venezolano de Investigaciones Científicas, San Antonio de Los Altos, Miranda, Venezuela; ⁵Universidad Centroccidental Lisandro alvarado, Barquisimeto, Lara, Venezuela; ⁶Centro Internacional de Agricultura Tropical, Cali, Valle del Cauca, Colombia; ⁷Universidad Federal de Santa María, Santa María, Río Grande do Sul, Brazil; ⁸Universidad Federal de Porto Alegre, Porto Alegre, Río Grande do Sul, Brazil; ⁹University of California, Davis, California, United States of America; ¹⁰Dale Bumpers National Rice Research Center, Stuttgart, Arkansas, United States of America; ¹¹BASF Ltda. Uruguay, Montevideo, Uruguay; ¹²BASF Venezolana S.A., Maracay, Aragua, Venezuela

Some of the local rice breeding programs in Latin America countries are incorporating genes that confer tolerance or resistance to the imidazolinone herbicides, so it is critical to have clear information for farmers and for farmer advisers in order to use this technology properly. In

the medium run, no adequate use of it will induce that weeds populations including red rice become uncontrollable by imidazolinone herbicides.

I. INTRODUCTION

Clearfield® technology will simplify weed control. It will allow the treatment of important acreage in the same way with herbicides that are very potent, have wider spectrum of weed control and are more persistent in the soil than those used in rice.

II. GENERAL OBJECTIVE

To generate recommendations for a rational management of imidazolinones herbicides and resistant rice in order to maintain Clearfield® technology sustainable over time.

III. SPECIFIC OBJECTIVES

SO1 To establish dissipation response for imazethapyr, imazapyr and imazapic in soil and in water. To determine half life of them in the soil using a bioassay.

SO2 To prevent and detect resistance induced by ALS inhibitors in weedy rice (red rice) and other weeds of rice crop.

SO3 To study the maximum hybridizing rate between Clearfield® rice and weedy rice (red rice) biotypes. To determine frequency of plants that escape control in fields with contrasting intensity of use of imidazolinones. To study life cycles of F1 and F2 hybrids.

SO4 To reinforce the skill of technical personnel in specific methods that will be used in the project.

IV. MATERIALS AND METHODS

SO1

(i) Field experiments will be conducted to study carry-over effect of imazethapyr, imazapyr and imazapic on crops after Clearfield® rice when imidazolinone herbicides were applied in postemergence.

(ii) Plots treated with 1X rate (i) will be used to determine the dissipation curve of herbicides on soil and water.

(iii) Soil from plots treated with 1X rate will be sown with indicator species in individual pots and soil without treating will be used to fit standard curves.

SO2

(i) Fields with different Clearfield® rice uses and fields where it never was used before will be selected to take samples from weedy rice (red rice) populations and to detect individuals that survive.

(ii) At the same fields, when treatment with Clearfield® technology will be repeated, weed plants will be sampled.

(iii) In fields where other herbicides ALS inhibitors, different from imidazolinone herbicides, had been used heavily, the relevant weed populations will be selected for collecting accessions of everyone.

(iv) At the same fields where Clearfield® technology was used heavily and moderately, seeds will be collected from plants that survive to the treatment. Every time that this technology will be used, the sampling procedure will be done.

(vi) Seeds from those population and those collected in (i) will be used to conduct plant bioassays to estimate mean lethal dose and resistance rate.

(vii) An experiment will be conducted to detect drift species composition changes by the repeated use of Clearfield® technology.

(viii) With the information obtained from genetic and gene flow studies, which already exist of rice and weedy rice (red rice) biology, a prediction model will be constructed and validated.

(ix) The knowledge and the activities that will be coming up from this Project will be used to teach through local and national farmers and millers associations.

SO3

(i) The maximum hybridization rate will be measured between local material Clearfield® (donors) and red rice biotypes dominants (receptors) at two contrasting sites.

(ii) Putative hybrids will be made between local varieties Clearfield® and red rice biotypes. The cycle of life will be studied for F1 and F2 generations.

(iii) Transects at the same sites that those of SO2 will be established to estimate plants of weedy rice (red rice) frequency that escape to the Imidazolinones application. Plants will be collected to further study resistance.

(iv) At the transects, weedy rice (red rice) soil seed bank will be sampled intensively to study genetic diversity.

(v) Plant materials confirmed to be resistant will be stored and will be determined by means of molecular techniques if resistance comes from hybridizing or from a new mutation.

SO4

(i) Two short scholarships have been planned to train technical personnel on methods of detection for herbicide resistance. Albert J. Fischer (UCD).

(ii) Four places have been provided for training technical personnel in molecular markers use. Zaida Lentini (CIAT).

V. FUNDING

This project was approved by FONTAGRO (acronyms in sp) 2006 call for proposal and it receives financial support from the World Bank.

VI. STARTING DATE AND DURATION

June 1st 2007. The project will need thirty six months to be completed.

271. Density, Shattering and Seed Bank of Weedy Rice (*Oryza sativa* L.) under Commercial Conditions in Costa Rica. Carlos Rivera-Carballo¹, Bernal Valverde², Carlos Rodríguez³, Kathrine Madsen⁴, ¹Hacienda El Pelón de la Bajura, Bagaces, Guanacaste, Costa Rica; ²The University of Copenhagen, Taastrup, Denmark; ³Corporación de Desarrollo Agrícola Del Monte, S. A., San José, Costa Rica; ⁴Danish Institute of Agricultural Sciences, Slagelse, Denmark

Weedy rice (*Oryza sativa* L.) seed shattering and soil seedbank were characterized at two commercial rice fields in Costa Rica. Based on plant density, weedy rice infestation at both locations was 10% - 12%. Cultivated rice produced more tillers per plant than weedy rice at both locations. At the first location (Roble Norte, RN) where there was more variation in plant density among sampled areas, a single weedy rice plant was equivalent to 1.3 crop plants in decreasing crop-plant tillering whereas a single crop-plant decreased weedy rice tillering at a rate equivalent to 0.4 weedy plants. A similar trend was observed at the second location, Roble Sur (RS) but the equivalencies were uncertain. Weedy rice shattered 3440 and 1230 seeds m⁻² compared to 1025 and 120 seeds m⁻² for cultivated rice at RS and RN, respectively. On a per plant basis, weedy rice shattered 32-39 times more seed than the crop. The great majority of the shattered seed of both weedy and cultivated rice was filled. The weedy- and cultivated-rice soil seedbank was larger at RS than at RN but at both locations most of the predominantly-dormant weedy rice seed (64% to 77%) was found in the upper 10-cm of soil. A greater proportion of seeds buried at higher depths germinated when extracted from the soil and placed under suitable germination conditions. Current season contribution of weedy and volunteer rice for the following sowing was estimated at 42 and 13.5 million seeds ha⁻¹ at RS and RN, respectively, which added to the existing soil seed bank represents a major agronomic problem and emphasizes the importance of control methods that prevent seed production and deplete soil seed bank as the basis of integrated weedy-rice management.

272. Weedy Rice in Italy: Present Situation and Perspectives. Barbara Basso¹, Luca Militano¹, Alberto Spada¹, Francesco Sala¹; ¹University of Milan, Milano, Italy

Rice was introduced in Italy in 3rd century by Arabians as a commercial good, but a certified documentation about rice cultivation dates to 15th century. Rice was first planted in Lomellina, a wetland in the northern part of Italy between Turin and Milan, where Leonardo da Vinci designed a wide canalization system for field irrigation. Since then, rice fields diffused on the Italian territory, wherever the presence of abundant water met the plant growing needs, but the main cultivations remained limited to the first planting area.

Since the beginning of 19th century, the presence of an infesting rice variety (weedy rice) was reported among other weeds. It was identified by the local name of 'riso crodo' recalling its habit of dispersing the seeds by shattering at maturity. Generally, these shattering plants present peculiar morphological characters (e.g., plant vigour, large size, more tillers, coloured pericarp, and strong dormancy) in comparison with cultivated rice, but over time, they can also be confused with cultivated varieties before maturity, when seeds of weedy rice are not

yet shattering. This is because weedy rice is highly crossable with cultivated rice. The presence of weedy rice in Italy was restrained till the '60s when the technique of direct seeding was adopted. In the '70s a significant augmentation of weedy rice infestation followed the introduction of varieties imported from Spain, where the problem was already largely spread, still increasing in the '80s, in coincidence with a stronger demand from the market of *indica* varieties, reaching in some cases the 30% of contamination.

The main problems caused by weedy rice infestation are represented by the loss of productivity due to competitive effects in the field and to higher processing costs. The weedy grains not yet shattered at harvest are collected with the commercial crop, reducing its value, unless of a careful selection. Moreover, with the diffusion of herbicide-resistant varieties of cultivated rice, the risk of resistance-gene flow to weedy rice is very high, with possible dramatic effects on rice cultivation yield.

In the framework of a bilateral Italian-Chinese project, a collaborative study on the characteristics of Italian weedy rice and the relationships with its Chinese progenitor has been initiated. The study will imply the following goals: (a) Update on the current situation of weedy rice in Italy, especially in the northern regions where cultivations are maximally spread and intensive, without any crop rotation; (b) Characterize morphological and agronomical traits of Italian weedy rice and comparison of these characters with those of Chinese weedy rice; (c) Study the population genetic diversity of Italian weedy rice in relation to the situation in China, exploring the possible origin of weedy rice; (d) Determination of outcrossing rate of weedy rice populations, (e) Study of genetic diversity, outcrossing rate, and distribution patterns of weedy rice in Italy and China comparatively; and (f) Identification of relationships between genetic diversity and invasiveness of weedy rice for strategic management.

273. Morphologic Characterization of Weedy Rice in Two Major Rice Growing Provinces in the Philippines. Madonna Casimero¹, Dindo King Donayre¹, Edwin Martin¹; ¹Philippine Rice Research Institute, Munoz, Nueva Ecija, Philippines

Weedy rice is an invasive weed that is closely related to rice and very difficult to control. It has spread widely in rice fields in other countries in Southeast Asia and the rest of the rice growing areas in the world. Lately, it has been observed that its occurrence has been increasing in rice fields in the Philippines. It is therefore imperative to survey and characterize the weedy rice biotypes infesting rice fields in the country. This will serve as the basis in designing information campaigns and development of management strategies for weedy rice.

Weedy rice samples were collected from the direct-seeded rice areas of Nueva Ecija and Iloilo provinces,

Philippines. Laboratory and greenhouse experiments were conducted to determine their morphologic and agronomic characteristics. Five biotypes were found in rice fields in 32 of the 35 municipalities of Nueva Ecija with a level of infestation ranging from 5 to 50%. Eight biotypes were found in five municipalities of Iloilo with infestations ranging from 5 to 60%. WR-NE 1 biotype, a biotype with dark red to light brown awn, and light yellow with reddish tip grains was most common in Nueva Ecija. WR-ILO 3 which has yellow awn, light yellow grain color and red pericarp was prevalent in Iloilo.

All weedy rice biotypes had variable morphological characteristics of the leaves, stem, grain and awn. These were also taller, germinated and matured earlier than the cultivated rice varieties, namely; PSB Rc-82, PSB Rc14 and IR-64. Maturity of weedy rice biotypes in Nueva Ecija ranged from 90-97 days after seeding (DAS) while Iloilo biotypes matured in 72-92 DAS. Weedy rice biotypes in Nueva Ecija had no shattering ability while those in Iloilo shattered easily. The early germination, short maturity duration and shattering characteristics confer a highly competitive ability of weedy rice. The same characteristics had been found in weedy rices infesting fields in Thailand and Malaysia where it is considered as a scourge in rice fields.

Little awareness of weedy rice exists in the Philippines although these are known to be a weed of concern in direct-seeded rice fields in many Asian countries. Information dissemination has been done to create more awareness among farmers and extension workers on the problems associated with weedy rice. Management strategies of weedy rice are currently being developed with farmers.

274. Southern U.S. Weedy Red Rice (*Oryza sativa*) Accessions for Entry into the National Small Grains Collection. David Gealy¹, Harold Bockelman²; ¹USDA-ARS, DBNRRC, Stuttgart, Arkansas, United States of America; ²USDA-ARS, NSGC, Aberdeen, Idaho, United States of America

Red rice (*Oryza sativa*) is a troublesome weed in rice (*Oryza sativa*) production systems in the southern U.S. and throughout the world, especially where direct seeding methods are employed. Diverse biotypes of red rice infest rice in the southern U.S. This creates a challenge for management and control of red rice, but also creates an opportunity for detailed biological and genetic studies of this introduced weed in relation to rice and other relatives. DBNRRC receives frequent requests for germplasm of red rice accessions by researchers working in areas of weed biology and control, genetics, gene flow, molecular biology, and evolutionary biology. These requests, however, are not always filled satisfactorily due to time constraints or seed shortages. The National Small Grains Collection (NSGC) is designed to provide such service, but

emphasizes maintenance and distribution of crop rice germplasm and not weedy rice. A single U.S. weedy red rice accession, CIor 9749, that was originally acquired by the NSGC from Louisiana in 1969, is no longer available for distribution from that germplasm source. Thus, adding a collection of new red rice germplasm accessions to the NSGC would satisfy a real need in the rice-weedy red rice community. In order to accomplish this, 28 accessions of red rice that had been acquired at DBNRRC from 1994 to 2000 from geographically diverse locations in Arkansas, Mississippi, Louisiana, Missouri, and Texas, have been processed for entry into the NSGC. All accessions have been evaluated in field plots at Stuttgart, AR for several years in order to characterize key agronomic traits and to remove off-types. Approximately half of the accessions were developed from single seed descent, and thus, should be well suited for molecular biology studies. Phenotypes are typically blackhull or strawhull, and awned or awnless. Days from emergence to heading range from 71 to 90 d, plant heights range from 149 to 182 cm, and kernel length/width ratios range from 2.5 to 3.3. Tillering and grain yield potential of the accessions also differ significantly. Specialty traits present in some accessions include cold tolerance or susceptibility, blast disease tolerance or susceptibility, herbicide tolerance, and seed dormancy. Seed samples will be available for scientific purposes in 5-g quantities from the NSGC through the Germplasm Resources Information Network (GRIN; <http://www.ars-grin.gov/npgs/>). Additional detailed background information on these accessions will also be available on this website.

275. Potential Gene Flow from Transgenic Rice (*Oryza sativa* L.) with Bar Gene to Different Weedy Rice (*Oryza sativa* f. *spontanea*) Accessions under Controlled Pollination Based on Compatibility. Xiaoling Song¹, Sheng Qiang¹, Linli Liu¹, Zhou Wang¹; ¹Nanjing Agricultural University, Nanjing, Jiangsu, China (Peoples Republic of)

The potential of gene flow from two transgenic rice lines containing bar gene to five accessions of weedy rice (WR1-WR5) was studied by hand pollination. The germination and growth of rice pollen grains on stigmas of the accessions of weedy rice were observed with fluorescence microscopy. Double fertilization and embryo development of self-pollinated WR2 and the cross between WR2 and Y0003 were observed by the traditional paraffin wax method. Rice pollen grain germination on the stigma, growth in the style, and entry into the ovary of all weedy rice accessions were similar with self-pollination of weedy rice. However, double fertilization was delayed 2-3 hours and embryo abortion caused by failure of the endosperm in crosses between WR2 and Y0003 was observed. When crossed with transgenic rice Y0003 pollen, seed set in weedy rice ranged from 12 to 76%. WR2 rate was the lowest, WR1 and WR3 were similar (< 18 %), while WR4 and WR5 were more than 72 %. Crossed with transgenic

rice 99-t, seed set in WR1, WR2, WR4 and WR5 were more than 70 %, but the rate in WR3 was only 8%. Repeating pollination increased the seed set of four of the five weedy rice accessions. Seed set of WR2, WR3, WR4 and WR5 were increased by 9 % to 20 %. However the rank of the seed set of the different weedy rice accessions did not change when pollination was repeated. This indicated that sexual compatibility was shown to be a key factor affecting possible gene flow and the extent of sexual compatibility between different transgenic rice lines and weedy rice accessions differed. The germination rates of F1 hybrids were similar or greater compared to respective females. All F1 expressed resistance to glufosinate. Germination rates of the F1 originating from crosses between WR1 and WR2 and the two transgenic rice lines were more than 95% and there was no difference with rates from their female parents. Germination rates of the F1 between WR3, WR4, WR5 and the two transgenic rice lines were higher than that of their female parents. It is possible that hybrids may have lost seed dormancy and, consequently, gained a more synchronous germination, which is a characteristic that could negatively impact their survival in wild habitats. We have demonstrated that gene flow from transgenic rice to weedy rice may occur, but the frequency of gene flow between different biotypes of weedy rice and transgenic herbicide-resistant rice may differ due to different sexual compatibility.

276. Transfer of Herbicide-Resistant Gene to Weedy Rice Populations and its Implications. Vinod Shivrain¹, Nilda Burgos¹, Marites Sales¹, Kenneth Smith¹, David Gealy², Yong In Kuk³, Andy Mauromoustakos¹; ¹University of Arkansas, Fayetteville, AR, United States of America; ²USDA-ARS, Stuttgart, AR, United States of America; ³Suncheon National University, Suncheon, Korea, South

Red rice diversity in terms of phenology, sexual compatibility with cultivated rice, and the wide window of rice planting time can affect the rate of herbicide-resistant gene transfer from rice to RR. Experiments were conducted to a) determine the effect of red rice, rice cultivar, and planting date on outcrossing rate, b) evaluate phenotypes of outcrosses, and c) assess sexual compatibility between rice and red rice biotypes. Clearfield? (CL) rice cultivars CL161 and CL hybrid rice were planted with 12 RR biotypes on four planting dates in 2005 and 2006. Red rice seed was harvested at maturity and a sub-sample was planted in subsequent years. Red rice seedlings were tested for resistance to imazethapyr. The survivors were confirmed as outcrosses by DNA analysis and were characterized at maturity. Manual crosses were also performed between red rice biotypes and CL161 to determine their sexual compatibility. The outcrossing rate of different RR biotypes varied from 0.01 to 0.20 and 0.03 to 0.52% with CL161 and CL hybrid rice, respectively. CL hybrid rice had higher outcrossing with all red rice biotypes than did

CL161. Outcrossing rate differed between red rice biotypes in the same planting date due to variability in their flowering time. Brownhull RR had the highest outcrossing rate followed by blackhull and strawhull types. CL161 x red rice outcrosses were phenotypically uniform unlike the CL hybrid rice x red rice outcrosses, which segregated. Differences in outcrossing rate between red rice biotypes and CL cultivars are also dependent on their sexual compatibility. These experiments demonstrate that various factors affecting outcrossing rate need to be considered in planning gene flow mitigation strategies for rice.

277. Base Temperature Estimation of 21 Weeds and Crops. Ivan Sartorato¹, Guido Pignata¹; ¹National Research Council - CNR, Legnaro, Padova, Italy

Temperature is an important factor for seed germination and, in spring-summer crops of temperate regions, it is the driving force governing weed emergence from non-dormant seeds.

The temperature requirement for germination is therefore fundamental information for any modelling approach aiming to predict weed emergence dynamics. These models can be used to estimate the efficacy of weed control practices and to optimize their timing.

The aim of this research was to assess the minimum temperature required for the germination of various weed and crop species and the effect of temperature on the dynamics of the process.

The experiments were conducted at constant temperature in a growth cabinet on 17 weed and 4 crop species; up to 8 different temperatures were used for each species, ranging from 4 to 35 °C. Five selected species were also kept under alternating temperature, with an amplitude of 10 °C. Dormancy breaking treatments were done if necessary, seeds were then surface sterilised with a 0.5% hypochlorite solution and placed in Petri dishes (100 seeds per dish, three to four dishes per treatment). The large and prickly fruits of *Xanthium strumarium* L. were placed in rectangular plastic boxes filled with moist sand. Germination was checked daily until either all seeds had germinated or no further germination had occurred for 7 days.

The base temperature for germination was estimated from the linear regression of reciprocal times to median germination, where time to median germination was obtained fitting a logistic curve to the cumulative germinations over time at each temperature. A bootstrap simulation technique was used for the estimation of base temperature and its confidence limits based on the 5th and 95th percentiles of the empirical distribution.

All the considered species, excepting *Ammannia coccinea* Rottb., germinated at constant temperature; maximum germination reduced with temperature decrease in almost all species.

Estimated base temperature ranged from 0.7 °C (*Polygonum lapathifolium* L.) to 14.5 °C (*Cyperus difformis*

L.). Apart from *C. difformis*, only *Amaranthus cruentus* L. and *Echinochloa crus-galli* (L.) Beauv. showed a base temperature higher than the threshold of 10 °C that is usually adopted as reference level for weed growth in summer crops like corn and soybean.

The adopted logistic function also permits evaluation of the maximum germination rate at each temperature; species with a similar base temperature sometimes show very different responses of germination rate to increasing temperature. This influences weed emergence dynamics and should therefore be considered in simulation models.

278. Influence of Population Origin and Cohort on the Seasonal Emergence of *Galium* species. Aritz Royo-Esnal¹, Àngels Blázquez¹, Josep Antoni Conesa¹, Jordi Recasens¹; ¹University of Lleida, Lleida, Spain

In crop fields, the studies on weed emergence are focused on the influence of climatic factors. In winter cereals of Mediterranean areas these factors seem to have great relevance due to the weed emergence response to winter temperatures and rainfall regimes. However, for several species, it has been demonstrated that the variability of the emergence depends on both environmental and maternal factors. Maternal factors could be considered as the intrinsic adaptation of a population to a habitat, as well as the climatic conditions occurred during the seed production. This work was carried out with the aim to analyse differences on seedling emergence of different populations of *Galium* species (*G. aparine*, *G. spurium* and *G. tricornutum*) with different origin. Four *G. aparine* origins were considered: two Spanish (one from dry land and another from a river bank), one from UK and one from Germany. *G. spurium* seeds were obtained from two origins (Spain and UK), and only one *G. tricornutum* origin (Spanish) had been considered. Seeds of these seven populations were sown in Lleida (Spain) in a dry land area with Mediterranean climate. The experimental design was a randomised block with three replicates, each block containing 21 plots of 2x1m. The species were sown at a density of 400 seeds m² at three different dates (cohorts): 6th November 2006, 1st January 2007 and 14th February 2007. In each plot the new emergences occurred were followed weekly in three 0.33 x 0.33 m². Overall, the greater emergences were observed in the Spanish dryland populations of *G. aparine* (76%, 53% and 97% for 1st, 2nd and 3rd cohort), and *G. spurium* (89% 48% and 64%). The others origins showed lower emergences, depending on the cohorts. Spanish river bank population of *G. aparine*: 49%, 46% and 57%; British populations of *G. aparine*: 25%, 21% and 21%; German population of *G. aparine*: 53%, 37% and 46%; British population of *G. spurium*: 24%, 65% and 68%; Spanish population of *G. tricornutum*: 54%, 28% and 43%. Significant differences on the emergence between the three cohorts were observed only within the dryland population

of *G. aparine* and within the British population of *G. spurium*. For all origins, the emergences were fitted significantly to cumulated degree days by Weibul model except those from the third cohort. The rains occurred in April 2007 provoked a flux of emergences in all origins and, in consequence, the third cohort showed a faster emergence (estimate as a mean time of emergence) than the others two cohorts. However these differences between cohorts disappear -mainly between the 1st and 3rd cohorts- when the degree days needed to start the emergence were estimated (about 400 and 450 DDG, respectively). The results demonstrate the different emergence behaviour of dryland populations of *G. aparine* and *G. spurium* respect all of the other populations. The differences found in this work seem to rely on the origin of seeds and intrinsically on the effect of environmental conditions where the parent plants grew.

279. Effect of Sowing Depth and Temperature Regime on Wild Barley (*Hordeum spontaneum*) and Wheat Seedling Emergence and Early Growth. Farnaz Kordbacheh¹, Eshagh Keshtkar¹, Mohsen Mesgaran¹, Hamid Mashhadi¹, Hassan Alizadeh¹; ¹University of Tehran, Karaj, Tehran, Iran

Wild barley (*Hordeum spontaneum*) is a problematic weed in wheat fields of Iran. The integrated weed management requires knowledge of weed biology; however, the biology of this weed has rarely been studied. Experiment was conducted under controlled conditions to study the effects of different temperature regimes (15/10, 20/15 and 25/20 C (day/night)) and sowing depths (0, 2, 4 and 6 cm) on seedling emergence and early growth (height gain) of wheat (cv. Marvdasht) and wild barley. Cumulative emergence and plant height gain over time were modeled using a logistic function. For a particular temperature regime, the wheat maximum percent emergence (Emax) was higher than that of wild barley across all sowing depths. Maximum and minimum Emax values for both species occurred at 20/15 and 25/20 C, respectively. Time to reach 50% of Emax (i.e. E50) increased with sowing depth in both species under all temperature regimes. Wild barley E50 was greater than that of wheat for all temperature regimes with maximum differences observed at 20/15 C. The greatest maximum plant height (Hmax) was observed at the surface planting for both plants, but wild barley was more sensitive to sowing depth and each unit (1 cm) of increased depth resulted to 1.9 cm reductions in Hmax. Hmax was reduced at temperatures either lower or higher than 20/15 C, with more a notable reduction in wild barley. At all temperature regimes, time to reach 50% of Hmax (i.e. H50) increased linearly with sowing depth, but at higher temperatures the accelerated growth rate reduced H50. Wild barley seedling emergence and height gain rate expressed relative to wheat revealed the highest superiority of wheat when sown shallow at 20/

15 C. When delineated in terms of relative Emax and Hmax parameters, wheat took the most advantages over wild barley at 25/20 C and sowing depth of 4 cm. The findings of this experiment contribute to improve the integrated wild barley management in wheat crop by providing information about planting conditions under which the wheat would take advantage of an early establishment over wild barley, or in other words, wild barley is retarded in favor of wheat.

280. The Ability of *Medicago sativa* (alfalfa) to Establish Feral Populations in Natural and semi-Natural Environments in Western Canada. Muthukumar Bagavathiannan¹, Rene Van Acker²; ¹University of Manitoba, Winnipeg, Manitoba, Canada; ²University of Guelph, Guelph, Ontario, Canada

Medicago sativa (alfalfa) is an important forage crop in North America. Apart from cultivated fields, alfalfa is also found along road sides and other natural and semi-natural habitats. However, little information is available on the establishment capabilities of alfalfa in non-cultivated areas and the potential of these founding populations to become feral. This information will help us to understand whether feral alfalfa populations would become invasive and displace the natural vegetation, affect the ecological balance and become a barrier for the co-existence of cultivated alfalfa containing novel traits with conventional alfalfa.

The objective of this study was to investigate the establishment capabilities of alfalfa populations occurring in natural and semi-natural environments. Research sites were identified in three rural municipalities in Southern Manitoba (Western Canada) in 2006. Within each municipality, four sites each about 150-200m long and 10-15m wide were marked using global positioning system (GPS) way points. Within each site, 30 alfalfa plants of different age and size were randomly selected and tagged. A total of 360 plants were studied. Three soil cores (15cm diameter and 7cm deep) were taken from around each tagged plant. The soil samples were twice cycled through a freezer and a subsequent grow out in a greenhouse. The number of seedlings recruiting around each plant was also noted. Mowing was usually done by the rural municipality two times per season (late June, late August). A planned experiment was also carried out to investigate the establishment potential of alfalfa in a grass sward after being subjected to different disturbance treatments including herbicide spray, mowing and sward scarring.

In general, almost 93% of the non-mowed alfalfa plants and about 29% of the mowed plants were reproductively successful. This may be sufficient for replenishing a seed bank. Because alfalfa is a perennial crop, mowing did not kill plants but only delayed reproductive maturity. We found a viable and active seed bank at the roadside sites. Viable seed content levels were higher next to non-mowed

plants but were low on average (3.6 seedlings/plant) suggesting that the seedbank may be relatively ephemeral. Interestingly, about 90% of shed seeds survived the winter and a significant portion of them were dormant but viable in the spring. Herbicide (2, 4-D) application had an adverse effect on the survival of recruiting seedlings. Sward scarring did not significantly improve seedling recruitment and recruitment levels were relatively high in undisturbed plots (around 9 %).

The results of our study revealed that alfalfa populations are reproductively successful in road verges and that they can effectively establish self-perpetuating populations. The data from this study is sufficient to create a dynamic predictive model for feral alfalfa population establishment and growth. These data and this type of model will be useful for the biosafety assessment of alfalfa in relation to the production of novel traits in this species.

281. Leaf Vertical Distribution of Common Cocklebur and Jimsonweed in Competition with Maize Crop. Hassan Karimmojeni¹, Hamid Rahimian Mashadi¹, Hassan Mohammad Alizadeh¹, Mehdi Nassiri Mahallati², Mohsen Beheshtian Mesgaran¹; ¹University of Tehran, Karaj, Tehran, IraU; ²University of Mashhad, Mashhad, Khorasan Razavi, Iran

Among many weed species in maize fields that caused reduction in yield, jimsonweed (*Datura stromonium*) and common cocklebur (*Xanthium strumarium*) are the most serious weeds. The presence of these weeds almost accompany with competition for light. This effect determined by plant height and position of the maximum leaf area. The aim of this work was to study the effects of interference of common cocklebur and jimsonweed alone and combined in competition with maize on vertical distribution of leaf of common cocklebur, jimsonweed and maize in relation to interference from the other species and to determine the effect of these weed interference on maize height, leaf senescence and leaf area index in maize silking growth stage when the maize canopy was closed. Field experiment were conducted in 2006 and 2007 at the research farm of Natural Resources and Agriculture Paradise, University of Tehran, Karaj, Iran. An addition series experiment was conducted at targeting total weed densities of 4, 8, 12 and 16 plants m⁻². For each density, common cocklebur and jimsonweed were planted at five proportions (0:100, 25:75, 50:50, 75:25 and 0:100) in competition with maize. Pure stands of common cocklebur and jimsonweed at densities of 4 and 16 plants m⁻² and pure culture of maize at 6.06 plant m⁻² constituted no competition treatment. Maize, Common cocklebur and Jimsonweed heights were measured 5 week after planting (WAP) and biweekly after that in 2006 and 2007. Height measurements were obtained by randomly selecting 4 plants from each species within each plot and measuring the distance from the ground to the tip of stem. At 50%

silking, 4 plants of maize, common cocklebur and jimsonweed randomly selected from each plot and then were clipped at the soil surface, plants were divided into 0-30, 30-60, 60-90, 90-120, 120-150, 150-180, 180-210 and > 210cm layers. Fresh Leaves and senesced leaves were separated. Individual fresh leaf area was measured. Leaves from each species in each layer separately dried and then weighted. Leaf area at a particular layer was expressed as a percentage of the total plant leaf area. Senesced Leaves from different layers of each species were added and counted as total Senesced plant leaves for that species and then dried at 80 centigrade degree. Total canopy leaf area index (LAI), LAI within the maize canopy layers and plant height were decreased more by common cocklebur than by jimsonweed competition. Maize and jimsonweed were taller than common cocklebur throughout growing season. Competition from the weeds accelerated maize leaf senescence. Very different canopy architecture was found for three species in monoculture and competition. Competition with the high density of common cocklebur or jimsonweed reduced the LAI of maize in the lower canopy layer (0-90 cm) by 75% and 37%, respectively. Jimsonweed retained few to no leaves within the low layers of canopy, but common cocklebur had leaves in all layers and could even develop its lower leaf canopy under the shaded condition. It seems that more competitive ability of common cocklebur over jimsonweed was mainly due to its growth habit, with the leaves concentrated evenly in the canopy.

282. Seed Predation Assessment - Comparing Methods.

Stanislava Koprdoва¹, Pavel Saska¹, Zdenka Martinkova¹; ¹Crop Research Institute, Prague 6-Ruzyne, Czech Republic

Post-dispersal predation by vertebrates and invertebrates accounts for a large part of seed mortality, but the values strikingly differ between studies. Various methods are used to estimate seed loss in the field, usually using sentinel seeds, and this is a possible source of bias introduced to the data. The comparison of the methods commonly used to assess seed predation is of prime importance. This study aims to compare seed predation levels obtained by three different methods of seed exposure with combination of two types of substrate in laboratory: i) placed on moist filter paper; ii) glued to a card of sand paper placed on moist filter paper; iii) dtto placed on sieved moist garden soil; iv) stuck in plasticine trays placed on moist filter paper; and v) dtto placed on sieved moist garden soil. *Stellaria media* was used as model species of seed, and two carabid beetles (Coleoptera: Carabidae: *Amara aenea*, *Pseudoophonus rufipes*) and two terrestrial isopods (Isopoda: Oniscoidea: *Armadillidium vulgare*, *Porcellio scaber*) were used as model granivorous invertebrates. For each species and method of exposure ten replications were made, each represented by a Petri dish (6

cm in diameter, 2 cm in height) containing 50 seeds. The dishes were kept in a climatic chamber (mean temperature: 20°C, photoperiod: 17h light: 7h dark) for three days. Each day the number of seeds was counted and if > 50% was missing, they were replenished to 50. Total seed consumption was summed over the experimental period, and standardized over dry body mass of each individual. Standardized seed consumption was used as a response variable and the differences were compared using ANOVA for each species separately. Seed consumption varied with the method used in three out of four species of the predator (*P. scaber*: F_{1,48} = 236.1, p << 0.001; *A. vulgare*: F_{1,45} = 108.1, p << 0.001; *P. rufipes*: F_{1,47} = 14.88, p << 0.001), with exception of *A. aenea* in which no effect of the method could be found (F_{4,45} = 1.07, p = 0.383). In the former three species, seed consumption was generally highest on a filter paper and seed cards placed on top of soil. Predation on plasticine trays was consistently lower (except *A. aenea*) compared to seed cards. Filter paper (easy to use in lab experiments) and seed cards (convenient for use in the field) thus give similar results. Laboratory and field data are thus comparable when using these two methods. Supported by the project No. 521/07/0978 of the Grant Agency of the Czech Republic.

283. **Weed Seed Burial Rate as Affected by Seed Size and Crop Environment.** Paula Westerman¹, Philip Dixon², Matt Liebman²; ¹Universitat de Lleida, Lleida, Catalunya, Spain; ²Iowa State University, Ames, Iowa, United States of America

Seed losses due to predators can be huge and affect weed population dynamics. Seeds are most vulnerable to post-dispersal predators when exposed on the soil surface. Modelling has shown that enhancing seed availability might be more effective in increasing seed losses due to predation than enhancing demand. Seeds can enter the soil matrix via tillage or natural processes. However, the dynamics of natural and anthropogenic seed burial are not fully understood, nor have they been quantified. Here, we studied and quantified variation in seed burial as influenced by seed size and crop type.

Sets of 50 ceramic beads of three size categories (1.1-1.5 mm, 1.5-2.0 mm, and 2.25-3.0 mm diameter) were scattered on the surface of two small arenas (25 cm diameter) per plot between August and October in 2004 and 2005. Plots included corn and soybean of a 2-yr rotation (C2 and S2), triticale + red clover of a 3-yr rotation (T3), and corn, soybean, triticale + alfalfa, and alfalfa of a 4-yr rotation (C4, S4, T4, and A4) in a cropping system experiment in Iowa, USA. Beads were counted immediately after application and twice per week thereafter, until the end of October. Generalized linear mixed regression models (Proc GLIMMIX; SAS, version 9.1.3) were fitted to the counts beads, using a binomial variance function and a log link function.

Thirty-one percent of the small, 25% of the medium, and 16% of the big beads were lost from the soil surface immediately after application (I). Burial rate (b) was 0.046 (beads.bead⁻¹.day⁻¹) for small, 0.044 for medium and 0.029 for big beads. Both I and b decreased from forage crops to small grain cereals to corn and soybean. Rain events made beads disappear or reappear, but the magnitude of the effect differed among crops and changed over time, as a result of changes in the condition of the canopy, which intercepted rain, and the soil surface, which entrapped beads. Crop harvest in corn and soybean and manure application in the forage crops (R) covered 72% of the small, 67% of the medium and 65% of the big beads, but differed between crops.

Results indicate that the bigger the seed, the longer the availability on the soil surface. Both I and b were higher in crops of the 4-yr than the 2-yr rotation, suggesting that the duration of seed exposure to predators is potentially longer in corn and soybean than in other crops and longer in the 2-yr rotation than in the 4-yr rotation.

284. The Impact of Water Stress on Wild Radish (*Raphanus raphanistrum* L.) Seed Dormancy. Seyed Vahid Eslami¹, Gurjeet Gill², Glenn McDonald², Bill Bellotti²; ¹The University of Birjand, Birjand, South Khorasan, Iran; ²The University of Adelaide, Adelaide, South Australia, Australia

The environment experienced by the parent plant during seed development can affect seed dormancy in many species. There is a lack of information on the effects of climatic factors on wild radish seed dormancy. Spring rainfall in South Australia can be quite variable. Low spring rainfall could have an impact on the quality of weed seeds in particular their dormancy status. The effects of water stress on morphometric characteristics of wild radish seeds as well as the expression of its seed dormancy were investigated in a pot trial at Roseworthy, South Australia in 2005. This experiment was carried out in a completely randomised design with five water regimes (control, S4, S5, S6 and S8) and four replicates. The water stress was applied by withholding irrigation and placing the pots under a rain shelter at different growth stages starting with the onset of flowering (S4) and ending with the completion of flowering (S8). Wild radish pods from all the treatments were collected fortnightly from November 11 to December 23, 2005 (four collection dates). Seed dormancy was tested with and without pod for all treatments in January and May 2005. Water stress reduced the leaf relative water content (LRWC) in stressed plants relative to the control. At the time of last measurement, treatment S4 (the highest stress level) had almost completely senesced. The stressed plants matured sooner and produced significantly smaller seeds compared to the control (10-35%). Water stress had a greater impact on seed number per plant (9-85% reduction compare to nonstressed plants) relative to the

other traits measured in this study. All morphometric characteristics of pods including pod wall weight and seed weight were negatively affected by water stress. Pods sampled earlier had thicker pod walls and greater pod segment weight. Application of water stress to maternal environment caused an increase in total germination percentage in both January and May germination tests. The dormancy level tended to be lower in later collected pods. This Study showed that expression of seed dormancy was influenced by water stress during reproductive development. The climatic conditions experienced in agricultural areas of South Australia can be quite variable; it might have a wet or dry spring in different years. The ecological implication of these differences is that seeds produced in a wet spring are likely to have slower rate of dormancy release than those produced in a dry spring. Thus, seeds from a wet year may be more likely to become part of the persistent soil seedbank than those produced in a dry year.

285. Simulating the Effects of Solarization on Seed Germination of False Jagged-Chick Weed (*Lepyrodictis holosteoides* C.A.Mey). Zoheir Ashrafi¹, Hamid Mashhadi¹, Hassan Alizade¹, Sedighe Sadeghi¹; ¹University of Tehran, Karaj, Tehran, Iran

Solarization is one of the physical practices for controlling weeds and also pest and diseases. Soil solarization has proven to be among the most effective methods of weeds control in open field crops (Haidar and Sidahmad 2000; Jacobsohn et al. 1980; Mauromicale et al. 2001; Sauerborn et al. 1989). Temperature, moisture and the duration in which seeds of weeds are exposed to the achieved temperature are major determinants of the effectiveness of this approach. In this study effect of solarization on the seed germination of False jagged-chick weed (*Lepyrodictis holosteoides* C.A.Mey) was simulated by imposing imbibed and dry seeds of the plant to 40,50,60 and 70°C and exposure times of 0-8 h. Results revealed significant differences between temperature, exposure times and dry and imbibed seeds with germination at P<0.01. Increasing temperature reduced germination of imbibed seeds significantly. Exposure times of 1 h at 70°C or 6 h at 40°C reduced germination of imbibed seeds to zero. In comparison to control there was just significant reduction in germination of imbibed seeds at 50°C as duration increased, otherwise within exposure times germination did not differ significantly. Germination of dry seeds was not affect by either temperature or exposure times, in some cases even increased temperature and duration enhanced seed germination. There are advantages to using solarization: specifically, it is a simple, nonchemical, nonhazardous method that avoids the use of any toxic materials, does not contaminate the site, and is, therefore, suited to organic farming or other low-input agricultural systems. As global environmental quality considerations

grow in importance, along with an increasing human population, evolving concepts, such as soil solarization and other uses of solar energy in agriculture, will become more important (Stapleton 2000). Further research is necessary to determine the degree of this weed seedbank viability down the soil profile and its relationship with soil temperature reached during solarization to facilitate strategies to completely eradicate the parasite weed from the soil.

286. Genetic Diversity Analysis on *Commelina communis* L. by RAPD. Hong Ma¹, Bo Tao¹; ¹Northeast Agriculture University, Harbin, Heilongjiang Province, China (Peoples Republic of)

Dayflower *Commelina communis* L. was a kind of worst weed in soybean field in Heilongjiang Province in China and showed resistance to some herbicides in soybean field. Dayflower period of emergence had persistence in growth time of soybean. Germplasm gene was analyzed for forty cultivars of dayflower in different districts in Heilongjiang Province in China through 104 primers and PCR amplification by RAPD. It was used to analyze genetic diversity by 35 primers through filtration. The results showed that there was diversity of germplasm among forty cultivars of dayflower, germplasm gene of dayflower in Heilongjiang Province was classified into three groups, north, east and south, and there was specialization in different group, but there was high gene similarity in the group.

287. Relationship between morphological diversities and geographical distribution of jointed goat grass in Iran. Behnam Bakhshi¹, Muhammad Jafar Aghaei², Muhammad Reza Bihamta³, Farrokh Darvish Kajouri¹; ¹Islamic Azad University, Tehran, Iran; ²National Gene Bank of Iran, Tehran, Iran; ³University of Tehran, Tehran, Iran

Jointed goat grass (*Aegilops cylindrica* HOST), a wild and weedy relative of bread wheat, is an important weed in most of winter wheat farms all over the world. Management of Jointed goat grass in winter wheat farms is difficult because of the similarity in genetics and growth patterns between these two species. Also, it reduces winter wheat yields by input interference and harvested grain quality. Average yield loss has been estimated to be 25% under moderate to dense infestations. Jointed goat grass has a wide distribution in Middle East and West Asia. Geographical distribution studies of 360 collected accessions of jointed goat grass held at National Plant Gene Bank of Iran showed that jointed goat grass is widely distributed in North, North West and West of Iran, but it is rarely distributed in East South of Iran. All collected accessions were evaluated for morphological traits according to IPGRI descriptors. Accessions of different provinc-

es were significantly different for the morphological traits. The highest morphological diversity was observed among accessions originated from Fars provinces. Cluster analysis for morphological traits identified three different groups. Interestingly, accessions of the first group were geographically distributed in the North West provinces of Iran. While accession of central and north provinces were clustered in the second group. Likewise, accession collected from west, center and east provinces were clustered in the third group. Therefore, that data indicated there is a significant relationship between morphological diversities and geographical distribution of jointed goat grass in Iran.

288. Brassica vs. Brassica: Evaluating *Brassica napus* Potential Impact on Vegetable Seed Production. Michael Quinn¹, Carol Mallory-Smith¹, James Myers¹; ¹Oregon State University, Corvallis, Oregon, United States of America

In Oregon's Willamette Valley, a combination of the need for rotational crops with grass seed production, and an increased desire for local biofuel production has created interest among growers about planting *Brassica napus* (canola). Until recently, canola was only permitted in the Willamette Valley as a small scale seed crop. However, serious questions have arisen over the potential damage large scale canola production could have on the preexisting *Brassica* vegetable seed production. To address these concerns we have developed three objectives: 1.) Determine the potential of gene flow and hybridization via pollen flow from *Brassica napus* to related *Brassica* vegetable crops; 2.) Evaluate the potential for transgenic volunteer canola to become a contaminant in the *Brassica* vegetable seed crops by correlating seed shatter, soil persistence, and resulting volunteers over subsequent crop-rotations; 3.) Evaluate whether transgenes from *Brassica napus* will be detectable in viable and non-viable outcrossed *Brassica* vegetable seed. For objective 1, two sites, previously planted only to grass crops, were fall planted with conventional *Brassica napus*. At one site, two independent crossing experiments were conducted, one using a self incompatible *Brassica rapa* var. *chinensis* (Chinese cabbage), and a second using cytoplasmic male sterile (CMS) *Brassica oleracea* (broccoli) line, to evaluate gene flow and hybridization via pollen. Each experiment consisted of 13 potted plants arranged in a 15 x 15 m block. Once siliques had set, both species were returned to the greenhouse. Results of the crossing studies indicate that hybridization between these related species occurs, but the number of germinable seed produced from these crosses varies by species. For objective 2, after *Brassica napus* harvest at both sites, shattered seed were collected from both windrow and non-windrow locations in 0.25 m² quadrats along 30 m transects randomly distributed across the fields, and their positions recorded. Approximately 30 days after the shatter samples were taken, seedling

recruitment counts were made, using the same protocol as the shatter sampling, in quadrats placed immediately adjacent to the mapped location of the shatter samples. Results of volunteer assessment displayed differences in seed shatter between location and windrow vs. non-windrow, but only difference in location was observed in seedling recruitment. For objective 3, greenhouse crosses were conducted using transgenic (CP4) *Brassica napus* and the previously mentioned vegetable species, both to quantify outcrossing rates and address objective two. Results of these experiments indicate that transgenes are detectable in both germinable and non-germinable seed produced on non-transgenic female plants.

289. How to Evaluate the Probability of Natural Crossing between Cultivated Soybean and Wild Soybean? – A method Focused on the Flowering Overlap. Kentaro Ohigashi¹, Aki Mizuguti¹, Yasuyuki Yoshimura¹, Kazuhito Matsuo¹; ¹National Institute for Agro-Environmental Sciences, Tsukuba, Iba, Japan

Whenever genetically modified (GM) crops are cultivated, we must concern and make efforts to minimize the impact to biodiversity. Gene flow from GM to wild species is one of the important issues. Soybean (*Glycine max*) has the compatible wild relative, wild soybean (*Glycine soja*). Natural crossing will occur in the case three conditions are all met; flowering period overlap, existence of pollinators and the distance between wild and cultivated soybean. It will be impossible to know the latter two conditions before sowing, but we can predict and control flowering period of soybean from the model. If the condition of pollinators and distance are fixed, the extent of flowering overlap will be proportional to the probability of natural crossing. Hence, it is important to quantify the extent of flowering overlap for evaluating natural crossing frequency. Conventionally, the number of overlapped days tends to be used in such estimation of mating rate, however, it does not indicate the extent of overlap accurately, as the number of flowers differs over each flowering period. In this study, we sowed wild soybean adjacent to GM soybeans (glyphosate tolerant, 40-3-2 line) so that wild soybean can climb the stem of GM soybean. This conducted three times from 2005 to 2007 in Tsukuba, central Japan. We used several maturity groups of GM soybean and sowed in different timings for varying extents of overlap. We counted the number of flowers as time-series data, and checked whether hybridization occurred or not. In the seeds harvested in 2005 and 2006, we found only one hybrid seed from wild soybean (1/11860). We approximated flowering frequency by gamma distribution to quantify the extent of flowering overlap using the similarity measurement between probability density functions (PDFs) such as overlapped area of distributions. The hybrid seed was matured between the pair whose PDFs of flowering period were most similar. The natural crossing

frequency in field is difficult to be directly assessed due to its exceptional-lowness. This method enables to assess the probability of natural crossing by comparing the similarities of PDFs under sufficient conditions of pollination. This evaluation is useful to establish the most suitable cultivating system that minimizes natural crossing frequency and design the sampling method for screening the natural crossing in field.

290. Weather Variability and Its Impact on Agricultural Crops and Weeds. Muhammad Khan¹; ¹Lethbridge, Alberta, Canada

Ecology is the major field of science that can solve many agricultural problems. Many habitats are changing due to changing weather conditions and thus indirectly deprive millions of human beings from food. For this purpose, a study was conducted to investigate the competitiveness of a weed with wheat in different weather conditions. Field trials were conducted at Peshawar to study the competition between wheat (*Triticum aestivum*) and Holy thistle (*Silybum marianum*) in two different seasons (2003-04 and 2004-05). There was considerable variation in wheat grain yield between the two years under *S. marianum* densities. The *S. marianum* growth, dry biomass and seed production was dependent on wheat seed rate in the first year and independent in the second year. Similarly the yield losses were greater in the second year as compared to first year. The vegetative growth of *S. marianum* was greater in the later year and thus proved more detrimental to the crop yield. The variation in the grain yield of wheat and competitiveness of *S. marianum* in the two years could better be explained by the weather variability. As the average maximum and minimum temperature were 24 & 21C and 8 & 7C during 2003-04 & 2004-05, respectively. Similarly the total rainfall was 140 mm and 316 mm during the respective years. Low temperature and higher rainfall in the second year enabled the *S. marianum* to achieve greater canopy coverage and vegetative growth and thus become dominant over the crop and proved more harmful to the grain yield. Hence it can be concluded from the results that weeds being more tolerant to stresses can take advantage of the environmental variation at the expense of crop plants. Similarly global warming can alter the competitiveness of crop plants with weeds and thus needs to be addressed. Thus preventive measures are the best option for the growers so that weeds may not spread to uninfested areas. Because slight changes in the environment may benefit weeds more as compared to crop.

291. Studies on Competitive Interaction of Wild Oats and Spring Wheat at Varying Densities and Nitrogen Regimes. Imtiaz Khan¹, Gul Hassan¹, Muhammad Ishfaq Khan¹; ¹Department of Weed Science, Peshawar, NWFP, Pakistan

Wild oat (*Avena fatua* L.) is one of the most widespread, noxious and harmful weeds in wheat. Therefore, two separate experiments were conducted at Agricultural Research Farm for two crop seasons i.e. 2004-05 and 2005-06. Experiment was comprised of wild oats population and nitrogen levels on some agronomic and physiological traits of wheat and laid out in Randomized Completed Block (RCB) design with split plot arrangement, with four replications. Three nitrogen levels (75, 100 and 125 kg/ha) were kept in main plot while five wild oat densities (0, 10, 20, 30, and 40 plants m²) were kept in sub plot. The data were recorded on some morphological, physiological and agronomic parameters of wild oats. The statistical analyses of data exhibited non-significant differences for nitrogen levels in all the parameters of wheat and wild oats studied, while oats density and interaction of density with nitrogen levels were significant for all the parameters studied. Less than one wild oat plant m² inflicted 1% reduction in wheat yield, while 30% reduction in yield was predicted with the infestation of 15, 17 and 16 plants m² under 75, 100 and 125 N kg/ha fertilizer regimes. We also discovered a wild oats density related reduction in grain protein content which is further alarming. About 16 wild oats m² reduced protein content by 1%, which is alarming in vegetarian diets like Pakistan. Judicious control measures for wild oats are recommended to be adopted for harvesting better quantity and quality of wheat.

293. Seedbank Size and Composition after 6 Years Intercropping of Saffron (*Crocus sativus*) and Black Zira (*Bunium persicum*). Hamid Rahimian Mashhadi¹, Mohsen Msegaran¹, Mahmood Khosravi², Eskandar Zand³, Hassan Alizadeh¹; ¹University of Tehran, Karaj, Tehran, Iran; ²Ferdowsi University of Mashhad, Mashhad, Khorasan, Iran; ³Plant Pathology Institute of Iran, Tehran, Iran

Weed seedbank is of vital importance not only for studying the weed population dynamics but also for developing long-term weed management programs. A 6-year study was initiated in 1999 and the response of weed seedbank to the intercropping of saffron (*Crocus sativus* L.) and black zira (*Bunium persicum* (Boiss.) B. Fedtsch) was investigated. Mixtures consisted of 0/100, 25/75, 50/50, 75/25 and 100/0 saffron/black zira ratios, each planted at 3 densities of 30, 50 and 70 plant m². A split plot design based on randomized complete blocks with 4 replications was used. Densities were assigned to main plots with mixture ratios constituted the subplots. Soil was sampled from 0-5, 5-15 and 15-25 cm soil depths in the last year of study (2005). Viable and dead seed densities were estimated by direct extraction method. Soil was not disturbed during the experiment since both crops are perennials. *Amaranthus* spp. (Pigweeds), *Polygonum aviculare* L. (knotweed) and *Chenopodium album* L. (lambs-quarter), respectively, with relative densities of 48, 28 and

8% dominated the viable seedbank. Canonical Discriminant Analysis (CDA) was performed on data that were pooled across mixture ratios since planting densities had negligible effect on weed seedbanks. Grass weeds and *Fumaria vaillantii* Lois. (eartsmoke) were highly associated with crop mixtures containing higher saffron percentages (100/0 and 75/25). On the contrary, most weeds like *Veronica persica* L. (Persian speedwell) *C. album* L., and Asteracea or Brasicaceae complexes showed the highest association with purer stands of black zira. Seedbanks of few number of weed species were affected by mixture ratios in soil layers beneath 5 cm and CDA showed a decline in data variability as soil depth increased. Seed density decreased as soil depth increased, leading to the accumulation of 66%, 22% and 12% of seeds in soil layers of 0-5, 5-15 and 15-25 cm, respectively. These results provide a better understanding of weed seed bank compositional changes and may, therefore, be helpful in developing integrated weed management programs for a saffron-black zira intercropping system.

294. Branching Patterns of *Melastoma malabathricum* L. as Influenced by Density Regimes. Baki Bakar¹, Mahdi Faravani¹; ¹University of Malaya, Kuala Lumpur, Federal Territory, Malaysia

We assessed the architectural branching models of *Melastoma malabathricum* describing branching networks, directionality and dispersion with respect to the mother plant as influenced by density. Matured plants of *M. malabathricum* at the density of 1, 2, and 3 plant/box were raised in wooden boxes. The primary, secondary and tertiary branches, their respective angles and lengths were measured to assess branching patterns as influenced by density. Mean vectors of branches concentration were measured for every 50 cm intervals of plant pressure of the neighbors. The competitive height in each density. Circular statistics was applied to test whether the plant in a high density would preferentially bend towards the incoming solar radiation or otherwise. Most branches are concentrated in the opposite direction, and away from each other with a mean vector of 212.9°. Rayleigh's test (z values) showed the branches were distributed uniformly in different direction (0°- 360°) throughout the plant height around the mother plant. An increase in plant density has led to an apparent increase in modular competition affecting distribution of branch modules, their directionality and dispersion registering mean vectors of 222°, 208.9° and 214.2° for plants at the density of 1, 2 and 3 plants/box, respectively. The concentrations of branch modules were quite uniform around the mother plant. We found that the concentrations of axial branch modules devolved away from the maximum competitive pressure in terms of branch axial angle was higher among neighbours at the density of 3 plants/box compared with those plants at the respective densities of 1 or 2 plants/box. The

resultant spatial pattern of competing plants displaying reduced overlapping of branches was a manifestation of the competitive vectors integrating neighbour effects.

295. Directionality and Dispersion Analysis on Branching Patterns in *Melastoma malabathricum* L. Baki Bakar¹, Mahdi Faravani¹; ¹University of Malaya, Kuala Lumpur, Federal Territory, Malaysia

Rhododendron (*Melastoma malabathricum*traits) L. is a scourge in arable lands, abandoned farmlands, secondary forest openings and derelict areas in Malaysia. We assessed branching patterns of Straits Rhododendron at three planting densities through directionality and dispersion analysis using circular statistics with ORIANA and S-Plus computer softwares. Plants of *M. malabathricum* at the density of 1 (D1), 2 (D2), and 3 (D3) plant/box were raised until maturity in wooden boxes measuring 1 m x 1 m and 30 cm in depth, previously filled with garden soil. Plant height; primary, secondary, and tertiary branch lengths, numbers, and their respective angles and lengths were measured to assess branching patterns as influenced by density. The position of each branch was characterized by three parameters: horizontal rotation (branch azimuth), vertical rotation (branch base inclination), and translation (branch height). The number of branches for each 50 cm interval through plant height was also recorded. The azimuth of the branch was measured within 45°, using a circular protractor, divided into 8 angular sectors and orientated clockwise. All azimuth angles were measured from the north direction (0°) and the leaf base height above the soil was measured using a rule tape. These plants, either singular or in competition with neighbours did not display any preferential expansion into the gap, but showed morphological plasticity in the lateral growth. No preferential directionality in the distribution of branches of the crown mass center from the stem base positions upwards. Most branches were concentrated in the opposite direction and away from each other with a mean vector of 212.9°. The Rayleigh's uniformity tests showed the distribution of the branch azimuths was centrally symmetrical in plants at the densities D1, D2 and D3 registering respective *r* values of 0.032, 0.047 and 0.014. The computed *r* values were so small hence, no significant direction of orientation of the branches in a particular preferential direction after 161 days from seedling stage. The axial angles were not uniformly distributed in the plant canopy.

296. Interaction of Wild Oata (*Avena fatua*) and Wheat Seeded at Various Rate. Ijaz Ahmad Khan¹; ¹NWFP Agricultural University, Peshawar, NWFP (Pakistan), Pakistan

In order to study the effect of wild oat densities and proportions on yield and yield components of wheat, field trials were conducted at Malakandher Research Farm, NWFP Agricultural University Peshawar for two crop seasons i.e. 2004-05 and 2005-06. The experiments were laid out in randomized complete block (RCB) design with split plot arrangement. Four seed rates viz. 100, 130, 160 and 190 kg/ha were assigned to main plots, while wild oat densities 0, 0, 5, 10, 15, 20, 25 and 30 seed m² were kept into sub plots. Data were recorded on tillers m², days to heading, plant height wheat (cm), number of spikes m², days to maturity, leaf area (cm²)/tiller of wheat, spike length (cm), spikelets/spike, grains/spike, 1000 grain weight (g), biological yield (kg/ha), protein content (%) in wheat grain, grain yield (kg/ha) and various parameters of wild oat. Statistical analysis of the data showed that in both years most of the parameters were statistically affected by wild oat densities and seed rates, while the interaction of seed rates with wild oat densities was non-significant for all the parameters investigated. Maximum number of tillers m², spikes m², spike length, spikelets/spike, grains/spike, 1000 grain weight, leaf area and protein content (%) in wheat grain and grain yield were recorded in wheat monoculture (0 wild oat density plot). Among the seed rate 160 kg/ha had significantly the highest yield components and grain yield in both years. Thus the seed rate of 160 kg/ha is recommended for suppression of wild oat population in wheat crop. The losses in grain yield at the highest density of wild oats were estimated at 23 and 21% during 2004-05 and 2005-06, respectively.

297. Effect of Wheat Cultivars and Seed Rate on Weeds and Yield of Wheat. Muhammad Khan¹; ¹NWFP Agricultural University Peshawar, NWFP, Pakistan

An experiment was conducted to study the effect of wheat cultivars and seed rate on weeds and yield of wheat at Agricultural Research Farm, NWFP Agricultural University Peshawar during November, 2006. The experiment was laid out in randomized complete block design (RCBD) with split plot arrangement, having three replications. The wheat seeding rates 100, 120 and 140 kg/ha were assigned to main plots while wheat cultivars i.e. Pirsabak-83 (PR-83), Pirsabak-84 (PR-84), Khyber-87, Suleman 1996 and Saleem - 2000 were assigned to sub plots. Analysis of data showed that most of the parameters were significantly affected by wheat cultivars and non-significantly affected by seed rate. Maximum leaf area (38.66 cm²)/plant, number of wheat tillers (119.7 m²), plant height at maturity (100.9 cm), number of spikes (117.77 m²), spike length (11.8 cm), number of spikelets/spike (20.58), 1000-grain weight (-41.8 g), biological yield (10944.4 kg/ha), and grain yield of wheat (20.58 kg/ha) were obtained from wheat cultivar Suleman-1996 which was statistically at par with PR-83. Increasing seed rate of

wheat significantly decreased the weed density 30 and 60 days after sowing while different cultivars non-significantly affected the weed density. Overall the results indicated that seed rate as well as different cultivars can be used in integrated weed management package.

298. Effect of Environmental Factors on the Germination of *Ipomoea purpurea*. Megh Singh¹, Shiv Sharma²; ¹University of Florida, Lake Alfred, Florida, United States of America; ²University of South Florida, Bartow, Florida, United States of America

The information on various ecological factors on the germination of *Ipomoea purpurea* and seedling establishment is very limited. An understanding of germination and emergence would help predict its potential spread into new areas and would be useful in developing effective control measures in agricultural fields. Therefore this study was conducted to characterize the effects of environmental and chemical factors, e.g., temperature (12.5/7.5, 15/10, 20/12.5, 25/15, 30/20, 37.5/25, 42.5/30, and 45/35°C), photoperiods (0/24, 4/20, 8/16, 12/12, 16/8, 20/4, and 24/0h), osmotic stress (0.0, -0.3, -0.4, -0.6, -0.9, and -1.3 mPa), salt stress (0, 50, 100, 150, 200, 250, and 300 mM), pH (4, 5, 6, 7, 8, 9), seed burial depths, and simulated flooding periods on seed germination and emergence of *Ipomoea purpurea*. In this study the seeds of *Ipomoea purpurea* were collected from a citrus grove in Polk County, FL and were sterilized by immersion in a 0.5% solution of sodium hypochlorite for 10 min. The seeds were washed with 4 to 5 flushes of distilled water and allowed to dry at room temperature. Individual treatments for all laboratory germination experiments consisted of four replicates of 25 seeds placed on two sheets of Whatman #4 filter paper in 9-cm Petri dishes. Seeds were covered with one sheet of filter paper. The filter papers were moistened initially with 7.5 ml of distilled water or test solution. All dishes were sealed with parafilm to stop or slow desiccation. A seed was considered to have germinated when protrusion of the radicle was visible. The optimum temperature range for the germination was 20/12.5 to 37.5/25°C and the maximum of 88.5% seeds germinated at 30/20°C. Temperatures higher and lower than the optimum ranges significantly reduced the germination. Alternate light and dark photoperiod did not have any adverse affect on the germination of *Ipomoea purpurea* seeds. The germination of seeds was only about 10% at an osmotic stress of -0.3 and -0.4 MPa; thereafter, there was no germination. Seed germination showed some tolerance to salt stress. The germination was 40% at a salt stress of 50 mM NaCl and 12% germination occurred even at 200 mM NaCl. Maximum germination of seed occurred at pH 6 and, thereafter, the germination was significantly reduced indicating that the seeds of *Ipomoea purpurea* germinated better at lower pH values. Maximum germination of seeds was 83 to 94% when placed at 0 to 2 cm depth in soil,

within a week of sowing. Germination of seeds significantly reduced when placed at a depth of 5 cm and deeper. No germination was observed after first week after sowing. Under no-flood treatment, 87% of seed germinated, but simulated flooding even for 4 days reduced germination of *Ipomoea purpurea* seeds. The information on the germination of *Ipomoea purpurea* will be very important, while developing an understanding for its germination and emergence requirement.

299. *Sonchus oleraceus* Ecology and Management in the Subtropical Region of Australia. Michael Widderick¹, Steve Walker¹, Brian Sindel²; ¹Queensland State Government, Toowoomba, Queensland, Australia; ²University of New England, Armidale, New South Wales, Australia

Rationale

Sonchus oleraceus L. (common sowthistle) is a common weed of the subtropical grain region of Australia. The weed has also been identified as at moderate risk of developing glyphosate resistance, while many populations already have resistance to acetolactate synthase inhibiting herbicides. Hence, *S. oleraceus* is a weed that not only requires better management but also strategies that reduce the risk of resistance to herbicides. To elucidate the ecology of *S. oleraceus* to assist devising sustainable management strategies for this weed. A series of field, glasshouse and laboratory studies were undertaken to study seed germination, emergence, persistence, dormancy, and production, as well as plant morphology, competition in crop, and response to tillage and herbicides. *S. oleraceus* seed germinated readily across a wide temperature range (5 ? 35°C) at a water potential of 1.0MPa or greater. Germination was optimal at water potentials of 0.4MPa or greater and no seeds germinated below 1.0MPa. Germination was favoured in light, although 20% of seed germinated in darkness. Seeds germinated readily (65-100%) soon after harvest, demonstrating little innate dormancy. *S. oleraceus* emerged all year round from the top 2 cm of soil, with the majority of emergence from the top 1 cm. Few seeds buried in the top 2 cm of the soil maintained their viability beyond 8 months. Seeds buried deeper than 2 cm persisted for up to 30 months. Emergence was greatest under zero tillage, which had a greater number of seeds persisting in the top 2 cm of soil than systems with tillage. *S. oleraceus* has a great capacity for seed production with up to 8000 seeds/plant in a glasshouse environment and on average 68340 seeds m² in a winter fallow. Morphological diversity both within a population and between populations suggests great genetic diversity. A competitive crop, such as barley, or wheat grown at narrow row spacing (25 cm) and high plant density (>100 plants m²), greatly reduced the number of *S. oleraceus* plants, their biomass and their seed set. Glyphosate alone was effective in controlling *S. oleraceus*. However, glyphosate mixtures, paraquat + diquat, and the

sequential treatment of glyphosate followed 7 days later by paraquat + diquat were very effective with 98-100% control. The characteristics identified as most important for better management of this weed are the weed's prolific seed production, the weed's ability to germinate all year round and the ability of the weed to grow and produce seed across diverse environments. The ecological characteristics of the weed have been considered when developing an integrated and sustainable approach to management of *S. oleraceus*. An integrated approach should include growing competitive crops, strategic tillage, follow-up herbicide applications to control seed set on escapes, and rotation of herbicide groups especially for glyphosate and acetolactate synthase inhibiting herbicides. This research has increased the understanding of this weed's ecology and the management strategies devised have effectively been used on farm to improve management of this weed.

300. The Role of Temperature, Nitrogen Containing Compounds, Gibberellins and Red-Light in Seed Germination of Winter Annuals. Dongsheng Tang¹; ¹Kyungpook National University, Daegu, Korea, South

Seed germination is influenced by varieties of environmental stimuli such as temperature, nitrogen containing compounds and red-light. Gibberellins (GAs) are considered to play vital role in seed germination of many species.

We conducted a research study, to evaluate the effect of temperature, nitrogen containing compounds, red light and GAs on germination of *Alopecurus aequalis* Sobol. var. amurensis (Komarov) Ohwi, *Poa annua* L., and *Stellaria aquatica* (L.) Scop. Six incubation temperatures, five nitrogen-containing compounds and two GAs (GA3 and GA4 7) were used to observe seed germination of three winter annuals under red light and dark regime.

We observed that the winter annual seeds showed increased germination at low temperature, when the seeds were sown immediately after harvesting of plants. *A. aequalis* var. amurensis germination rate was 52 percent and 67.3 percent at 13°C, *P. annua* germination rate was 34.7 percent and 61.3 percent at 13°C, and *S. aquatica* germination rate was 39.3 percent and 42 percent at 19°C under dark and red-light regime respectively. Nitrogen containing compounds nearly failed to induce germination of *P. annua* at 25°C (germination rate <5 percent), while NH₄NO₃ and NaNO₂ were most effective in inducing higher germination in *A. aequalis* var. amurensis and *S. aquatica* at 25°C. GA4 7 in germination enhancement was more effective than GA3 in two winter annuals i.e. *P. annua* and *A. aequalis* var. amurensis, while GA3 effectively increased germination rate of *S. aquatica*. Moreover, red-light played an additive effect to stimulate germination in N-containing compounds and GAs treatments.

We concluded that low temperature treatment was more effective in germination induction than nitrogen and

gibberellins. Nitrate, nitrite and ammonium were effective at high temperature, to induce maximum germination in *A. aequalis* var. amurensis and *S. aquatica*, while they had little effect on *P. annua*. GA3 was more effective in case of *S. aquatica*, while GA4 7 increased germination of *P. annua* and *A. aequalis* var. amurensis.

301. Morpho-Physiological Plasticity of *Ranunculus acris* and *Ranunculus repens* and their Distribution in Serbia. Valentina Atanackovic¹, Ksenija Jakovljevic¹, Vladimir Randjelovic², Branka Stevanovic¹; ¹Institute of Botany, Belgrade, Serbia, Yugoslavia; ²PMF, Nis, Serbia, Yugoslavia

Ranunculus acris and *R. repens* are widely spread species in Serbia distributed at the altitudes from 100 to 2000 meters. *Ranunculus acris* inhabits the borders of wet meadows and pastures, whereas *R. repens* settles continually flooded, as well as occasionally dried swampy sites.

The aim of this study was to investigate the differences in morpho-physiological adaptations and possibilities for germination of *R. acris* and *R. repens*, collected from ecologically different localities. Measurements of leaves (30 replicates) were carried out using the light microscope (Leica DMLS) with a special image analyzer (Leica Q-Win). Relative water content (RWC) was determined by standard method, while the leaf water potential was measured by a pressure chamber (PMS instruments). *R. acris* is the terrestrial species with lower leaves much longer and wider than the upper ones. It is short-living plant, dominant in the meadows only during 1-2 spring months. This hygromesophyte is characterised by RWC between 40-68% and the water potential of about -1MPa. *R. repens* from the littoral habitats can change its habit by producing land and aquatic forms. Its aerial leaves are bigger and thicker than the aquatic ones. This plant could be recognized as the transitional hygromesophyte to mesophyte (from aquatic to land form), characterised by great variations in RWC, being between 30-73% in aerial leaves and 40-88% in the aquatic ones. The water potential ranged from -0.4 to -1.2.MPa in the aquatic form and from -1MPa to -2 MPa in the land form. The structural and physiological differences of this species imply its adaptability to the specific environmental conditions with reasonable facility. The rapid spreading out is additionally advanced by numerous stolons produced when *R. repens* grows in wet, peat bog habitats.

302. Temporal Pattern of Weeds Infesting Melon Crop in Castilla-La Mancha (Spain). Ricardo Ponce¹, Jose Manuel Martin¹; ¹Centro de Ciencias Medioambientales, CSIC, Madrid, Spain

Melons are an important summer crop in Castilla-La Mancha. However, the high temperatures reigning in this

region during the growth season and the use of fertirrigation favour serious weed infestations. Knowledge of the biology of the different weeds that appear is vital in their control. Four microplots (0.5 x 0.5 m.) were established in a field devoted to *Cucumis melo* L. (melon) cv. Sancho, planted on the 5th May 2006 (spacing between plants 1.5 x 1.5 m.). Each microplot contained one melon plant. These microplots were examined non-destructively for the emergence of weed species on five occasions up to beginning of harvest time at the end of July. Their phenology, estimated coverage and height were also recorded and compared with those of the crop. The weed *Amaranthus blitoides* was the most abundant, followed by *Chenopodium album*. *Diplotaxis eruroides*, *Diplotaxis virgata*, *Fumaria parviflora*, *Heliotropium europaeum* and *Salsola kali* appeared in smaller numbers. *A. blitoides*, *D. eruroides* and *H. europaeum* suffered increasing mortality as the crop growth season progressed. Although the melon plants extended outside the microplots, within the latter the weed cover was always greater than the cover crop. A harmful index (IH), was used to determine the competitive ability of the different weeds. This index is calculated using the formula $IH = I_{ph} \times I_{ab} \times I_{fr} \times I_h \times 1.852$, where I_{ph} is an index of the weed's phenological stage, I_{ab} an index of abundance (cover), I_{fr} an index of frequency and I_h an index of height. According to IH, only *A. blitoides* and *Ch. album* were harmful, but from the beginning of flowering to fruit maturity. The first of these became harmful because of this high cover and frequency, the second because of its great height and frequency. The other weeds identified appear to cause a potential little harm.

303. Evaluation of the Diversity of Weed-Ruderal Flora in order to Find out the Measures for its Protection. Marko Nestorovic¹; ¹Natural History Museum, Belgrade, Serbia, Yugoslavia

This study represents results lasting three year (2004-2006) investigations of weed flora in the region of Belgrade (Stara Palilula) and Belgrade's pale (Krnjaca, Ovca, Kovilovo, Glogonjski Rit, Jabucki Rit, Dunavac, Mirijevo, Slance, Veliko Selo and Vinca). A total of 175 taxons of vascular plants classified into 136 genera and 39 families were found at various types of ruderal and agricultural habitats. In the ruderal habitats 137 species of weed have been ascertained. In the crops and implantations 104 species of weed have been ascertained. In the wheat crop are consolidated 58, corn 37, sugar beet 40, soybean 46, potatoes 29, fruit-gardens 35, vineyards 44, peas 38, onion, garlic and leek 31, cabbage 27 and pepper 56 weed species. By an analysis of the present life forms of the plants belonging to the investigated weed flora, its hemicryptophytic - therophytic character has been established (49.12%:36.26%). By analyzing ecological indices for 5 main ecological factors, it's determined a domination of plants that prefer submesophyte and subxerophyte

habitats, mostly those of neutral to slightly basic reaction, with medium and high availability of minerals, predominantly semi-open to open in character, and mesothermic to thermophilic regarding temperature regime. Phytogeographic analysis of the weed flora revealed the presence of 170 different floristic elements grouped into 8 main area types. The most numerous was the group which belongs to Eurasian areal type (33.14%). Second part of the assay contains compared analysis efficacy of herbicides applied in the crops and implantations.

304. Distribution of Seeds of Giant Sensitive Plant (*Mimosa invisa* Mart) in the Soil Seed Bank. Frank Ekhat¹, Oluyemisi Akinyemiju², Celestine Ikuenobe¹; ¹Nigerian Institute for Oil Palm Research, Benin City, Edo, Nigeria; ²Obafemi Awolowo University, Ile Ife, Osun, Nigeria

Giant sensitive plant (*Mimosa invisa* Mart) has recently been invading road sides, farmlands, newly established oil palm plantations and fallows in Southern Nigeria, forming dense thickets where it occurs. It relies mainly on re-infestation from the soil seed bank. The weed annually infests young oil palm plantations and fallow fields at the Nigerian Institute for Oil Palm Research (NIFOR) Benin City, Nigeria. It is not known if the weed seeds are native or newly introduced into these areas. Studies were carried out to determine the distribution of its seeds in soils with different cropping histories at NIFOR. Soil cores were collected from two areas with history of *M. invisa* infestation. One area (Field 18) had been under fallow for more than 10 years and prone to burning annually, while the other area (Field 21) had been permanently under cultivation of oil palm for about six years. The soil cores were collected at three depths (0 - 7, 7 - 15 and 15 - 30 cm) sieved to remove large debris including root fragments and placed in germination trays (34 x 24 x 4 cm) in the screen house at the Department of Plant Science, Obafemi Awolowo University, Ile Ife for germination. Results showed no significant differences in the seed populations of *M. invisa* between the depth of 7 - 15 and 15 - 30 cm in both fields. Although only significant in the upper soil layer (0 - 7 cm) in the fallow field, the distribution pattern of *M. invisa* seeds was similar in soils of the cultivated and fallow fields, decreasing down the depth. Seeds of *M. invisa* were significantly ($P > 0.05$) more in fallow fields than in the field planted to oil palm. Seeds of other weed species found in association with *M. invisa* in the soil seed bank were *Panicum maximum* Jacq. *Chromolaena odorata* (L.) R. M. King and Robinson, *Cyperus species*, *Aspilia africana* (Pers) C.D. Adams and *Boehavia coccinea* Mill. Seeds of weed species were more diverse in the seed bank of the cultivated field than in the fallow fields as indicated by the Shannon-Weiner diversity index.

305. Germination Response of Bluegrass (*Poa annua* L.) and Canary Grass (*Phalaris minor* Retz.) to Light Treatments and Storage Conditions. Sara Ohadi¹, Hamid Rahimian Mashhadi¹, Reza Tavakol Afshari¹, Shahrzad Noroozi¹; ¹Tehran University, Tehran, Iran

Light is an important factor in low level of physiological dormancy which stimulates germination of photoblastic weed seeds species, even non sensitive seeds germinate better in light. In this experiment the effects of light and darkness on seed germination of *Phalaris minor* and *Poa annua* under different storage conditions was studied. The experiment was conducted in research laboratory of College of Agriculture and Natural Resources, University of Tehran, Iran. Seeds stored at room temperature ($22\pm 1^\circ\text{C}$), under cold ($2\pm 1^\circ\text{C}$) condition, or buried at soil depths of 10, 20 and 40 cm. were then exposed to a germination test every two months (after storage) for three times. Germination test was carried out under full light or full darkness conditions at constant temperature of 20°C . There were significant differences between light and darkness with germination of both species. Average of *P. minor* germination in 1st, 2nd and 3rd harvest were 43.17, 45.46 and 39.06%, respectively and germination of annual *P. annua* was 26.65, 15.82 and 22.52% respectively. At first and second sampling dates the highest germination was observed at burial depth of 40 cm, however, maximum seed germination for *P. minor* and *P. annua* occurred at room temperature and burial depth of 20 cm at the latest sampling date, respectively. Both species had the lowest germination under cold storage condition. Generally, germination of both species decreased over time, regardless of storage or light conditions. Light had a positive effect on the seed germination of both species with 36.76 and 52.73% germination for *P. minor* and *P. annua*, respectively, while those of darkness were 7.59 and 32.39%. This significant difference was observed for all storage conditions and harvest dates. Results showed that germination responses of species were various during the storage conditions which could be due to the alteration of dormancy level over time. Knowledge of weed species germination behaviors could has an implication for developing the integrated weed management strategies.

306. Seed germination responses of four *Brassica* species to light under different storage conditions. Sara Ohadi¹, Hamid Rahimian Mashhadi¹, Teza Tavakol Afshari¹, Sahrzad Noroozi¹; ¹Tehran University, Tehran, Iran

One of the important factors which could induce germination in weed seed is light. Germination of many weed species can be promoted by light, while seeds of most crops do not need light to germinate. In 2007, an experiment was conducted at the University of Tehran, Iran, to evaluate the effects of light and storage conditions on weed seed germination. Four species from Brassicaceae

family including *Sisymbrium irio* L., *Descurνια Sophia* L., *Rapistrum rugosum* L. and *Capsella bursa-patoris* L. were stored at room temperature ($22\pm 1^\circ\text{C}$), under chilled condition ($2\pm 1^\circ\text{C}$) or buried at soil depths of 10, 20 and 40 cm. The germination of seeds at 2 months intervals (with three harvest dates) was examined under light and dark conditions at constant 20°C temperature. A factorial arrangement of treatments (storage by light conditions) based on a completely randomized design with four replications was used. To account for the effect of harvest date and its interaction by treatments, it was included as subplot i.e. data were analyzed as factorial split in time design. Regardless of harvest dates and storage conditions, for all species germination varied between light and dark treatments. With exception of *D. sophia*, for all other species seed germination in darkness was higher than that of light. Germination percentage of *S.irio*, *C.bursa-pastoris* and *R.rugosum* in light were was 60.8, 60.8 and 13.6%, respectively. However, germination of these species in dark was 51.2, 48.5 and 10.5%, respectively. Although, for all species, the highest germination was observed at burial depth of 40 cm, maximum germination of London rocket occurred at burial depth of 20 cm. Regardless of weed species; seeds kept under chilled condition had the lowest germination. Seed germination differed among harvest dates which show the alteration in seed dormancy of weed species. In general, germination of all weed species decreased over time e.g. *C.bursa-pastoris* germination declined form 65.66% for the first harvest date to 38.83% for the last date i.e. 6 months later. Results showed that different species have different response to light and storage conditions and this response would further vary with time. The findings of this experiment, by providing more information on seed germination ecology of above weed species, could contribute in developing integrated weed management programs.

307. Effect of Wild Oat (*Avena ludoviciana*) Densities and Nitrogen on Morphophysiological Traits of Wheat (*Triticum aestivum* L.). Meysam Ebrahimi¹, Hossein Ghadir¹, Eskandar Zand²; ¹Shiraz University, Shiraz, Fars, Iran; ²PPDRI, Tehran, Iran

In order to investigate the competitive effects of different densities of wild oat (*Avena ludoviciana*) with winter wheat (*Triticum aestivum*L.) under different levels of nitrogen fertilizer, a two year experiment was conducted in the research field of weed research department of Plant Protection Institute at Karaj-Tehran during 2004-2005. The first year experiment consisted of 2 factors; 8 wheat cultivars and 2 weed densities with randomized complete block design using four replications. Weed density was considered constant (80 plants per meter square) for weedy plots and none for weed free plots. The eight wheat cultivars that were utilized were as follows: Tabasi, Roushan, Karaj2, Azadi, Nicknejad, Mahdavi, Shiraz,

and Pishtaz. At the end of first year experiment, two wheat cultivars named Roushan and Shiraz were introduced into the second year experiment as the least competitive and most competitive cultivars, respectively, in order to perform complementary studies. In the second year experiment, the additive competition of wild oat with winter wheat was studied. Analysis of variance was conducted for each measured variable as a split factorial design for three factors of variety (Roushan and Shiraz), nitrogen (0, 100, 200 and 300 kg of N per hectare) that had been provided from urea and wild oat densities (0, 80, 160 and 240 plants per meter square). The results of second year investigation indicated that, in all densities of wild oat, by increasing nitrogen fertilizer to 100 kg per hectare, grain yield, biological yield, spike length, fertile spikelet per spike and wheat mean kernel weight increased significantly. However, further increase in nitrogen to 200 kg per hectare in the infested plots decreased the mentioned traits significantly. However, for some traits like wheat tiller per meter square, plant height and wild oat biomass the increasing trend continued at higher nitrogen levels. Also the harvest index showed a negative correlation with nitrogen increase. Wheat grain yield, harvest index, fertile spikelet per spike and kernel number per spike decreased as wild oat density per unit area increased.

308. Differences in Early Vigor and Phenological Development of Two Horseweed (*Conyza canadensis*) Biotypes in California. Anil Shrestha¹, Matthew Fidelibus¹, Marisa Alcorta¹; ¹University of California, Parlier, CA, United States of America

Horseweed is native to North America and is commonly observed growing in agricultural and natural ecosystems in California. In recent years, increased densities of this species have been observed in vineyards, orchards, roadsides, and canal banks. Interest in this species and the reasons for its increased prevalence in California have heightened following the discovery in 2007 of a glyphosate-resistant (GR) population. Initial observations suggested that GR populations developed more rapidly than glyphosate-susceptible (GS) populations. Therefore, field studies were conducted in 2006 and 2007 to monitor the development of GR and GS plants. Seeds of GR and GS plants were collected and germinated in the laboratory. Glyphosate-resistance of the seedlings was confirmed using an enzyme assay. In early April of each year, single seedlings of each biotype were planted in separate 8-L pots filled with an organic potting media amended with a commercial slow-release fertilizer. Each potted plant was placed outside, in a non-shaded area, and supplied with tap water as needed. The potted plants were arranged in a completely randomized design with five replications in 2006 and four replications in 2007. Plants were monitored daily and the number of days after transplanting (DAT) required to form a rosette (more than 20 leaves), to bolt

(extension of the main stem), to form the first visible flower buds, to open a flower, and to seed was recorded. Data were analyzed using the PROC GLM procedure of SAS statistical software. There were no interactions ($P>0.05$) between years and biotype for any of the parameters so only the main effect of biotype is discussed.

Both biotypes reached the rosette stage at the same time, but the GR horseweeds bolted 17 days earlier ($P<0.05$) than the GS horseweeds. The advanced developmental rate of the GR biotype continued, and it formed buds, flowers, and seeds 21, 26, and 30 days earlier ($P<0.05$) than the GS biotype, respectively. The rate of stem elongation was also observed to be more rapid in the GR than the GS biotype. However, final plant shoot and root dry weight, number of flowers, and number of seeds were similar ($P>0.05$) for both biotypes. Therefore, this study showed that the GR biotype grew more rapidly and required fewer days to reach each phenological stage compared to the GS biotype even though final plant productivity was similar. The early vigor and accelerated rate of phenological development of the GR biotype may have implications for intra-specific competition and the ecology of these two biotypes in agro- and natural-ecosystems. Studies need to be conducted to ascertain the reason for the differences in rate of developmental between the two biotypes and if this accelerated development is responsible for differences in glyphosate-tolerance of the two biotypes.

309. The Biology of Canadian Weeds. Paul Cavers¹, David Clements²; ¹University of Western Ontario, London, ON, Canada; ²Trinity Western University, Langley, British Columbia, Canada

Since its founding in 1972, more than 137 accounts on the Biology of Canadian Weeds have been published in this series in the Canadian Journal of Plant Science. The first 130 papers have also been collected and republished in five volumes. Four of these volumes are on display at the CWSS-NRC booth and copies can be purchased.

Each paper contains a description of the species (one or more), economic aspects, geographical distribution, habitat, history, growth and development, reproduction, hybrids, population dynamics, responses to herbicides and other chemicals, responses to other human manipulations and response to parasites. Updated accounts have been published for some major species. Our display will provide information on all published accounts, a list of accounts in preparation and a list of species for which accounts are needed. Authors from outside of Canada with special knowledge of Canadian weed species are encouraged to register to write accounts.

310. Effect of Competition with Perennial Grasses on the Growth and Nutrient Concentrations of *Bromus tectorum* L.

Robert Blank¹, Tye Morgan¹; ¹USDA-ARS, Reno, NV, United States of America

We investigated the effect of established perennial plants on growth of the invasive annual grass *Bromus tectorum* L. (cheatgrass, downy brome). Seeds of *B. tectorum* were planted between two established plants (competition) and individually (no competition) in separate (4 replicates) rhizotrons (30 cm x 10 cm x 100 cm deep), using the A horizon of a fine sandy loam field soil presently invaded by *B. tectorum*. Perennial plants used were *Achnatherum hymenoides* (Indian ricegrass), *Leymus triticoides* (Creeping wildrye), and *Elymus wawawaiensis* (Snake River wheatgrass). Treatments for each growth cycle (90 days) were as follows: 1st cycle no trimming of established perennials before planting of *B. tectorum*; 2nd established plants trimmed at 5 cm immediately before planting; 3rd plants trimmed and activated charcoal mixed with soil between established plants before planting; 4th plants trimmed and soil top dressed with complete fertilizer before planting. Throughout the experiment, all rhizotrons were placed in plastic buckets and kept continually watered from beneath and periodically watered from above with dionized water. Relative to *B. tectorum* plants grown individually, growth between established perennials significantly reduced the growth of *B. tectorum*. Fertilizer application significantly increased the N concentration of *B. tectorum*, but did not significantly increase its growth. Our data suggest that competition with established plants greatly reduces the growth of *B. tectorum*. The reduced growth is not a function of water or nutrient limitation, nor allelopathic agents that could be removed with activated charcoal.

311. Crop Type Affects *Commelina benghalensis* Growth. Theodore Webster¹; ¹USDA-ARS, Tifton, Georgia, United States of America

Commelina benghalensis (Benghal dayflower or tropical spiderwort), an exotic invasive weed in the Southern US, has become one of the most troublesome weeds of agronomic crops in Georgia, in part due to its ability to tolerate glyphosate. One of the earliest identified areas invaded by *C. benghalensis* was Grady County, Georgia. Grady County is unique in that it historically includes corn in the typical cotton and peanut rotations. Field studies were conducted between 2005 and 2007 to determine if corn allowed for more *C. benghalensis* growth than the other crops and evaluate the reproductive potential of this weed when competing with standard agronomic crops. Corn was planted approximately one month prior to broadleaf crops (cotton, peanut, and soybean), a typical pattern in Georgia. Plots were 7.6 m long 1.5 m wide and arranged as a RCBD with four replications. One month following broadleaf crop planting, 12 *C. benghalensis* plants were transplanted at the cotyledon stage in each

plot; this timing coincides with peak emergence in naturalized populations of *C. benghalensis*. Four plants were destructively harvested at 6, 10, and 14 weeks after transplant. At each harvest, the number of aerial spathes, subterranean spathes, leaf area, leaf biomass, and plant width were quantified. Data were analyzed using ANOVA and treatment means separated using Fisher's Protected LSD. There were significant differences in *C. benghalensis* growth among the crop types and harvest times, but there were no interactions among these factors. Peanut permitted the most *C. benghalensis* growth of any of the crops, with double the plant width and number of aerial spathes, and greater leaf area and leaf biomass relative to cotton and corn. Soybean permitted the least growth, with less than a quarter of the plant width, number of aerial and subterranean spathes, leaf area and leaf biomass of cotton, corn, and peanut. Corn did not appear to permit greater weed growth in the crop, though the crop was not harvested in this study. Corn is typically harvested in Georgia between August and early-September, which eliminates crop competition for light and allow *C. benghalensis* to grow unimpeded. Often, these fields are left fallow following corn harvest, likely allowing *C. benghalensis* populations to increase, though this was not evaluated as part of this study. While peanut appears to allow a great amount of *C. benghalensis* growth, there are a number of herbicide tools that can be used to effectively manage this species, including s-metolachlor, paraquat, bentazon, diclosulam, and imazapic. In contrast, cotton does not permit as much *C. benghalensis* growth as peanut, however successful management revolves around s-metolachlor.

312. Effect of Density and Time of Removal of Volunteer Canola (*Brassica rapa* L.) on Yield Loss of Wheat (*Triticum aestivum* L.). John O'Donovan¹, K. Neil Harker¹, Don Dew¹; ¹Agriculture & Agri-Food Canada, Lacombe, Alberta, Canada

Canola production in western Canada has increased dramatically since the introduction of herbicide-resistant canola in 1995. This has resulted in an increase in volunteer canola as a weed and has raised concerns on its impact on wheat and other crops grown in rotation with canola. There is little or no published information on the effect of volunteer canola on wheat or on the most effective time to remove the volunteers to avoid yield losses. This knowledge would facilitate making decisions on if and when it needs to be controlled to avoid financial losses. Field experiments were conducted at Lacombe, Alberta, Canada in 1976, 1978 and 1979 to determine the effects of density and time of removal of volunteer canola on yield loss of wheat. Nonlinear regression analysis of the data indicated that the effect of volunteer canola on wheat yield loss was variable. Initial slopes (% wheat yield loss at low canola densities) varied from 0.29% in 1979 to 2.44%

in 1978. However, volunteer canola at densities of 47 (1976), 345 (1978) and 251 (1979) plants per square metre had little effect on wheat yield if the canola was removed at approximately 25 days after wheat emergence or earlier. Allowing canola to interfere beyond this time resulted in a sharp yield decrease for every day volunteer canola was allowed to remain in the crop.

313. Systematic Study of Phalaris (Poaceae) in Iran. Maryam Keshavarzi¹, Mahanaz Khaksar¹; ¹Alzahra University, Tehran, Iran

Members of the genus *Phalaris* L. are mainly distributed in temperate regions throughout the world. *Phalaris* species are distributed in open habitats in various regions of Iran. *Phalaris* with four species in Iran (*Ph. minor*, *Ph. brachystachys*, *Ph. paradoxa* and *Ph. arundinacea*) shows a great variation. These are plants of forage and weed importance and play a critical role in drylands vegetation of Iran. As there was no report of systematic study, or chromosomes counts on *Phalaris* species of Iran, the present study considers the numerical taxonomy, anatomical and cytological study of 38 populations belonging to 5 taxa growing in Iran, trying to reveal the inter-population morphological variations and inter-specific relationships. Numerical taxonomy was concerning intra and inter-populations variations as well as inter-specific relationships. Anatomical study was done on leaf dorsal epidermis and trans-sections. Dorsal epidermis was studied after tissue removal and leaf blades were studied by making hand made trans-sections and double staining. Chromosome counts at root tips were done for the first time. In statistical analysis the most variable morphological characters in the species delimitation were also determined. The studied species differed significantly in most of chosen qualitative characters. The clustering showed clear separation of studied species because populations of each species placed close to each other and separate from the other species. Species variations, relationships and diagnostic characters were considered. The most variable species in Iran is *P. minor* which seems to make some ecotypes. Based on studied diagnostic characters, an efficient identification key for these weeds in Iran is provided.

314. Effect Growth-Promoting Bacteria on Germination of *Datura stramonium* L., *Abuthilon theophrasti* Medik., *Onopordon acanthium* L. and *Verbascum thapsus* L. Sava Vrbnicanin¹, Ljubinko Jovanovic², Dragana Bozic¹, Danijela Pavlovic³, Vera Raicevic¹; ¹Faculty of Agriculture, University of Belgrade, Belgrade, Serbia, Yugoslavia; ²University of Belgrade-Center for Multidisciplinary studies, Belgrade, Serbia, Yugoslavia; ³Institute for Plant Protection and Environment, Belgrade, Serbia, Yugoslavia

The essential effects of microorganisms on germination and seedling growth of crops have been studied by many scientists, but effects of microorganisms on seed germination and young seedlings of weed species have been rarely studied. A fundamental understanding of interactions between weed seeds and microorganisms will have important implications for the future weed management systems. The seedlings of weed species emerge more uniformly when seed germination is stimulated, so that they could be killed in the next step of weed control. That is a way of reducing the seed bank in the soil. The objective of this article is to provide an overview what is known about the ecology of microorganism-weed seed relationship and effects of different media on the seed germination of *Datura stramonium* L., *Abuthilon theophrasti* Medik., *Onopordon acanthium* L. and *Verbascum thapsus* L. Media with *Bacillus lichenyphormis*, *B. subtilis*, *B. megatherium*, humates and distilled water have been used in this study. Incubation of weed seeds was done with 24h old inoculate with cell concentration of 108/ml. The used strains belong to plant growth-promoting bacteria (PGPB). A hundred seeds of each species were selected and their dry mass weighed. The seeds were placed in Petri dishes for imbibition and treated with solutions containing different media. The number of germinated seeds was recorded daily (germination rate), and the final percentage of germination was measured after 8 days. All experiments were carried out in an incubator (Binder CE) at 25°C. Each experiment was conducted three times. All data were subjected by analysis of variance and means were separated by least significant differences test.

The highest germination in all treatments was recorded for *Verbascum thapsus* seeds, and the lowest germination was scored by *Datura stramonium* seeds, respectively.

315. Systematic Study of some Bromus (Poaceae) Species of Iran. Maryam Keshavarzi¹; ¹Alzahra University, Tehran, Iran

Bromus is on the grass elements of Iran with almost 26 species, some of which are of forage and weed importance. *Brome* grasses are distributed in different habitats of Iran. These are traditionally arranged in 6 sections. In this study I collect 100 accessions (10 individuals of each sampling site) from east, center and west of Iran. Morphological variation was studied biometrically. Almost 60 qualitative and quantitative characters were measured and evaluated. I use Factor and Cluster Analysis to define the species relationships. I find that the variation in these taxa is more than what is mentioned in literature for Iran. A comparison was made among geneus sections. An identification key based on diagnostic key is provided for studied species of *Bromus* in Iran.

316. Preliminary Study on Biological Characteristics of Dayflower. Chun-yan Huang¹; ¹Plant Protection Institute of Heilongjiang Agricultural Academy, Harbin, Heilongjiang, China (Peoples Republic of)

Dayflower (*Commelina communis* L.) is an annual weed belong *Commelina* L. Due to some common herbicides could not control effectively, it already became one of malignant and difficult controlled weeds in farmland of Heilongjiang province recent years. Research it biological characteristics can provide the theory and technique foundation for controlling in agricultural production.

1 Material and Methods

Confirming points and investigating dayflower occurring dynamics in field. Planed plot in meshwork house, study on dayflower emergence depth. Confirming plants and studying dayflower growth rule. Drawing, basking and transplanting with water, studied seedling ability of resisting adversity.

2 Results

2.1 Dayflower emerges in the first ten-day of May and occurring peak period is in the middle ten-day of May in the farmland of Harbin city, Heilongjiang province, China, and in Jiamusi city above times is later.

2.2 The rate of dayflower germination is highest (22.0%) while seeding depth was 5cm and no dayflower seedling germinated at 20~30cm depth. The optimum depth of dayflower emergence is 5~10cm.

2.3 Dayflower plants of occurring at peak stages grow faster than others, and they needed the time from emergence to branch is short, the leaves were little and the plant height was shorter while they branched.

Dayflower grow slowly at 1-2 leaves stage, 3-4 leaves stage grow speed fast, the plant height and fresh weight increased rapidly later.

Dayflower plant 4-6 leaves begin branch, regenerate roots on node of laying land, branch can branch again, there are a great many branch in one plant. Dayflower flower gradually from underside to top, flowering peak stage can last one month. Florescence is 2 days. One plant flower number maybe over sixty. The seed mature after flowering 10 days and fall to the ground while mature. Average number of seed is about 164.1 grain/plant.

2.4 Dayflower of 1 leaf stage couldn't all survive by transplanting with water after basking 3-7day. The surviving rate of 7-10 leaves stage dayflower is 100% after basking 3day, which is 75.0%-87.5% basking 5day and 50.0%-62.5% basking 7day.

3 Conclusions

The occurring time of dayflower is concentrative and the peak stage is obvious reversely. Dayflower emergence and reach peak stage earlier in the region of geography latitude is partial to southern. The optimum depth of dayflower emergence is 5-10cm. Dayflower growth speed is faster occurring at peak stages. Dayflower plant could branch time after time and touchdown node could reascent roots, so it grows very luxuriance. The ability of dayflower

resisting adversity increase after 4 leaves and its surviving rate at 7-10 leaves stage is 50.0%-100% after basking 7day hereinafter. These results showed that the acclimation of dayflower is very strong. This is one of reasons that dayflower became malignant and difficult controlled weeds in farmland in Heilongjiang province.

317. Annual Cycle of *Oxalis latifolia*. Aritz Royo-Esna¹, María Luisa López²; ¹University of Lleida, Lleida, Spain; ²University of Navarra, Pamplona, Navarra, Spain

Knowledge about the annual cycle of weeds is useful in order to find the best way to control them. *Oxalis latifolia* is a little weed that is becoming very frequent in the Spanish maize fields and orchards and its distribution is amplifying throughout the years. Even though it only competes with the crop in its early growing stages, it may cause some yield loses. In this work the annual cycle of *O. latifolia* grown outdoors in a temperate climate is studied with the aim to seek weak points for its control. We will regard to weak points those where the plant could be naturally killed. Bulbs were planted in a plant nursery and in a farm at 1 and 7 cm depth. Sampling took over nine months, from March to November 1999 and it was done fortnightly. Every sampling date five bulbs from each three replicates were dug out and washed and their phenological state was noted down. The sampling showed a sequence of stages and steps morphologically very easy to separate. A eight stage cycle was determined, from activation of the bulbs to dormancy, that include active wait, roots and leaves are ready for elongation; root elongation, when roots grow longer; leave brotation, petiole elongation seeking the surface; emergence, eventual meeting of the petiole and leaflets with light; summer growth, externally the most active stage, when assimilation and multiplication, as well as flowering occur; and senescence, storage of useful metabolites from roots, stolons, petioles and leaflets and loss of these organs. In this cycle three mortal points had been observed. Death by starvation when trying to emerge, that could be caused by burial depth or any other way to obstruct the emergence of leaves; death caused by a severe drought in the early growing stages, when the bulbs have not recovered from the costs of the first leaves production and that is possible in Mediterranean climates; and death when bulbs get frozen with temperatures below 0°C, available in continental climates. These three strategic points could be used in different ways to try to control *O. latifolia* in an infested field.

318. *Delphinium occidentale* (Dunecap Larkspur) has Two Chemotypes that Differ in Biogeographical Distribution and Toxicity. Daniel Cook¹, Kevin Welch¹, Dale Gardner¹, Kip Panter¹, Ben Green¹, Jessie Roper¹, Jim Pfister¹; ¹USDA ARS Poisonous Plant Research Laboratory, Logan, Utah, United States of America

Larkspurs (*Delphinium* spp.) are poisonous plants found on rangelands in the western North America. They are responsible for significant losses to the cattle industry. Larkspur-induced poisoning is due to diterpenoid alkaloids produced by the plant. The norditerpene alkaloids are the most toxic of the diterpenoid alkaloids and are divided into two main structural groups, the N-(methylsuccinimido) anthranoyllycoctonine type (MSAL-type) and 7,8-methylenedioxylycoctonine type (MDL-type) norditerpenoid alkaloids. The MSAL-type alkaloids are the most toxic based upon the LD50 of the individual compounds when tested in mice. Plants high in the MSAL-type alkaloids are thought to be the most toxic to cattle and the concentrations of these alkaloids have been used as a predictor of plant toxicity. Recent research identified five accessions of *D. occidentale* that contained the MSAL type alkaloids and five accessions that contained very little or no MSAL type alkaloids. The objective of this study was to determine if the five accessions that exhibit the chemical phenotype lacking the MSAL type alkaloids are sporadic or if they are more widespread geographically. Electrospray mass spectrometry was used to define the chemical fingerprints of each specimen. We analyzed over 1200 specimens of *D. occidentale* representing approximately 500 herbarium specimens and 700 plants collected from 30 locations. We report here that *D. occidentale* has two defined chemotypes that have distinct geographical distributions. In addition, these chemotypes differ in their toxicity based upon the LD50 of a total alkaloid extract in mice. Furthermore, these results will be discussed in the context of the historical reports of cattle losses on high mountain ranges due to *D. occidentale*.

319. Effects of Nitrogen Fertilizer on Weed Density and Growth of Aerobic Rice. Sariam O.¹, Azmi M.¹; ¹Malaysian Agricultural Research & Development Institute, Kepala Batas, Penang, Malaysia

A wider range of weed species and more serious weed problems are found under aerobic rice system. Prolonged weed competition during critical period will usually affect the growth and yield of aerobic rice. A higher nitrogen (N) rate is normally applied to aerobic rice. Unfortunately, increasing N rate will also increase weed density. A field experiment was conducted in MARDI Seberang Perai during season 2007 to determine the effects of N rate on weed population density and the growth of aerobic rice. The N rate tested was 0, 60, 120, 180 and 240 kg/ha applied in four splits at 3, 35, 55 and 75 days after seeding (DAS). Rice variety MR 253 was row seeded, 25 cm between rows using seed rate of 120 kg/ha. The plot size of each treatment was 5 m x 5 m and treatments were arranged in a split plot design. Rice plant and weeds were sampled at 30, 55 and 80 DAS.

The weed dry weight sampled at all sampling dates did not differ significantly between N rates. However, it indicated an increasing trend, with the highest weight was at 240 kg N/ha during 30 and 55 DAS but at 180 kg N/ha during 80 DAS. The dominant weeds observed at all the sampling dates are the grasses which is more than 75% of the total weed density. This is followed by broadleaf weeds (8-21%) and sedges was the least (3-6%). *Paspalum vaginatum* was the dominant grassy weed observed at 30 DAS, *Leptochloa chinensis* and *Ischaemum rugosum* at 55 and 80 DAS, respectively. For the broadleaf, *Monochoria vaginalis* was the most common under aerobic condition. The rice-shoot dry weight at 55 DAS was significantly lower when weed was not controlled, but did not differ significantly at 30 and 80 DAS. However, rice-shoot dry weight was significantly influenced by N rate. A higher rate of N fertilizer application resulted in better aerobic rice growth and canopy coverage which helps suppress weed growth and density. From the study, weed density is not significantly affected by N fertilizer rates especially when the increase in N fertilizer also improved the growth of aerobic rice which indirectly reduce weed density .

320. Germinability of *Xanthium strumarium* Seeds from Different Parental Competition Conditions and Canopy Positions. Farnaz Kordbacheh¹, Hamid Rahimian-Mashhadi¹, Hassan Mohamad Alizadeh¹, Reza Tavakol-Afshari¹, Hassan Karimmojeny¹; ¹University of Tehran, Karaj, Tehran, Iran

The ambient condition to which the parent plant is subjected may influence the subsequent germinability of seeds. Seeds may experience different microenvironments depending on the crowdedness of neighbors and their position on the plant and, therefore, may show variation in germination response to such environments. This hypothesis was examined by conducting field and laboratory experiments in 2006 and 2007. *Xanthium strumarium* (cocklebur) was planted at 4, 8, 12 and 16 plant m² in competition with corn or at 4 and 16 plant m² without corn competition as monocultures. In 2006, seeds were collected from the whole plant canopy, while in 2007, the canopy of *X. strumarium* was divided into 6 stratified layers (including 0-90, 90-110, 110-130, 130-150, 150-180, >180 cm) and seeds were harvested from each layer separately. Seeds were then incubated at alternating temperature regime of 26/32°C under 16-h photoperiod. Germinated seeds were counted every other day for 14 d. The effect of competition on seed germination was only significant in 2005 but this response to competition intensity did not follow a predictable trend e.g. both the maximum(60%) and minimum(20%) germination percentages were observed at the tow highest planting densities of 16 and 12 plant m² (both with corn competition), respectively. Seeds from the upper canopy layers had significantly higher percent germination than those from

the lower ones. Generally, about 50% of the total layers germination occurred at the two uppermost layers of 150-180 and >180 cm, with four other basal layers contributed to the 50% of remainder germination. Seed germination rate response to competition and position on the plant was the same as for percent of germination. The result of this study demonstrated the importance of developmental microenvironment on seed germinability and may help to develop integrated programs for *X. strumarium* management.

321. Influence of Selected Environmental Factors on Seed Germination and Emergence of Major Monocotyledon Weed Species in Coconut Plantations. Sri Haren Sumith Senarathne¹; ¹Coconut Research Institute, Sri Lanka, Lunuwila, North Western, Sri Lanka

Weeds are a perennial problem in coconut plantations which causes significant losses in crop yields. The occurrence of a wide range of weeds also causes problems of eradication. The ecology of these species which are diverse and persistent has not been clearly identified. Thus, field, laboratory and green house studies evaluated the effect of three different environmental factors on the seed germination, emergence and survival of two major monocotyledon weed species in coconut plantations, namely *Panicum maximum* and *Pennisetum polystachyon*.

Germination percentage of *Panicum maximum* and *Pennisetum polystachyon* was very high in the absence of moisture stress (0.0MPa) and it was significantly reduced with increasing soil moisture stress, no germination was observed at -0.9MPa. Germination of both grass seeds ranged from 8% to 25% and 10% to 45% as moisture stress decreased from -0.4MPa to 0MPa (distilled water) respectively. *Pennisetum polystachyon* seeds germinated over a wide range of soil pH values with the highest germination occurring at pH 6. However, *P. maximum* seeds germinated successfully under acidic conditions and germination percentage was gradually decreased with increasing pH. In both species, seedlings emergence was very high when placed on the soil surface (0.5cm) and declined rapidly with increasing depth, where *P. maximum* seed germination was lower than that of *P. polystachyon*. The studies illustrate the adaptability of these persistent weeds to different environmental conditions which would enable the development of management strategies to reduce their populations below economic threshold levels in coconut plantations.

322. Nassella Trichotoma and Allelopathy; Effects on the Germination and Growth of two Native Australian Pasture Grasses. Aaron Simmons¹; ¹Charles Sturt University, Orange, NSW, Australia

Nassella trichotoma (serrated tussock) is an unpalatable grass weed that invades temperate pastures, and is a considerable problem in south-eastern Australia. It causes substantial reductions in production and is difficult and costly to control. *N. trichotoma* accumulates large amounts of senescent leaf material and has a large fibrous root mass, however, it is unknown whether the presence of *N. trichotoma* litter and roots affects the germination and growth of native Australian pasture grasses. Accordingly, two experiments were conducted to determine whether the roots or leaves of serrated tussock had a negative effect on the germination and growth of the C3 perennial grass *Microlaena stipoides* and C4 perennial grass *Chloris truncata*. In the first experiment, teas were made from the leaves and roots of *N. trichotoma* to examine the effects of chemicals present in *N. trichotoma* litter and roots on germination. Seeds of both native grass species were placed on filter paper moistened with the teas, or water as a control, in a petri dish and the numbers of seeds germinating in each petri dish recorded daily. Results suggest that although the final numbers of germinated seeds did not differ between treatments, germination was slower in petri dishes that were moistened with teas. For the second experiment, seeds were germinated in potting mix and then transplanted into separate pots and covered with *N. trichotoma* litter. After two months growth, the height, leaf width, root:shoot ratio and biomass of plants were measured. Results suggest that the presence of litter significantly affected the growth of native grasses. Although the differences found may be small the ecological implications of these results on the management of *N. trichotoma* may be significant and will be discussed.

323. Physiological Markers in *Amaranthus dubius* Mart., *Lycopersicon esculentum* Mill, *Phaseolus vulgaris* L, *Vigna unguiculata* L Walp under Phosphorus Stress. Olga Arnaude de Chacon¹, Jocelyne Ascencio²; ¹Universidad Nacional Experimental del Tachira, San Cristobal, Tachira, Venezuela; ²Universidad Central de Venezuela, Maracay, Aragua, Venezuela

In an experiment under greenhouse conditions the effect of phosphorus deficiency on the growth of *Amaranthus dubius* Mart., *Lycopersicon esculentum* Mill, *Phaseolus vulgaris* L y *Vigna unguiculata* L Walp was examined in order to find physiological markers for P-stress (P-deficiency). Plants were grown from seed in 900 ml pots filled with sterilized and decarbonated sand under a completed randomized experimental design, and supplied with Hoagland solutions with 1.0, 0.01 and 0.005 mM P during the whole experimental period. Three plants per treatment were harvested every third day during the exponential growth phase of each species for dry weights (organs and total), leaf area, P concentration in the dry matter, morphological studies of the root system (total length, mean diameter, volume and specific surface area)

and respiration in apical root segments were as well measured at three harvest dates. Results indicate that, relative growth rates and P-absorption indexes (mg P/g DW roots) decreased with age and P- deficiency, but significant differences were found between species, P-absorption capacity was significantly higher in the *Amaranthus dubius*. Not significant differences were found for total root respiration under P-stress, but the activity of the alternative cyanide resistant respiration pathway changed with species, plant age and P-treatment. According to the results, total leaf area, relative growth rates, P-absorption indexes and the activity of the alternative respiration pathway (specifically for *Amaranthus dubius*), may be used as adequate physiological markers for P-deficiency (P-stress) in screening programs.

324. Seed Germination of *Datura stramonium* as Affected by Parental Competition Intensity. Farnaz Kordbacheh¹, Hamid Mashhadi¹, Hassan Alizadeh¹, Reza Tavakol-Afshari¹; ¹University of Tehran, Karaj, Tehran, Iran

Seed germination and dormancy may be affected by the environment under which the seed developed on the parent plant. The effect of competition intensity on seed germination has rarely been studied. Thus, field and laboratory experiments were conducted in 2006 and 2007 to study the germination of *Datura stramonium* seeds obtained from different competition environments. In both years, *D. stramonium* was planted at 4, 8, 12 and 16 plant m⁻² in competition with corn or at 4 and 16 plant m⁻² without corn competition as pure stands. In 2005, from each plot seeds were collected at maturity and subjected to a germination test at alternating temperature of 26/32 under 16-h photoperiod. In 2006, *D. stramonium* canopy height was stratified into five layers of 90-110, 110-130, 130-150, 150-180 and >180 from which seeds were then collected and tested for germination as described above. Seed germination was affected by competition environment in both years but the results were not consistent across years. In 2005, percent germination increased with competition intensity, with minimum (20%) and maximum (55%) germinations for densities of 4 and 16 plant m⁻², respectively. In 2006, however, the lowest (38%) and highest (73%) germination percentages, respectively, were observed in seeds from plants grown in competition with or without corn at the same planting density of 4 plant m⁻². For both years of study, the results of seed germination rate were similar to those of percent germination. The particular position of seeds on the plant had no significant effect on germination characteristics i.e. seeds from different canopy layers had the same contribution (about 20%) to the total layers germination. The variation in seed germination of *D. stramonium* response to parental competition status, even though did not follow a predictable pattern, might be thought as an adaptive

strategy by which the weed can extend its regeneration niche, thus making its control difficult.

325. *Sorghum halepense* Displaces the Native Plants: the Possible Role of Allelopathy. Hongjuan Huang¹, Chaoxian Zhang¹, Qinghui Meng¹; ¹Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing, China (Peoples Republic of)

One of the most successful invasive weed species in China is *Sorghum halepense* (Johnson grass). This exotic species from the Mediterranean region produces many seeds and grows clonally via extensive rhizome production. The successful invasion of this weed is due to its higher growth rate, wider environmental adaptability, higher reproductive potential, better resource utilization. In addition, the allelopathic properties of *S. halepense* have been well documented. What has been lacking is evidence of negative effects of these allelochemicals in natural communities, particularly on native species undergoing invasions by this exotic grass. In agro-ecosystems, a number of weeds exhibit allelopathy against crop plants, and many of them, particularly invasive, have rather developed it as a successful strategy for their establishment. Not only living plants, even the weed residues that remain in the soil after completion of life cycle are inhibitory in nature. It is thus necessary to determine the allelopathic interference of *S. halepense* and its residues. This study evaluated the effects of *S. halepense* residues root decomposed in the soil on growth of the native crops including peanut, wheat, cotton and lettuce. In the greenhouse, the crops were treated with *S. halepense* residues root while control plants received water. The crops treated with residues root of *S. halepense* had significantly less biomass, seedling growth and fewer reproductive structures than control plants. Determining these allelochemicals may be leaving in the soil and what effects these toxins may have on growth of crops even after *S. halepense* is removed requires further study. Overall, these results suggest that allelopathy is contributing to the competitive success of *S. halepense* in the displacement of native crops in a natural community by inhibiting both overall biomass and the development of reproductive structures in the native crops. The potential impact this exotic allelopathic invader may have on the genetic diversity of crops requires consideration for successful restoration of currently invaded communities. The results implied that the allelopathy of *S. halepense* in part for the displacement of native plant.

326. Species Composition and Characterization of Weed Community in Oilseed Rape Fields in Hubei Province. Wei Shouhui¹, Zhu Wenda², Zhang Chaoxian¹; ¹Chinese Academy of Agricultural Sciences, Haidian, Beijing, China

(Peoples Republic of); ²Hubei Academy of Agricultural Sciences, Wuhan, Hubei, China (Peoples Republic of)

Weed survey was conducted by sampling methods of inverted W-pattern to determine the species composition and structure of weed communities in oilseed rape fields in Hubei Province. The results showed that 135 weed species (including varieties) belonging to 26 families and 74 genera were found. Among them, 8 species were considered as dominant weeds, including *Alopecurus aequalis*, *Veronica persica*, *Polypogon fugax*, *Malachium aquaticum*, *Beckmannia syzigachne*, *Galium aparine* var. *tenerum*, *Poa annua*, *Alopecurus japonicus*; 13 species were regional dominant weeds; 26 common weed species and 88 normal weed species. The overall abundance of *Veronica persica*, *Alopecurus aequalis*, *Polypogon fugax*, *Malachium aquaticum*, *Beckmannia syzigachne*, *Galium aparine* var. *tenerum*, and *Avena fatua* were relatively higher and were the main components of weed communities in all oilseed rape regions in Hubei province. Weed community is mainly consisted of *Alopecurus aequalis*, *Beckmannia syzigachne*, *Polypogon fugax*, *Malachium aquaticum*, in rice-wheat rotation fields, and *Veronica persica*, *Avena fatua*, *Galium aparine* var. *tenerum* *Mazus japonicus* in continuous drycrop fields. The species richness and diversity of weed community in oilseed rape fields in Jiangnan Plain region were higher than other regions, but the Simpson's index and evenness index was relatively lower. Based on the Sorensen's similarity index, the structure of weed community in Wehuang region was similar to that of rice-wheat rotation fields. The difference of weed occurrence and community structure might result from the crop type, farming system and edaphic condition.

327. The Advancing Sphere of Weed Dominance: Understanding Weed Biomass Allocation Strategies in Indian Dry Tropical Peri-Urban Region. Rup Narayan¹, Shachi Gupta¹; ¹I. P. (Post-Graduate) College, Bulandshahr, Uttar Pradesh, India

Human intervention has altered primary ecosystems into anthropoecosystems. This alteration of ecosystems by humans is most apparent in and around urbanizing landscapes, which account for 2% of the earth surface. Such landscapes have attracted cosmopolitan weedy flora that threatens surrounding natural habitats. Presently, few habitats exist on the earth without weeds. The advancing influence of botanical invaders has adversely affected the biodiversity reservoir that is discernible at different spatial scales. The exotic invaders may eliminate native species by shifting strategies of growth for optimum and efficient utilization of resources, thus widen areas of dominance. Ecological studies were carried out across various disturbed peri-urban habitats in Indian dry tropical region to understand the expanding sphere of weed dominance through their biomass allocation strategies. A total of 210

monoliths (each 400 sq. cm surface area and 20 cm depth) were extracted in three seasons, from four different sites namely, grazing land, bank of polluted river Kali, abandoned brick kiln and agricultural land, for above-ground and belowground biomass estimations. 240 individuals of three weeds *Parthenium hysterophorus* L, *Cassia obtusifolia* L. and *Chenopodium murale* L., representing different developmental stages and habitat conditions, were extracted and fractioned for estimating biomass of root, leaf, stem and reproductive parts. The surface soil samples from all sites and seasons (n = 48) were analyzed for soil moisture content, pH, organic C and total N. Predominant annuals in the weedy vegetation showed spatial and temporal dynamics with increasing dominance of exotic species like *Parthenium hysterophorus*. Diversity of weeds was higher at both low and high biomass production systems. The belowground allocation in dry and infertile soils was higher. Higher reproductive allocation by species was recorded in relatively more disturbed sites like abandoned brick kiln, whose soils showed lower soil moisture, organic C and total N. Allocational plasticity was observed to be higher in exotic invasive weed *Parthenium hysterophorus* compared to other weeds. The allocation of biomass to different plant components varied with weed species, ontogeny and with the environment experienced by the plants. In conclusion, weed dominance increased in open and disturbed habitats. Allocational shift by weeds appears to be an important strategy for their advancements in wide variety of environmental conditions.

328. Allelopathic Effects of Barley (*Hordeum vulgare*) on Germination and Growth of Wild Barley (*Hordeum spontaneum*). Zoheir Ashrafi¹, Hamid Mashhadi¹, Sedigheh Sadeghi¹, Hassam Alizade¹; ¹University of Tehran, Karaj, Tehran, Iran

Allelopathy is defined as the direct or indirect harmful or beneficial effects of one plant on another through the release of chemical compounds into the environment. Several phytotoxic substances causing germination and or growth inhibitions have been isolated from plant tissues and soils. Barley is well known for its allelopathic compounds. Several phenols and terpenes have been reported in various cultivars of Barley. Allelochemicals that inhibit the growth of some species at certain concentrations might in fact stimulate the growth of the same or different species at different concentrations. The objectives were to determine the effects of (i) preceding crops on germination and seedling growth of wild barley, (ii) fresh Barley residue incorporation on early growth of wild barley, and (iii) the effects of water extract concentration of various Barley parts on wild barley seed germination and seedling growth. Barley [*Hordeum vulgare*(L.) Koch.] contains watersoluble allelochemicals that inhibit the germination and growth of other species. This

characteristic could be used in weed management programmes. Greenhouse and laboratory experiments were conducted to determine the effects on wild barley (*Hordeum spontaneum* Koch.) germination and seedling growth of preceding crops, (ii) fresh Barley residue incorporation, and (iii) Barley leaf, stem, flower and root water extract concentrations.

Results and Discussions, Greenhouse experiments

Growth of Barley, as indicated by plant height and fresh weight of 35 days grown plant, was significantly reduced in soil previously cropped to Barley compared with that cropped to wild barley. However, the preceding crop did not affect Barley germination. In case of wild barley, differences in germination percentage, plant height and fresh weight per plant caused by preceding crops were all significant. All variables were significantly lower when the preceding crop was Barley than when it was wild barley.

Effects of residue incorporation

Wild barley germination percentage, plant height and dry weight of 35 days grown plant were all significantly lower with fresh Barley or wild barley residue incorporation than the controls, suggesting the presence of short-term allelopathic and autotoxic effects. However, germination and growth inhibition of wild barley were 16 to 28 % greater with Barley than with wild barley incorporation. Allelopathicity and autotoxicity were also greater when whole plants were incorporated than when roots only were incorporated. This response could be attributable to a greater contribution of allelochemicals from leaves or simply to the greater amount of residues incorporated with whole plants.

Laboratory experiment , Germination

Extracts from fresh Barley leaves, stems, flowers, roots and their mixture greatly inhibited wild barley seed germination at all concentrations compared to water control . Germination reductions ranged between 12 and 67 %. The degree of inhibition increased for all tissues with increase in extracts concentration from 4 to 20 g per 100 ml of water. Plant parts varied in their allelopathicity to wild barley germination. Leaf extracts had the greatest allelopathic potential at all concentrations and stems had the lowest. Leaf extract reduced germination by 34, 48, 53, 59 and 64 % at concentrations of 4, 8, 12, 16 and 20 g per 100 ml of water, respectively.

Seedling length

All extracts, except that of stems, significantly reduced hypocotyl length at all concentrations compared to water control (Table 4). Reductions ranged between 7 and 46 %. Hypocotyl length was not affected by stem extracts at any concentrations. For all other extracts, allelopathicity increased with increases in concentrations. At all concentrations, reduction was greatest with leaf extracts compared to extracts from other parts. Radicle length appeared more sensitive to allelochemicals than was hypocotyl length. Extracts from all plant parts caused a marked reduction in radicle length of wild barley seedlings, ranging between 11 and 55 % compared to water control.

Again, allelopathicity increased with an increase in extract concentration of all plant parts and was greatest with leaf extracts. Radicle length inhibition was lowest with root extracts. Besides the inhibition of radicle elongation, many of the extracts also altered radicle morphology, appearing distorted and twisted compared to control seedlings

Seedling weight

All Barley extracts caused a marked reduction in wild barley hypocotyl dry weight at all concentrations compared to water control, ranging between 30 and 77 % (Table 5). For all tissues, hypocotyl dry weight also decreased as the extract concentration increased. Leaf extracts were again the most inhibitory at all concentrations compared with the water control, and reduced hypocotyl dry weight by 58, 64, 68, 72 and 76 % at concentrations of 4, 8, 12, 16 and 20 g 100 ml per water, respectively. The response of wild barley radicles was similar to that of hypocotyls, although inhibition was somewhat lower, Barley extracts causing weight reductions ranging between 5 and 58 %.

329. Study of Effect of Vernalization on the Development and Growth of False Jagged-Ckicweed (*Lepyrodielis holosteoides* (C.A. Mey)). Zoheir Ashrafi¹, Hamid Mashadi¹, Hassan Alizadeh¹, Sedighe Sadeghi¹; ¹University of Tehran, Karaj, Tehran, Iran

Lepyrodielis holosteoides is an annual winter weed present in many winter and spring crops. The vernalization responses of populations of *Lepyrodielis holosteoides* were assessed using natural exposure during winter in two field experiments and using cold exposure of imbibed seeds in a refrigerator in two greenhouse experiments. It was observed that a period of chilling during the pre-germination phase had a marked effect on subsequent phenology. In the greenhouse, the major effect of vernalization was the reduction in the vegetative period because of an early reproductive induction of the apex. Plant morphology was affected by vernalization via a decrease in biomass resulting from a reduced tiller number. In all experiments, the time to panicle emergence and the number of leaves on the main stem were reduced by the chilling treatment in field and greenhouse experiments. *Lepyrodielis holosteoides* appears to be a species with a partial (quantitative) requirement for cold vernalization, but polymorphism for vernalization requirement was observed within and between populations. Depending on the sowing date, 850-1200C degree-days were required for flowering. The possible existence of different annual life forms within *Lepyrodielis holosteoides* is discussed.

Introduction.

Lepyrodielis holosteoides (false jagged-ckicweed) is generally described as a winter annual species, which over winters in a vegetative state and produces mature seeds in the summer (Stryckers & Delputte, 1965 *Lepyrodielis* is a member of the Pink family with a prostrate habit except

when given something to climb upon. *Lepyrodielis* infests grain and pea fields where it grows up and over crops forming a canopy that shades the crop from sun. *Lepyrodielis* occurs in grain fields and pea fields. To obtain a better linearization of the leaf number evolution, a thermal scale was chosen. The phyllochrons were calculated for each treatment in each experiment with different bases of temperature ranging from - 5°C to 7°C in 1°C increments. For each base temperature, the coefficient of variation for the mean phyllochrons obtained on the four different experiments was calculated. The lowest value of variability was obtained for positive base temperatures close to 0°C. Subsequently, for the studied populations of *Lepyrodielis holosteoides* and the experimental conditions used in this study, the base temperature used for calculating sum of day degrees from emergence was 0°C.

In all experiments, the time to panicle emergence and the number of leaves on the main stem were reduced by the chilling treatment in field and greenhouse experiments. *Lepyrodielis holosteoides* appears to be a species with a partial (quantitative) requirement for cold vernalization, but polymorphism for vernalization requirement was observed within and between populations. Depending on the sowing date, 850-1200 C degree-days were required for flowering. The possible existence of different annual life forms within *Lepyrodielis holosteoides* is discussed.

Discussion.

Under experimental conditions in this study, the *Lepyrodielis holosteoides* base temperature for accumulating day degrees from emergence was 0°C. In a previous study, a base temperature of 1°C was found for a population of *Lepyrodielis holosteoides* studied in different growth conditions (Chauvel et al., 2000). These low values for the base temperature are reasonable as *Lepyrodielis holosteoides* is preferentially a winter weed that is capable of early spring germination (Stryckers & Delputte, 1965; Harris et al., 1998). As with other annual weeds, *Lepyrodielis holosteoides* must complete its life cycle earlier than the crop. These experiments show that vernalization is one of the main factors that reduced the vegetative period and enhanced flowering induction. The greenhouse experiments showed a major effect of vernalization on development and morphogenesis. Vernalized plants were morphologically different (taller with more panicles) from unvernallized ones. These results are similar to those reported for *Bromus* species (Gleichsner & Appleby, 1996) and *Avena sativa* L. (King & Bacon, 1992). As observed in wheat, the phyllochron of *Lepyrodielis holosteoides* was not significantly affected by vernalization (Cao & Moss, 1991; Mosaad et al., 1995). Very low differences were observed in phyllochron values between populations, and the population sample was too low to observe variation, as has been shown previously for cultivars of wheat and barley (Frank & Bauer, 1995).

330. Investigation in Weed Communities Regarding Crop Type and Management. Maria John¹, Baerbel Gerowitt¹; ¹University of Rostock, Rostock, Mecklenburg-Western Pomerania, Germany

During the last decades weed species richness in fields has decreased as a consequence of intensive farming practices. The composition of weed communities has changed as well. The objective of this paper is to determine the existence of typical crop adapted weed communities in an intensive large-scale agricultural region in northern Germany.

The survey was carried out on 100 plots randomly distributed in the district of Doberan in Mecklenburg-Western Pomerania. Both conventional and organic fields grown with different crops like *Triticum aestivum*, *Secale cereale*, *Hordeum vulgare*, *Beta vulgaris*, *Solanum tuberosum*, *Zea mays* were surveyed. Herbicide abandoned plots were arranged to investigate species numbers, the species and their relative dominance. In addition to vegetation mapping, management and field data were collected.

Within the survey 119 weed species were identified in total. If the plots are grouped according to their long-term cropping management practices, differences in species numbers become noticeable. The average number of species was highest in organic fields with 19.6 species and lowest in sprayed plots of conventional fields with an average of 8.6 species. The unsprayed plots of conventional fields contained an average number of 17.3 species providing evidence for the existence of persistent species-rich soil seedbanks.

Dominance values of weeds in plots appeared from <1 % to 90 % dominance. Summer cereals had the lowest average of dominance of weed species with 18 %. Their rapid growth in spring favours weed suppressing. The unified group of crops including *Beta vulgaris*, *Solanum tuberosum*, *Zea mays* had the highest value of average dominance of species with 40 %. The named crops are rather weak in competition at the beginning of their life cycle.

Analysis of species richness and dominance values of weeds per plot showed a highly significant positive correlation (linear model, calculated with R [R 2.5.1, www.r-project.org]).

With the help of the Correspondence Analysis (CA) the surveyed plots can be compared according to differences in species compositions. The ordination occurs by means of gradients which results from abundance of species in the different plots. Composition of weed species differed significantly between winter cereals and all other crop types. Further partitioning of the other crop type was not successful. These two groups could be allocated to different sowing dates (winter and summer crops respectively).

Despite the clear findings regarding winter and summer sown crops there is still a high variation within the

composition of weed communities investigated. The strong variation indicates that site conditions are also of major importance for weed diversity.

331. Light and Temperature Influence on the Germination of the Weed *Borreria densiflora*. Bianca Martins¹, Daniela Neves¹, Pedro Christoffoleti¹; ¹University of Sao Paulo, Piracicaba, Sao Paulo, Brazil

The knowledge of germination has extreme importance to the understanding of weed dynamics, as well as to aid and complement information in weed management programs. Light and temperature ranges affect the germination processes, and therefore, the ecological adaptability of the weed species in the agro-ecosystems. The weed *Borreria densiflora* DC. has been presenting an increase on its infestation in soybean and sugarcane crops, in North and Northeast of Brazil. There is no information in the literature about the germination responses of this species in different light and temperature conditions. Based on that, the present study aimed to evaluate the germination of this species in five temperatures (constant 20°C, 25°C, 30°C, 35°C and alternated 20-30°C), in the presence of light (photoperiod of 12h-light/12h-dark) and constant dark, establishing a 5x2 factorial interaction, with four replications. The experimental design used was randomized complete blocks. The experiment was carried out in 2007, using germination chambers of the Seed Laboratory of the Crop Science Department, University of Sao Paulo, Piracicaba, Brazil. It was evaluated percentage of germination (PG) at 60 days after installation (DAI), and the germination speed rate (GSR) was calculated. Data were submitted to variance analyses by Tukey test (5%). It was concluded that this weed is a positive photoblastic species, since its germination is favored by presence of light. It was observed significant interaction for temperature within the light factor. At 60 DAI, the higher PGs and GSRs were reached under the higher temperatures (30°C, 35°C e 20-30°C); however, there were at least 25% of non germinated seeds, under those temperatures. It was not possible to develop an accurate procedure to realize the tetrazolium test on non germinated seeds to determine whether those seeds were viable and dormant or dead. The difficult of separate embryo from tegument was the obstacle, due to the very small size of the seeds (1.0 mm). These results showed that the population dynamics of *Borreria densiflora* DC. is influenced by higher temperatures, and conditions of high luminosity, justifying its occurrence in the tropical regions of Brazil. The knowledge of dormancy dynamics allows farmers predicting timing and extent of weed emergence. Therefore, future studies about the dynamics of dormancy presented by this species are necessary. Germination and dormancy data play an important role for future management decisions in those infested areas, leading to changes in current strategies of weed seed bank management.

332. Effect of Burial Depth on Seed Germination and Viability of Local Common Weeds of Wheat. Seyed Vahid Eslami¹, Fatemeh Afghani¹, Saeed Hosseini Bojd¹, Sohrab Mahmoodi¹; ¹The University of Birjand, Birjand, South Khorasan, Iran

Burial depth of seeds affects seed germination and seedling emergence and these depths vary in availability of moisture, diurnal temperature fluctuation, and light exposure. All these attributes of the micro-environment have the potential to influence the behavior of weed seeds. Seeds of four common weeds of wheat including hoary cress (*Cardaria draba*), downy brome (*Bromus tectorum*), mouse barley (*Hordeum murinum*) and knotweed (*Polygonum aviculare*) were after-ripened at different depths of soil (0, 2, 5, 10 and 20 cm) in the field. The seeds after burial were arranged in a randomized-block design with three replications. Knotweed and hoary cress showed the most and least dormancy amongst all studied weed species, respectively. In fact, hoary cress seeds did not show any obvious dormancy level from the beginning of the experiment and were able to show more than 80% germination when they were remained on the soil surface. In contrast, knotweed and downy brome exhibited a very low germinability (~1 and 10%, respectively) even following a 180-day after-ripening period in the field. Increasing the depth of burial (especially at 20 cm) had a negative effect on germination of hoary cress and mouse barley. Results showed that these seeds were more persistent at deeper burial depths, particularly at 20cm. This persistency clearly indicates that at deep soil depths, where there are less favourable conditions for germination, seeds are more persistent and hold their dormancy for a longer time. Our study suggests that burial of these seeds by deep tillage may prevent germination and help the seeds of these species to form long-lived seed banks allowing for reinfestations when seeds are brought to the surface by subsequent tillages.

333. Study of Desiccation and Freezing on Vegetative Reproduction of Russian Knapweed (*Acroptilon repens* L.). Reza Ghorbani¹, Mohammad Alebrahim¹, F. Maighani¹, Mohammad Rashed¹, M Baghestani¹, Mehdi Nassiri¹; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan, Iran

In order to examine the effect of desiccation and freezing on Russian knapweed (*Acroptilon repens*) root regrowth, two experiments on basis of completely randomized design were conducted in Weed Research Department, Plant Pests and Diseases Research Institute of Tehran in 2003. To examine the effect of desiccation, the first experiment was a factorial arrangement with 4 replications. First factor (A) was desiccation length time (control, 24, 48, 96 and 192 hours), and second factor (B) was desiccation temperatures (5, 15 and 25°C). To examine the effect of

freezing, second experiment was also a factorial arrangement with 4 replications. First factor (A) was the freezing length time (control, 24, 48 and 96 hours) and second factor (B) was freezing temperatures (-1 , -3 and -5°C). In the effect of desiccation experiment on root regrowth, factors A and B were significant on all of measured characters (water loss percent, shoot numbers, dry weight, leaf number and shoot length). Increasing in temperature and length time of desiccation leads to low regrowth. The interaction effect (AB) on water loss percent, shoot number and shoot length was significant. Regrowth stopped in 5°C after 96 hours desiccation and in 15°C and 25°C after 24 hours. In freezing experiment, factors (A), (B) and their interaction were significant on all of measured characters (shoot number, leaf number and shoot length). Decreasing in temperature and increasing in freezing length time, leads to low regrowth. Regrowth reduced in -1°C with decreasing storage period from 96, to 48 and 24 hours. However, regrowth stopped in -3°C and -5°C after 48 and 24 hours freezing, respectively.

334. Study of Phenological Stages in Russian Knapweed (*Acroptilon repens* L.). Reza Ghorbani¹, Mohammad Alebrahim¹, F Maighani¹, Mohammad Rashed¹, M Baghestani¹, Mehdi Nassiri¹; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan, Iran

Russian knapweed (*Acroptilon repens*) is a perennial and noxious weed. This experiment was conducted to determine phenological stages and their duration in an experimental plot based on degree-days. The Results indicated that emergence of root occurred in 0 degree-days, until 3823.3 and 8 phenological stage was recorded. These stages were shoot emergence from root, changing rosette to main stem, secondary shoot producing, main stem branching, bloom stage, flowering, flower drying and shoot yellowish. This study showed that the seeds of Russian knapweed could identify in bloom production stage. Seeds turned into milky stage at 10 days and matured at 30 days after blooming.

335. Seasonal Pattern in Seed Dormancy of *Parthenium hysterophorus* L. Arshad Javaid¹, Sobiya Shafique¹, Shazia Shafique¹; ¹University of the Punjab, Lahore, Pakistan, Lahore, Punjab, Pakistan

During the last century, parthenium weed (*Parthenium hysterophorus* L.) has spread from its endemic habitat, mainly the region around the Gulf of Mexico including West Indies and presumably central Argentina, throughout the tropics and has become a serious problem in many parts of the world including Pakistan. Most of the weed scientists focused their research on management of this noxious weed while knowledge about its regeneration biology is rather limited and conflicting. Earlier non-

conclusive results have been reported on the initial dormancy status of parthenium seeds. During various studies, we found different percentage and rate of germination of parthenium seeds in different seasons round the year. We hypothesized that initial dormancy in parthenium seeds could be dependant on various environmental factors viz. light, temperature, rainfall, humidity etc. during the seed formation period. The present study was, therefore, designed to investigate the seasonal dormancy pattern of parthenium in Lahore, Pakistan where there are four distinct seasons viz. summer, autumn, winter and spring in a year.

Mature parthenium seeds were collected on the last day of each month from January to December 2006 and investigations for their germination percentage and rate of germination were started on the next day. Data regarding different environmental conditions viz. minimum and maximum temperatures, solar radiation, humidity, precipitation and wind velocity were obtained from Pakistan Meteorological Department, Islamabad, Pakistan. Parthenium seeds collected during coldest months of January and December showed highest germination of 100% with germination rate of 33.3% per day. Conversely, seeds collected in summer months of April to September exhibited lowest germination of 0-7% and germination rate of 0-1.75% per day. Seeds collected in rest of the months showed variable final germination percentage and germination rate ranging from 30-97% and 3.8-17.4%, respectively. Both the final germination and germination rate showed a highly significant negative correlation with the solar radiation and environmental temperature during the seed development period. The final germination percentage as well as germination rate exhibited an insignificant negative correlation with wind velocity, total precipitation, number of rainy days and relative humidity

The present study concludes that parthenium seeds show a variable dormancy during different months of the year. Seed dormancy depends on the prevailing environmental conditions during the seed formation period and is negatively correlated with solar radiation and prevailing temperature.

336. Relationship between Crops, Weeds and Soil Factors: a Phytosociological Study. Christian Andreasen¹, Ib Skovgaard¹; ¹Faculty of Life Science, University of Copenhagen, Taastrup, Denmark

Ecological and phytosociological studies of weeds are necessary for understanding the relationship between crops and the weed flora. Weed communities are affected by the environment and studies of weed communities may increase our knowledge of the relationship between the weed flora, soil management, fertilizer usage and the use of herbicides. Analyses of spatial variation in multi-species weed communities together with environmental factors,

may be useful for developing a sustainable weed control and soil management strategy.

The aim was to illustrate the relationship between soil factors and the occurrence of weed species based on a weed survey in Denmark. By using cluster analysis we illustrate the relationship between various agricultural crops, and identify crops, which resemble each other with respect to their associate weed flora. Using cluster and correlation analysis, we illustrate how the incidences of 40 common weed species relate to each other and to important soil factors.

We present an analysis of species in eleven crops recorded 491 fields surveyed in 2001-04. The surveys were conducted between June and August. The fields were selected randomly according to a stratification scheme to ensure approximately equal geographical and crop-type representation. Each field was monitored once. The fields were in conventional agricultural use (tilled and sprayed with pesticides), but were unsprayed with herbicides in the survey area in the sampling years, such that the weeds had only been affected by the respective crops throughout the growing season. The frequency of weed species in a field was recorded by listing the presence or absence of each species in 20 randomly selected, circular sample plots of 0.1 m² within the field. Soil samples were taken in the uppermost 20 cm. Phosphorus, exchangeable potassium and magnesium, pH and total nitrogen and carbon and clay content in the soil were determined.

Cluster analysis based on the total flora was carried out to illustrate relations between crops; and a cluster analysis based on 40 species to illustrate the relation between the occurrences of these species. Statistical analyses were carried out for the 40 weed species occurring in at least 10 percent of the fields. The number of occurrences of a weed species among 20 random samples in a field, f , was assumed to follow a beta-binomial distribution. The probability P_f was modelled on a logistic scale, i.e.

$\text{logit}(P_f) = \ln[P_f / (1 - P_f)]$, by main effects of the factors and linear effects of covariates in the form $\text{logit}(P_f) = \ln[P_f / (1 - P_f)] = \text{year-effect crop-effect-soil-effect}$. Results are shown in cluster analysis dendrograms and tables.

337. Interaction between *Galium aparine* and *Lolium italicum* under Different Nitrogen Supply. Sava Vrbnicanin¹, Mirjana Kresovic¹, Dragana Bozic¹, Aleksandar Simic¹, Nenad Zivkovic¹; ¹University of Belgrade Faculty of Agriculture, Zemun-Belgrade, Serbia, Yugoslavia

This paper tests the hypothesis that increased soil nitrogen supply reduces the growth of late-emerging weeds (*Galium aparine*) in Italian ryegrass (*Lolium italicum*) seed crop by enhancing SPAD reading and nitrogen content in the crop. The SPAD-502 chlorophyll meter provides a simple, fast and non-destructive method for estimating relative amounts of leaf chlorophyll. The leaf SPAD reading gives a close correlation between leaf chlorophyll

content and leaf nitrogen concentration in a plant. Field trials were conducted on the private farm near Sabac, Serbia (44° 47'N, 19° 35'E, 83 m altitude), during 2006 in order to define the competitive ability between *G. aparine* and *L. italicum* to nutrition as affected by different level of nitrogen fertilization. The experiment was set as a randomized block design (4 crop densities: 5 kg ha⁻¹ of seeds/60 cm between row, 5 kg ha⁻¹/20 cm, 20 kg ha⁻¹/60 cm, 20 kg ha⁻¹/20 cm; x 4 level of nitrogen supply: 0 kg N ha⁻¹, 50 kgN ha⁻¹, 100 kgN ha⁻¹, 150 kgN ha⁻¹; x 4 plant sampling dates) with 10 m² plot size. The experiment was conducted in four replications. Italian ryegrass seed crop was established in October 2005. The established *G. aparine* densities varied between treatments, ranging from 10 to to 44 plants m⁻². The maximum density in the whole experiment did not exceeded 50 plants m⁻².

In both plant species (*G. aparine* and *L. italicum*) SPAD readings were moderately to highly positively correlated with level of leaf nitrogen content in all the plots (in all the crop densities and all the doses of fertilization). SPAD readings were higher in *L. italicum* in compared to *G. aparine* (42.93 to 56.86 by *L. italicum*; 35.02 to 48.86 by *G. aparine*) during the season (from tillering to flowering and spike formation).

Higher soil nitrogen supply increased the biomass of both plant species into all crop densities. However, as a consequence of dry period in May, a decrease of biomass per plant was recorded in the second sampling in both plant species and in all plots.

In the first sampling the level of leaf nitrogen content was high in both plant species (for example, at the supply of 150 kg N ha⁻¹ it ranged from 4.20 % to 5.04 % in *L. italicum*; and 3.24 % to 3.60 % in *G. aparine*, depending on crop densities). During the second and the third sampling a decrease was recorded, but in the final sampling an increased level of leaf nitrogen content was recorded again. Such trend could be explained as a result of drought in May and early June.

Conclusion based on the results: Nitrogen utilization is slightly better in *L. italicum* compared to *G. aparine* when the seed density is 20 kg ha⁻¹ with 60 cm of inter-row space.

338. Weed Flora of Gladiolus Fields in Punjab, Pakistan. Salik Khan¹, Tariq Riaz¹, Arshad Javaid¹; ¹University of the Punjab, Lahore, Punjab, Pakistan

Agriculture in the Punjab province is mainly confined to the cultivation of few major conventional crops including wheat, rice, cotton and sugar cane. However, growers in some parts of the Punjab, Pakistan have found that floriculture is capital intensive so they are switching to alternative crops. One of the members of family Iridaceae, Gladiolus has got a primer status among the floriculture crops in Pakistan. Many hybrids of Gladiolus are commercially cultivated by the growers of Punjab. Being

a newly emerging floral crop little is known about the weed flora associated with Gladiolus. Surveys of different Gladiolus growing areas of the province Punjab, Pakistan, were, therefore, undertaken during 2005-06 and again in 2006-07 to study the distribution of various weed species in Gladiolus fields. A total of 60 weed species belonging to 24 angiospermic families, were found growing in the fields of Gladiolus. *Ageratum conyzoides* L., *Amaranthus viridis* L., *Coronopus didymus* (L.) Sm., *Chenopodium album* L., *Chenopodium murale* L., *Convolvulus arvensis* L., *Cyperus rotundus* L., *Cynodon dactylon* Pers., *Poa annua* L., *Oxalis corniculata* L., *Rumex dentatus* L., *Melilotus parviflora*, L. *Cenchrus pennisetiformis* Hochest and *Eragrostis poaeoides* Beauv. were found to be the most prevalent weed species occurring in 90% or more studied areas during one or the other growing season. The frequently occurring weeds with absolute frequency above 40% were *C. didymus*, *C. arvensis*, *R. dentatus*, *C. pennisetiformis* and *C. dactylon*. *R. dentatus* was found to be the most frequently and densely populated weed species with absolute frequency of 57% and absolute density of 1.2 during 2006-07 growing season. Other densely populated weed species with absolute density above 0.50 were *A. conyzoides*, *C. didymus*, *C. arvensis*, *C. rotundus*, *Euphorbia prostrata*, *C. pennisetiformis* and *C. dactylon*. The results of the present study conclude that *R. dentatus*, *C. album*, *C. murale*, *M. parviflora*, *M. polymorpha*, *C. didymus* and *P. annua* were common in the Gladiolus fields of the surveyed areas. These weeds are also common weeds of wheat and some other winter crops growing in the area where they cause tremendous yield losses. It is, therefore, recommended to take measures to manage these weeds in the commercial fields of Gladiolus to improve quality and yield of this precious and popular cut-flower.

339. The Effect of Diurnal Temperature Fluctuations on Germination of Common Reed (*Phragmites australis*). Sedighe Sadeghi¹, Hassan Alizade¹, Zoheir Ashrafi²; ¹University of Tehran, Karaj, Tehran, Iran; ²Imp, A-CREAR, Karaj, Tehran, Iran

Fluctuation temperature is important factor initiating seed germination. The requirement for fluctuating temperature, however, is less clear as a predictor of soil seed bank occurrence. The germination of many ruderal and wetland species is stimulated by fluctuating temperatures. Near the soil surface, diurnal temperature fluctuate less below a vegetation cover, on under water, than on bare soil. Therefore, the requirement for fluctuating temperatures may stimulate seeds to germination in vegetation gaps and, in the case of wetland plants, in shallow water or on bottoms exposed to the air. Most studies on fluctuating temperature have concentrated on the effect of a series of increasing amplitudes. But there are few reports on the effect of an increasing number of fluctuations. *P. australis* is an amphibious grass with tall annual shoot emerging

from perennial underground rhizomes, often forming large monodominant stands in wetlands of many parts of the world numerous small seeds are produced annually, but they are scarce or absent in the persistent soil seed bank. Although germination of *P. australis* has received attention relatively little information is available on germination responses to fluctuation temperature and the possible requirement for, and interactions with light. In a previous study, it has been shown that germination of *P. australis* required a high amplitude (>10°C) of fluctuations over a wide range of mean temperatures, rather than a requirement for a high temperatures. We did one germination experiments with *P. australis* seeds from a Iran population. In the experiment, we quantified the size of the amplitude on germination.

Materials and methods

Seeds of *P. australis* were collected in Khoozestan province. The position Khoozestan province is est. south of Iran. All panicles were randomly collected in colonies of *P. australis* on two stage and dried at room temperature (25 °C) for 2 weeks. Seeds were separated from the panicles by blending pieces of panicles in tap water. The seeds were allowed to the bottom of glass vials (1000cc). The seeds dried on filter paper at room temperature for about 12 h and separated from any remaining panicles material. The process from mixer to drying on filter paper required about 15 min. Small seeds (length < 1 mm) and seeds that were not fully development, were discarded. The germination response were examined to temperature fluctuation in three trial with different minimum temperatures (8, 15, and 22 °C). In the first trial the minimum temperature was set 8°C with fore maximum component of (8, 15, 22 and 29°C), in the second trial the minimum temperature was set 15°C with three maximum component of (8, 15 and 22°C) and in the third trial the minimum temperature was set 22°C with two maximum component of (8 and 15°C). therefore, temperature treatments were including (8-8°C), (8-15°C), (8-22°C), (8-29°C), (15-15°C), (15-22°C), (15-29°C), (22-22°C) and (22-29°C). The thermoperiod was 12 h. The experiment was done in August 2007, on seeds collected in September 2006. Three batches of 20 seeds were used in each treatment (3*20*9 temperature regimes = 540 seeds). The three seed batches were considered replication in the subsequent analysis. The number of germinated seeds was counted often 7 d. a seed was considered to have germinated when the radical had emerged through the seed coat.

Result

Germination often 7d was low at constant temperature, but it increased with an increase in amplitude of temperature fluctuation. The effect of increased amplitude, which in this case also led to increased mean temperature, was highly significant in the trial with 8°C and 15°C minimum temperature. This experiment was conducted on seeds that had been stored for 15 months.

A parallel test with fresh seeds from the some population did not reveal any significant differences from stored seeds. (Data not shown)

340. Factors Affecting Weed Community Dynamics in Sugarcane Cropping Systems of Northern Argentina. Diego Ferraro¹, Darío Rivero¹, Claudio Ghersa¹; ¹Facultad de Agronomía, Universidad de Buenos Aires/CONICET, Buenos Aires, Argentina

Sugarcane production in Argentina is restricted to northern areas of the country, originally covered by forests. Yields and management intensity levels are frequently high. However, weeds are still a major problem, and the hierarchy of factors affecting weed communities is still poorly understood. This study is aimed at determining the magnitude of temporal changes in composition of weed community in sugarcane fields, and environmental and management factors that drive these changes. We surveyed 91 crop fields in farms of Northern Argentina during the spring of 2004 and 2005. Change in species composition was assessed using the interannual euclidean distance of each crop field along the non-metric multidimensional scaling (NMS) ordination space. Distance values were clustered in three different groups (i.e. low, medium and high change) through a k-means cluster algorithm. Classification and regression trees (CART) were used for partitioning the clustered groups of weed community change into subsets with the highest attainable homogeneity defined by several explanatory factors. The explanatory factors for each crop field were: 1) farm; 2) crop variety; 3) area; 4) number of ratoon crops; 5) month of harvest; 6) number of herbicides applied; 7) geographical coordinates; and 8) biomass yield. NMS ordination using presence-absence and abundance data explained 76% and 77 % of weed community data, respectively. Final CART configuration explained 44% of the variation in the presence-absence weed clusters. The first tree splitting variable was farm and the model also included latitude, number of ratoon crops and field crop area. When the contribution of explanatory factors to the construction of the whole tree was assessed the number of ratoon crops was the most important factor. Final CART configuration explained 49% of the variation in the presence-absence weed clusters. However, in this case, sugarcane biomass yield was the most important factors for node splitting. Other variables included in abundance CART model were farm and crop variety. NMS and CART models used in this study were able to explain almost 50 % of weed composition changes due to several explanatory factors. Moreover, CART models suggested different controls for both changes in presence and abundance in sugarcane weed communities. However, patterns emerged from this exploratory study should be further examined using larger databases. Although CART are not inference tools, their results can be very useful for suggesting futures mecha-

nistic studies and designing more comprehensive weed management decision for the sugarcane farming systems.

341. *Borreria densiflora* Emergence as Affected by the Interaction between Seed Burial and Presence of Crop Residue on the Soil Surface. Bianca Martins¹, Daniela Neves¹, Pedro Christoffoleti¹; ¹University of Sao Paulo, Piracicaba, Sao Paulo, Brazil

The weed *Borreria densiflora* DC. is becoming common in soybean and sugarcane crops, in North and Northeast of Brazil. This weed has been presenting difficulties to be controlled in those fields. A greenhouse experiment was conducted to determine the effect of the interaction between seeding depth (0; 0.5; 1 and 2cm) and presence of crop residue in the soil surface in different amounts (0; 1,000; 2,000 and 4,000 kg.ha⁻¹) on the emergence of the weed. The study was conducted in 2007, in the greenhouse of the Crop Science Department, Piracicaba city, Brazil. The experimental design used was complete blocks, in a 4x4 factorial combination, and four replications. It was evaluated percentage of emergence (PE) and fresh shoot biomass (g) - FB - at 25 days after installation (DAI) of the experiment. Data were submitted to variance analyses by Tukey test (5%). The increase in both factors, seeding depth and presence of crop residue, resulted in the decrease of *B. densiflora* DC. emergence. Since 1 and 2cm, PE and FB was not influenced by the interaction; for 0.5cm, only the highest amount of crop residue showed lowest means in comparison with the others. For presence of crop residue of 0; 1,000 and 2,000 kg.ha⁻¹, PE and FB showed the same decrease as the seeding depth increased. The amount of 4,000 kg.ha⁻¹ reduced PE and FB in 100% since 0.5cm of seeding depth. As showed, the lowest seeding depth the higher PE and FB of *B. densiflora* DC. It is known that no-till concentrate seeds in lower soil depths, however, the presence of crop residue may be an advantage in this weed management in medium and long term, due to the more rapid decrease in the number of seeds in the seedbank, through processes like germination, predation, and deterioration. Although we observed the influence of those factors interaction, it was not observed 100% of emergence in any interaction. More studies must to be carried out in order to determine weather those non emerged seedlings did not germinate or did germinated but died right after that due to the lack of reserves to pass over the crop residue, since the seeds are small (1mm) and positive photoblastic. This fact leads to think also about the mechanism of dormancy, that is, those non germinated seeds might have become part of a more persistent seedbank. This information may help the understanding of *B. densiflora* DC. seedbank dynamics. These observed results are important to favor weed control timing decisions and provide data to enhance the integrated control of this problematic weed.

342. Exploring the Mechanisms Underlying the Critical Period for Weed Control in *Zea mays* (L.). Eric Page¹, Matthijs Tollenaar¹, Elizabeth Lee¹, Lewis Lukens¹, Clarence Swanton¹; ¹University of Guelph, Guelph, Ontario, Canada

Previous research has demonstrated that early season weed interference can significantly affect *Zea mays* L. (maize) growth, development and yield. It has been hypothesized that early detection of weeds through reflected light quality (i.e. the ratio of red to far-red light or R:FR), may be an important mechanism affecting the onset and outcome of crop-weed competition. The objectives of this research were to quantify the impact of early season weed interference on maize growth and development during the critical period for weed control. A maize hybrid was grown in a greenhouse under ambient and reduced R:FR conditions, simulating weed-free and weedy conditions, respectively. These light quality environments were established by planting maize seeds in pots surrounded by surface (a baked clay medium with high or ambient R:FR) or commercial sod (low R:FR), such that there was no below ground competition. Using these two light environments, a classical critical period experiment was conducted with weed-addition and -removal series. Five weedy or weed-free durations were used in each series (E.g. Weed removal series: 0, 3, 6, 9, 12 or 15 days weedy). Maize seedlings were harvested 15 days after emergence. Seedling biomass and leaf area decreased linearly as the duration of weed competition increased in the weed-removal series. In contrast, weed addition following a weed free period had little impact on either of these parameters. These results suggest that the detection of weedy competitors occurs during the very early stages of maize development (~3-4 leaf tips). Furthermore, effective weed control at or near the time of crop emergence may reduce the impact of subsequent weed emergence events.

343. Seed Dynamics of the Invasive Geophyte *Lilium formosanum* on Lord Howe Island, Australia. Susie Warner¹, Anthony Grice²; ¹CRC for Australian Weed Management, Townsville, Queensland, Australia; ²CSIRO, Townsville, Queensland, Australia

Weeds pose a significant threat to the conservation values of islands, many of which have histories of high extinction rates. *Lilium formosanum* (Taiwan lily) is naturalised and widespread in native ecosystems on the World Heritage Listed Lord Howe Island. There have been no studies of Taiwan lily as an invasive species and very little research on ways to effectively manage geophytic weeds in general. There is a need for basic ecological studies on geophytic weeds to help focus management actions. Within the current study we describe and quantify, at both plant and population levels, the seed production,

seed viability and longevity of seed in the soil of this invasive geophyte, Taiwan lily.

Ten sites were selected across the island where infestations were present. Plants were individually tagged and monitored by measuring plant height, shoot basal diameter, flower number and capsule number. Seed bags were placed over capsules to collect seed for visual assessment and counts, as well as to test seed for germinability and longevity. Seed longevity testing was conducted under both field and laboratory conditions.

Results indicate seed production and levels of seed viability are high. Viability of fresh seed is high, but under typical field conditions, the majority of these germinate within 3 months or decay in the leaf litter and sub-soil environments within one year. The wind-dispersed seeds are most likely responsible for the majority of the long-distance dispersal of naturalised populations, and drive establishment of new infestations. Once established, continued persistence of infestations relies on a 'bulb-bank' rather than a seed-bank. Implications from this study suggest management of *L. formosanum* should focus on curtailing seed production and removing established plants to prevent further long distance dispersal events. The major management issue of invasive geophytes such as *L. formosanum* is reduction of the 'bulb-bank'. This presents a much greater challenge for weed managers and current research is examining methods to effectively control underground storage organs of invasive geophyte species.

344. Shoot Damage Affects Growth of *Lilium formosanum* on Lord Howe Island, Australia. Susie Warner¹, Anthony Grice²; ¹CRC for Australian Weed Management, Townsville, Queensland, Australia; ²CSIRO, Townsville, Queensland, Australia

Geophytes are plants whose shoots die off during unfavourable seasons then regrow using resources stored in underground organs. The resources captured in their underground storage organs ensure rapid growth during favourable conditions and give them a competitive advantage over slower growing species. Management options for such species need to target both above and underground reproductive capacity. Within the current study we considered management options for Taiwan lily, an invasive perennial geophyte introduced to eastern Australia as an ornamental plant from its native Taiwan. It is especially prevalent on the World Heritage Listed Lord Howe Island (LHI), 720km off the eastern Australian coast. It poses a threat to the island's many endemic and other native species and unique habitats. The species' life-cycle traits (e.g. high seed production, wind-dispersed seeds, and capacity to sequester and store resources in underground organs) and broad ecological tolerances have allowed it to spread to virtually all habitats, it is especially abundant on open cliffs, ledges and dunes which provide

niches for many endemic species. Currently, there are few practical management options. Informal, manual control on LHI involves breaking off or pulling up shoots. The current study was undertaken to determine whether shoot damage is an effective control method. We investigated the effects of four levels of shoot damage on shoot and bulb dynamics. Results to date show that shoot removal curtails seed production and disrupts photosynthesis in the season of treatment. Bulb size in the subsequent season is reduced by approximately 50% and this is associated with reduced shoot size. These results indicate a role for manual control even though one-off treatments generally do not kill the plant. Manual treatments may be practical where sites are difficult to access and herbicides may damage non-target species. Weed management methods as demonstrated within the current study may also have implications for other invasive geophytes, especially in areas of high conservation value.

345. Assessment of the Weed Seed Production in Maize Crop Managed with Different Agricultural Practices. Federica Graziani¹, Euro Pannacci¹, Gino Covarelli¹; ¹University of Perugia, Perugia, Italy

Weed seed production is an important and complex element of the weed seedbank dynamics and a deep knowledge of the effects of different management factors is essential for the development of better strategies to reduce weed seedbanks. The control of spring-summer weeds in the Mediterranean area is important as these species contribute mainly to the increment of weed seedbank due to high rate of emergence and greater seed production potential. A 2-year maize-wheat crop rotation was carried out in order to determine the effects of different agricultural management practices (i.e. conventional, low input and organic) on weed density and relative weed seed production. The experimental trial was carried out from 2005 to 2007 in central Italy (42°57'N-12°22'E, elev.165m) on a clay-loam soil. In each year a randomized block design with 3 replicates was used and the treatments compared in maize-wheat crop rotation were: a) mineral N (240 kg/ha in maize and 150 kg/ha in wheat) applied in the untreated weed check and in the chemical weed control (pre-emergence in maize and post-emergence in wheat) attributable to conventional practices; b) mineral N (160 kg/ha in maize and 100 kg/ha in wheat) applied in mechanical weed control (hoeing ridging in maize and spring-tine harrowing in wheat) attributable to low input practice; c) organic N (160 kg/ha in maize and 100 kg/ha in wheat) applied in mechanical weed control (hoeing ridging in maize and spring-tine harrowing in wheat); d) organic N (80 kg/ha in maize and 50 kg/ha in wheat) applied in the untreated weed check and attributable to organic practices. The assessment of weed seed production was carried out in 2005 and in 2007 on spring-summer weed species in maize. The results obtained in 2005 show that different

rates and forms of N did not influence significantly weed density and seed production (42428 seeds/m² with 240 kg/ha of mineral N and 46669 seeds/m² with 80 kg/ha of organic N) even if the weed biomass was different (242 g/m² with 240 kg/ha of mineral N and 125 g/m² with 80 kg/ha of organic N). The higher seed production value in low organic N (46654 seeds/m²) was confirmed in 2007 and was due, in both years, mainly to the broadleaved weed species, highlighting the ability of *Portulaca oleracea*, and *Polygonum lapathifolium* to take advantage of low and slowly available N level. Mechanical weed control allows a strong reduction of weed seed production (up to 6 times less) compared to results obtained in the untreated check, proving to be a good means to contain weed flora which could increase in organic agriculture.

346. Effect of Corn Density and Spatial Arrangement on *Amaranthus retroflexus* L. (Redroot Pigweed) Growth Indices. Alireza Yadavi¹, Majid Agha Alikhani², Amir Ghalavand², Heshmat Omid³; ¹Yasuj University, Yasuj, Kohgiluyeh va Boyer Ahmad Province, Iran; ²Tarbiat Modares University, Tehran, Tehran Province, Iran; ³Shahed University, Tehran, Tehran Province, Iran

In order to study the effect of corn density and spatial arrangement on growth and physiological indices of *Amaranthus retroflexus* L. a field experiment was carried out at Esfahan agricultural research station 2003. Treatments were arranged in a factorial split experiment based on RCBD with three replications. Factorial arrangement of corn densities (74000 and 111000 plant ha⁻¹) and planting patterns (single row, rectangular twin row and zigzag twin row) formed the main plots. Split-plots referred to *Amaranthus retroflexus* L. densities (0, 4, 8 and 12 plant m⁻¹). In addition three experimental plots *Amaranthus retroflexus* L pure stand (4, 8 and 12 plant m⁻¹) established in each block. In order to determine *Amaranthus retroflexus* L. leaf area and dry matter accumulation, destructive sampling of *Amaranthus retroflexus* L. started at 29 days after corn emergence with 14 days interval. Results indicated that *Amaranthus retroflexus* L. leaf area index (LAI), total dry matter accumulation (TDM) and weed growth rate (WGR) decreased in corn existence. More corn density, more decrease in weed growth, in such a manner dense corn population, lead to 26.2, 16 and 19.7 percent loss in *Amaranthus retroflexus* L. LAI, TDM and WGR respectively. These indices influenced more by corn twin row patterns compare to single rows, also effects of zigzag twin row were higher than rectangular twin row, in such a manner in the highest pigweed density, zigzag twin row reduced *Amaranthus retroflexus* L. LAI, TDM and WGR about 7.9, 4.1 and 6.1 percent more than rectangular twin row pattern. Finally results showed that corn planting pattern effect on pigweed growth indices were lower than corn density. So extending of twin row patterns with

increase density of corn can develop its competition ability and suppress the *Amaranthus retroflexus* L. growth without chemical herbicide application

347. Growth Dynamics of *Ambrosia artemisiifolia* L. in Response to Plant Density and Mowing. Cristina Patracchini¹, Francesco Vidotto¹, Silvia Fogliatto¹, Aldo Ferrero¹; ¹AGROSELVITER, Università di Torino, Grugliasco, To, Italy

Ambrosia artemisiifolia L. (common ragweed) is an annual species of the Asteraceae family originating from southern North America. This plant, which was introduced in Europe in the early 1940s, is nowadays one of the major causes of summer pollinosis in several European countries. In Italy, *A. artemisiifolia* distribution includes mainly the northern regions. Since the mid-1990s, the species has been increasingly reported as a weed of annual summer crops, even in regions where it has been present for decades only in field edges or in non-agricultural areas. This trend suggests the need to obtain more information on the growing behaviour of *A. artemisiifolia* from a weed ecology perspective. The objectives of this research were to assess the effect of plant density on plant growth dynamics and to study the response of the plant to mowing. Two field experiments were carried out in 2006-2007, starting from a natural infestation of more than 300 seedlings/m². In the first experiment, seedlings were thinned to densities of 4, 12.5 or 25 plants/m², arranged according to a RCB design with 3 replicates. Plant height, biomass, number of leaves and leaf area were measured weekly on 3 plants per plot, starting from the 2-leaf stage until seed production. In the second experiment, a single starting density of 12.5 plants/m² plants was considered. The plants were mowed, cutting them at 3 cm from the soil at different growth stages: 20 cm (3 cuttings in total per season), 50 cm (3 cuttings) or 80 cm (1 cutting) plant height. Treatments were arranged according to a CR design with 3 replicates. The percentage of surviving plants and the number of flowered plants per unit area were assessed.

Thanks to more favorable meteorological conditions, plant growth was significantly higher in 2007. In both years, plant height was not influenced by density during the entire considered period. Final height ranged from 105 to 110 cm. The number of leaves per plant and the leaf area per plant were inversely related to density. In particular, 2,100 (in 2006) and 4,400 (2007) leaves per plant and 5,600 (2006) and 12,900 (2007) cm²/plant were recorded at 4 plants/m². The number of leaves per unit area peaked 12,400 (2006) and 44,300 (2007) at 25 plants/m² and was directly related to density. Similar behaviour was observed for LAI, that reached 4.5 (2006) and 12.8 (2007) at 25 plants/m². The biomass per plant was similar between densities until about 90 days after emergence and then significantly higher at 4 plants/m².

Mowing resulted only in a partial reduction of the surviving plants. Even in the most disturbing conditions (mowing at plant height of 20 cm), total plant density was lowered only by about 30%. The number of flowered plants ranged from 60% to 78% of surviving plants and was not related to the treatment.

A. artemisiifolia showed a high plasticity in the response of the main growth parameters to different pure-stand densities. This plasticity was consistently recorded, despite a remarkable difference between years, in total plant growth. Mowing resulted in reduction of plant density but did not prevent flowering.

348. Acclimation of *Amaranthus palmeri* to Shading. Prashant Jha¹, Jason Norsworthy², Douglas Bielenberg¹, Melissa Riley¹, Mayank Malik¹; ¹Clemson University, Clemson, South Carolina, United States of America; ²University of Arkansas, Fayetteville, Arkansas, United States of America

Amaranthus palmeri (Palmer amaranth), a dioecious summer annual, is one of the most problematic weeds in row crop production in the southeastern United States. Characterizing the physiological and morphological response of *A. palmeri* to shading would improve our understanding of crop-weed competition and weed population dynamics. The objectives of this research were to 1) investigate the effects of shading on *A. palmeri* photosynthetic light response and 2) describe *A. palmeri* physiological and morphological characteristics typically associated with shade acclimation. Experiments were conducted in June and July 2007 at Clemson, SC. Plants were grown in the field beneath black shade cloths providing 47 and 87% shade and in full sunlight (no shading). *A. palmeri* photosynthetic rate at the highest measured PAR (1200 $\mu\text{mol}/\text{m}^2/\text{s}$) was 45.8 and 42.4 $\mu\text{mol}/\text{m}^2/\text{s}$ in 0 and 47% shade, respectively, and was reduced to 24.9 $\mu\text{mol}/\text{m}^2/\text{s}$ in 87% shade. Light-saturated photosynthetic rates were predicted to occur at intensities of 2953 and 2865 $\mu\text{mol}/\text{m}^2/\text{s}$ PAR for plants grown under 0 and 47% shade; however, 1388 $\mu\text{mol}/\text{m}^2/\text{s}$ PAR were predicted to cause light-saturating photosynthetic rates in plants grown under 87% shade. Plants acclimated to increased shading by decreasing light-saturated photosynthetic rates per unit leaf area from 60.5 to 26.4 $\mu\text{mol}/\text{m}^2/\text{s}$. Rate of increase in plant height was similar among shade levels. Plants responded to increased shading by a 13 to 44% reduction in leaf appearance rate (leaf number/GDD) and a 22 to 63% reduction in main stem branch appearance rate (main stem branch number/GDD) compared with full sunlight. *A. palmeri* specific leaf area increased from 68 to 97 cm²/g as shading increased to 87%. Plants acclimated to 47% shade by increasing total leaf chlorophyll from 22.8 $\mu\text{g}/\text{cm}^2$ in full sunlight to 31.7 $\mu\text{g}/\text{cm}^2$ when shaded. However, plants grown under 87% shade failed to increase leaf chlorophyll content, which resulted in reduced photosyn-

thetic rates. In conclusion, *Amaranthus palmeri* is well adapted to elevated PAR environments. Photosynthetic efficiency of plants was reduced under 87% shade, but plants showed some physiological and morphological acclimations to shading.

349. Glucosinolate Profile Variations among Different Accessions and Growth Stages of *Raphanus raphanistrum*.

Mayank Malik¹, Jason Norsworthy², Melissa Riley¹, Prashant Jha¹; ¹Clemson University, Clemson, South Carolina, United States of America; ²University of Arkansas, Fayetteville, Arkansas, United States of America

Raphanus raphanistrum L. (Wild radish), a member of the Brassicaceae family, produces several glucosinolates. These glucosinolates play an important role in weed, insect, and pathogen suppression when converted to isothiocyanates following tissue maceration. Experiments were conducted to (1) quantify the glucosinolate content and composition at different growth and developmental stages of *R. raphanistrum* and (2) compare the glucosinolates at flowering stage among different accessions of *R. raphanistrum*. *R. raphanistrum* seeds collected from South Carolina were planted in pots, placed in a growth chamber, and harvested at five growth stages: cotyledon, 6- to 8-leaf stage, bolting, flowering, and 50% silique formation. Seeds of 15 *R. raphanistrum* accessions were collected from states of Alabama, Florida, Georgia, Maine, Mississippi, New York, North Carolina, and South Carolina in the United States. Glucosinolate profiles were compared in roots, shoots, primary branches, and flowers harvested at flowering stage using High Performance Liquid Chromatography.

The total glucosinolate concentration ranged from 19 $\mu\text{mol/g}$ in shoots at the 6- to 8-leaf stage to a high of 182 $\mu\text{mol/g}$ in flowers at the flowering stage. The glucosinolates 4-(methylthio) butyl, benzyl, 4-(methylsulfinyl) but-3-enyl, indol-3-yl methyl, and 2-phenylethyl glucosinolates were the most common from the cotyledon to the flowering stage. Individual glucosinolate concentrations ranged from 0.5 $\mu\text{mol/g}$ to 157 $\mu\text{mol/g}$. Three additional glucosinolates, 3-(methylsulfinyl)-propyl, 4-(methylsulfinyl) butyl, and p-hydroxy benzyl glucosinolate, were identified at 50% silique formation stage, ranging from 0.1 $\mu\text{mol/g}$ to 6 $\mu\text{mol/g}$. The highest concentration of glucosinolates was found in flowers at the flowering stage followed by primary branches and shoots. Accumulation of 4-(methylthio) butyl glucosinolate at various growth stages was 157 $\mu\text{mol/g}$ in flowers followed by 138 $\mu\text{mol/g}$ in the primary branch and 48 $\mu\text{mol/g}$ in shoots. Seventeen glucosinolates were identified at the flowering stage among different accessions of *R. raphanistrum*. 4-(Methylsulfinyl)but-3-enyl, 4-(methylthio) butyl, 3-indolmethyl, and 2-phenylethyl were the dominant glucosinolates present in all the organs and accessions, ranging from 0.08 $\mu\text{mol/g}$ to

63.41 $\mu\text{mol/g}$. The highest total glucosinolate accumulation occurred in flowers from all accessions, with the concentration ranging from 44.36 $\mu\text{mol/g}$ in an Alabama accession to 115.89 $\mu\text{mol/g}$ in a Mississippi accession. The knowledge of glucosinolate accumulation in different organs and growth stages of *Raphanus raphanistrum* will help us better utilize its allelopathic potential.

350. Vernalization Responses of Jointed Goatgrass, Wheat and Wheat by Jointed Goatgrass Hybrid Plants. Elena Sanchez Olguin¹, Lynn Fandrich¹, Carol Mallory-Smith¹, Jennifer Hansen², Robert Zemetra²; ¹Oregon State University, Corvallis, Oregon, United States of America; ²University of Idaho, Moscow, Idaho, United States of America

Aegilops cylindrica Host (jointed goatgrass) infestations in *Triticum aestivum* L. (wheat) from the Pacific Northwest have resulted in multi-million dollar losses in the *T. aestivum* market. Because *A. cylindrica* is a winter annual, the use of spring *T. aestivum* is one management tactic for *A. cylindrica*. However, the repeated use of spring *T. aestivum* could shift *A. cylindrica* populations in favor of a spring habit. The study of vernalization requirements and vernalization genes in *A. cylindrica* will help to evaluate the effectiveness of spring *T. aestivum* as a control tool. A greenhouse study was established to compare the reproductive responses of five *A. cylindrica* populations, winter *T. aestivum*, spring *T. aestivum*, and *A. cylindrica* by *T. aestivum* reciprocal hybrid plants to different vernalization conditions. Variability in the vernalization response among the *A. cylindrica* populations was observed. All spring *T. aestivum* and spring *T. aestivum* related hybrid plants were vernalization insensitive. Plants of one *A. cylindrica* population, winter *T. aestivum*, and winter *T. aestivum* related hybrids were unlikely to reproduce in the absence of vernalization. Plants from the other four *A. cylindrica* populations reproduced in the absence of vernalization, but at lower levels than spring *T. aestivum*. Winter *T. aestivum* and *A. cylindrica* plants that entered their reproductive phases together, as measured by the first reproductive node, were no longer in synchronous development at anthesis. Our results reveal that the reproductive behavior of vernalized *A. cylindrica* plants at anthesis is one to two weeks delayed compared to vernalized winter *T. aestivum* and related hybrid plants. Differences in vernalization requirements among *A. cylindrica* populations and the frequencies of the vernalization genes within each population will determine the effectiveness of this management strategy for *A. cylindrica*.

351. Response to Light Quality As a Competitive Mechanism: Biomass Partitioning Associated With Shade Avoidance Characteristics in *Glycine max* L. Merr. (Soybean). Emily Green-Tracewicz¹, Elizabeth Lee¹, Lewis Lukens¹,

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It has recently been proposed that plants can detect surrounding plants by perceiving differences in light quality or red: far-red (R: FR ratio). Research has yet to link the reduced light quality of weedy environments to the shade avoidance response as a mechanism of competition in crops. Shade avoidance responses, such as stem elongation, altered flowering time, and increased apical dominance allow for successful reproduction in natural systems. In agricultural systems, these mechanisms are proposed to give crops a competitive advantage over weeds. Whether this competitive response affects reproductive fitness (yield), or above and below ground resource partitioning, remains unknown. We hypothesize that soybean plants will initiate shade avoidance as a competitive response due to changes in light quality when weeds are present. As a result, biomass allocation may be altered, at a potential cost to reproductive fitness. To address these hypotheses, field experiments were conducted in 2007 at the Arkeil Research Station, where soybean plants were grown using a fertigation system, in two light quality environments: (1) High R: FR and (2) Low R: FR representing weed-free and weedy conditions respectively. Soybean plants grown in weedy conditions were planted with turfgrass (a weed simulator). To prevent direct competition for light water and nutrients, soybean plants were not shaded, and root systems of soybean plants and turfgrass were self-contained. Within this design, the effects of light as an indirect competitive variable were isolated, and the impact of high and low R: FR ratios were examined on: (1) total height, internode elongation and stage of development, and (2) biomass partitioning measured through a sequential harvest. At early developmental stages, in the presence of weedy competitors, soybean plants had greater total height, hypocotyl and epicotyl elongation, leaf area and stem biomass compared to soybean plants grown in weed-free conditions. At later developmental stages, soybean plants grown in the presence of weeds were developmentally delayed by 1-3 stages, while soybean plants grown in weed-free conditions had greater total height, leaf area, and stem biomass. Root biomass of soybean plants grown in weed-free conditions were consistently greater than those grown in weedy conditions throughout the duration of the life cycle. These results provide insight to the mechanisms of weed induced yield losses and shade avoidance as a competitive response in agricultural systems.

352. Distribution and Origin of Herbicide-Resistant *Echinochloa oryzoides* in Rice Fields of California. Marie Jasieniuk¹, M. D. Osuna¹, Miki Okada¹, Riaz Ahmad¹, Albert Fischer¹, Marie Jasieniuk¹; ¹University of California, Davis, California, United States of America

Echinochloa oryzoides (early watergrass) is an aggressive weed in California rice fields that has evolved resistance to several herbicides. To provide insight into the origins and spread of resistance, 434 individuals from 23 populations (12 resistant, 11 susceptible) across California were genotyped using seven microsatellite primer pairs. The total number of alleles detected was 47, ranging from three to 11 alleles per primer pair. Genetic diversity within populations, as measured by the Shannon-Weaver diversity index (Hsw), indicated that susceptible populations, with Hsw ranging from 0.17 to 0.58, were more genetically diverse than resistant populations, with Hsw ranging from 0.04 to 0.38. Mean allelic richness (A), which ranged from 1.71 to 2.99 among populations, was also higher in susceptible (A = 1.27) than resistant (A = 1.13) populations. Selection at the locus or loci conferring herbicide resistance probably also reduced diversity at neutral loci due to the genome-wide lack of recombination in the highly selfing *E. oryzoides*. No isolation by distance was detected within resistant or susceptible populations or across all populations. Clustering analysis using UPGMA revealed one satellite cluster, consisting of a single population, and one main cluster consisting of resistant and susceptible populations from different geographical regions of California. The lack of geographical and population structuring suggests spread of resistant biotypes in California has involved long distance dispersal events.

353. How does Water Stress Affect Weed-Crop Competition: Studies of *Alternanthera tenella* and Soybean. Rafael Vivian¹, Pedro Christoffoleti¹, Durval Neto¹, Ricardo Victoria Filho¹; ¹ESALQ, Piracicaba, Sao Paulo, Brazil

The aim of this study was to evaluate *Alternanthera tenella* and soybean competition cultivated under normal and water stress conditions. The experiment was carried out in to growth chamber in controlled conditions of temperature, radiation and relative air humidity. Cultivation was done in pots with four liters prior filled with soil and weighed. The fertilizing was done by nutritive solution since the beginning of the experiment. In each pot only two plants were cultivated, changing their composition according to the treatment (T1- soybean + soybean (monoculture), T2- soybean + *A. tenella* (competition) and T3- *A. tenella* + *A. tenella* (monoculture). The period of water stress was from the 20th till 40th day after emergence (DAE), with half of storage water soil capacity. The evaluations were at 20, 35, 50, 70 and 90 DAE, with measurements of total dry mass and leaf area, besides follow up the nitrate reductase (NR) enzyme, net photosynthesis (A) and up take of macronutrients. The competition of soybean and *A. tenella* was lower than soybean in monoculture, such as higher growth of *A. tenella* monoculture was observed. However, under water stress competition, the leaf area of soybean was reduced to

8.4%, and of *A. tenella* was increased at 43.26%. Soybean showed higher NR activity than the weed to every period evaluated, with or without water stress. On the other hand, the NR reduction of soybean and *A. tenella* competition was higher than monoculture conditions. The net photosynthesis of soybean was higher than the weed, though both had reduced under water stress. Significant potential of absorption and accumulation nutrients by *A. tenella* were checked, mainly from potassium (K) and magnesium (Mg+2) contents verified at stems and leaves. Even in competition conditions *A. tenella* showed higher content to major macronutrients, emphasizing its high competitive capacity, mainly when under water stress. The K content by soybean was 64% less than K from *A. tenella*. However, the total content of macronutrients, from total dry mass, was lower than soybean, mainly when in crop competition.

354. Integrated Management for *Avena fatua* and *Lolium multiflorum* in Winter Cereals: Contribution of Summer No-Till and Seed Predation. Motoaki Asai¹, Tomoko Shibuya¹, Yasuhiro Yogo², Hiroaki Watanabe¹; ¹National Agricultural Research Center, Tsukuba, Ibaraki, Japan; ²National Institute for Agro-Environmental Sciences, Tsukuba, Ibaraki, Japan

Avena fatua (wild oat) and *Lolium multiflorum* (Italian ryegrass) are problematic in continuous winter cereal cropping system in temperate regions of Japan. Cultivation and herbicides alone are not completely effective as control measures. Delayed emergence and fewer herbicide options available for control prompt farmers and researchers to develop integrated weed management systems.

To determine the effect of tillage, straw mulch and calcium cyanamide (CC) on emergence and persistence of these species as part of an integrated weed management strategy, factorial field experiments were conducted at the National Agricultural Research Center (NARC), Tsukuba, Ibaraki, Japan. Removal rates of *A. fatua* and *L. multiflorum* seeds were monitored to determine the cause and rate of post-dispersal weed seed depletion through predation in no-till soybean cropping seasons. Invertebrate seed predator activity-density was also monitored using adhesive traps.

Field experiments confirmed that cropping systems involving a summer no-till period after cereal harvest reduces the density of the subsequent generation of these weeds in comparison with tilled rotation systems. Extending the duration of the no-till period later than September markedly suppressed seedling recruitment of these species. A defined period of no tillage subsequent to the cereal harvest, when combined with CC application, is expected to contribute to seed depletion of these species. Earlier emergence in *A. fatua* under no-till conditions is probably due to an expansion of the temperature range allowing for germination in seeds on the soil surface.

In August and September, 90% of *L. multiflorum* seeds and 30 % of *A. fatua* seeds were consumed. Ryegrass seeds were consumed throughout the season. The seasonal patterns of seed predation were similar between years. Vertebrate exclusion decreased predation rate markedly for *A. fatua* seeds. A surveillance camera deployed in the field showed that crickets (*Teleogyllus emma*) were the primary seed predators. The activity-density of the primary seed predator, *T. emma*, peaked during August to September, coincident with the season of highest predation. Predation by crickets plays a primary role in seed depletion of these species during the summer under no-till conditions on the field. Cricket activity-density was much higher than at other farms; surrounding grassy borders may be cricket habitat. Further researches on spatiotemporal variation in seed predation, as well as seed rain and prey preference, are needed.

355. Factors Influencing Seed Dispersal in *Glycine soja* Sieb. Yasuyuki Yoshimura¹, Aki Mizuguti¹, Kazuhito Matsuo¹; ¹National Institute for Agro-Environmental Sciences, Tsukuba, Ibaraki, Japan

Wild soybean is a wild species closely related to cultivated soybean, endemic to East Asia. The wild soybean's major habitats include riversides, roadsides, and furrows. Recently, as more genetically modified (GM) soybeans are grown worldwide, there are concerns about the gene flow from GM soybean to wild soybean because the two species can cross with each other.

When wild soybeans advance maturity, they naturally shatter and disperse their seeds to enable distribution over a large area. Therefore, it is worth examining how far wild soybean seeds disperse and what factors affect their dispersal.

In this experiment, we surveyed the number of seeds that dispersed from individual plants and their dispersal distance in order to clear how wild soybean seeds actually disperse. We then analyzed the factors that affect dispersal, such as the weight of the dispersed seeds, the timing of dispersal, and the weather conditions. We sowed five wild soybean seeds along each of the four sides of a box-shaped net, and drew concentric circles at every 0.5 m, with the outermost circle 7 m away from the center. Almost every day from Oct. 26 through Nov. 17, we collected dispersed seeds at each distance within the circle. On Nov. 20, when seed dispersal had almost stopped, we collected all the remaining seed pods. On average, we collected about 12,777 wild soybean seeds per location. Of these, 42.4% had dispersed, while some other pods did not naturally explode and some seeds remained in their pods even after shattering. More than 50% of dispersed seeds were found within 0.5 m of the center. Beyond the 0.5 m mark, the number of dispersed seeds gradually declined as distance from the plants increased. While more than 80% of all the collected seeds were found within 2.5 m of the center, seeds

were also observed at distances of 6.5 to 7 m. This proved that seed dispersal took place over a large area around the plant. We also found that pods containing larger seeds naturally shatter earlier and disperse their seeds farther and the number of dispersed seeds and the relative humidity were correlated: the lower the humidity, the more seeds were dispersed.

356. Comparison of the Flowering Phenology among the Regional Populations of Wild Soybean (*Glycine soja*) in Japan. Aki Mizuguti¹, Yasuyuki Yoshimura¹, Kentaro Ohigashi¹, Kazuhito Matsuo¹; ¹National Institute for Agro-Environmental Sciences, Tsukuba, Iba, Japan

To control gene flow from genetically modified (GM) soybean to wild soybean is an important issue to be resolved, in order to cultivate GM soybean commercially in Japan. It is expected that the gene flow will occur in the case their flowering periods overlap, because they have compatibility. We must clarify their flowering phenologies to establish the suitable cultivation system of GM soybean and weed management system which control this gene flow. The flowering period of wild soybean is generally from August to September and the flower initiation starts caused by short photoperiod. Wild soybean distributed widely from north to south in Japan may have regional-populations with different flowering phenologies. In this study, seeds of 12 wild soybean populations were obtained from different latitude regions (42°N to 32°N) throughout Japan in order to clear among-population differences in flowering phenology. The seeds sowed in April, 2006 and then five individuals from each regional population were cultivated under the same conditions in Tsukuba (at 36°N). The number of flowers was counted every 1-3 days in order to obtain the data of flowering start, peak and end. The northern 4 populations obtained at the regions, higher than 39°N, started flowering in June and had flowering period, 69-85 days. The other 8 populations started flowering in August or later and had flowering period, 20-40 days. And the southern populations had the later day of initial flowering. The flowering peaks of all populations showed a latitudinal decline. And the southern populations had the later flowering peaks. The northern populations had slightly earlier flowering ends, but the flowering of all populations ended in late September, regardless of the flowering start dates. This study showed that populations of wild soybean are genetically differentiated in flowering phenology along latitude, and that each character, flowering start, peak, and end, had different reactivity to the regional factors.

357. Effect of Herbicide Application on Weed Seed Bank Size and Composition in Corn-Barley Rotation System. Mostafa Oveisi¹, Hassan Alizadeh¹, Ebrahim Raismohamadi², Hamid Mashhadi¹; ¹The University of Tehran,

Karadj, Tehran, Iran; ²The University of Tehran(Abur-eihan Campus), Pakdasht, Tehran, Iran

Changes in weed seed bank due to crop production practices are an important determinant of subsequent weed problems. To study the effect of chemical control on agricultural rotation systems, a study was conducted during 2004 and 2005. Corn-barley was the selected rotation with and without applying of herbicide. Method of sampling was systematic (zigzag) and the time of the sampling stages were in two dates on before sowing and after harvesting of barley. To compare the diversity between farms, Shannon-Weiner diversity index was calculated. Based on results, weed seed bank densities in chemical managed farms (CMFs) was generally higher than those farms without chemical control (NMFs). At first sampling, average weed seed bank populations in CMFs, were 49 and 31 seeds/ kg of soil, and for NMFs were 136 and 177 seeds/kg soil in 2004 and 2005, respectively. The weed seed bank density in second sampling date (post harvesting of barley) for CMFs were 33 and 30.5 seeds/kg soil, and for NMFs were 210 and 254 seeds/kg soil in 2004 and 2005, respectively. seed bank density decreased over sampling times (growing season) for CMFs in 2004 as contrasted to those of none chemical controlled. In 2005, The variation trend of the seed bank densities for managed farms, was constant between the two stages of sampling. But the trend of variation in NMFs was similar to previous year. Shannon-Weiner diversity index in CMFs was higher than those of not controlled. Probably, herbicide spraying had caused to prevent the seed production cycle of weeds and reduced the rain of weed seed into soil. Result of this study demonstrated the importance of weed control practices in reducing weed seed bank size.

358. Ten Years of Colorado Weed Shift Studies in Glyphosate Resistant Crops. Philip Westra¹, Dale Shaner¹, Todd Gaines¹; ¹Colorado State University, Fort Collins, Colorado, United States of America

Large-scale field studies on weed shifts in glyphosate resistant crops have been conducted over 10 years in CO, NE, WY, and KS. Colorado has conducted two such studies comparing weed shifts under various combinations of glyphosate-based, or conventional weed control technology. Nearly 700 georeferenced data collection points are used every year to evaluate the soil weed seed bank, and weed population dynamics three times during each growing season including at harvest. Colorado data generally demonstrates excellent grass control with glyphosate, and very good broadleaf control except for inherently tolerant species such as wild buckwheat, toothed spurge, and common lambsquarter. Weed dynamics are influenced by annual environmental conditions, especially for select species such as hairy nightshade.

Overall weed control has generally been best in plots treated with the full labeled rate of glyphosate, especially when less competitive crops are grown. Adding a pre-emerge herbicide split in plots after 6 years improved corn yields by 10-15 bu/acre, suggesting that very early season weed competition does impact final corn yield.

359. Evenness as an Indicator of 'Good' Weed Diversity. Anne Légère¹, Craig Stevenson; ¹AAFC, Saskatoon, Saskatchewan, Canada

Synthetic diversity indices, such as Shannon's H', take into account two components of diversity: the actual number of species, i.e., the richness of the community, and also the relative contribution or evenness of each species to this community. Evenness values (Shannon's E) can range between 0 and 1.0: a value of 0 corresponds to a community of one species (total dominance), and a value of 1.0 corresponds to a community where all species are equally abundant. We hypothesized that weed communities with greater evenness (E approaching 1.0) will be indicative of more stable and productive cropping systems. We used weed density and crop yield data collected over four years in an experiment that included three factors: crop rotation (barley monoculture vs. barley red clover rotation); tillage (MP: moldboard plow; CP: chisel plow; NT: no-till); weed management (intensive; moderate; minimum). A mixed model analysis of yield was conducted using E as a covariable. Barley yield decreased as weed management was reduced, particularly when E approached 0. As weed community evenness increased, yield differences between weed management treatments lessened. For the barley monoculture, yield increased for MP and NT as E increased, whereas CP yield was stable, regardless of E. Yield was lower but similar across tillage treatments as E approached 0. For the barley rotation, yield increased for MP and CP as E increased, whereas NT yield decreased as E increased. Yield differences between tillage treatments were reduced as E increased. In many instances, weed communities with high evenness were associated with crop yields that were not only greater but also less affected by treatments. Some of the exceptions, i.e., the monoculture-CP and the rotation-NT treatments, may be responding differently because weed density is beyond an acceptable threshold or because of the presence of relatively more competitive species.

360. Changes in Floral Composition of Segetal Communities of Cereal Crops in the South of Poland. Denise F. Dostatny¹; ¹Plant Breeding and Acclimatization Institute, Warsaw, Mazowieckie, Poland

Poland is one of the most abundant countries in Europe in terms of biological diversity. It is due to both convenient natural conditions and its difference in the influence of

human management in comparison to other European countries. As GUS (Central Statistical Office) claims more than a half of the area of Poland is arable land of which almost 80% is cultivated. Therefore, we may assume how important maintenance of diversity is in the case of arable land.

This research presents distribution of cereal field weeds in the South of Poland, as well as their diversity depending on habitat and methods of management. The research was carried out in one of Poland's most abundant and oldest agricultural areas in Poland, in 2004-2005. Results were compared with previous research conducted by the author between 1995-1999, and with literature of other researches conducted in the 70's, between 1986-1988 and 2000-2001. Phytosociological records performed in cereal crop fields were compared. All records were made according to the Braun-Blanquet method of vegetation surveying and all revealed occurrence of vanishing weed species in the area. The results showed that some of the threatened and quite common but 'demanding' weeds species that were still occurring in the 70's have become extinct or significantly reduced their number in the 80's, 90's and 2000; however, for the last years some of the said species have been occurring as single plants in the fields. This is mostly due to the method of management and particularly to intense use of herbicides which was observed during the last 30-40 years in Poland. Recently, many farmers have switched to ecological farming and discontinued using herbicides. Thus, seeds of rare weed species that were dormant in the soil for many years started to germinate. A part of this research is supporting the contribution of my Institute to the Endure (an European Union project).

361. Using Allelopathic Potential of Rye (*Secale cereale* L.) as an Effective Tool for the Control of Common Weed Species of Maize (*Zea mays* L.). Seyed Vahid Eslami¹, Soheila Poorheidar Ghaffari¹, Hassan Mohammad Ali-zade², Gholamreza Zamani¹; ¹The University of Birjand, Birjand, South Khorasan, Iran; ²The University of Tehran, Karadj, Tehran, Iran

The widespread and repeated use of herbicides led to the appearance of herbicide resistant weed biotypes which has often increased the cost of weed control. In the wider community this reliance on herbicides has also raised concerns about the negative effects of herbicides on the environment. The application of allelopathy is an alternative weed control technique that could be incorporated into an integrated weed management program, thereby reducing the dependence on herbicides and extending the commercial life of valuable chemicals. Rye is an example of a plant which provides excellent weed suppression through allelopathic mechanisms. Laboratory experiments were conducted to investigate the allelopathic effects of rye aboveground parts on seed germination and seedling growth of corn and its local important weeds including

wild proso millet (*Panicum milliaceum*), johnsongrass (*Sorghum halepense*), lambsquarters (*Chenopodium album*) and redroot pigweed (*Amaranthus retroflexus*). The different concentrations of rye water extracts (0, 2.5, 3.75 and 5.0 %) were applied to determine their effects on germination parameters (percentage of seed germination and mean germination time) and also seedling growth indices (seedling dry weight, length of root and shoot). Increasing concentrations of aqueous extracts of rye inhibited germination of all weed species. Moreover, all tested weed species showed a significant increase in MGT (mean germination time), indicative of slower germination as extract concentration increased. In contrast, germination percentage of maize was not affected by different levels of extract concentration. Maize appeared to be more tolerant than the tested weed species to the agents affecting germination. In addition, none of solution concentration levels affected the MGT of maize. The results indicate that extracts prepared from rye aboveground parts caused obvious reductions in seedling root length which ranged between 10 and 80% depending on extract concentration and species tested. In spite of the less sensitivity of maize germination to aqueous extracts, its root length slightly reduced by exposure to extract solutions. Although there was some decline (up to 15%) in shoot length of all tested species, shoot length was less sensitive to the extracts than was root length. The stronger inhibitory effects that rye extracts had on roots might have been caused by the fact that roots were in direct contact with the extract and subsequently with inhibitory chemicals. Exposure to rye extracts significantly reduced seedling dry weight of weed species. Results clearly indicate that rye residues have an enormous potential to suppress weed species with no harmful influence on maize.

362. Comparison Between Rice (*Oryza sativa* L.) Cultivars for Competitiveness Against Barnyard Grass (*Echinochloa crus-galli*). Ali Soroshzadeh¹, Hashem Aminpanah¹, Eskandar Zand², Ali Momeni³; ¹Tarbiat Modares University, Tehran, Iran; ²Plant Pest and Diseases Institute, Tehran, Iran; ³Rice Research Institute, Amol, Mazandaran, Iran

The aim of this research was to compare between seven cultivars and three lines of rice (*Oryza sativa* L.) for competitiveness against barnyard grass (*Echinochloa crus-galli*). A field experiment was conducted in 2007 growing season in Mazandaran province, North of Iran. In this experiment seven rice cultivars (include: Khazar, Sepidrood, Nemat, Dorfak, Fajr, Shiroodi, and Dailamani) and three lines (Line 830, Line 841 and Line 843) were sown with and without competition with barnyard grass. Layout of the experiment was a factorial design with four randomized complete blocks. Each cultivar or line was planted at its own optimum density, while density of barnyard grass was 20 plants per square meter. The traits

such as rice grain yield, rice yield components include: fertile tiller number per square meter, grain number per panicle, and thousand grain weight were measured in both weed free and weedy conditions. Moreover Yield Reduction Percentage (YRP), Competitive Index (CI), and Ability Withstand Competition (AWC) were calculated.

The results showed that in all rice cultivars and lines tested, yield and its components were significantly reduced by barnyard grass competition. Correlation analysis confirmed that there was a positive significant correlation between rice yield, CI and AWC. The Cluster Analysis showed that all cultivars and lines fall into four different clusters:

1- Khazar cultivar has high yield potential under weed-free conditions, but low weed tolerance and ability to reduce weed biomass production.

2- Line 843 has high yield potential under weed-free conditions, and high weed tolerance and ability to reduce weed biomass production.

3- Sepidrood cultivar has high yield potential under weed-free conditions, and high weed tolerance but low ability to reduce weed biomass production

4- Other lines and cultivars have low weed tolerance and ability to reduce weed biomass production

Furthermore Line 843 had minimum YRP (18%) and highest CI (2.43), while Khazar cultivar had maximum YRP (50.5%) and lowest AWC (49.5%). Therefore this experiment demonstrated that line 843 is more competitiveness and Khazar cultivar is less competitiveness against barnyard grass.

363. Allelochemicals Involved in Rice Allelopathy. Chuihua Kong¹, Xiaohua Xu²; ¹Chinese Academy of Sciences, Shenyang, Liaoning, China (Peoples Republic of); ²Nankai University, Tianjin, China (Peoples Republic of)

A few rice (*Oryza sativa* L.) varieties or rice straw can produce and release allelochemicals participating in its defense against paddy weeds. However, it remains obscure which allelochemicals are predominantly involved in rice allelopathy. In this presentation, many types of compounds were systematically isolated and identified from an allelopathic rice PI312777 variety. Among them, alkaloids, alkylresorcinols, cyclohexenone and urea derivatives, flavonoids and their glucosides, diterpenoids and triterpenes had inhibitory activities on the growth of *Echinochloa crus-galli*, *Cyperus difformis* and *Leptochloa chinensis* weeds associated with rice. However, the presence of these compounds in allelopathic rice plants does not necessarily mean that they can be released into the environment to demonstrate their allelopathic effects under natural field conditions. Accordingly, allelochemicals released from selected rice seedlings or straw into soil were determined and analyzed by LC/MS and HPLC. Phenolic acids, flavonoids, diterpenoids and cyclohexenone and urea derivatives were found in soil. Particularly, 3-isopropyl-

5-acetoxy- cyclohexene-2-one-1, momilactone B and 5,7,4-trihydroxy-3,5- dimethoxyflavone occurred in the soil at day 15 after rice seedlings emergence, and reached the concentration initiated for inhibition on associated weeds at day 30 after rice emergence, while other compounds were not detected or they were as trace only in the soil. The results indicated that allelopathic rice seedlings can establish their own weed defense mechanism through production and release of 3-isopropyl-5- acetoxycyclohexene-2-one-1,momilactone B and 5,7,4-trihydroxy -3,5-dimethoxyflavone. However, either allelopathic or non-allelopathic rice straw released momilactone B and lignin-related phenolic acids (p-hydroxybenzoic, p-coumaric, ferulic, syringic and vanillic acids) into the soil during decomposition to inhibit successive plants. As a result, allelochemicals involved in rice allelopathy from living and dead plants are substantially different.

364. Allelopathic Potential of *Brassica juncea* (L.) Czern.-var. Ensabi as a Natural Herbicide. Abbas Fallah Toosi¹, Baki Hj Bakar¹; ¹University of Malaya, Kuala Lumpur, Federal Territory, Malaysia

The wild brassica (*Brassica juncea* (L.) Czern. var. Ensabi) with its pungent and slightly bitter aromatic taste has been domesticated as a local vegetable and planted between rows in hill paddy by Malays and natives in the Malaysian states of Sabah and Sarawak. Laboratory experiments were conducted to assess the allelopathic potential of *Brassica juncea* (L.) Czern var. Ensabi extract as a natural herbicide. Five respective dilutions from each of the aqueous extracts of fresh and dried leaf, stem and root were prepared, with deionized distilled water, as a control, were prepared. These solutions were tested on seed germination and seedling growth of barnyardgrass (*Echinochloa crus-galli* L. Beauv.) and radish (*Raphanus sativus* L.). In this bioassay, the extracts from dried leaves of Ensabi exhibited the highest suppression of seed germination and seedling growth of *E. crus-galli* and *R. sativus*. Aqueous extracts of the dried leaves, stems and roots of Ensabi, each at 300g/L, strongly inhibited germination of barnyardgrass and radish seeds. Highly significant deleterious growth effects of aqueous extracts of dried Ensabi leaves, stems and roots, each at 150 g/L were registered on seed germination, dry weights and lengths of radicle and hypocotyls of barnyardgrass and radish seeds. Measurable concentration-mediated reductions in seed germination, radical and shoot lengths of radish and barnyardgrass with increasing concentration of aqueous extracts of dried Ensabi. Seeds of barnyardgrass and radish failed to germinate when exposed to aqueous extracts of dried Ensabi leaves, stems or roots, each at 300g/L. The potentials of Ensabi extracts as a component of the cultural management of weeds in hill paddy are discussed.

365. Evaluation of Irrigation Regime on Allelopathic Potential of Sorghum and its Effects on Germination and Seedling Growth of Sorghum and Lambsquarter. Omid Younesi¹, Allahverdi Haghpanah¹, Sedighe Sadeghi¹, Zoheir Ashrafi²; ¹University of Tehran, Isfahan, Iran; ²Imp, Karaj, Tehran, Iran

Allelopathy offers potential for selective biological weed management through the

production and release of allelochemicals from leaves, flowers, seeds, stems, and roots of living or decomposing plant materials. Allelopathy is strongly coupled with inherent stresses of the crop environment, including insects and disease, temperature extremes, nutrient and moisture variables, radiation, and herbicides. Economic and environmental constraints of crop production systems have stimulated interest in alternative weed management strategies. Allelopathy offers potential for selective biological weed management through the production and release of allelochemicals from leaves, flowers, seeds, stems, and roots of living or decomposing plant materials. Allelopathy is the direct or indirect, useful or harmful effects of allelochemicals of one plant on other plant. Several researchers have documented the existence of allelochemicals in higher plants. These chemicals are produced in above or below ground plant parts or in both to cause allelopathic effects in a wide range of plant communities. Environmental stress can affect of allelopathic potential of plants and increase its negative effects on germination and seedling growth of other plants. In the present work an attempt has been made to evaluate the effects of irrigation regime on allelopathic potential of sorghum and its effects on germination and seedling growth of sorghum and lambsquarter. The experiment was conducted with a factorial arrangement based on completely randomized design with three replications. Treatment were: 1- irrigation regime (full irrigation (Control), irrigation until flowering stage, irrigation until doughing stage and irrigation until eight-leaf stage) 2- organelles plant (seed, shoot) 3- extracts plant (0 (control),5,10,25 and 40 concentrations).The effects of all treatment and their interactions on germination percentage, germination rate, radicle length and plume length were significant. In extract concentration of 40% germination percentage, germination rate,radicle length and plume length of lambsquarter and sorghum decreased compared to control. Withholding irrigation at eight-leaf stage had the highest allelopathic effects on the evaluated traits. Withholding irrigation at flowering stage or doughing stage had a little effect on allelopathic potential of sorghum. In all irrigation regime treatments, Inhibitory effect was directly proportional to the increasing concentration of the aqueous.

366. Seasonal Variation in Phytotoxic Potential and the Composition of Volatile Compounds in *Artemisia princeps* var. *Orientalis* Leaves. KyeongWon Yun¹, M.I.R. Ma-

mun², Eun-Ho Shin², Jae-Han Shim²; ¹Sunchon National University, Suncheon, Chollanamdo, Korea, South; ²Chonnam National University, Gwangju, Korea, South

Leaves from natural populations of *Artemisia princeps* var. *orientalis* in Suncheon, South Korea, were examined for phytotoxic effect and the composition of volatile compounds was analyzed. The volatile substances of *Artemisia princeps* var. *orientalis* were prepared from samples collected monthly from April to October. Their effects were assessed on seed germination and seedling growth of *Achyranthes japonica*. It was found that the higher the concentration of volatile substances, the lower the seed germination and seedling growth and the plant samples collected in July and August were the most detrimental. The phytotoxic effect of volatile substances of *Artemisia princeps* var. *orientalis* collected in April and October was weaker than the other months. An identification of volatile compounds from the leaves of *Artemisia princeps* var. *orientalis* leaves was carried out with a GC-MS coupled with a solvent-free solid injector (SFSI). A total of 180 compounds were extracted and identified including acids, alcohols, aldehyde, ketones, amides, amines, esters, pyrazines, pyrroles, pyridines, hydrocarbons as well as other miscellaneous compounds. Twelve volatile compounds were detected: decanal, tetradecanoic acids, dibutyl phthalate, hexadecanoic acid, 1-chloro-octadecane, hexadecanoic acid (dioctyl ester), tritetracontane, hexadecanoic acid [bis(2-ethylhexyl) ester], bis(2-ethylhexyl)-phthalate, heneicosane, 2,6,10-trimethyldodecane and squalene. In addition, a further 168 compounds were found in the *Artemisia princeps* var. *orientalis* leaves. The emission of volatile compounds varied significantly during the experimental period. The highest number of compounds was isolated in June followed by April and September. The largest number of compounds were various hydrocarbons (29) and different terpenes (22) including mono-, di-, sesqui-, and tri-terpenes. The concentration of terpenes was highest in July and lowest in October. Presence of a large number of heterocyclic compounds (14) helps explain the self-protecting capability of the plants as these compounds are known to be bitter tasting toxins.

367. *Salvadora persica*: From Weed to Medicinal Tree. Muaz Masoom¹; ¹Khyber Medical University, Peshawar, NWFP, Pakistan

Salvadora Persica is a weedy tree of marginal, arid and sandy soils of Pakistan spreading from Southern N-W Frontier Province to Sindh. With the advent of its use for dental care, the tree has become under tremendous pressure for the past decade or so and therefore, its population has been decreased abruptly. The article deals with autecology of *Salvadora Persica* and a comprehensive review of its uses, special in dental care.

368. The Studies of Effect of Aquatic and Alcoholic Extracts of *Datura stramonium* on Iranian *Candida albicans* and *Aspergillus fumigatus*. Seyedmasoud Hashemi Karouei¹, Seye Jamal Hashemi², Ali Reza Khosravi²; ¹Azad Islamic University Tonekabone Branch, Iran, Babol, Mazandaran, Iran; ²Tehran University, Iran, Tehran, Iran

With growing incidence of fungal infectious diseases, the resistance of fungi to antifungal drugs, non-effectiveness of some antifungal synthetic drugs on some pathogenic fungi as well as side effects of synthetic drugs, there is an urgent need for new materials exploited for the ideal treatment of fungal infectious diseases. In current study whose aim is to determine antimycotic effect of *Datura stramonium* extracts on *Candida albicans* and *Aspergillus fumigatus* by disk diffusion, well diffusion, palet count and Minimum inhibitory concentration (MIC) method, it was found that aquatic, methanolic and ethanolic extracts the flower, seed, leaf, stem and root did not have any effect on *Candida albicans* where as ethanolic and methanolic extract of flower, seed, leaf, stem and root inhibited *Aspergillus fumigatus* growth. According to the data collected, the reported MICs are as follows the leaf aquatic fraction 50 mg/ml, the leaf methanolic fraction 6.25 mg/ml; the leaf ethanolic fraction 12.5 mg/ml; the flower aquatic fraction 100 mg/ml; the flower methanolic fraction 6.25 mg/ml and the flower ethanolic fraction 50 mg/ml.

The results were compared with Terbinafine with 2 mg/ml of MIC on *Candida albicans* and 1 mg/ml of MIC on *Aspergillus fumigatus* which were all determined by the researcher of the present study.

369. The Studies of Effect of Alcohol & Aqueous Extract Provided from the *Echinochloa crus-galli* on Bacteria Growth in vitro. Elahe Hadavi¹, Masoud Hashemi Karooyi, Masoud Ghane; ¹Member of Young Research Club of Tonekabon, Tehran, Iran

The antagonistic effects that plants have on different microorganisms can be used to protect microorganism from the environment. The *Echinochloa crus-galli* with a universal growth, is found in paddy fields in the north of Iran. named sorroof, in the weed form. In this research, different methanolic, ethanolic and Aqueous extract have been provided from *Echinochloa crus-galli* and studied their effects on gram positive & gram negative bacteria growth using disk diffusion, well diffusion, plate count, Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) method.

It concluded that different types of methanolic, ethanolic & aquatic extract inhibited *Staphylococcus aureus* (ATCC = 1431) and *Bacillus cereus* (ATCC = 1247) growth while did not have any effect on *Escheichia coli* (ATCC = 1399) and *Pseudomonas aeroginosa* (ATCC = 1430) growth .

370. The Potential Use of Vinegar in Vegetable Crops.

Glenn Evans¹, Robin Bellinder¹; ¹Cornell University, Ithaca, New York, United States of America

Vinegar (acetic acid) may aid in weed control. Vinegar works on contact to burn back exposed plant parts. Two limitations to its use in vegetable crops are: 1) injury to the crop, and; 2) the cost of the high volume needed for adequate weed control. Directed applications of vinegar below a crop canopy could minimize product contact with the crop. Banded vinegar applications in-row, coupled with between-row cultivation, could reduce product usage and expense. Field trials were conducted in 2007 using 200-grain vinegar (20% acetic acid), at 68 GPA, in transplanted bell peppers and brussel sprouts. Treatments were applied as 10-in wide bands, centered on each crop row. Applications were made with a customized tractor-mounted sprayer, with nozzles oriented below, and to each side, of the crop canopy. This sprayer was fixed onto an S-tine cultivator to allow for simultaneous in-row spraying and between-row cultivation. Vinegar treatments were compared to between-row cultivation, between-row cultivation with in-row handweeding, and a weedy check. Applications were made to pepper varieties 'Ace' and 'Lipstick' either 27 or 33 days after transplanting. Weeds in the early and late treatments were, on average, at the 2-leaf or the 4-leaf stage, respectively. Initial injuries to the peppers 2 days after treatment (DAT) were less than 10%, and included lower leaf dieback and scarring of the stem. However, by 29 DAT, the early injury to the stem facilitated a basal rot and subsequent death of a number of pepper plants. Yields were significantly reduced in both vinegar treatments. Applications were made to brussel sprouts 'Oliver' at either 28 or 34 days after transplanting. Injury was greater in the early vinegar application (43%, 2 DAT). An uneven soil surface and a small margin between the height of the sprayer nozzles and the height of the plants contributed to increased spray contact on the brussel sprouts. By the late application, the height differential between the sprayer nozzles and the plant apexes had increased, and only the lowest leaves were injured (10%, 2 DAT). Yields in both vinegar treatments were not significantly different from the handweeded treatment. In both crops, 2 days after the early application of vinegar, there was an 88% reduction in the number of in-row weeds present, relative to the weedy check. The later application of vinegar reduced the number of weeds in both crops by greater than 74%. By 15 DAT, the number of weeds in the early vinegar-in-pepper treatment was still 82% less than the weedy check. In comparison, 15 days after weeding the handweeded pepper treatment, there remained only a 47% reduction in the number of in-row weeds. Vinegar can provide adequate weed control and may offer a longer window of suppression than handweeding. However, crop injury remains an issue. Directed applications around more mature plants, particularly tough-stemmed plants like brussel sprouts, may

reduce crop injury to tolerable levels. The use of spray shielding may also limit crop injury.

371. **Algicidal and Herbicidal Activity of Falcarinol Isolated from Roots of *Ledebouriella seseloides*.** Jong Yeong Pyon¹, Seok-Ki Min², Jung-Sup Choi², Jin-Seog Kim²; ¹Chungnam National University, Yuseong, Daejeon, Korea, South; ²Korea Research Institute of Chemical Technology, Yuseong, Daejeon, Korea, South

Introduction

Control of harmful algae and aquatic weeds are important for both water environment management and culture of fishes. Natural products are more useful and reasonable to develop as lead compounds which may be environmentally friendly and safe for control of aquatic weeds. Falcarinol was isolated and identified from root extracts of *Ledebouriella seseloides*, which showed algicidal and herbicidal activities and its action mechanism were examined to develop algicide and herbicide.

Material and Methods

Dry roots of *L. seseloides* were extracted by 11 different extract methods including solvent fractions. Bioassay-guided isolation for active compounds was performed and chemical structure of the most active compound was determined by GC/MS and NMR. Both algicidal and herbicidal activities were tested to *Microcystis aeruginosa*, *Anabaena affinis*, *Chlorella vulgaris*, *Scenedesmus* spp., *Lemna gibba*, *Abutilon avicennae* and growth inhibition mechanism of falcarinol was studied through the investigation of electrolyte leakage, chlorophyll breakdown, malonaldehyde production, and others.

Results

N-hexane fraction from the methanol extracts of *L. seseloides* roots showed highest algicidal activities. Falcarinol (1,9-heptadecadiene-4,6-diyne-3-ol) was isolated by bioassay-guided fractionation of the hexane extract by silica gel column chromatography, Sephadex LH-20 column chromatography and preparative TLC. Concentrations of falcarinol for GR80 to *M. aeruginosa*, *A. affinis*, *Scenedesmus*, and *C. vulgaris* were 0.4, 1.5, 2.9, 15.0 µg/ml, respectively. Growth reduction % by falcarinol at 100, 25, 6.3 µg/ml to *L. gibba* were 91.2, 72.2, 67.9%, respectively. Foliar application of falcarinol at 4,000 and 2,000 µg/ml to *A. avicennae* showed 100 and 60% herbicidal activities in greenhouse test, and herbicidal symptoms showed rapid necrosis/desiccation of leaves. Falcarinol treatment induced rapid MDA accumulation, electrolyte leakage followed by chlorophyll disruption and this effect was reduced by Trolox TM treatment, indicating that herbicidal activity was induced by active oxygen evolution and rapid membrane lipid peroxidation.

Conclusion

Falcarinol was especially effective to control blue-green algae. The chemical also showed herbicidal activity and its

action mechanism might be related to active oxygen evolution and rapid membrane lipid peroxidation.

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372. Utilization of the Noxious Weed *Lantana camara* L. in Drug Development: Antitumor Lantadene A and Congeners.

Manu Sharma¹, P. D. Sharma¹, M. P. Bansal¹, J. Singh²; ¹UIPS, Chandigarh, India; ²RRL, Jammu, J&K, India

Lantana camara L. has encroached upon a large land area in India as well as other parts of the world and imposed a great threat to grazing animals and overall ecology. Eradication of this weed cannot be expected in the near future by the use of conventional methods. During the past few years, a number of chemical compounds have been reported from this plant and have been investigated for their pharmacological properties. Recently, the triterpeds named lantadenes isolated from lantana leaves have been found to exhibit antitumor activities and therefore, studies for the development of lantadenes as potential antitumor agents will be a rational way to utilize this biomass as a resource for drug discovery and development. Lantadene A (22-angeloyloxy-3-oxoolean-12-en-28-oic acid) is a pentacyclic triterpenoid isolated from leaves of noxious weed *Lantana camara* L. Five congeners of Lantadene A (LA) were synthesized and screened for their cytotoxicity against four human cancer cell lines (HL-60, HeLa, Colon 502713 and Lung A-549) using the MTT assay. These congeners were further studied for their tumor inhibitory potential on two-stage squamous cell carcinogenesis in Swiss albino mice, induced by 7, 12-dimethylbenz [a] anthracene (DMBA) and promoted by 12-O- tetradecanoylphorbol-13-acetate (TPA). LA and its congeners showed significant cytotoxicity and antitumor activity. Typical morphological changes including cell shrinkage, chromatin condensation and characteristic DNA ladder formation in agarose gel electrophoresis were also observed. LA induced marked concentration and time dependant inhibition of cancer cell proliferation with IC50 value of 19.8 ± 0.10 $\mu\text{g/ml}$ following 48h incubation. Flow cytometric analysis showed suppressed cell proliferation associated with cell cycle arrest in the G0/G1 phase. LA significantly inhibited cell proliferation of HL-60 cells and induced cell apoptosis through down regulating Bcl-2 and up regulating Bax expression. The peptidic caspase-3 inhibitors DEVD-CHO (NH₂-Asp-Glu-Val-Asp-CHO, 2 μM), increased the viability of HL-60 cells, previously treated with LA. The results indicated that these compounds have the potential to be developed as potent antitumor agents and this is the best way to utilize the biomass of noxious weed *Lantana camara* L.

373. Allelochemicals of Three Weeds (*Ambrosia trifida* L., *Lantana camara* L. and *Ageratum conyzoides* L.) and Their

Use in Crop and Weed Management Systems. Chuihua Kong¹; ¹Chinese Academy of Sciences, Shenyang, Liaoning, China (Peoples Republic of)

A heavy infestation of weeds results in adverse effects on the growth and establishment of crop plants. Nowadays, crop production is characterized by heavy use of herbicides that may cause environmental and health problems. Attempts to lessen reliance on herbicides have met with limited success so far. It is well known that numerous weeds may use allelopathy to interfere with the growth and establishment of crop plants. Allelopathic weeds releasing specific metabolites (allelochemicals) have critical impacts on crop plants. Through the production and release of a wide variety of allelochemicals, these weeds inhibit the growth of crop plants and impact the soil microbial community in their immediate vicinity. However, clarification of the chemical interactions between weeds and other organisms can potentially be used to improve their management as well as the management of certain pests. Despite this, relatively little attention has so far been paid to investigate how allelopathic weeds and their allelochemicals may also be used as an important part of crop and weed management systems. The presentation aims to outline recent advances in the use and role of allelochemicals in certain agro-ecosystems by studying the case of three weeds *Ambrosia trifida* L., *Lantana camara* L. and *Ageratum conyzoides* L. that are economically destructive weeds to produce and release allelochemicals to interfere with other species. It would be helpful to further our understanding of allelopathy and develop new strategies to improve management of the worst weeds, as well as to incorporate them into management strategies for other pests.

374. Biological Activity of the 2 Artemisia Plants used as InJin. KyeongWon Yun¹, KyoungSun Seo²; ¹Sunchon National University, Suncheon, Chollanamdo, Korea, South; ²ShinHung Pharmaceutical Co., Yeosu, Chollanamdo, Korea, South

Artemisia capillaris and *Artemisia iwayomogi* are weeds and medicinal plants used as InJin (Korean herbal name) in Korea. To elucidate biological activity of the 2 Artemisia plants used as InJin, we investigated the phytotoxic, antimicrobial and antioxidative activities of the 2 Artemisia plants. The effect of aqueous extracts and volatile substances of the 2 Artemisia plants was assessed on the seed germination and seedling growth of the 2 Artemisia plants. The seed germination and seedling growth of 2 Artemisia plants was inhibited by the aqueous extracts of the 2 Artemisia plants and the degree of inhibition was proportional to the extracts concentration. The volatile substances of *A. capillaris* did not affect the seed germination of *A. capillaris*, but the radicle elongation was inhibited. The seed germination of *A. iwayomogi* was

decreased with higher concentration of *A. capillaris* volatile substances. The degree of inhibition of seed germination and radicle elongation of *A. iwayomogi* by the 2 *Artemisia* volatile substances was more than *A. capillaris*. The ethyl acetate and ether fractions of crude methanol extract from *A. capillaris* and *A. iwayomogi* were tested against 3 gram-positive, 2 gram-negative bacteria and 1 yeast. The antimicrobial activity of the ethyl acetate and ether fraction of *A. iwayomogi* extract for tested microbes was higher than *A. capillaris* extract. There was no difference in antimicrobial activity between young leaves extract and young leaves and shoots extract. Minimum inhibitory concentration (MIC) for *Pseudomonas fluorescens* by ether and ethyl acetate fraction was the highest value. The antioxidative activities of 5 fractions of methanol extract from *A. capillaris* and *A. iwayomogi* were measured by their scavenging activity on the free radical of 1,1-diphenyl-2-picrylhydrazyl (DPPH). The DPPH radical scavenging activities of the ethyl acetate fraction of the 2 *Artemisia* plants were higher than any other and similar to its antimicrobial activity. The DPPH radical scavenging activities of methanol fraction and water fraction showed a contrary value between young leaves extract and young leaves and shoots extract.

375. Evaluation of Potential Natural Herbicides for *Physalis viscosa* Control. Rex Stanton¹, Hanwen Wu², Min An¹, Deirdre Lemerle¹; ¹Charles Sturt University, Wagga Wagga, NSW, Australia; ²NSW Department of Primary Industries, Wagga Wagga, NSW, Australia

Physalis viscosa (prairie ground cherry), native to North and South America, is a weed in South Africa, Chile, Argentina, Brazil, Uruguay and through the western United States. This species was first recorded in Australia in 1909 in Melbourne and considered naturalised by 1914. It is a declared noxious weed in New South Wales, Victoria and Western Australia. *P. viscosa* grows from seed or roots in spring and is relatively hardy, capable of withstanding drought, trampling and shading. Established populations can not be readily eradicated using current control techniques.

There is no evidence in the literature of potential phytochemical evaluation for *P. viscosa* control. Eucalyptus species have been widely examined for allelopathic potential, with a diverse range of bioactive substances identified from the leaves, bark and roots. The aim of this research is to evaluate the phytotoxic potential of Eucalyptus species on *P. viscosa*.

Leaves were collected from *E. salubris*, *E. spathulata*, *E. brockwayi*, *E. dundasii* and *E. melliodora*. Leaves of *Arctotheca calendula* (capeweed) were collected as a control. Leaf samples were dried at 40 °C for 72 hours and ground. Aqueous extracts were formed by incubating 10 g powder in 100 mL deionised water at 20 °C for 72 hours. Solution were filtered and centrifuged to remove

particulate matter. Thirty *P. viscosa* seeds were placed on filter paper in Petri dishes and incubated for 14 days at 25/15 °C (8/16 hrs cycle) with four extract concentrations (0, 25, 50 and 100%) and germinated seeds counted.

A. calendula and *E. melliodora* extracts had the least impact on germination. All four remaining Eucalyptus species reduced germination to less than 2% at 100% extract concentration, with *E. spathulata* extract significantly inhibiting germination at all extract concentrations compared to *A. calendula* and *E. melliodora*. These preliminary results suggest that germination of *P. viscosa* can be inhibited by compounds present in aqueous extracts from several eucalyptus species.

The potential impact of the aqueous extracts on seedlings and young plants emerged from root stock will be critical in the evaluation of these compounds as herbicidal agents for controlling *P. viscosa* in the field. Should the impact observed on seed germination also occur in plants in the field there is the potential to develop a new herbicide, similar to the mesotrione herbicide developed from *Callistemon citrinus* for control of a range of broadleaf weeds. Further research is underway to determine the phytotoxic potential of Eucalyptus extracts on root stock regeneration of *P. viscosa* and to identify substances responsible for such inhibition.

376. Allelopathic Effect of *Asphodelus tenuifolius* cav. on Germination and Seedling Growth of *Triticum aestivum* L. Ahsan Aziz¹, Babar Babar¹, Asif Tanveer¹, Muhammad Nadeem¹, Ahsan Aziz¹, Zaheer Zaheer¹; ¹University of Agriculture Faisalabad, Faisalabad, Punjab, Pakistan

Laboratory experiments were conducted to assess the allelopathic effect of extracts from different parts of *Asphodelus tenuifolius* cav. (wild onion) on seed germination and seedling growth of *Triticum aestivum* L. (wheat). *A. tenuifolius* plants were uprooted at maturity and dried at room temperature. Plants were separated into roots, stems and fruits and were cut into small pieces. These plant parts were immersed in distilled water, separately for 24 hours at room temperature in the w/v ratio of 1:20. The aqueous extract of different plant parts was obtained by filtering the mixture through a sieve. Applications of extracts of different parts of wild onion increased the time for 50% germination and mean germination time of wheat seed. Whereas the germination index and germination percentage was decreased. Root, stem and fruit extract of wild onion produced significant effects on the growth of different parts of wheat seedlings. Stem extract showed 28.41%, 23.88% and 8.5% reduction in root length, dry weight and wheat seedling biomass respectively. While a significant reduction of 7.74% in wheat root length and 19.40% in root dry weight was recorded with root and fruit extract of *A. tenuifolius*, respectively over control. However an increase ranging from 11.59 to 51.59%, 5.47 to 50.95% and 14.42 to 28.45% was noted in shoot length,

shoot dry weight and biomass of wheat seedling with different types of extracts, respectively. Soil from wild onion grown field significantly inhibited the root, shoot length, shoot dry weight, total plant biomass and emergence percentage of wheat. This study establishes the allelopathic activity of *A. tenuifolius* to wheat through the release of phenolics in to the filterate.

377. Allelopathy and Allechemical in *Citrus junos* for Weed Management. Hisashi Kato-Noguchi¹, Yukihiro Tanaka¹; ¹Kagawa University, Miki, Kagawa, Japan

The place of origin of citrus is Southeast Asia and many kinds of citrus species are currently cultivated in the world. Some of citrus fruits are processed into juice as an ingredient in beverage, sauces and salad dressings for their special flavor. After juice extraction, these fruit pulp is mostly dumped as waste at large expense. The manipulation of food processing wastes is now becoming a serious environmental issue. It seemed, therefore, worthwhile seeking how to make use of the waste of citrus fruits. Since citrus fruits are known to contain a variety of biologically active compounds including terpenoids and flavonoids, *C. junos* fruits waste after juice extraction may possess allelopathic activity and may be effective as a weed suppressive agent. Therefore, in the present research, the allelopathic potential of *C. junos* waste was determined and the main allelopathic substance present in *C. junos* waste was isolated.

The *C. junos* fruit waste was obtained from a local food processing company and the fresh waste was freeze-dried and powdered. The powder inhibited the growth of roots and shoots of *Medicago sativa* L., *Lepidium sativum* L., *Lactuca sativa* L., *Digitaria sanguinalis* L., *Phleum pretense* L. and *Lolium multiflorum* Lam. Significant reductions in the growth were observed as the powder concentration increased. In order to isolate the allelopathically active substance, neutral, acidic and basic fractions were separated from the methanol extract of *C. junos* waste. All fractions inhibited the growth of lettuce seedlings, but by far the greatest inhibition was observed with the neutral fraction. Thus, the neutral fraction was further purified and an allelopathically active substance was isolated. The structure of the substance was determined from its spectral data as abscisic acid-bata-D-glucopyranosyl ester (ABA-GE). ABA-GE inhibited shoot and root growth of lettuce seedlings at concentrations greater than 0.3 μ M, and the concentrations for 50 % inhibition of shoot and root growth were 2.3 and 1.4 μ M, respectively. The concentration of ABA-GE in *C. junos* waste was 17.9 mg /kg dry weight. Its concentration in *C. junos* waste appears to account mostly for the observed inhibition of tested plant seedlings. Synthetic chemical herbicides may continue to be a key component in most integrated weed management systems, but controlling weeds through allelopathy is one strategy to reduce herbicide dependency. The present

research suggests that *C. junos* waste may be potentially useful for weed management in an agricultural field setting, which should be investigated further in the field for practical application of the powder. There may be the potential benefits of turning a previously useless waste product into a valuable soil amendment and improving the economics of the food processing industry.

378. ISSR-PCR Based Genetic Relationships between Populations of Six Chemotypes of North Indian Gokharu-*Tribulus terrestris* L. and Sequence-Characterized Amplified Region (SCAR) Analyses for Candidate Genes Related to Flavonoid (QUERCETIN) Biosynthesis. Neelam Verma¹, Ashwani Kumar¹, M I Saggoo¹; ¹Punjabi University, Patiala, Punjab, India

Tribulus terrestris(TT) is an annual herbaceous plant, belonging to family zygophyllaceae. It is a natural source treatment of human impotency and also produced many valuable biochemicals including essential oil. The key point to this selection is a comprehension of chemical and genetic variability and suitable selections of elites from within the available population. In the present study, ISSR analyses of selected chemotypes from a decade old introduced population in India were carried out using ISSR primers. Plants of *Tribulus terrestris* were randomly sampled from wild population raised at the six different districts, of North India. The plants were analyzed with respect to chemotypic characters, namely, saponins, flavonoids and alkaloids compositions. The chemotypic variability within these six randomly selected plants is determined. For DNA preparation and ISSR PCR conditions, young and healthy leaves from single plant of each accession were used for DNA isolation by CTAB method. In order to select optimal primers for effective use in ISSR-PCR analysis, ISSR primers (custom made from Bangalore Genei) were screened for repeatability, scorability, and their ability to distinguish within varieties. A total of 8 primers were tested to amplify DNA banding patterns using the total genomic DNA .

The ISSR data clearly indicate the distinction amongst these plants. Further, the detection of highly polymorphic profiles (114 polymorphic markers out of a total of 327 markers) suggests the existence of moderate levels of genetic variation in the Indian population despite geographical isolation and opens out a strong possibility of further genetic improvement for superior flavonoids (Quercetin) and saponins (Protodioscin) content. UPGMA analyses of ISSR and phytochemical trait data indicate that the wide phytochemical diversity is included within the genetic diversity. These results further support the prospects for selection and breeding of superior Quercetin and Protodioscin containing lines. Sequence-characterized amplified region analysis was performed using complete set of *Tribulus terrestris* to assign a segment of the coding region for flavonoid biosynthesis to chromosomes of

shallot. Outside- and inside-primer sets a pair of 20-nt-long oligonucleotides to amplify the objective were designed by Bangalore Genie, India. For each set, primers were designed based on a previously published sequence GenBank™ accession number of AY541035 (a gene sequence of flavonoid-3-hydroxylase, F3H). The primer sets were as follows. F3H: outside-forward 5-CAA AGA AGC ACG AAG GCA-3, outside-reverse 5-AAA CAC CTC CCA AAG CAT AC-3, inside-forward 5-CGT CAA CGA AAC AAC CGA TAC-3, and inside-reverse 5-GGA ACG TCT CCT TCA CTA TGG-3.

These primers were used in PCR reactions to amplify the corresponding regions. The BLASTn of a single fragment amplified from the DNAs of the *Tribulus* using the primer sets of F3H showed 99% homology with the original sequence (AY541035). These results revealed that the F3H was larger than expected. Alignment between the original sequence (AY541035) and our sequence data indicated that a 159-bp indel existed as an intron. The fact that the amplicons were larger than the expected size from this indel. This sequence has been deposited. As could be found from the known DNA sequence of F3H genes from *M. sativa* and *A. thaliana*, the organizations of the F3H genes were similar for the three species, but the length of introns varied much more than exons. The lengths of the introns varied ranging from 89 to 815 bp, for example, the lengths of intron 1 were 89, 90 and 244 bp for *G. biloba*, *A. thaliana* and *M. sativa*, and the lengths of intron 2 were 110, 83 and 815 bp for each respectively. Meanwhile, it was notable that there were also two introns for known FLS genes which also belong to the 2-ODD family, such as FLS genes from *G. biloba*, *A. thaliana* and *Allium cepa*. So the obtain of more introns of F3H genes would be helpful to understand the complete evolution relationship among plant 2-ODD genes.

379. Synergistic Role of Wood Vinegar in Retaining Efficacy of Low-Dose Bentazone Cyhalofop-butyl for Controlling Barnyard Grass. Manuel Esguerra¹, Souliya Souvanduane¹, Kyu Hong Heo¹, Sun Shik Cho¹, Sang Chul Lee¹; ¹Kyungpook National University, Taegu, Kyungsang, Korea, South

Development of weed resistance and environmental pollution are major consequences of repeated and high dose application of herbicides. These encourage scientist to search for ways on how to lessen herbicide application rate while keeping if not improving its efficacy. Among the options is the use of natural products, such as wood vinegar, popularly known as pyroligneous acid. This experiment was conducted to investigate the synergistic role of wood vinegar in the retaining efficacy of 50% Bentazone cephalo-butyl in controlling barnyard grass (*Echinochloa crusgalli* var. *crusgalli*). Two concentrations of wood vinegar (500 and 1000) applied either in separate or in mixture with 50% Bentazone-cephalo butyl were

tested. It aimed to establish the leaf stage and temperature where wood vinegar-herbicide efficacy will be optimized. Together with efficacy values and above-ground biomass, total protein, chlorophyll content and mortality rate were obtained. A 2-D gel electrophoresis was carried out to find for differentially expressed proteins which were further supported by total RNA analysis. Results showed that mixing wood vinegar with herbicide proved to be more effective in controlling barnyard grass than applying it separately. Wood vinegar-herbicide mixture proved to be comparable if not better than applying full recommended dose of Bentazone cyhalofop-butyl. Wood vinegar's synergistic effect varies with temperatures. The 2-D gel analysis confirmed the differences in protein and protein products expressed between barnyard grasses sprayed with and without wood vinegar. Total RNA analysis further supported these findings. Experiment results established the use of wood vinegar as a natural product that could retain herbicide efficacy at a lower dose.

380. Allelopathy Studies in Weed Science in Turkey: An Update. Ahmet Uludag¹, İlhan Uremis², Mehmet Arslan²; ¹Ministry of Agriculture and Rural Affairs, Alsancak, Izmir, Turkey; ²Mustafa Kemal University, Antakya, Hatay, Turkey

Allelopathy, which includes both inhibitory and stimulatory effects, is one of the ways plants interact. It is an approach which can be used as an alternative method to combat pests in alternative cropping systems, which resulted from arousing problems related to weed control such as herbicide resistant weeds and herbicide residues, expanding demand to organic crops, and increasing public concerns on environmental issues. Allelopathy in weed science covers weed interference on crops, effect of crop plants on weeds, relation between weeds and autotoxicity. Allelopathy has had great attention since 1980's in the world. However, researches on allelopathy started at late 1980's in Turkey. A great number of studies on allelopathy have been conducted in Turkey. Allelopathy studies in weed science in Turkey were reviewed by Uludag et al. before national allelopathy workshop of Turkey held in June 2006. The aim of this presentation is update allelopathy review and discuss about current and future trends. Garden radish (*Raphanus sativus*), a crop from Brassicaceae family which has glucosinolate compounds, is the first and most studied allelopathic plant in Turkey. Its and some other brassica plant's extracts have been tested to find out effect on growth and/or germination of many crop and weed species. It is possible to prepare a comprehensive list using data from those experiments. The latest field experiments showed that use of garden radish as a rotational crop or cover crop can control johnsongrass (*Sorghum halepense*) in cotton. Although promising results have been obtained from brassica species in laboratory and field experiments, use of allelopathic

plants stayed highly limited. Efforts to add new species with allelopathic effect or residual effect and to extent the range of effected plants have been continued mainly in controlled conditions. These studies included tree parts as well as herbs. Several species were suggested to use weed control in corn. Allelopathic chemicals such as juglon and dopa investigated for their effect on plants in addition to water or oil extracts of plants and plant residues. Alfalfa has been suggested as an allelopathic crop to control some weeds such as *Acroptilon repens* and *Artemisia vulgaris*. In vitro experiments were carried out to find out the possible crops that can succeed alfalfa without any chemical site effect of alfalfa. The allelopathic relations between *Artemisia vulgaris* and alfalfa were studied. The aim of studies is not only controlling weeds in crops but also understanding weed interference. Although experts who attended the National allelopathy workshop agreed on collaboration and a national network, no visible attempt has been made. However, allelopathy studies have been going on.

381. Phytotoxic Mechanisms of L-DOPA and M-Tyrosine. Hiroshi Matsumoto¹, Mayumi Hachinohe¹; ¹University of Tsukuba, Tsukuba, Ibaraki, Japan

L-DOPA (3,4-dihydroxyphenylalanine) is one of well-known allelochemicals that inhibits plant growth. In the survey of phytotoxicity among structurally related compounds with L-DOPA, we found that m-tyrosine has comparable phytotoxic potential with L-DOPA (Shirato et al., 2005). m-Tyrosine was also identified as the major component of phytotoxicity in fine fescue grasses (Bertin et al., 2007).

L-DOPA and m-tyrosine (10⁻⁴ M) inhibited the growth of lettuce root to 20% of non-treated control at 5 DAT. However, m-tyrosine did not show selectivity between lettuce and barnyardgrass that was observed in L-DOPA treatment. Our previous study showed that L-DOPA increased reactive oxygen species generated from the metabolic pathway from L-DOPA to melanin. Huge accumulation of melanin and typical oxidative damage were observed in L-DOPA -treated lettuce. m-Tyrosine also increased lipid peroxide formation in lettuce, but increase of melanin formation was less than that by L-DOPA. Exogenously-applied antioxidants, ascorbic acid and α -tocopherol, alleviated the phytotoxicity of L-DOPA but did not that of m-tyrosine. However, phenylalanine alleviated the phytotoxicity of m-tyrosine in roots of lettuce and rice. In a proteomics analysis, phenylalanine ammonia-lyase (PAL) was identified as one of responsive proteins in m-tyrosine treated rice. The amount of PAL expression decreased in m-tyrosine treatment, but did not decrease in m-tyrosine plus phenylalanine treatment.

These results suggest that phytotoxic action and mechanism are different between m-tyrosine and L-

DOPA. The decrease of PAL expression might be involved in the phytotoxic mechanism of m-tyrosine.

382. Effect of Aqueous Extract from *Flaveria bidentis* on Plant Germination. Xiangju Li¹, Miru Zhang¹, Yongjun Li¹; ¹Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing, China (Peoples Republic of)

Flaveria bidentis is an invasive plant recently found in north China. In order to investigate the invasive mechanism which is very important to the spread and ecological renovation of invasive plants, experiments were conducted in Petri dishes under laboratory conditions to study the effect of aqueous extracts of *F. bidentis* on plant germination and radical elongation. Among the 30 selected receiver plants, 29 species were inhibited in seed germination and 28 species were inhibited in radical length to varying degree in the extracts of *F. bidentis* at the concentration of 0.1g dry weight/mL, however, 2 species were stimulated in radical length in the extracts. There was a strong correlation between extract concentration and increased inhibition in test species. A gradually decrease of seed germination and radical length of *E. crus-galli* and *B. napus* was observed with increasing the concentration of the extracts. Radical length of *B. napus* was inhibited by 15.39% to 89.74% when extract concentration was 0.01 to 0.08g dry weight/mL and no germinated seed of *B. napus* was observed when extract concentration was 0.10g dry weight/mL. Seed germination and radical length of *E. crus-galli* and *B. napus* were inhibited more by extracts from mature plants than that from young plants of *F. bidentis* and more by extracts from leaves than that from stems, and roots was the last. These results indicated that *F. bidentis* may affect the germination and early growth of plants growing in the same ecosystem by releasing allelochemicals and the substances may accumulate and reduce the biodiversity in the invaded land if *F. bidentis* grows in high density.

383. Identification of Allelopathic Compounds from *Helianthus tuberosus* L. Leaves. Franco Tesio¹, Leslie Weston², Francesco Vidotto¹, Aldo Ferrero¹; ¹Università di Torino, Grugliasco, Torino, Italy; ²Environmentals, L.L.C. Consulting for the Landscape, Turf, and Ornamentals Industries, Ithaca, NY, United States of America

Allelopathy has been largely studied for several Compositae species, and a significant amount of information is available in particular on *Helianthus annuus* L.. Only a few studies, however, have considered the related perennial species *H. tuberosus* L. which is cultivated in Europe as vegetable and for industrial uses, and behaving as a weed in summer annual crops. The objectives of this study were to assess the allelopathic effects of different populations of *H. tuberosus* on germination and seedling growth of some

cultivated and weed species and to identify the allelochemicals responsible for the inhibitory activity. The release of the allelopathic compounds during the natural degradation of residues was simulated with a bioassay using Parker plates, filled with 150 g of soil and sand mixture, and different amounts of *H. tuberosus* dry leaf tissue (0.5, 1 and 1.5 g per plate). *H. tuberosus* rough material came from 4 cultivars (Fuseau, Red Fuseau, Stampede, Hybrid Stampede) and a weedy biotype (Italian). Inhibition of dry tissue was assessed in terms of seed germination, and shoot and root elongation of *Digitaria sanguinalis*, *Echinochloa crus-galli*, *Lactuca sativa*, and *Lycopersicon esculentum*. Fuseau resulted the most toxic cultivar on germination and growth of *D. sanguinalis*, showing an important inhibitory effect already at the lowest rate (0.5 g). None of the cultivars tested significantly inhibited the germination of *E. crus-galli*, even though root elongation was strongly affected at 1.5 g by almost all cultivars. Both shoot and root length of *L. sativa* was strongly affected by all cultivars. Root growth, in particular, was reduced for more than 78% at 1.5 g. On average, *L. esculentum* resulted the most sensitive indicator species, as no germination was observed, starting from the smallest amount of residues. Among the tested populations, the strongest inhibition activity, was recorded in the cultivars Fuseau and Stampede and in the biotype Italian. Powdered leaf tissues of these populations were used for the solvent extraction, with either hexane, ethyl ether, or ethyl acetate. Toxicity of the extracts on germination and shoot and root elongation of *L. sativa* was assessed in Petri dishes (5 cm). Ethyl ether fraction from the cultivar Fuseau was, on average, the most toxic. About 90% of shoot length reduction was achievable with only 0.21 µg/dish of extract. This fraction was analyzed with liquid-mass chromatography by detecting phenolic compounds. Salicylic acid was detected in all fractions tested at an average concentration of 10.16 mg/kg. Few amounts of o coumarinic and p coumarinic acids were also found. The phenols detected in this study are often associated with allelopathic behavior in Compositae weed species. Allelopathy may be advantageous to *H. tuberosus* cultivation, as it potentially reduces the sensitivity of this species to weed, theoretically allowing a reduction of inputs required for weed control, even in the successive crop, due to the release of phenolic compounds. On the other hand, allelopathic activity of *H. tuberosus* residues may be unfavorable to the sensitive crops cultivated after *H. tuberosus* or planted in an area infested by this species

384. Studies on Allelopathic Physiobiochemical Characteristics of *Solidago canadensis* L. Qiong-xia Guo¹, Li-hua Shen², Zhen Huang³; ¹Fujian Entry-Exit Inspection and Quarantine Bureau, Fuzhou, Fujian, China (Peoples Republic of); ²Key Laboratory of Biopesticide and Chemical Biology, FAFU, Fuzhou, Fujian, China (Peo-

ples Republic of); ³Graduate School of Hainan University, Haikou, China (Peoples Republic of)

The study on the physiobiochemical process and its mechanism of weed allelopathy has now become main issue in the world. For this purpose, wheat as receiver plant were cultured in 1/2 Hoagland nutrient solution which included extracts of allelopathic weed *Solidago canadensis* L. and non-allelopathic weed *Solidago decurrens* Lour., respectively. And then physiobiochemical approach was employed to get first insight into the mechanism of allelopathy in *Solidago canadensis* L.

The results were summarized as follows: the allelopathy of *Solidago canadensis* L. significantly decreased the activities of protective enzymes such as SOD, POD and CAT in wheat, coupling with the increase of free radical contents and serious membrane lipid peroxidation. It was also indicated that root activity in wheat was negatively affected, in turn decreased the uptake of nutrients(N, P, K elements) from the environment. The result also indicated that the extracts of *Solidago canadensis* L. reduced the chlorophyll concentration in wheat, then the weak photosynthesis was the result, consequently leading to decreased dry matter weight of wheat seedlings. The reverse was true in non-allelopathic weed *Solidago decurrens* Lour. The findings suggested that *Solidago canadensis* L. possess a strong allelopathic biological activity and exhibits strong inhibition of wheat.

385. Allelopathic Potential of Sunflower Plant (*Helianthus annuus* L.) on Soil Metals and its Leaves Extracts on Physiology of Wheat (*Triticum aestivum* L.) Seedling. Javed Kamal¹, Asghari Bano¹, Muhammad Riaz¹; ¹Quaid-I-Azam University, Islamabad, Pakistan

The allelopathic potential of cultivar Sunflower variety cv- Hysun 38 (*Helianthus annuus* L.) was studied and its effect on metals and leaf aqueous extract of sunflower at different concentrations were applied to determine their effect on wheat two varieties cv.Margalla 99 and cv.Chakwall 97 seed germination rate and hormonal analysis under laboratory conditions in petridishes were conducted. Commonly observed action of allelochemicals are inhibition of seed germination and abnormalities of seedling development. Catabolism of storage reserves and energy production are most important factors ensuring seed germination, seedling growth and on hormonal analysis of test plants in petridishes . Water extract using different concentrations of sunflower leaves significantly inhibited germination rate and seedling growth and effect on hormones of plants in petridishes as compared to control and in pots its effect on Ec, pH, Mn, Ca, K, and on P.

386. **Effect of Sunflower Extract on Wheat and Soil.** Javed Kamal¹, Asghari Bano¹, Muhammad Riaz¹; ¹Quaid-I-Azam University, Islamabad, Pakistan

The allelopathic potential of cultivated sunflower (*Helianthus annuus* L.) was studied leaf, stem and root extract of sunflower were applied on wheat seedlings after 20 days of emergence of wheat two varieties cv- Margalla 99 and cv- Chakwall 97. Growth and yield parameters, weeds density, hormonal analysis and physio-chemical of soil before sowing of sunflower and after harvesting of wheat crop.

387. **Study of Allelopathic Effects of Rye and Wheat on Germination and Early Growth of Lambsquarter (*Chenopodium album*) and Black Nightshade (*Solanum nigrum*).** Omid Younesi¹, Farzad Sharifzade¹, Allahverdi Haghpanah¹; ¹University of Tehran, Isfahan, Iran

Plants produce a large variety of secondary metabolites like phenols, tannins, terpenoids, alkaloids, polyacetylenes and steroids, which have an allelopathic effect on the growth and development of the same plant or neighboring plants. Considerable knowledge has been obtained concerning the chemicals involved in allelopathy. Allelopathy is the direct or indirect, useful or harmful effects of allelochemicals of one plant on another plant. Several researchers have documented the existence of allelochemicals in higher plants. These chemicals are produced in above or below ground plant parts or in both to cause allelopathic effects in a wide range of plant communities. In the present work an attempt has been made to study the allelopathic effects of two crops extracts (rye and wheat) on germination and early growth of lambsquarter and black nightshade. The experiment was conducted with a factorial arrangement based on completely randomized design with three replications in seed library research of university of Tehran, Karaj, Iran. Treatments were: 1 - extract concentrations (0 (control), 5, 10, 25 and 40) 2 - weed species (lambsquarter and black nightshade) 3 - crop plants (wheat and rye). The effects of all treatment and their interactions on germination percent, germination rate, radicle length and plumule length were significant. Germination percentage of black nightshade had more susceptibility to allelopathic mater when compared with lambsquarter. The extract of two mentioned crops had more inhibitory effects on germination rate than germination percentage. Low concentrations of extracts caused a higher reduction in germination rate. Early growth of lambsquarter was more tolerant than to allelopathic mater and root length was more sensitive than shoot length to extracts. allelopathic effects of rye was higher than wheat. Although in low concentrations of extracts did not significant difference between wheat and rye.

388. **Study of Allelopathic Effects of Cool Season Crops Stubble on Germination and Early Growth of Spring Crops.** Omid Younesi¹, Farzad Sharifzade¹, Allahverdi Haghpanah¹, Zoheir Yaghoubi¹; ¹University of Tehran, Isfahan, Iran

Chemicals that originate from plants or microorganisms impact many organisms in the ecosystem, but the term allelopathy has most referred to the activity of these chemicals on other plants or microorganisms. Many of the phototoxic substances suspected of causing germination and growth inhibition have been identified from plant tissues and soil. A wide array of these compounds is released into the environment. Most of these are phenolic compounds and are implicated in allelopathy, a process which includes the direct detrimental effect of one plant on the germination, growth and development of another plant. In the present work an attempt has been made to evaluate the allelopathic effect of cool season crops stubble on germination and early growth of sorghum, soybean and corn. The experiment was conducted in seed library research and greenhouse of College of Agriculture, University of Tehran, Iran in 2006. The experiment consisted of four cool season crops (wheat, rye, barley and pea) as main plots, four stubble concentrations (2/5 g/pot, 5 g/pot, 7/5 g/pot and control) and three crops (sorghum, soybean and corn) which were factorially assigned to the sub plots. The experiment was arranged as a split plot factorial in a completely randomized block design with three replications. All traits (germination percentage, plant height and shoot dry weight, root dry weight and shoot/root ratio) were affected by experimental treatments. Inhibitory effect of these crops plants was directly proportional to the increasing concentration of the aqueous. At the highest concentration studied was observed a maximum reduction in seed germination of the evaluated crops. Germination of soybean had the greatest susceptibility to inhibitor mater. Rye showed the highest inhibitory effect on plant height of several crops (corn, soybean and sorghum). Root dry weight of soybean was significantly affected when compared with corn and sorghum. By an increasing in stubble concentration to 7/5 g/pot, the most shoot/root ratio observed in soybean.

389. **The Impact of Weed-Leaf Residues on the Growth of Wheat and Tomato Plants.** Shachi Gupta¹, Rup Narayan¹; ¹I. P. (Post-Graduate) College, Bulandshahr, Uttar Pradesh, India

Due to human activities biotic invasions have grown considerably. The botanical invaders are supposed to alter the fundamental ecological characteristics like dominant species composition in a community, soil chemistry and plant productivity. Such alterations have been recognized to threaten efforts to conserve biodiversity, maintain productive agro-ecosystems, and sustain functioning nat-

ural ecosystems. The incomplete removal of these weeds commonly leaves their residue for decomposition in the field. These residues, especially of the exotic invasive weeds, may affect the soil characteristics and consequently the growth of next season's crops in agricultural lands or the associated plant species in natural field conditions particularly in open and disturbed areas. An ecological investigation was carried out to study the impact of leaf residues of three weeds *Parthenium hysterophorus* L., *Cassia obtusifolia* L. and *Achyranthes aspera* L. on the growth of *Triticum aestivum* L. (wheat) and *Lycopersicon esculentum* Miller (tomato) plants. Varying amount of weed-leaf residues (1 g, 2 g, 5 g, and 10 g) were added separately and in combination of two (5 g each), to 1 kg soil, and watered regularly. Ten days after soil amendment, wheat seeds were sown in the amended and control (unamended) soils in triplicates, and their growth (germination, shoot length and aboveground biomass) measurements estimated periodically for three months. For investigating the later impact of the weed-leaf residues in soils, tomato plants were transplanted into the amended and control soils, four months after soil amendment was done, and their growth measurements estimated. Higher amount of weed leaf residue (5 g, 10 g or 5 g each in combination of two) significantly impacted the crop growth. Wheat growth declined with increasing weed residue incorporation in soils. The initially retarded crop growth under control soils surpassed their growth under modified soils with the passage of time. No tomato plant survived in any *Parthenium*-amended soils, but enhanced tomato plant growth under *Cassia*-amended soils and declining growth in *Achyranthes*-amended soils was observed. The growth inhibition due to the combined impact of *Parthenium* and *Cassia* was greater than that by *Parthenium* and *Achyranthes*. The increase in below-ground biomass was more than the increase in above-ground biomass in soils with higher soil org. C. With increasing amount of leaf residue incorporated in soil, the soil org. C increased. In conclusion, the leaf residues of weeds altered the soil organic C and variably impacted the crop growth. This impact increased with time and quantity of residue incorporated in the soil.

390. Herbicidal Activity of Clove Oil and its Constituents.

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Health and environmental risks associated with some currently used synthetic herbicides has led to search for safer alternatives. Essential oils could offer safer options for chemical weed control. Herbicidal activity of clove oil and its constituents eugenol, caryophyllene and humlène (0.005 to 0.13M) on *Brassica oleracea* L. var. *italica*, cv. Purple Sprouting (broccoli) and *Chenopodium album* L. (lambsquarters) seedlings leaves were studied by measur-

ing their effects on cell membrane integrity. Leaf discs (10 mm diameter; n = 5), excised from *B. oleracea* (2nd true leaf) and *C. album* (6th true leaf) seedlings sprayed with essential oil solutions, were shaken in a rotary shaker at 90 rpm (3 hr) and the concentration of electrolytes leaked in the bathing medium was measured using a conductivity meter. Most of phytotoxicity of clove oil was due to eugenol, its largest (90.4%) constituent. Humlène and caryophyllene, constituting 3.6 and 6.1% respectively of clove oil, played smaller roles in determining clove oil phytotoxicity. In dose response studies, however, humlène was found to be more phytotoxic than caryophyllene or eugenol. In a separate study, effects of light intensity on susceptibility of *B. oleracea* and *C. album* seedling leaves to clove oil and eugenol were studied by growing seedlings under 1, 2, or 3 layers of black nylon mesh, spraying leaves with eugenol or clove oil, and measuring the tissue damage as described above. Retention of foliar-applied essential oil solutions was assessed using the methyl orange (0.01%) spray retention method. Seedling leaf area and the specific leaf weight (g.m⁻²) of the 2nd true leaf of *B. oleracea* and the 6th true leaf of *C. album* increased with increasing light intensity. Light intensity had a significant effect on phytotoxicity of clove oil and eugenol. Results showed that this effect could in part be due to the effect of light intensity on foliar retention of spray solutions. Increased production of leaf epicuticular wax in response to light intensity may be important in this regard.

391. Allelopathic Potential of Rice (*Oryza sativa* L.) Root Exudates on *Echinochloa crus-galli* (Barnyardgrass) and *Sagittaria trifolia* (Arrowhead) Seedlings Growth Traits.

Jafar Asghari¹, Saman Berendji¹; ¹University of Guilan, Rasht, Guilan, Iran

About three percent of rice varieties were found to inhibit the growth of several weeds when these cultivars were grown together with weeds under the field or laboratory conditions. Use of allelopathic potential of rice plants is a new option for sustainable weed management. Seven Iranian rice cultivars of Dashti-sard, Mehr, Anbarbu, Dasht, Ali-kazemi, Neda, Domsorkh, plus four foreign cultivars of USEN, Line-229, Dinorado and Dular were chosen as test plants to culture in a hydroponic system for evaluating their root exudates allelopathic potential on barnyardgrass and arrowhead seedlings in separate bioassays. The root system of rice seedlings was allowed to grow inside water during the incubation. This method is adapted from Kato-Noguchi, and Ino, [2005] with a slight modification. After 15 days, rice seedlings were harvested, and the hydroponics' water containing rice root exudates were collected to use in Bioassays and determine the allelochemicals with HPLC. Root exudates of Dinorado, Neda, and Domsorkh showed inhibitory effects (64.3, 50.8, and 45.9% of control, respectively) on barnyardgrass seedlings growth more than the other treatments. Dinor-

ado and Neda root exudates also had higher inhibitory effects (63.2 and 59% of control, respectively) on arrowhead seedlings growth parameters among the tested cultivars in bioassay. Rice root exudates obtained from hydroponics were qualified and quantified with HPLC method. Four phenolic acids (P-hydroxy benzoic acid, P-coumaric acid, m-coumaric acid and cinnamic acid) were identified in these three cultivars root exudates, indicated that, phenolic acids exudates from living rice root system and could involve in allelopathic activities on vicinity plants and weeds.

392. Screening Persian Rice (*Oryza sativa* L.) Allelopathic Varieties by Evaluating Hull Extracts on Two Important Weeds Seedlings Growth. Saman Berendji¹, Jafar Asghari¹, Amir Abbas Matin²; ¹University of Guilan, Rasht, Guilan, Iran; ²Food and Chemical Analysis Research Lab, Jahad-Daneshgahi, University of Urmia, Urmia, Western Azarbaijan, Iran

The use of allelopathic behavior of the rice crop is one of the new strategies for sustainable weed management. The environmental concerns about pesticide use and weed problems in paddies have been the driving forces behind rice allelopathic research in the last two decades. This study, at first, was the start of screening Persian allelopathic rice varieties in comparison with IRRI's approved allelopathic cultivars and some other foreign lines and varieties, and second, to evaluate possible involvement of six phenolic acids in allelopathic rice effects on two selected weeds seedlings growth traits. In two bioassays, the effects of three concentrations of 46 rice cultivars hull water soluble extracts on seedlings growth of *Echinochloa crus-galli* (barnyardgrass) and *Sagittaria trifolia* (arrowhead) were evaluated (method is adapted from: Ahn and Chung, 2000). Percent inhibitory / stimulatory effects of extracts on growth parameters were determined comparing with control. The full concentration of Dinorado, Neda and Dashti-sard cultivars hull extracts had the highest inhibitory activities (65, 53, 52 % of control, respectively) on growth traits of barnyardgrass, while, Line-229 in 50% and USEN in 100% concentrations had more stimulating effects on this plant. Arrowhead seedlings growth also was inhibited by full concentration extract of Dinorado, Neda and Dashti-sard (78.5, 63.9, and 55.5% of control, respectively) more than the other treatments. Hull extract of line-229 with 50% concentration had the highest stimulating effects on arrowhead shoot growth. High performance liquid chromatography (HPLC), method was used to analyze six phenolic acids in 15 rice cultivars hull water extracts as representative cultivars collected according to the results of bioassays. Dinorado hull extract had the highest phenolic acids content (97.461 µg/g) among the treatments. None of six phenolic acids were detected in Line-229 hull extract by HPLC, while, Dashti-sard had the highest p-

hydroxy benzoic acid content (38.2 µg/g). Dinorado and Dashti-sard hull extract phenolic contents had significant correlation with percent inhibition of two selected weeds root growth. So if a mixture of compounds is responsible for the growth inhibition of weeds, phenolic acids such as p-hydroxy benzoic acid could play a role in such a mixture. Although Dinorado (the IRRI's approved allelopathic cultivar) showed the highest inhibitory effect on both weed seedlings growth traits, Persian rice cultivars Dashti-sard and Neda also had a considerable inhibitory effect. Further studies may identify more Persian rice varieties with allelopathic characteristics and prove the results of this study.

393. Using Yellow Mustard Seed Meal and Seed Meal Extracts as Bioherbicides. Lydia Clayton¹, Donald Thill¹, William Price¹, Matt Morra¹, Vladimir Borek¹; ¹University of Idaho, USA, Moscow, Idaho, United States of America

Management of annual weed species continues to be one of the most troublesome and expensive components of organic agricultural production. Yellow mustard (*Sinapis alba* L.) seed meal and seed meal extracts contain secondary plant compounds such as the glucosinolate, 4-hydroxybenzyl. Glucosinolates are hydrolyzed by the enzyme myrosinase resulting in the formation of a number of compounds including ionic thiocyanate (SCN^-), which has been shown to be phytotoxic. A greenhouse dose response study was conducted to determine the effects of yellow mustard seed meal and seed meal extracts on the emergence and growth of common lambsquarters (*Chenopodium album* L.), 'Ya Ya' carrot (*Daucus carota* var. *sativa* L.), 'Baronet' lettuce (*Lactuca sativa* L.), and 'Cabernet' hard-red spring wheat (*Triticum aestivum* L.). Yellow mustard seed meal and seed meal extracts were applied preemergence (PRE) and postemergence (POST) to two-leaf plants at or equivalent to five rates (0.5, 1, 2, 3, and 4 mt/ha) in treatments that included water alone, water plus a synthetic nonionic surfactant (NIS), water plus an organic NIS, dry seed meal, seed meal extract plus synthetic NIS, and seed meal extract plus organic NIS. Above-ground dry biomass was determined for each species 19 days after application for PRE and POST treatments. Data were analyzed using regression analysis and the doses to reduce growth 50% (GR50) were determined. Dry seed meal treatments (GR50 PRE and POST = 0.7 and 2.1 mt/ha, respectively) and seed meal extract treatments plus a synthetic or organic NIS (GR50 POST = 0.3 and 0.5 mt/ha, respectively) reduced biomass of common lambsquarters more than other species. Carrot tolerated POST application of dry seed meal (GR50 = 8.5 mt/ha) and seed meal extracts plus an organic or synthetic NIS more than other species (GR50 = 2.5 and 6.2 mt/ha, respectively). Dry seed meal applied PRE did not affect carrot biomass. Seed meal extract treatments applied

POST with a synthetic or organic NIS did reduced lettuce biomass (GR50 = 1.2 and 1.4 mt/ha, respectively), while dry seed meal applied PRE did not affect lettuce biomass. Biomass of wheat was reduced more when seed meal extracts applied POST were mixed with organic compared to synthetic NIS (GR50 = 1.8 and 2.0 mt/ha, respectively). Dry seed meal applied POST did not affect wheat biomass. Across all species, seed meal extract applied POST with a synthetic NIS tended to reduce biomass more than any other treatment, followed by POST applied treatments of seed meal extracts plus an organic NIS. Dry seed meal treatments and PRE treatments of seed meal extract tended to reduce biomass less than POST seed meal extract treatments.

394. Phytotoxic Effects of *Croton bonplandianum* Residues on some Weed and Crop Plants. M Siddiqui¹, Swapnal Sisodia¹; ¹A.M. University, Aligarh, Uttar Pradesh, India

A study was conducted to assess the phytotoxicity of residues of *Croton bonplandianum* Baill, a noxious weed towards the growth of crops (*Brassica oleracea* var. botrytis L. and *Brassica rapa* L. and weeds (*Melilotus alba* Medik and *Medicago polymorpha* L.). The early growth of both (crops and weeds), measured in terms of root length, shoot length and dry weight, was significantly reduced when grown in soil amended with varying amount of Croton residues. A direct relationship was observed between the amount of residue incorporated in the soil and growth reduction. In order to test this, aqueous extract concentrations (0.5, 1, 2 and 4%) of residue were prepared. In a laboratory bioassay it was observed that, these extracts severely reduced the early growth of weed and crop plants. A significant amount of the phenolics (the largest group of secondary metabolites usually implicated in Allelopathy), was estimated in residues extracts, as well as in residue incorporated soil. The phenolic content increased with increasing residue concentration, thereby showing their direct involvement in the observed growth inhibitions. Therefore, the study establishes that Croton residue exert an allelopathic influence on the early growth of weeds and crops by releasing water-soluble phenolics into the soil.

395. Allelopathic Effects of *Parthenium hysterophorus* L. Extracts on Seed Germination and Growth of Wheat and Associated Weeds. Anees Amin¹; ¹NWFP Agricultural University Peshawar, Peshawar, NWFP, Pakistan

Parthenium hysterophorus L. being a declared invasive weed is threatening the biodiversity of Pakistan. To study its allelopathic potential a laboratory based study was undertaken during January 2007 in Weed Research Laboratory, Department of Weed Science, NWFP Agricultural University Peshawar, Pakistan to investigate the

allelopathic potential of aqueous extracts of leaves of *P. hysterophorus* against wheat, *Avena fatua* and *Lepidium* sp. The fresh leaves of *P. hysterophorus* were dried in shade and grinded. The powder was soaked @ 10g/L⁻¹, 20 g/L⁻¹ and 30g L⁻¹. Ten seed of each species were placed in Petri dishes and extracts were applied when needed. Control was also included for comparison. The experiment was laid out in completely randomized design with three replications. The result showed that with the increasing concentration of *P. hysterophorus*, the germination percentage, seedling length and seedling weight of all the three species tested were significantly decreased. The tolerance order of the species against the extract concentration of *P. hysterophorus* were *Triticum aestivum*, *Avena fatua*, *Lepidium* sp. Hence the present study suggest that *P. hysterophorus* affect the agro ecosystem and needs to be properly addressed.

396. The Evaluation of Metsulfuron -Methyl Formulations against Broad Leaf Weeds in Wheat (*Triticum aestivum* L.). Ramesh Singh¹; ¹Institute of Agri. Sci. Banaras Hindu University, Varanasi, Uttar Pradesh, India

Weeds remain the major constraint in wheat production under rice-wheat cropping in Indo Gangetic Plains of India. Emergence of broadleaf weeds, such as *Rumex* sp., *Chenopodium album*, *Vicia* sp. and *Melilotus alba* and *indica*, have made competition more severe to wheat crop. Metsulfuron-methyl has been widely used to control broadleaf weeds in small grain cereals. The major attraction to herbicide by farmers is its ease to measure, handling, flow from sprayer and low dust. Two formulations of the herbicide- Wettable powder (WP) and Water Dispersible Granule (WG) were evaluated at rates ranging from 2-8 g a.i./ha against broad leaf weeds in wheat. Application rate of 4gai/ha in form of WG was more effective in minimizing weeds growth than WP at same rate. It produced grain yield comparable to higher rates of the herbicide. No crop injury was observed even at application rate of 8g a.i./ha.

397. Adjuvant Effects on Performance and Rainfastness of Tribenuron-Methyl on Broadleaved Weeds. Euro Pannacci¹, Per Kudsk², Solvejg K. Mathiassen², Gino Covarelli¹; ¹University of Perugia, Perugia, Italy; ²Faculty of Agricultural Sciences, University of Aarhus, Slagelse, Denmark

The labels of many postemergence herbicides specify the use of certain types of adjuvants or combinations of adjuvants. Addition of a nonionic surfactant is generally recommended for tribenuron-methyl, but also vegetable oils are suggested as adjuvants on the label. The objective of this study was to examine the influence of three types of adjuvant, TREND® AS (a nonionic surfactant, 20% isodecyl alcohol ethoxylate, DuPont de Nemours IT),

CODACIDE® (a vegetable oil, 95% rapeseed oil, Microcide Ltd.) and BIOPOWER® (an anionic surfactant, 25.5% alkylethersulfate sodium salt, Bayer CropScience) on the performance and rainfastness of tribenuron-methyl (GRANSTAR® 50 SX, 50% a.i., DuPont de Nemours IT). In one experiment, plants of *Sinapis arvensis*, *Tripleurospermum inodorum*, *Papaver rhoeas* and *Chenopodium album* were grown outdoors in 2-litre pots in a soil-peat mixture containing all necessary macro and micro nutrients. The pots were placed on a table and sub-irrigated automatically. One day before herbicide application the number of plants per pot were reduced to four. The plants were sprayed at the 4-6 true leaves stage with six doses of tribenuron alone or in mixture with each of the adjuvants, using a laboratory pot sprayed equipped with two Hardi 4110-14 flat fan nozzle operated at 260 kPa delivering 143 L/ha. In a subsequent experiment, plants of *T. inodorum* were grown and sprayed as described above, where after groups of plants were subjected to 3 mm rain, at an intensity of 9 mm/h, 1, 2, and 4 hours after treatments (HAT) using a rain simulator. In both experiments plants were harvested 3 weeks after treatment and fresh and dry weights were recorded. The dry weight results were fitted to a logistic dose-response model, assuming that dose-response curves of tribenuron applied alone and in mixture with adjuvants were parallel within each weed species and relative potencies of tribenuron were estimated. Tribenuron activity was enhanced significantly by all adjuvants on all four weed species. The lowest and highest increase in activity were observed on *S. arvensis* and *C. album* respectively, probably due to their different wettability. The anionic surfactant tended to enhance tribenuron performance significantly more than the nonionic surfactant and vegetable oil. All adjuvants significantly improved the rainfastness of tribenuron, with differences between them being more pronounced when rain occurred shortly after herbicide application. In particular, the effect of the vegetable oil on tribenuron rainfastness was significantly lower than that of the surfactants with rain 1 and 2 HAT, whereas not significant differences were observed with rain 4 HAT.

398. The Response of *Phalaris minor* to Different Adjuvant and Herbicides. Atefeh Mousavi Nik¹, Eskandar Zand¹, Mohammad Ali Baghestani¹; ¹Plant Pests & Diseases Research Institute, Weed Science Department, Tehran, Iran

To evaluate the best adjuvant on different herbicide activities in canarygrass, an experiment was conducted in 2007 in a greenhouse- Tehran- Iran. The experiment was arranged as a factorial completely randomized design with 4 replications. 4 kinds of adjuvant were used in this experiment: Edigor, Cytotogate, Cytohef and Volk oil on different herbicides: Pinoxadone (Axial) in five doses (300,400,500,600 and 700), Clodinafop propargyl (Topik)

(dose 0.6, 0.8), Clodinafop propargyl (Behpic) (dose 0.6, 0.8) and Clodinafop propargyl (Karent) (dose 0.6, 0.8). We assessed the wet and dry weight, the number of live weeds and EWRC in 15 and 30 days after spraying. The results showed the best adjuvants were Edigor and Volk that control this weed completely (100%). The best herbicides were Axial 500,600 and 700 that control weed 100% and the weak herbicide was Axial 300 with 39% control.

399. Response of Three Weeds to Different Doses of Pinoxadone. Atefeh Mousavi Nik¹, Mohhammad Ali Baghestani¹, Eskandar Zand¹; ¹Plant Pests & Diseases Research Institute, Weed Science Department, Tehran, Iran

To evaluate the best dosage of Pinoxadone (Axial) and different adjuvants on *Avena fatua*, *Lolium temulentum* and *Phalaris minor*, an experiment was conducted in 2007 in a greenhouse in Tehran - Iran. The experiment was arranged as a factorial completely randomized design with 4 replications. We used Pinoxadone (Axial) in five doses (300,400,500,600 and 700), and four different adjuvants consisting of: Edigor, Cytotogate, Cytohef and Volk oil. The wet and dry weight, the number of live weeds and EWRC in 15 and 30 days after spraying were assessed. The results showed that in *Avena fatua* when adjuvants were not applied, doses 500,600 and 700 were the best effective but when the adjuvants were used, there was a non-significant difference among doses. In *Lolium temulentum* when adjuvants were not applied, dose 700 had the best control but, when the adjuvants were used, doses 500, 600 and 700 showed the best control. In *Phalaris minor* when we didn't use adjuvant doses 500, 600 and 700 showed the best control but, when the adjuvants were used, we had very good control in all doses except in 300.

400. The Effect of Various Adjuvants and Herbicides on *Avena fatua*. Atefeh Mousavi Nik¹, Eskandar Zand², Mohammad Ali Baghestani²; ¹The Institution of Pests & Diseases Research, Weed Science Department, Tehran, Iran; ²Plant Pests & Diseases Research Institute, Weed Science Department, Tehran, Iran

To evaluate the best adjuvant on different herbicide activities in wild oat, an experiment was conducted in 2007 in a greenhouse- Tehran - Iran. The experiment was arranged as a factorial completely randomized design with 4 replications. 4 kinds of adjuvants were used in this experiment: Edigor, Cytotogate, Cytohef and Volk oil on different herbicides: Pinoxadone (Axial) in five doses (300,400,500,600 and 700), Clodinafop propargyl (Topik) (dose 0.6, 0.8), Clodinafop propargyl (Behpic) (dose 0.6, 0.8) and Clodinafop propargyl (Karent) (dose 0.6, 0.8). We assessed the wet and dry weight, the number of live weeds and EWRC in 15 and 30 days after spraying. The results

showed that the best adjuvants were Volk, Cytohef, Cytogate and Edigor and they improved weed control 100%, 98%, 93% and 81% respectively. There weren't significant differences among Topik, Behpic, Karent and Axial (500,600,700) and they completely control the weeds (100%), but Axial (300) could just have a control of (82%).

401. Evaluation Varies Adjuvant and Herbicides on *Lolium temulentum*. Atefeh Mousavi Nik¹, Mohamad Ali Baghestani¹, Eskandar Zand¹; ¹Plant Pests & Diseases Reaserch Institute, Weed Science Department, Tehran, Iran

To evaluate the best adjuvant on different herbicide activities in ryegrass, an experiment was conducted in 2007 in a greenhouse- Tehran - Iran. The experiment was arranged as a factorial completely randomized design with 4 replications. 4 kinds of adjuvants were used in this experiment: Edigor, Cytogate, Cytohef and Volk oil on different herbicides: Pinoxadone (Axial) in five doses (300,400,500,600 and 700), Clodinafop propargyl (Topik) (dose 0.6, 0.8), Clodinafop propargyl (Behpic) (dose 0.6, 0.8) and Clodinafop propargyl (Karent) (dose 0.6, 0.8). We assessed the wet and dry weight, the number of live weeds and EWRC in 15 and 30 days after spraying. The results showed the best adjuvants were Volk, Edigor, Cytogate and Cytohef and they improve weed control 86%, 71%, 68% and 46% respectively. The best herbicide was Axial 700 that control weed 100% and the weak herbicide was Axial 300 with 49% control.

402. "Ultra High Throughput In Vivo Screening" - Fundamental Herbicide Research Screening Platform. Dirk Schmutzler¹, Hansjörg Krähmer¹, Mark Wilhelm Drewes¹, Christian Paulitz¹; ¹Bayer CropScience, Frankfurt/Main, Hessen, Germany

All new screening compounds need to find their way through Bayer's Research and Development cascade in order to become the next market product. The first test for some hundred thousand compounds a year is the Ultra high throughput in vivo screening (UHTVS). This real in vivo model defines the agrochemical potential of a compound besides Herbicides in all important agro indications on entire living organisms.

Starting point of this highly automated process is the preparation of the assay plates. An empty 96-well microtiter plate as a standard format has to be filled with soil, fertilizers, seeds and other different media to become the fundament of a powerful screening cascade.

The compound's application with a defined spraying on a 8 x 12 cm area is one of the most challenging parts of the process - Only some micro liters have to be distributed without cross contamination and high accuracy by a customized high throughput spraying device.

The assessment is done semi automatically - fully integrated in the UHTVS IT environment rated by a special trained technician to integrate longstanding biological and herbicidal experiences into the automated process.

Six years after implementation the UHTVS is an essential part of the herbicide screening cascade and an important source of new ideas for Bayer's chemist.

403. BAS 800H: A New Herbicide for Preplant Burndown and Preemergence Dicot Weed Control. Steven Bowe¹, Rex Liebl¹, Helmut Walter¹, Thomas Holt¹, Bernd Sievernich¹, William Patzoldt¹; ¹BASF, Research Triangle Park, NC, United States of America

BAS 800H is new herbicide being developed by BASF for dicot weed control. BAS 800H is a protoporphyrinogen-IX-oxidase (PPO) inhibitor belonging to the pyrimidine dione class of chemistry. BAS 800H is highly effective on dicot weeds controlling them through both contact and residual activity. BAS 800H has preemergence selectivity in multiple crops and has also demonstrated control of problem weeds in non-crop markets. BAS 800H is readily absorbed by root and shoot tissue of plants. Once absorbed, BAS 800H is predominantly translocated via the xylem, with limited movement via the phloem. Selectivity is conferred by physical placement and rapid metabolism of BAS 800H in tolerant crop species. BAS 800H has a very favorable regulatory profile. Research indicates that BAS 800H applied at 18 to 25 g ai/ha can be used alone or mixed with glyphosate and applied preplant for rapid and complete burndown of weeds in soybeans, cotton, cereals, maize and selected legumes. BAS 800H complements glyphosate by controlling glyphosate or ALS tolerant/resistant weeds including horseweed (*Conyza canadensis*) or prickly lettuce (*Lactuca serriola*). In tree fruit and nut crops, BAS 800H applied as post-directed treatment controls important dicot weeds such as flaxleaf fleabane (*Conyza bonariensis*) and *Malva* spp. Our research has shown that in maize, BAS 800H can be used preemergence at 63 to 125 g ai/ha for a complete dicot solution including control of troublesome large-seeded species such as velvetleaf (*Abutilon theophrasti*), common cocklebur (*Xanthium strumarium*), ragweed (*Ambrosia* spp.), common sunflower (*Helianthus annuus*) and morningglory (*Ipomoea* spp). BAS 800H does not require combination with atrazine to successfully control broad-leaf weeds preemergence in maize. BAS 800H's combination of broad dicot spectrum, complementary activity with glyphosate, and preplant crop safety makes it well suited to be an important component for preplant burndown and residual weed control in many cropping systems.

404. Managing Striga Infestation with Metsulfuron and Imazapyr Seed Treatments in Grain Sorghum Resistant to Acetolactate Synthase-Inhibiting Herbicides. Kassim Al-

Khatib¹, Souley Soumana², Newton Ochanda¹, Issoufou Kapran², Aboubacar Toure³, Issoufou Salami², Siaka Dembele³, Aad van Ast⁴, Lammert Bastiaans⁴, Mitchell Tuinstra⁵; ¹Kansas State University, Manhattan, Kansas, United States of America; ²INRAN, Niamey, Niger; ³IER, Bamako, Mali; ⁴Wageningen University and Research Centre, Wageningen, Netherlands; ⁵Purdue University, West Lafayette, Indiana, United States of America

Sorghum is a staple food crop in many parts of West Africa including Niger and Mali. Grain yields of sorghum in West Africa are severely constrained by biotic and abiotic stresses including drought, poor soils, disease, insect, and weeds. However, witchweeds (*Striga* spp.) is considered the most serious problem facing grain sorghum production in West Africa. Witchweeds are obligate parasitic weeds of sorghum and millet and have a significant economic impact on resource-poor farmers in Africa. In the Sahel region of West Africa, *Striga* is reported to be the single greatest obstacle to food production. *Striga* infests approximately 73 million hectares of cereal crop production in Africa with crop losses exceeding 70% in some areas. Field and greenhouse studies were conducted in 2005 to evaluate herbicide seed treatments to control *Striga* infestation in acetolactate synthase (ALS) grain sorghum. Seeds from an experimental sorghum hybrid (ATx623 x Tailwind) with resistance to ALS-inhibiting herbicides were treated with varying rates of imazapyr (0.018, 0.037, 0.075 mg ai seed⁻¹) and metsulfuron (0.003, 0.006, 0.012 ai seed⁻¹). These treatments were compared to an untreated control. Field studies in Konni, Niger showed significant differences between herbicide treatments. *Striga* emergence was delayed in plots produced using herbicide treated seeds compared to the untreated controls. *Striga* counts also were lower in plots produced from seed treated either with imazapyr or metsulfuron as compared to the control. Similar level of *Striga* suppression occurred with both herbicide. In greenhouse studies at Wageningen University, timing of *Striga* attachment as well as variation in sorghum and *Striga* growth and development were evaluated. The number of attached *Striga* at 32, 46, and 60 days after planting showed a dose response relationship in the imazapyr and metsulfuron treatments with the fewest attachments and greatest delay in attachment at the highest rates of herbicide application. The number of emerged *Striga* showed a similar trend with significantly fewer *Striga* observed in pots with the highest rates of herbicide application. These studies suggest that metsulfuron and imazapyr seed treatments may provide good suppression and delay of *Striga* infestation in ALS-resistant grain sorghum sorghum.

405. *Avena fatua* as a Natural Biosorbent for Cu(II) and Zn(II) and the Effect of these Metals on Weed Growth.

Maria Mar Areco¹, Maria Dos Santos Afonso¹; ¹Buenos Aires University, Buenos Aires, Argentina

Justification for the research of metal contamination is considered one of the most concerning types of contamination, they are bio accumulated along the trophic chain and are discarded from an enormous number of different industries, being the environment the disposal storage.

During the past few years different ways of effluent treatments are being studied.

Plants, such as weeds, can be used as biosorbents for metal uptake from the environment because metals are taken by plants and can be accumulate in them.

Objectives

The objective is to determinate if *Avena fatua* can be used as a metal biosorbent substrate in order to remove Cu(II) and Zn(II) from waste waters, as well as to determine the effect of these metals onto *A. fatua* growth when it is treated with different concentrations of metal solutions.

Methods

A. fatua was collected in Buenos Aires, Argentina. Seeds were separated. The biomass was washed, dried and crushed. Batch biosorption experiments were carried out using solutions of Zn(II) and Cu(II). Assays were conducted with a fixed metal (50 mg/l) and weed (1 g/l) concentrations for 24 hours. Aliquots of the different solutions were filtered and analyzed by spectrophotometric techniques. Kinetic biosorption experiments were carried out for both metals at the best pH value for metal removal (pH = 5).

The Langmuir sorption model was chosen for the estimation of maximum metal uptake (q_{max}).

The effect of Zn(II) and Cu(II) concentration on *A. fatua* growth was studied by planting two seeds of *A. fatua* on each of a total of 22 flowerpots. The flowerpots were grouped in pairs and each pair was irrigated with a different metal concentration solution (1, 10, 20, 50 and 100 ppm), two of them were used as controls so they were irrigated only with tap water.

Results

A. fatua biosorbs Cu(II) and Zn(II). Adsorption of copper was much more efficient than zinc. Maximum metal equilibrium concentration was reached after three hours for both metals.

A. fatua biosorbs more than 30% of the initial Cu(II) concentration in the solution. This result confirms the capacity of this weed to biosorb copper from waste waters. Zn(II) uptake were much less efficient.

The effect of metal concentration on *A. fatua* growth was marked. The effect of zinc concentration for the development of *A. fatua* was less than the copper effect.

Conclusions

A. fatua can be used as a biosorbent for Cu(II) uptake from contaminated effluents. For the uptake of Zn(II) other kind of biomasses should be considered, such as

seaweeds, which are much more efficient for Zn(II) biosorption from waste waters.

Natural substrates should be considered as an alternative technique for effluent treatment.

Metals affect *A. fatua* growth. The presence of copper on the water affect more the growth of this weed than the same concentration of Zn(II).

406. Comparing Roundup Ready Alfalfa to Conventional Alfalfa for Weed Control , Yield, and Forage Quality. Philip Westra¹, Neil Hanson¹, Joe Bremmer¹, Bill Wailes¹, Shawn Archibeque¹, Terry Angle¹, Brian Larson¹; ¹Colorado State University, Fort Collins, Colorado, United States of America

Two field studies were initiated in the spring of 2007 to directly compare an elite Roundup Ready alfalfa with an elite conventional alfalfa for weed control, alfalfa yield, and forage quality. The studies were arranged in a randomized complete block design which also incorporated several levels of dairy manure to evaluate potential manure disposal where alfalfa is going to be planted. Stand establishment of both alfalfa varieties was good to excellent. Weed control was significantly better in the Roundup Ready alfalfa, although at harvest 1 it was not weed free. Two harvests were obtained in the year of establishment with yields over 2 cuttings averaging nearly 2.5 tons/acre of dry matter. Forage quality analysis has been obtained on all samples, and an economic analysis of the two production systems is being performed. Commercial alfalfa producers express high interest in the Roundup Ready alfalfa production system because of crop safety, the simplicity of the weed control system, and the flexibility available for weed control. Economic analysis conducted to date shows that the tech fee for Roundup Ready alfalfa is very reasonable.

407. Comparison of Broadcast and Wet-Blade Applications of 2,4-D and Triclopyr for Control of Woody Species and off Target Impacts on Conservation Reserve Program Lands in Alaska. Steven Seefeldt¹, Jeffery Conn¹, Phil Kaspari²; ¹USDA/ARS, Fairbanks, Alaska, United States of America; ²University of Alaska Fairbanks, Delta Junction, Alaska, United States of America

Mowing every 2 to 3 yr is not controlling woody plant species on Interior Alaska Conservation Reserve Program lands, therefore alternative methods for managing these plant species need to be developed. A new application technology, the wet-blade mower, which pumps herbicide out to the mower blades where it coats the cut surface of plants, may provide growers with a cost-effective way to use herbicides to control these woody species while minimizing off target impacts. The objectives of this research were to: compare efficacy of the wet-blade

mower, a broadcast application, and traditional mowing; compare off-target impacts of the wet-blade mower and broadcast application; and compare 2,4-D and triclopyr for efficacy on woody vegetation and off-target plant species. The study was conducted on two fields using a randomized complete block experimental design. On each field there were four blocks with seven treatments applied on July 18, 2006. Amine formulations of 2,4-D (2.2 kg/ha) and triclopyr (1.7 kg/ha) were used with the wet-blade mower and ester formulations of 2,4-D and triclopyr (both 2.2 kg/ha) were broadcast with a 15 m boom. Mow treatments were cuts at 38 or 15 cm. Wet-blade treatments were applied with a 38 cm high cut to provide a physical separation of the herbicide from off-target plants whereas farmers typically cut at 15 cm. Plots were 18 x 60 m and plant cover was measured before and 1 yr after herbicide application. Triclopyr was more efficacious (16% cover) than 2,4-D (22% cover) on shrub species, broadcast application was slightly more efficacious (15% cover) than the wet-blade (23% cover) on shrub species. Only 21% of the *Salix* species were killed with 2,4-D, but triclopyr killed over 54%, with broadcast more efficacious than the wet-blade (68 and 37%, respectively). *Betula species* and *Populus tremuloides* were not killed by either herbicide. Off-target impacts were similar for both broadcast and wet-blade applications. No treatments resulted in satisfactory control of woody species. The impact of the wet-blade mower on low growing desirable forbs is an indication that the herbicides were not sticking to the blades. An experiment started in 2007 will determine if lowering the application height of the wet-blade mower to 15 cm will improve control of woody species as translocation distance to roots will be reduced.

408. Advances in Determining Soil Water Potential Using an Engineered Porous Ceramic and Dielectric Permittivity. T-Jay Clevenger¹, Doug Cobos¹, Colin Campbell¹, Gaylon Campbell¹; ¹Decagon Devices, Inc., Pullman, WS, United States of America

Soil water potential is a key parameter for determining water availability for plant growth, water flow, and soil stability. Although an in situ measurement of water potential has been the focus of considerable research over the years, existing solutions still have many draw backs such as necessary routine maintenance, limited longevity, individual calibration requirements, high cost, and small measurement range. The objective of this research was to develop a sensor that could be used in the field to accurately measure soil water potential without the limitations noted above. The sensor, which consists of a dielectric sensor sandwiched between porous ceramic, was tested over a range soil types, electrical conductivities, and temperatures to calibrate and characterize its output. Data show consistent calibration curves between sensor output and actual soil water potential over a variety of soil

textures and electrical conductivities. Although temperature showed an effect on sensor output, it was small compared to overall sensor output. Likewise, salt effects were not visible in saturated matrices up to 10 dS/m. Data suggest the sensor will be an effective and robust tool to determine in situ soil water potential.

409. Comparison of Three Methodologies for Efficient Weed Seed Extraction in Studies of Soil Weed Seedbanks.

Mohsen Mesgaran¹, Hamid Mashhadi¹, Eskandar Zand², Hassan Alizadeh¹; ¹University of Tehran, Karaj, Tehran, Iran; ²Plant and Pest Disease Research Institute, Tehran, Iran

Determination of weed seeds in the soil is tedious and time consuming. It is necessary to evaluate the different seed extraction methods to improve seed bank estimations. Three extraction methods (sieving, cloth bag and flotation) were compared based on their accuracy and time needed for separation processes and enumeration. The experiment was carried out in a factorial arrangement based on a completely randomized design with four replications. Seeds of *Datura stramonium* L., *Amaranthus retroflexus* L., *Portulaca oleracea* L. and *Plantago major* L. were used to artificially infest soil samples of four textures namely clay, clay loam, loam and sandy loam containing 19, 27, 38 and 65.5% sand, respectively. Soil textures had significant effect on counting time in all extraction methods. In flotation, four sub-methods involving different solutions and centrifuge rotation speed were examined, but showed no differences and then pooled into the single method of flotation. Counting time in flotation, cloth bag and sieving methods was 9, 16 and 30 min, respectively. However, when the time needed for other processes was taken into consideration, flotation and bag method did not differ significantly. Species-wise seed recovery was not affected by soil texture in bag method, suggesting an advantage for this approach since its accuracy is not soil texture-dependent. Total seed recovery for flotation, sieving and bag methods was 61, 67 and 75%, respectively, and was not significantly different. Considering the efficiency of methods, cloth bag technique could be recommended because it was as time consuming as the flotation method but required the same minimum equipments and costs as the sieving method.

410. Innovating Practices for Vegetation Management in the Historic Sites.

Garyfallia Economou¹, Maria Papafoitiou¹, Ioanna Kanellou¹; ¹Agricultural University of Athens, Athens, Greece

Weeds, bushes and shrubs cover in some cases a great part of the monuments constituting a severe problem. The control of the undesirable vegetation by herbicides is considered prohibitive in order to avoid the deterioration

of the monuments. We recorded the vegetation following a stratified procedure in selected sites, whereas we applied alternative methods which were proved effective to control the undesirable vegetation. The soil solarization was applied for weed control, while an integrated method consisted by mechanical and chemical means was applied to bushes and shrubs. On this type of vegetation, after cutting the branches, we treated with a paste of glyphosate by specialized application. Additionally, the glyphosate was directly applied, in a dense suspension formula, by injection inside the cambium. A particular problem is the olive trees seedlings occurrence on the monuments. Spraying with 400 mg l-1 naphthalinacetic acid, at the end of the spring, resulted in complete fruit abortion, suggesting an effective control of the great distribution of olive trees. It is worth mentioning the particular method applied for weed control on a mosaic floor in a Romanic Villa. The floor was covered with layers of quartz sand, matting, LECA and gravel, inhibiting the weeds development. Furthermore, a study was carried out for installation of particular plant species aiming to the restoration of the historic environment.

411. The Effect of Suitable Methods of Controlling Destructive Weeds of Urban Foundation (Pavements, Side Walks of the Parks and Landscape).

Sedighe Sadeghi¹, Zoheir Ashrafi¹, Hassan Alizade¹; ¹University of Tehran, Karaj, Tehran, Iran

A weed in a general sense is a plant that is considered by the user of the term to be a nuisance, and normally applied to unwanted plants in human-made settings such as gardens, lawns or agricultural areas, but also in parks, woods and other natural areas. More specifically, the term is often used to describe native or nonnative plants that grow and reproduce aggressively. This vegetation is unsightly and sometimes even hazardous, and it grows in those hard-to-manage areas where landscaping is not feasible because mowing is impossible or risky. The need for roadside vegetation control is fueled not only by aesthetic considerations, but also must be managed with limited use of pesticides out of concern for safety, environmental mitigation, storm water pollution prevention, and erosion control. These methods not only help control vegetation, but can also make your roadsides more attractive. Invasion to landscape is one of these examples but worse still is weed invasion to pavement, sidewalks and asphalt, etc. we can use mechanical methods like weeding, plough, mulching and flaming to control weeds. Continuous use of contact herbicides and simplistic and absorptive herbicide are other recommended ways. The situation and square of the region, weed growth, weed type and economic situation affect the methods of controlling.

Material and Methods.

In order to study the effects of physical, mechanical and chemical methods of weed control landscape and urban

conditions, a experiment was conducted in years 2005-2006. The experiment design was a randomized complete block with three replications. Treatments consisted of 1- weeding, 2- soil cover (soil mulch) 3- mulch 4- fry (flame) 5- heavy Irrigation (shipwreck) 6- Glyphosate (1 lit/ha) 7- Glyphosate(2 lit/ha) 8- Paraquat (1 lit/ha) 9-Paraquat (2 lit/ha) 10- Oxyfluorfen (2 lit/ha) 11-Oxyfluorfen(3 lit/ha) 12- check (not control weed). All experiments were repeated twice and pooled mean values were separated using least significant differences (LSD) at the 0.05 probability level following an analysis of variance; except for the experiment investigating the effects of preceding crops, for which t-tests were used. Statistical analyses were made with the MSTAT statistical program (Michigan State University, East Lansing, MI).

Result and discussion.

These weeds are generally perennial and have strong and wide roots and rhizomes that make weed control much more difficult and time consuming, so contact treatment which have been applied temporarily are inefficient and have little effects. According to the latest research, destructive weeds of the road and pavement and sidewalks of the parks and buildings, etc are mainly: Nutsedge (*Cyperus* sp), camelthorn (*Alhaji* sp), Johnsongrass (*Sorghum halepense*), Bermudagrass, (*Cynodon dactylon*), Russian thistle (*Salsola* sp), field bindweed (*Convolvulus arvensis*), Barnyardgrass (*Echinochloa crus-galli*), Caper (*Capparis spinosa*), Syrian rue (*Peganum harmala*), Small Caltrop (*Tribulus terrestris*), Purslane (*Portulaca oleracea*), ect. which belong to different plants families. According to the examinations, treatment effects on weed control have been significantly positive; even though these effects were different from each other there fore soil and mulch treatment on these weeds wasn't so successful. Never the less herbicides treatment on the weeds had a good effect and limited the growth. Paraquat effect was temporary, because it is a contact herbicide and destroys only the upper parts of the weeds in case of quality and quantity. Different dose effect of glyphosate and oxyfluorfen was better. According to easy application of these herbicides and their long-lasting effects in comparison with other treatment, these treatments are recommended. Flaming method rather had good effect on destructive weeds of pavements but the perennials start to grow the next year. Among all the treatment, the best one was glyphosate, which was proved that it is long-lasting and no weed grew again up to six months after the application. Oxyfluorfen had good effect on destructive weed as well, and its speed in controlling broadleaf weeds like camelthorn and field bindweed, was also good, but not for grasses in comparison with other herbicides; oxyfluorfen controls the weeds better and quicker but not nutsedge and Bermudagrass. We studies the treatment effects on the weeds and also the sensitivity of each weed to the treatments. Each weed showed a specific sensitivity toward the treatments and so the range of sensitivity determined the most effective method to control the mentioned weed.

The differences among the weeds are because of ecophysiological differences.

412. Weed Management Potential for EPTC Applied Preplant for Sod Production. Sheryl Wells¹, R. H. Walker¹, J. L. Belcher¹; ¹Auburn University, Auburn, Alabama, United States of America

A high degree of weed control is necessary for production of quality sod. This is particularly important during the establishment phase. Loss of methyl bromide has increased the need for more effective preemergence-applied herbicides. Herbicides with short soil residual such as EPTC may offer potential to control troublesome species such as bermudagrass (*Cynodon dactylon*). Sod producers are generally willing to delay planting up to 6 weeks after herbicide treatment. Objectives were: 1) identify safe plant-back intervals for selected turf species; 2) determine potential for control of bermudagrass with rates up to 11.9 kg ai/ha. EPTC requires immediate soil incorporation since it is highly volatile. Greenhouse experiments were conducted using a sandy loam soil. Soil samples of 1 kg were placed in bags and EPTC (Eptam 7 EC) diluted in water was added. Bags were sealed and hand tumbled to emulate soil incorporation. Soil was placed in 1-L cups and 10 seeds of centipedegrass [*Eremochloa ophiuroides* (Munro) Hack.] or tall fescue (*Festuca arundinacea* Schreb.) were seeded at 7, 14, 28, and 56 days after soil treatment (DAT). Plant count and dry weight data showed a safe plant-back interval of 56 DAT for centipedegrass with EPTC rate of 8.9 kg ai/ha. Dry weight data for tall fescue also showed a safe plant-back interval of 56 days. However, the 8.9 kg ai/ha was too injurious for fescue and produced the lowest dry weight. There was no differences in the other 3 rates. The plant count data for fescue showed the 1.12 and 2.24 kg ai/ha rates to produce the best counts with no differences. In greenhouse efficacy trials, bermudagrass stolons were planted into treated soil immediately after the soil mixing process. Visual control evaluations data showed 74 to 94% control for the 3.9 and 11.8 kg ai/ha rates of EPTC, respectively. In field studies, EPTC at 7.8 kg ai/ha was applied to sandy loam soil that had been tilled and common bermudagrass regrowth treated twice with glyphosate + fluazifop. Bermudagrass control was 98% or greater. Common centipedegrass was successfully seeded into these areas 28 days after EPTC application. Good to excellent control of pigweed (*Amaranthus* spp.), crabgrass (*Digitaria* spp.), crowfootgrass (*Dactyloctenium aegyptium*), and goosegrass (*Eleusine indica*) was obtained with this system. An integrated approach of tillage, glyphosate + fluazifop, and EPTC shows excellent potential for preplant weed management in warm-season sod production.

413. Centipedegrass Response to Mesotrione Applied Alone and in Combination with Atrazine. Jason Belcher¹, Robert Walker¹, Joseph McElroy¹; ¹Auburn University, Auburn, Alabama, United States of America

Centipedegrass [*Eremochloa ophiuroides* Munro. (Kunz)] is a common turfgrass grown in the southeastern United States. It is a low maintenance turfgrass that grows well in lower pH soils and has lower fertility requirements when compared to other warm-season turfgrasses. Atrazine is one herbicide commonly used on centipedegrass turf. It controls a wide range of weeds and has good tolerance on centipedegrass. Mesotrione is a newly-registered compound under the trade name Tenacity. It is labeled for use on golf courses and sod farms, with registration for commercial and residential use anticipated in 2008. Mesotrione controls several species of both broadleaves and grasses, most notably crabgrass species (*Digitaria* spp.). Established centipedegrass has excellent tolerance to mesotrione, but research on newly-seeded centipedegrass is limited. Therefore, research was conducted in order to evaluate mesotrione alone and in combination with atrazine for centipedegrass tolerance when applied 2 weeks after emergence. Two greenhouse experiments and one field experiment were conducted. In greenhouse studies, atrazine rates were 0.28, 0.56, 1.12, and 2.24 kg ai/ha and mesotrione rates were 0.03, 0.07, 0.14, and 0.28 kg ai/ha. Tank-mixes included either all atrazine rates with 0.28 kg/ha mesotrione, or atrazine at 2.24 kg ai/ha with all mesotrione rates. Data was collected for centipedegrass injury and biomass production. Greenhouse studies revealed that atrazine alone and atrazine plus mesotrione resulted in more injury and less biomass than mesotrione applied alone. From these studies, the maximum rate of atrazine that should be applied to seedling centipedegrass is 0.28 kg ai/ha when applied in combination with mesotrione. The second experiment evaluated the effects of atrazine at 0.28 kg ai/ha tank-mixed with mesotrione (0.03-0.28 kg ai/ha) on the establishment of seeded centipedegrass in a field setting. Percent ground cover was evaluated utilizing the computer program Sigma Scan. While all combinations of atrazine plus mesotrione reduced groundcover 28 DAT (days after treatment), no treatment reduced groundcover 49 DAT. Results from these studies indicate that either mesotrione alone or combined with a low rate of atrazine have good potential to be used on young stands of centipedegrass for weed control.

414. Watch on 'T' Weeds in Golf Turf in China. Xue Guang¹; ¹East China Weed Technology Institute, Nanjing, Jiangsu, China (Peoples Republic of)

The author puts forward the concept of 'Watch on 'T' weeds in golf turf in China', which was based on a study in 68 Golf courses in China during 1998 and 2007. The

observation indicated that 'T' weeds meant trouble weeds including weedy turf, weeds transformed from turf and grass-like weeds in golf turf. In Chinese, these plants are also called 'Teshu' weeds (particular weeds) or 'Tongke' weeds (Same family in gramineae). These trouble weeds are spreading and becoming more serious in golf turf. 'T' weeds always occur in the cultivated turf for more than 4 years. Weedy turf only occurs in bermudagrass. Weeds transformed from turf and grass-like weeds occur in all cultivated turf. Twenty six 'T' weeds have been found in golf turf in China. Type 1. Weedy turf: 1. weedy turf is in bermudagrass, mostly in southern part of China.

Type 2. Weeds transformed from turf include: 1. Bermudagrass in seashore paspalum; 2. Bermudagrass in Zoysia grass; 3. Bermudagrass in Kentucky bluegrass or in the mixture of bluegrass and ryegrass; 4. Bermudagrass in tall fescue; 5. Seashore paspalum in bermudagrass; 6. Seashore paspalum in zoysiagrass; 7. Ryegrass in bermudagrass; 8. Ryegrass in seashore paspalum; 9. Bentgrass in bermudagrass; 10. Tall fescue in bermudagrass; 11. Tall fescue in bermudagrass; 12. Kentucky bluegrass in bermudagrass; 13. Bentgrass in Kentucky bluegrass; 14. Carpetgrass in bermudagrass; 15. Zoysiagrass in Kentucky bluegrass

Type 3. Grass-like weeds include: 1. *Poa annua* L. (Annual Bluegrass); 2. *Digitaria sanguinalis* (L.) Scop. (Common Crabgrass); 3. *Eleusine indica* (L.) Gaertn. (-Goosegrass); 4. *Panicum repens* L. (Torpedograss); 5. *Paspalum conjugatum* Bergius (Hilograss); 6. *Polypogon fugax* Nees et Steud. (Common polypogon); 7. *Paspalum distichum* L. (Knotgrass); 8. *Dactyloctenium aegyptiacum* (L.) Willd (Durban crowfootgrass); 9. *Brachiaria villosa* (Lam.) (Hairy paragrass); 10. *Microstegium vimineum* (Trin.) A Camus. (*Vimineous microstegium*)

The author proposed the possible factors contributing to the formation of T weed in turf. A systematic method for controlling T weeds is in setting up. The author also appeals to watch on T weed in order to maintain a weed free turf for golf players.

415. A Precision Conservation Approach for the Efficient Management of a Woody Invasive Riparian Weed. Melissa Bridges¹, Dan Wolford², Ken Wicklund², Philip Westra¹; ¹Colorado State University, Fort Collins, Colorado, United States of America; ²City of Longmont, Colorado, Longmont, Colorado, United States of America

Precision conservation is an emerging management concept adapted from ideas based in precision farming where technologies and protocols that implement spatial and temporal variability are applied for efficient and effective environmental management. Precision conservation for invasive weed management requires that the spatial variability of the species of interest and other environmental attributes be characterized at a resolution relevant for management. Taking a technology-based approach by employing global positioning systems (GPS)

and geographic information systems (GIS) can enhance the ability to accurately spatially quantify attributes of and ultimately prioritize and prescribe management for invasive weed species within an area of interest. The overall objective for this study is to develop a management plan for the exotic, invasive species, *Elaeagnus angustifolia* L. (Russian-olive), within a riparian public park that optimizes the use of limited time, labor, and financial resources. Specific objectives include i) developing and administering an efficient survey measuring the abundance of *E. angustifolia* and of other native species within the park, ii) developing analytical geographic products depicting the locations prioritized for weed eradication and native species re-vegetation, and iii) establishing long-term monitoring plots for assessment of management practices over time. The project will be conducted between March and June of 2008. A GPS-based survey will be used to map several attributes describing the abundance of *E. angustifolia* and of other existing native species. Statistical techniques such as interpolation and logistic regression will be used to derive maps describing the suitable habitats for and the variation in abundance of *E. angustifolia*. These map products will be used to generate additional maps prioritizing locations for management. Specific methods employed and results of this precision conservation approach to invasive weed management will be presented in June of 2008 at the International Weed Science Congress.

416. **Herbicide Combinations to Reduce Application Rates of 2,4-D for Pasture Weed Control.** Trevor James¹, Anis Rahman¹; ¹AgResearch, Hamilton, Waikato, New Zealand

Pastoral farming in New Zealand utilizes a *Lolium perenne* and *Trifolium repens* mixture as the principal component of its grazing sward. This combination of a monocot and a legume presents a major challenge for suitable candidate herbicides to achieve good weed control while causing minimal damage to both desired pasture species. For 50 years the phenoxy herbicide 2,4-D has been the predominant chemical used for weed control on New Zealand farms. However, its continuous use has led to 2,4-D resistance in some of the major weeds. This, combined with regulatory pressure to reduce the amount of herbicide used in our primary industry has promoted the search for ways to reduce the use rates of 2,4-D.

Greenhouse and field experiments investigated the efficacy of lower rates of 2,4-D when used in combination with either chlorsulfuron or mesotrione, for control of two common pasture weeds, *Senecio jacobaea* and *Carduus nutans*. Both the ethylhexyl ester and dimethyl amine salt formulations of 2,4-D were included in these studies. The greenhouse experiment evaluated the herbicide combinations at several growth stages from small rosettes to pre-bolting plants while the field experiments tested the

herbicides on weeds at the flowering stage. The full recommended rate for 2,4-D was 1040 g ai/ha and 1200 g ai/ha for the ester and amine formulations respectively, while chlorsulfuron was used at 4 g ai/ha and mesotrione at 83 g ai/ha.

In the greenhouse experiments, for *S. jacobaea*, the half rate of 2,4-D plus either chlorsulfuron or mesotrione performed equal to or better than the full rate of 2,4-D alone, with quicker brownoff for plants up to 20 cm in diameter. The half rate of 2,4-D in combination with either chlorsulfuron or mesotrione generally resulted in significantly better control at all stages of growth, than the half rate of 2,4-D alone.

For *C. nutans*, mesotrione proved a better additive than chlorsulfuron. Mesotrione plus the half rate of 2,4-D always performed as well as the full rate of 2,4-D alone and generally provided significantly better control than the half rate of 2,4-D alone. Comparatively, the chlorsulfuron/half-rate of 2,4-D combination in many instances resulted in significantly poorer control than both the half and full rates of 2,4-D alone.

There were no significant differences between the two formulations of 2,4-D at any growth stage or on either weed species. However, stage of growth made a significant difference with the smaller plants controlled more quickly and effectively.

In the field trials, control of both *S. jacobaea* and *C. nutans* from the half rate of 2,4-D plus either chlorsulfuron or mesotrione was equal to or significantly better than that from the full rate of 2,4-D alone. However, in some instances there was also greater pasture damage, particularly to the *T. repens* plants, and mostly from the combination with the ester formulation of 2,4-D.

417. **Effect of N and Weed Control Methods on Weed Management in Lawn.** Fazal Munsif¹, Muhammad Waqas²; ¹Agricultural Research Institute, Tarnab, Peshawar, Peshawar, NWFP, Pakistan; ²NWFP Agricultural University Peshawar, Peshawar, NWFP, Pakistan

Weeds are among the great problems of lawn management. The experiment was conducted at Agricultural Research Farm, NWFP, Agricultural University, Peshawar, Pakistan during spring 2007. The experiment was laid out in randomized Complete Block design with split plot arrangement having three replications. Nitrogen levels i.e. 0 and 50 kg/ha were allotted to the main plots while weed control treatments i.e. weedy check, hand weeding and herbicide application to the subplots. The effect of N was significant on weed density m², fresh weight and dry weight of weeds and total weed biomass. Higher fresh weight of weeds was recorded in plots applied with 50 kg N plots as compared to control plots. The effect of weed control methods was significant for weeds density m², fresh weight, dry weight and total weed biomass. Lower weed density, fresh and dry weight and total weeds biomass

were recorded in plots where herbicide was applied for weeds control. It was concluded that herbicide (broad leaf) can be effectively used to control weeds in lawns.

418. The Response of *Fimbristylis cymosa* (A Native Hawaiian Sedge) to Fluazifop-p-butyl and Triclopyr. Orville Baldos¹, Joseph DeFrank¹; ¹University of Hawaii at Manoa, Honolulu, Hawaii, United States of America

The Hawaii Department of Transportation has provided funding to develop protocols for the establishment of native Hawaiian plants to curb roadside erosion and mitigate the spread of invasive species. Postemergence weed control is an important aspect during the establishment of native plantings. In this study, two postemergence herbicides were evaluated for use on *Fimbristylis cymosa* (mau'u 'aki'aki) at 3 stages of development (43, 98 and 224 days after planting seeds). Fluazifop-p-butyl (0.28 and 0.42 kg a.i./ha) and triclopyr (4.48 and 8.97 kg ae/ha) were applied as an over the top spray to plants growing in multi cell trays. Twenty eight days after spraying, visual injury ratings and above ground biomass were measured. Both rates of triclopyr caused severe injuries and death of *F. cymosa* plants in all stages. Fluazifop-p-butyl applied at both rates caused little to no injury and did not reduce the growth of *F. cymosa*. Fluazifop-p-butyl can be safely used for grassy weed control in *F. cymosa* plantings.

419. Fall Applications of Glyphosate for Selective Control of Dallisgrass in Hybrid Bermudagrass Turf. Robert Walker¹, Jason Belcher¹; ¹Auburn University, Auburn, Alabama, United States of America

In the Southern United States, dallisgrass (*Paspalum dilatatum* Poir.) is a difficult-to-control perennial grass in hybrid bermudagrass [*Cynodon dactylon* (L.) Pers. x *C. transvaalensis* Burtt-Davy] turf. It is commonly found growing as individual clumps, but over time can form dense stands, particularly where there is soil compaction due to heavy traffic. MSMA at 2.2 kg a.i./ha applied every 5 to 10 d for a total of 3 to 4 applications has been the standard recommendation for control. However, the United States Environmental Protection Agency has scheduled cancellation for all uses of MSMA. Therefore, research was conducted in an attempt to find an alternative. Research was initiated fall 2006 to evaluate glyphosate at 0.26 kg a.e./ha + sulfosulfuron at 0.066 kg a.i./ha applied either 1 or 3 times on weekly intervals beginning September 7, 2006. MSMA at 2.2 kg a.i./ha was applied four times on weekly intervals. Fall application was chosen in an attempt to improve bermudagrass tolerance to glyphosate. Data was collected for dallisgrass control and bermudagrass injury and ground cover for 413 days after treatment (DAT). Dallisgrass control with MSMA averaged 87% 413 DAT. A single application of

glyphosate + sulfosulfuron provided 71% control and three applications provided 96% control 413 DAT. Bermudagrass browning 21 DAT averaged 16% for MSMA; 50% for the single application of glyphosate + sulfosulfuron and 70% for the three applications. Green bermudagrass turf 196 DAT (16, April 2007) was 28% for the non-treated, 26% for MSMA, 20% for the single application of glyphosate + sulfosulfuron and 18% for three applications. On June 1, 2007 (242 DAT), bermudagrass ground cover in the non-treated was 41%, 75% for MSMA, 66% for glyphosate + sulfosulfuron and 74% for three applications of glyphosate + sulfosulfuron. Data show that glyphosate + sulfosulfuron could be used as an alternative for dallisgrass control in hybrid bermudagrass turf. Turf injury was generally acceptable with fall applications.

420. Floristic Studies in Urban Park Areas of Mashhad (Iran). Mohammad Bazoobandi¹, Alireza Ghorsi Anbaran, Reza Sadrabadi Haghghi¹; ¹Azad University of Mashhad-Golbahar, Mashhad, Khorasan Razavi, Iran

Weed control in various ecosystems including urban park areas may not be achieved without enough information about their population dynamics and floristic studies during their growth period. To investigate same objects in three different urban green area including forest, gardens and grasslands, the present study was conducted in Mashhad city (Iran) during 2005-2006. Floristic indices including species number in each ecosystem were recorded after enough sampling. Shannon-Wiener species diversity index, Eshtain-House and Sorenson indices were calculated for these systems. Adaptability strategies of species under study were investigated according to crime triangle method. Results revealed that more than 50 different species were found in these ecological environments. Asteraceae, Poaceae and Fabaceae recorded the highest density and diversity. *Taraxacum* spp, white clover and *Poa* spp were the most dominant species in rose gardens, grasslands and forest respectively which all are perennials. Species diversity in forest was significantly different compared to grassland system. However no difference was found between forest and rose garden concerning weed species diversity. It may be concluded that different weed management strategies should be followed in these three ecological bodies according to the dominant species.

421. Response of *Dichondra (Dichondra micrantha)* Turf to Postemergence Herbicides. Vahid Zabihollahi¹, Fariba Maighany², Mohammad Ali Baghestani², Mohammad Javad Mirhadi³; ¹ Tehran, Iran; ²Iranian Crop Protection Research Institute, Tehran, Iran; ³Science and Research Campus, Islamic Azad University, Tehran, Iran

Weed species on turfgrass cause many problems, because they reduce the quality of turf and their control is very difficult. *Dichondra micrantha* is a small genus of flowering plants and prostrate perennial herbaceous in family of Convolvulaceae very popular in southern California during 1950s and 1960s for lawns. In United States *Dichondra* is also considered as a weed. In order to evaluate the effect of herbicides usage on biomass *dichondra*, an experiment was conducted during 2006 in IRAN, using randomized complete block design with 4 replications. The experimental was carried out in pots. herbicide treatments were 2,4-D plus MCPA at 1080 and 1440 g a.i. ha⁻¹, Dichlorprop-p plus Mecoprop-p plus MCPA at 1200 and 1500 g a.i. h⁻¹, Bromoxynil plus MCPA at 150 and 200 g a.i. ha⁻¹, Diclofop methyl at 900 and 1080 g a.i. ha⁻¹, Fenoxaprop-p-ethyl at 60 and 75 g a.i. ha⁻¹, Clodinafop propargyl at 48 and 64 g a.i. ha⁻¹, Tralkoxydim at 250 and 30 g a.i. ha⁻¹, Sulfosulfuron at 18.9 and 24.5 g a.i. ha⁻¹ and untreated control. All treatments were repeated 3 times on the established *dichondra*. The results showed that after 10 days from the first spraying, 2,4-D plus MCPA, Dichlorprop-p plus Mecoprop-p plus MCPA and Bromoxynil plus MCPA (both doses) decreased biomass of *dichondra*. *Dichondra* was controlled completely and it could not recovery after first spraying. biomass of *Dichondra* was not decreased by Diclofop methyl, Fenoxaprop-p-ethyl, Clodinafop propargyl and Tralkoxydim (both doses). In addition, biomass of *Dichondra* was not decreased by using sulfosulfuron (both doses) after first herbicide application, but after second and third application of mentioned herbicide the biomass was decreased and the recovery of *Dichondra* was not observed. Overall, it could be concluded that Diclofop methyl, Fenoxaprop-p-ethyl, Clodinafop propargyl and Tralkoxydim are suitable selective herbicide for grasses control in *Dichondra* stand. In addition, using sulfosulfuron (one time) can be recommended treatment.

422. Chemical Control of Dandelion (*Taraxacum officinalis*) in Turf. Vahid Zabihollahi¹, Fariba Maighany², Mohammad Ali Baghestani², Mohammad Javad Mirhadi³; ¹Tehran, Iran; ²Plant Protection Research Institute, Tehran, Iran; ³, Science and Research Campus, Islamic Azad University, Tehran, Iran

Dandelion (*Taraxacum officinalis*) is an important weed in lawns. In order to evaluate the effect of herbicide usage on biomass and density of dandelion (*Taraxacum officinalis*) on turf (*Lolium perenne* 20%,*Poa pratensis*.20%,*Festuca rubra*.20%and *Festuca arundinaceae* 40%), an experiment was conducted during 2006 in IRAN, using randomized complete block design with 4 replications. Treatments were Dichlorprop-p plus Mecoprop-p plus MCPA at 1200 and 1500 g a.i. h⁻¹, Bromoxynil plus MCPA at 150 and 200 g a.i. ha⁻¹, Metribuzine at 525 and 700 g a.i. ha⁻¹ and untreated control. All treatments were

repeated 3 times during the growth period of dandelion. The results showed that turf biomass was not decrease by Dichlorprop-p plus Mecoprop-p plus MCPA and Bromoxynil plus MCPA (both doses), 12 days after last spraying. Turf biomass was decreased completely by metribuzine (both doses) and it could not recovery. Dichlorprop-p plus Mecoprop-p plus MCPA at 1200 and 1500 g a.i. h⁻¹ decreased biomass of dandelion 94.77 and 96.36 percent and density of dandelion 95.18 and 95.78 percent, respectively. Furthermore, biomass and density of dandelion was decreased by Bromoxynil plus MCPA at 150 and 200 g a.i. ha⁻¹, 43.74 and 36.31 percent (biomass) and 33.88 and 28.91 percent (density), respectively, but Metribuzine (both doses) has no effect on biomass and density of mentioned weed. Overall, it could be concluded that Dichlorprop-p plus Mecoprop-p plus MCPA is suitable selective herbicide for dandelion control.

423. Study of Postemergence Herbicides Efficacy in Control of Yellow Foxtail (*Setaria glauca* (L.) P. Beauv) in Turf. Vahid Zabihollahi¹, Fariba Maighany², Mohammad Ali Baghestani², Mohammad Javad Mirhadi³; ¹Tehran, Iran; ²Iranian Crop Protection Research Institute, Tehran, Tehran, Iran; ³Science and Research Campus, Islamic Azad University, Tehran, Iran

Foxtail is an important lawn weed problem at lower elevations in Iran. This weed belongs to a group called summer annual grasses. In order to evaluate the effect of herbicide usage on biomass and density of yellow foxtail (*Setaria glauca*) on mixture turf (*Lolium perenne* 20%,*Poa pratensis*20%,*Festuca rubra*.20%and *Festuca arundinaceae* 40%), an experiment was conducted during 2006 in Tehran, using randomized complete block design with 4 replications. Treatments were Diclofop methyl at 900 and 1080 g a.i. ha⁻¹, Fenoxaprop-p-ethyl at 60 and 75 g a.i. ha⁻¹, Clodinafop propargyl at 48 and 64 g a.i. ha⁻¹, Tralkoxydim at 250 and 30 g a.i. ha⁻¹, Sulfosulfuron at 18.9 and 24.5 g a.i. ha⁻¹ and untreated control. All treatments were repeated 3 times during the growth period of yellow foxtail. The results showed that 16 days after last spraying, biomass of yellow foxtail was decreased by diclofop methyl at 900 and 1080 g a.i. ha⁻¹, clodinafop propargyl at 48 and 64 g a.i. ha⁻¹, tralkoxydim at 250 and 30 g a.i. ha⁻¹ and sulfosulfuron at 18.9 and 24.5 g a.i. ha⁻¹ 65.44, 61.50, 66.21, 61.15, 67.09, 66.47, 68.16 and 68.76 percent, without significant difference. Density of yellow foxtail was decreased by mentioned treatments, 66.46, 69.57, 66.46, 75.78, 68.33, 76.40, 72.67 and 75.16 percent, respectively. Biomass of yellow foxtail was decreased by fenoxaprop-p-ethyl at 60 and 75 g a.i. ha⁻¹, 48.54 and 51.43 and density of yellow foxtail was decreased, 48.45 and 49.70, respectively. On the other hand, turf biomass was decreased by diclofop methyl and clodinafop propargyl more than 20 percent. Turf was damaged by diclofop methyl under 20 percent and clodinafop propargyl more

than 20 percent. Other treatments were safe for turf. Overall, it could be concluded that fenoxaprop-p-ethyl, tralkoxydim and sulfosulfuron are suitable selective herbicides for comparative yellow foxtail control.

424. The Efficacy of Phenoxy Herbicide in Controlling Lawn Weeds. Sedighe Sadeghi¹, Zoheir Ashrafi², Hassan Alizade¹, Mohsen Mesgaran¹; ¹University of Tehran, Karaj, Tehran, Iran; ²Institute of Medicinal Plants, Academic Center for Education and Cultural Research Complex, Karaj, Tehran, Iran

Weeds are plants growing where they are not wanted or simply, plants growing out of place. A major reason weeds are controlled in turf is they distract from the overall appearance of the turf. High-quality turf is often judged by its uniformity. Weeds, having different leaf shapes, sizes, colors, or growth habits, can reduce uniformity within a turf area. The homogeneity and a harmonious scenery is thought as an indication for a high quality lawn. Weeds not only disrupt the suitability of lawn due to the differences in form, color, size and growth habits, but also compete for light, water, nutrients and space, decreasing the quality and quantity of lawn. Thus one experiment was conducted in a lawn field a blend of green fescue (*Festuca longifolia*) and quackgrass (*Agropyron repens*) to evaluate the effectiveness of phenoxy herbicides in controlling weeds. An experiment was conducted in research greenhouse agronomy college, University Of Tehran in Karaj, in during 2006-2007, as randomized complete block design with three replications. Treatments included: 1- 2,4-D (1 L/ha) 2- 2,4-D (1.5 L/ha) 3- 2,4-D plus MCPA(1 L/ha) 4- 2,4-D plus MCPA(1.5 L/ha) 5- pre-mixture of bromoxynil plus MCPA (1.5 L/ha) 6- pre-mixture of diclofenac plus MCPA (1 L/ha) 7- pre-mixture of mecoprop + diclorprop + MCPA (2 L/ha) 8- weed free and 9-weedy controls. There were significant differences among treatment in terms of both weed control levels and lawn quantitative and qualitative attributes. The lowest phototoxicity in lawn was observed with 2,4-D + MCPA(1 L/ha) whereas diclofenac + MCPA (1 L/ha) caused serious injuries to lawn, labiate providing the greatest field bindweed (*Convolvulus arvensis*) control 88%. The latter treatment was also the best in controlling common mallow (*Malva parviflora*) 92%. 2,4-D (1 L/ha) controlled dandelion (*Taraxacum officinale*) acceptably but failed to cause markedly reduction in slender knotweed (*Polygonum persicaria*) biomass. The greatest total weed control 93.6% obtained from 2,4-D (1.5 L/ha) while the least 62.4% was observed with mecoprop + diclorprop + MCPA (2 L/ha). Considering both weed control level and phototoxicity to lawn, applying 2,4-D (1.5 L/ha) could be recommended as an effective treatment.

425. Aquatic Weeds and Native Macrophytes in Zambia. Kevin Murphy¹, Pauline Lang¹, Magdi Ali², Michael Kennedy³, Adam Hastie¹; ¹University of Glasgow, Glasgow, Scotland, United Kingdom; ²South Valley University, Aswan, Aswan Province, Egypt; ³University of Aberdeen, Aberdeen, Scotland, United Kingdom

Straddling the catchments of two major African rivers, the Congo and Zambezi, Zambia was the location of the massive 1960s *Salvinia molesta* outbreak on Lake Kariba, a large impoundment of the Zambezi. This species no longer causes major problems in Zambia, but river systems remain highly vulnerable to invasion by alien aquatic weeds, especially *Myriophyllum aquaticum* and *Eichhornia crassipes*: to date most problems have been experienced in the Zambezi catchment. In 2007 infestations by *Eichhornia crassipes* occurred in the Zambezi River and small tributaries near Livingstone; plus one major tributary, the Kafue River. The first Zambian record of *Myriophyllum aquaticum*, a weed aggressively spreading in southern Africa was in sewage settling ponds in Livingstone, in 2004. Further northward spread of this plant in Zambia is probable. By contrast the Congo catchment in northern Zambia is to date largely free of invasive aquatic weeds (though major problems exist downstream in the Democratic Republic of the Congo; and in the Bangweulu swamps area in Zambia). In 2006 a survey of 22 Congo headwater streams, and associated waterbodies, located within a 460 km² area of Kasanka National Park recorded high-diversity communities supporting native macrophytes (often Afrotropical endemic species) including *Aponogeton vallisnerioides*, *Potamogeton nodosus*, *Nymphaea caerulea*, *Phragmites australis*, *Ludwigia repens*, *Cyperus alopecuroides* and *Panicum obtusifolium*. Flow regime and water chemistry were likely controlling factors for the 2 main communities recorded. Both communities are vulnerable to invasion by aquatic weeds (but especially the Group II community type, occurring in slower-flowing, more eutrophic streams, and already dominated by floating species), especially in the light of likely eutrophication problems associated with increasing large-scale irrigated agricultural development in northern Zambia, over the next 10 years.

426. Effects of Doses of Glyphosate on Water Hyacinth Control and some Water Quality Parameters under Mesocosm Conditions. Robinson Pitelli¹, Claudinei Cruz¹, Aritana Basile¹, Luiz Luna¹, Antonio Nader Neto¹; ¹Sao Paulo State University, Jaboticabal, Sao Paulo, Brazil

Water hyacinth (*Eichhornia crassipes*) is a important aquatic weed in lentic water bodies in Brazil. In this country there is no herbicide registered for the control of floating aquatic weeds. Studies are being conducted to evaluate herbicides to the control of these weeds and the

impacts of their control on the water quality and on the bio-indicator organisms, aiming to provide data for the governmental institutions responsible for the herbicides registration for aquatic systems. An experiment was carried out in 1060 L mesocosms (1.80 m of diameter, 0.5 m deep) with a water removal time of 4,5 days, to evaluate the water hyacinth control with three doses of glyphosate and the effects of some water quality parameters, the tropical fish *Hypessobrycon eques*, the algae *Pithophora* sp and *Lemna minor*. Rodeo® was the glyphosate commercial formulation and the doses were 2.88, 3.32, and 3.84 Kg/ha (active ingredient) with the addition of Aterbane 0.5%. The experiment was set up in a completely randomized experimental design with four replications. The herbicide was applied with a precision sprayer at pressure of 25 psi, using the rate of 200 L/ha. The results showed that glyphosate in the three tested doses was very efficient in the water hyacinth control and until 45 days after the spraying there was no evidence of plant re-growth. As the water hyacinth plants were dying the level of dissolved oxygen, pH and electric conductivity increased significantly in relation to the plots without control. These results probably are related to the radiation penetration in water column and the release of nutrients by the water hyacinth decomposition and the consequent algae growth. The growth of *L. minor* biomass in the mesocosms with water hyacinth control is a strong evidence of the nutrient release, but the growth of *Pithophora* sp was smaller, probably due to the duckweed shading. The number of adults fishes disposed in the mesocosms did not differ expressively at the end of experimental period, but the numbers of larvae were higher in the control plots. The presence of suitable niches for the fish reproduction (water hyacinth) and the protection against predators were the possible explanation for this result, since prior experiments showed that glyphosate plus Aterbane had very low toxicity to this fish.

427. Evaluating Potential of Cross-Resistance Development in Fluridone-Resistant Hydrilla to other Bleaching Herbicides. Atul Puri¹, William Haller¹, Michael Netherland²; ¹University of Florida, Gainesville, FL, United States of America; ²USACE, Gainesville, FL, United States of America

The development of fluridone resistance by hydrilla (*Hydrilla verticillata*) has significantly impacted hydrilla management and research is ongoing to develop alternate herbicides for effective hydrilla control. Fluridone disrupts the carotenoid biosynthetic pathway by non-competitive inhibition of enzyme phytoene desaturase (PDS). We determined the potential development of cross-resistance in fluridone-resistant hydrilla to other bleaching herbicides such as norflurazon, mesotrione and topramezone-methyl. Norflurazon has same target site on PDS as fluridone, whereas mesotrione and topramezone-methyl affect carot-

enoid biosynthesis indirectly by inhibiting enzyme 4-hydroxyphenyl pyruvate dehydrogenase in the biosynthesis of plastoquinone, which is a critical cofactor for PDS. Experiments were conducted to monitor changes in phytoene, β -carotene and chlorophyll contents as a function of hydrilla biotype and herbicide treatment. Hydrilla shoot tips were collected from fluridone-susceptible (S) and resistant (R) biotypes and exposed to 5, 25, 50, 75 and 100 $\mu\text{g L}^{-1}$ of herbicide. The susceptible biotype showed an increase in phytoene and decrease in β -carotene and chlorophyll contents when treated with 5 $\mu\text{g L}^{-1}$ fluridone, whereas higher doses of fluridone were required to affect these pigments in the resistant biotype. There was no difference in response by S and R biotypes to mesotrione and topramezone-methyl and both biotypes showed significant affect in these pigments at 5 $\mu\text{g L}^{-1}$. Higher doses of norflurazon were needed to affect these pigments in R as compared to the S biotype. Regression analysis was utilized to calculate EC50 values to quantify the relationship between herbicide dose and pigment contents. The S biotype had EC50 values of 12, 12 and 5 $\mu\text{g L}^{-1}$ fluridone, whereas R biotype had EC50 values of 56, 41 and 42 $\mu\text{g L}^{-1}$ fluridone for phytoene, β -carotene and chlorophyll, respectively. There was no difference in EC50 values between S and R biotypes for mesotrione and topramezone-methyl and EC50 values were 13-14, 13-12 and 5-6 $\mu\text{g L}^{-1}$ topramezone-methyl and 12, 10-13 and 3-5 $\mu\text{g L}^{-1}$ mesotrione for phytoene, β -carotene and chlorophyll, respectively. For norflurazon, S and R biotypes had EC50 values of 33, 45 and 41 $\mu\text{g L}^{-1}$ and 85, 81 and 93 $\mu\text{g L}^{-1}$ for phytoene, β -carotene and chlorophyll, respectively. These studies confirmed negative cross-resistance of fluridone-resistant hydrilla to mesotrione and topramezone-methyl and a positive cross-resistance to norflurazon.

428. Controlling Aquatic Weeds in Irrigation Canals with Endothall. Cody Gray¹, Gerald Adrian¹, Jayne Walz¹; ¹United Phosphorus, Inc., Peyton, CO, United States of America

The task of controlling aquatic vegetation in irrigation canals is an extremely important venture, especially in the western United States. The waters supplied by these canals are the primary, and in some locations the only, source of water for irrigating agronomic crops. In other locations, these waters supply industrial water users as well. Therefore, the control of aquatic weeds in irrigation canals becomes extremely critical; however, the tools available to canal managers for weed control are limited. Grass carp are used in some locations, but the task of keeping the carp in the desired location is difficult, and they do not provide adequate control of some aquatic weeds. Dredging and chaining canals can be employed for weed removal; however, these tactics are dangerous, very labor intensive, expensive, and offer only a temporary solution to the problem. The final option is the use of herbicides for weed

control. Herbicides currently labeled for use in irrigation canals are acrolein, xylene, and copper formulations. The copper formulations are effective in removing problematic algae infestations, but provide minimal control of vascular plants. Acrolein and xylene have label restrictions that do not allow their use in some canal locations, and they are not labeled in all states. In addition, these products are extremely hazardous to applicators and handlers. At recommended labeled rates, these products are toxic to fish and other aquatic organisms. Endothall has been used since the 1960's for controlling aquatic vegetation in ponds, lakes, and streams. In recent months, residue trials (EPA Guidelines, OPPTS 860.1500 Crop Residue Trials) have been conducted for endothall as required for an EPA approved unrestricted FIFRA Section 3 label to allow treated water to be used on irrigated crops during herbicide applications. *Stuckenia pectinatus* (L.) Börner (sago pondweed) is a native aquatic perennial that forms dense troublesome infestations in irrigation canals and drainage ditches; thereby, not allowing for proper water delivery or flow. In 2007, experimental trials were conducted to evaluate endothall efficacy for *S. pectinatus* control in irrigation canals. Treatments resulted in greater than 95% *S. pectinatus* control for up to 8 weeks after treatment. Results from these trials indicate endothall will provide a safer, more effective tool for controlling aquatic weeds in irrigation canals compared to other alternative control methods.

429. Competitive Interaction between Two Aquatic Weeds: Water Hyacinth (*Eichhornia crassipes*) and Alligator Weed (*Alternanthera philoxeroides*). Grama Nanjappa Dhana-pal¹; ¹University of Agricultural Sciences, Bangalore, Karnataka, India

For the past ten years alligator weed (*Alternanthera philoxeroides*) was found naturally growing on the live substrate of water hyacinth (*Eichhornia crassipes*) and suppress its growth and eventually killing it. I tested this process in the controlled laboratory conditions by incubating the two weeds in pure and mixed stocks. Even small proportions of alligator weed inhibited the growth of water hyacinth within 15-20 days, later showed stunted growth and the leaves turned yellow and died in about 30 days. On the other hand alligator weed grew better in the presence of *Eichhornia* than in the pure stocks. This inhibitory effect of alligator was found to be due to water soluble leachates that suppress the uptake of nutrients by the roots of *Eichhornia* plants. Alligator contains about 21% protein and is a good source of fodder especially, for milch animals. I discuss the possible methods of controlling *Eichhornia* using this inhibitory process of alligator weed.

430. Use of Aquatic Weed as Organic Fertilizer in Eucalyptus. Thais Clemente¹, Robinson Pitelli²; ¹Ouro Fino Group, Ribeirão Preto, São Paulo, Brazil; ²University of the State of Sao Paulo, Jabotical, São Paulo, Brazil

In Brazil, the aquatic weeds are very troublesome in artificial lakes and the mechanical control is the more important method for their management. The macrophyte biomass collected from the lake must be disposed in environmentally correct way? as a requirement for government authorization of this process. So, two trials were carried out aiming to evaluate the effects of the soil incorporation of different doses of two aquatic weeds, *Eichhornia crassipes* and *Salvinia herzogii*, and chemical fertilization on the growth of two eucalyptus clones. The first trial conducted in 20L pots filled up with sandy soil and the treatments were arranged in a factorial design 2 x 2 x 5, with the following variables: two aquatic weeds, two clones (VCP-C1 and VCP-C2) and five organic fertilization doses (0, 5, 10, 20 e 40 t/ha of macrophyte dry biomass). The second trial was carried out in 5L pots containing the same soil but the treatments were arranged in a factorial design 2 x 2 x 2 x 5, with the following variables: two aquatic weeds, two clones, two conditions of chemical fertilization (90 g/5L of the formula 04-28-06 and no fertilizing) and five organic fertilization doses (0, 5, 10, 20 e 40 t/ha of macrophyte dry biomass). The organic fertilization with aquatic weeds promoted a better development of eucalyptus plants related to the used dose. The water hyacinth fertilization was more effective on the eucalyptus growth and favorable soil features, mainly sum of exchangeable bases, CEC, organic matter, calcium and phosphorus contents in the soil. Larger doses promoted better increases in the eucalyptus growth and doses over 20 t/ha are required for expressive results. The clone VCP-2 showed better growth characteristics, mainly under the stress conditions of the experiment conducted in 5L pots. The chemical fertilization did not promoted expressive effects on the plant growth. In summary, the use of aquatic macrophytes is feasible for reforestation improvement in areas near lakes and reservoirs.

431. New Herbicide Application Techniques for the Management of Aquatic Weeds in Australasia. Bill Chisholm¹, Nimal Chandrasena², Peter Harper³; ¹Aquatic Weed Control Ltd, Dunedin, Otago, New Zealand; ²Ecowise Environmental Pty Ltd, Penrith, Sydney, New South Wales, Australia; ³Bettersafe Pest and Weed Management, Sydney, New South Wales, Australia

Submerged aquatic weeds pose serious problems in Australian and New Zealand waterways. Three of these species- *Lagarosiphon major* (Ridley) Moss (*Lagarosiphon*), *Egeria densa* Planch (*Egeria*) and *Ceratophyllum demersum* L. (Hornwort) prefer clear water, where they form dense stands, out-competing native vegetation and

causing problems for water users. The problem in controlling these plants relates to their mode of spread; the smallest viable vegetative fragment can re-establish a population. Left uncontained, these aquatic weeds often fully colonize all available habitats, within a short period of time. In most cases, aquatic weed eradication is not an option, but they can be judiciously and cost-effectively managed using aquatic herbicides.

While the aquatic herbicides Diquat and Endothal have been around for a long time, new application techniques have been developed in New Zealand and Australia, which significantly improve their efficacy and cost-effectiveness. Results from New Zealand and Australian trials using these new techniques are presented, along with a description of the situations where they can be utilised.

The improvement in Diquat efficacy has enabled the eradication of *Ceratophyllum* in several New Zealand streams. In several test trials conducted in NSW, Australia, similar success has been achieved in the management of *Egeria* and *Ceratophyllum*. This involved the use of guar gum, and formulating a Diquat gel (Aquagel), which was then applied to the water.

The herbicide Endothal (Aquathol K) is also available for use in New Zealand waterways, and if applied correctly, it has shown the potential to eradicate a range of submerged aquatic weeds. There is further scope for significant expansion of using Aquagel and Aquathol K to control submerged aquatic weeds in Australia and New Zealand without undue environmental impacts.

432. Constraints to Managing Alligator Weed [*Alternanthera philoxeroides* (Mart.) Griseb] in Australia. Nimal Chandrasena¹; ¹Ecowise Environmental Pty Ltd, Penrith, NSW, Australia

Alligator Weed has continued to expand its invaded territory in Australia in both aquatic terrestrial habitats. Despite control efforts over five decades, there are still several knowledge gaps, which constrain successful management. Several case studies are presented to demonstrate that large-scale re-infestations of creeks and river systems have occurred in the past three years, largely due to inadequate follow up in many local government areas. Deficiencies in current control techniques, insufficient funding for on-ground management, lack of quality control in managing weed contractors and inadequate institutional planning frameworks are among the reasons for the lack of overall success.

For the past 15 years Alligator Weed management in Australian waterways has largely relied upon containment using glyphosate. However, these efforts have had limited success, due to an inadequate appreciation of plant surface characteristics, spray-related factors and environmental factors that limit herbicide uptake and translocation in the field. The use of glyphosate 'over water' has been essentially hampered by the absence of a surfactant or

other additive to assist its uptake. Plot-based field applications indicate that incorporating a biodegradable additive, such as BS 1000 or a vegetable oil (canola Oil), increases glyphosate efficacy on Alligator Weed several folds and ensures cost-effective and reliability of treatments. Even with an additive, multiple glyphosate treatments with relatively short gaps between treatments are required to contain deeply entrenched infestations in many difficult-to-access situations. Metsulfuron-methyl, used since early 1990s for treatment of terrestrial infestations, continues to be a better alternative to glyphosate, although its use 'over water' has been on a trial basis for the past three years. Other herbicides with proven potential- dichlobenil and triclopyr- are yet to be widely tested for applicability in the field. Whilst the effective herbicide rates are known, treatment regimes for different situations are yet to be optimized.

R&D efforts for finding more effective biological control agents are still continuing. Recent efforts to improve Alligator Weed management in NSW include a GIS-based initiative to map the current levels of infestations in 'core' infestation areas in order to establish a new baseline. Renewed attempts are also being made to promote early detection and prevention of spread and to prioritize infested areas for targeted control. Attempts are also being made to improve the coordination of the implementation of a Alligator Weed Regional Weed Management Plan and to address organisational causes for the limited success, which include lack of resources, insufficient funding, stakeholder commitment and inadequate priority attached to the Alligator Weed problem.

433. Technical Approaches for the Use of Fluridone (Tradename: Sonar) in Management of Invasive Submersed Aquatic Plants. Mark Heilman¹, Tyler Koschnick¹; ¹Se-PRO Corporation, Whitakers, NC, United States of America

Since its USEPA registration in 1986, fluridone (trade-name: Sonar) has become an important herbicide tool for effective management of invasive submersed weeds including *Hydrilla verticillata* and *Myriophyllum spicatum* (Eurasian watermilfoil). Early field use of fluridone after its US registration began with two herbicidal formulations: a 0.48 kg/L suspension concentrate (Sonar AS) and a single 5% active, slow-release pellet material (Sonar SRP). These formulations were utilized in block treatments typically at maximum use rates (150 µg/L) within larger lake sites, and treatment effects well beyond the application zone were noted. In 1996, a fluridone-specific immunoassay was developed to monitor operational treatments and improve research understanding of fluridone use patterns. In the late 1990s, the immunoassay combined with targeted field and laboratory research documented that sustained exposure (45-90 days) at fluridone concentrations <10 µg/L provided selective,

systemic control of sensitive target species like *H. verticillata* and *M. spicatum*. Additional lab-based, operational assays have also been developed to quantify responses of target plant populations to fluridone prior to and during treatment. Since 2000, pre-treatment laboratory susceptibility assays (PlanTESTs) of field sampled *H. verticillata* and *M. spicatum* along with several additional species have been used to ascertain fluridone levels that will provide effective treatment response. In-treatment assays (EffecTESTs) have also been used to determine real-time plant biochemical response to Sonar treatment. In 2002, two additional Sonar pellet formulations (Sonar PR and Q) were also registered. These formulations demonstrated more efficient fluridone release than the original SRP pellet to provide improved performance on less susceptible target weeds and in treatment scenarios with greater water exchange or organic sediment types. Along with historical review of these developments, current strategies for the use of fluridone will be reviewed including efforts to deplete/eradicate early infestations of *H. verticillata*, integration with other herbicide modes of action, and dewatered applications for pre-emergent weed control in canals and other seasonally-flooded sites.

434. Invasion of Loch Lomond Scotland by Alien *Elodea* Species. Kevin Murphy¹, Sandrine Picq²; ¹University of Glasgow, Glasgow, Scotland, United Kingdom; ²ENSAM Montpellier, Montpellier, France

Loch Lomond is one of the largest lakes in the British Isles. It is an important freshwater asset for potable water supply, recreation and amenity, hydroelectric power generation, and as a habitat supporting aquatic biodiversity, including breeding populations of rare fish such as the brook lamprey (*Lampetra planeri*) and powan (*Coregonus clupeoides*: a non-migratory member of the salmon family, only two populations of which occur in Scotland), plus a diverse flora of native submerged aquatic macrophytes. In differing degree, all these functions are threatened by invasion of two submerged aquatic weed species originating in North America; first *Elodea canadensis*, and more recently *Elodea nuttallii*. In 2007 quantitative survey of 42 sites within Loch Lomond recorded 20 macrophyte species, and showed that within the lake as a whole, *Elodea nuttallii* was co-dominant with three native species (*Littorella uniflora*, *Isoetes lacustris* and *Myriophyllum alterniflorum*). *Elodea canadensis* was a minor component of the flora and has declined sharply since surveys early in the 1990s. Four separate communities of aquatic plants were identified. Three were indicated by native species only: *Callitrich hamulata* (at 7% of sites); *M. alterniflorum* (14%); and a mixed community of *L. uniflora*, *I. lacustris* and *Potamogeton perfoliatus* (40%). The fourth (38%) was co-dominated by *L. uniflora* and *Elodea nuttallii*: and was predominantly located in shallow areas of the loch

sheltered from wind and wave action, where the tall, sub-surface canopy forming stands of *E. nuttallii* were clearly at an advantage. The evidence suggests that *E. nuttallii* has increased its distribution and abundance in the Loch since the previous survey, in 2000, but that it may be approaching a more stable condition, preferentially occupying a clearly-defined habitat type within the lake ecosystem, at the expense of native species which occur in sheltered areas. Unfortunately, such areas of the lake are heavily favoured for tourist use (especially boat mooring, sailing and kayaking, miscellaneous shoreline recreation, and fishing), all of which are interfered with by dense growths of *E. nuttallii*. There may therefore be a need for localized weed control efforts in such areas to reduce *E. nuttallii* problems to manageable levels.

435. Management of *Myriophyllum spicatum* and *Myriophyllum heterophyllum* in the United States. Mike Netherland¹, LeeAnn Glomski¹, Angela Poovey¹, Jeremy Slade²; ¹US Army Engineer Research and Development Center, Gainesville, FL, United States of America; ²Mississippi State University, Mississippi State, MS, United States of America

The exotic invasive submersed plant *Myriophyllum spicatum* L. [Eurasian watermilfoil] has spread throughout the northern tier of the United States and it has required intensive management for several decades. The recent discovery of a hybrid genotype between exotic *Myriophyllum spicatum* and the native *Myriophyllum sibiricum* Komarov [Northern watermilfoil] has led to numerous questions regarding the ecological fitness of the hybrid as well as the potential for differences in response to herbicide management. In order to address these questions, both laboratory and mesocosm studies were conducted to evaluate the response of hybrids and parental species to herbicide management and different environmental conditions. Prior to conducting studies, genotypes were verified via genetic analysis. Laboratory and mesocosm trials evaluating various use rates of the herbicides 2,4-D, triclopyr, fluridone, and diquat revealed no difference in response between the hybrid and *Myriophyllum spicatum*. In contrast, *Myriophyllum sibiricum* often showed reduced herbicide susceptibility compared to the hybrid and Eurasian plants. Outdoor mesocosm studies initiated in May 2007 and September 2007 evaluated the growth response of the three *Myriophyllum* genotypes to 3 different levels of light, 3 levels of nutrient regimes, 3 water depths, and low concentrations of the herbicide triclopyr. The hybrid genotype and *Myriophyllum spicatum* showed a similar response to both the varying light intensities and nutrient regimes. One of the key early findings of this work indicates that the hybrid genotype forms a turion similar to the parental plant, *Myriophyllum sibiricum*. The ecological implications of turion formation for the hybrid genotype remain unknown at this point in

time. Current studies have not detected a strong difference in response to herbicides or environmental factors between the hybrid genotype and the invasive *Myriophyllum spicatum*. In addition to *Myriophyllum spicatum*, the native plant *Myriophyllum heterophyllum* Michx [variable leaf watermilfoil] is considered highly invasive in the low alkalinity water bodies of the Northeastern United States. Laboratory and mesocosm trials were conducted to determine the relative sensitivity of this plant to ten different aquatic herbicides. Key findings of this work suggest that the ester formulation of 2,4-D was much more effective than either 2,4-D amine or triclopyr at equivalent use rates. In addition, evaluation of contact herbicides indicated that protoporphyrinogen oxidase inhibitors carfentrazone and flumioxazin were highly effective compared to the maximum label use rates of the traditional contact products diquat and endothall. Evaluation of the slow acting enzyme inhibitors indicate that fluridone and penoxsulam were effective at use rates between 5 and 20 µg ai/L while imazamox and bispyribac were not effective at use rates lower than 50 µg ai/L. Findings from this research suggest that *Myriophyllum heterophyllum* responds quite differently to herbicide applications when compared to the exotic *Myriophyllum spicatum*.

436. Selective Control of *Myriophyllum spicatum* L Using Diquat – A Five Year Case Study in Long Term Selective Plant Management. James Petta¹, Marc Bellaud², Gerald Smith², Michael Lennon²; ¹Syngenta, Corpus Christi, TX, United States of America; ²Aquatic Control Technology, Inc., Sutton, MA, United States of America

Myriophyllum spicatum L. [Eurasian watermilfoil or EWM] is a serious invasive weed problem in the United States. EWM is a serious problem to native plant species and habitats, water quality, and recreational water use including boating, swimming and fishing. While studies have been conducted to observe short-term effects of management tools such as diquat and other aquatic herbicides, few have continued to monitor the potential long term impacts of repeated control measures. In this situation, EWM infested the majority of the littoral zone of the 324 hectare Twin Lakes system located in Salisbury, Connecticut. These lakes are in an ecologically sensitive region and support several state protected aquatic plant species in addition to a prized warm water and cold water fishery. Annual mechanical harvesting efforts were no longer providing acceptable levels of EWM control during the summer recreation season. Through close collaboration with state regulatory agencies, a partial-lake diquat (REWARD) herbicide treatment program was developed and commenced during the 2003 season. Treatment of 30.4 hectares along developed shorelines and high-use areas in two of the three major lake basins was permitted. No-treatment buffers were established between documented

beds of state listed species, and the middle basin was left as an untreated refuge area. EWM was successfully controlled and no adverse impacts were documented. The treatment program continued during 2004, 2005, 2006, and the 2007 seasons. Results of the annual comprehensive monitoring program have been favorable. No significant changes to water quality, phytoplankton, zooplankton, or state protected plant populations have occurred. The diquat treatments have shown a high selectivity for EWM. Native aquatic plants have recolonized areas previously dominated by EWM, as shown by the consistency and increase in measured indices such as plant cover, plant biomass, species richness, while EWM cover has declined and it does not interfere with recreational use of the lake in managed areas.

It is the intention of this paper to contend that seasonal management programs using EPA-approved aquatic herbicides can be very effective in invasive plant management, habitat protection, and recreational water use.

437. Imazamox Absorption and Metabolism by *Myriophyllum spicatum* (Eurasian Watermilfoil). Joseph Vassios¹, Scott Nissen¹, Galen Brunk¹; ¹Colorado State University, Fort Collins, CO, United States of America

The submersed macrophyte *Myriophyllum spicatum* (Eurasian watermilfoil) is an invasive species currently infesting 45 states, including Colorado. Field experiments conducted under an Experimental Use Permit found that imazamox could provide significant *Myriophyllum spicatum* control. Laboratory experiments were conducted to determine imazamox behavior in *Myriophyllum spicatum*. Radiolabeled imazamox was used to determine; 1) herbicide absorption, 2) the influence of external herbicide concentration on internal herbicide concentration, 3) herbicide desorption when plants were transferred to clean water, and 4) herbicide metabolism. The initial absorption experiment showed that approximately 75% of total absorption occurred within the first 48 hours following treatment and reached a maximum of 1%. The external concentration did influence internal imazamox concentrations. At 200 ppb imazamox the internal concentration was approximately 0.5 µg/plant, while at 800 ppb the internal concentration was 3.0 µg/plant. Imazamox absorption, as a percent of herbicide applied, was the same regardless of the external concentration, which indicates the absorption results from simple diffusion driven by a concentration gradient. Desorption occurred rapidly and reached equilibrium 24 h after plants were transferred to clean water with approximately 43% of absorbed imazamox desorbed. Imazamox metabolism occurred rapidly with a corresponding increase in bound metabolites 24 hours after treatment. By 48 hours after treatment metabolism stabilized with approximately 70% of absorbed radioactivity as insoluble metabolites, 20% as soluble metabolites and only 10% intact imazamox. Even

though imazamox absorption was found to be less than 1%, this herbicide has provided excellent *Myriophyllum spicatum* control in whole lake studies.

438. Effect of Tank Mixing of Herbicides and Fertilizers on Wheat (*Triticum aestivum*) Yield and Weed Management. Zoheir Ashrafi¹, Hamid Mashhadi¹, Hassan Alizade¹, Sedighe Sadeghi¹; ¹University of Tehran, Karaj, Tehran, Iran

Wheat grain production will not be sufficient for the increasing world population demands in next decades. On the other hand, human health may suffer from the deficiency of microelement (Zn, Fe, etc.) due, in part, to the lack of these mineral in wheat grain. Quality and quantity may further decrease as a result of weed competition. Tank mixing of herbicides with fertilizers is among the strategies applied to overcome these problems. For this reason an experiment was carried out in the research farm of Agronomy department, College of Agriculture and Animal Science, University of Tehran, in 2005-2006. Experimental design was a factorial arrangement of herbicides treatment including: 1- clodinafop 0.7 L/ha + tribenuron-methyl 20 gr/ha 2- Diclofop methyl 2.5L/ha + tribenuron-methyl 20 gr/ha 3- Sulfosulforun 27gr/ha 4- Iodisulforun + mesusulforun + safener (prepackaged formulation 250gr/ha) and fertilizers including: 1- Urea 5% w/n at 10 kg/ha 2- Zinc sulphate 0.3% w/n 3 kg/ha 3- Urea + Zinc sulphate 4- Control (Not application of fertilizer) based on complete randomized blocks with 3 replications. Weedy and weed free checks were also included. There were significant effect of treatment on wheat biomass with clodinafop + tribenuron-methyl + urea + zinc sulphate yielding the highest biomass (7710kg/ha). There were no significant difference among treatment with wheat grain yield, however, the highest and lowest yield were obtained with clodinafop + tribenuron-methyl + urea + zinc sulphate (7940kg/ha) and iodisulforun + mesusulforun (6030kg/ha), respectively. Harvest index was significantly higher than other treatments in weedy check and clodinafop + tribenuron-methyl applied alone. Seed thousand weight (STW) was significantly affected by treatments and the highest STW of 47 g was achieved with iodisulforun + mesusulforun. Plant number per m², plant height, spike number and protein content were not affected by treatments. Leaf area index (LAI) was significantly higher in clodinafop + tribenuron-methyl + zinc sulphate and Iodisulforun + mesusulforun + urea + zinc sulphate plus Diclofop methyl + tribenuron-methyl exhibiting the lowest LAI. All herbicide (± fertilizer) treatments provided effective control of weeds with no significant difference among them (in terms of both broad-leaved and grass weed control) clodinafop + tribenuron-methyl + urea + zinc sulphate controlled grass weed 88%. Broad-leaved weed control was as much as 94% with Iodisulforun +

mesusulforun + urea and clodinafop + tribenuron-methyl + zinc sulphate (91%).

439. Weed Management in Field Crops Using Allelopathy in Pakistan. Zahid Ata Cheema¹, Abdul Khaliq¹, Muhammad Naeem Mushtaq¹, Muhammad Farooq¹; ¹University of Agriculture, Faisalabad, Punjab, Pakistan

Allelopathy is now recognized as an important component of weed control research. Water leachates of allelopathic plants as foliar sprays, combination of their leachates with low herbicide doses, allelopathic plant herbage as mulches, intercropping of allelopathic crops and inclusion of allelopathic crops in rotation systems, are possible ways of utilizing allelopathy for weed management. Various field experiments for controlling weeds in wheat, rice, corn, cotton and canola crops using allelopathy were conducted at Agronomic Research Area, University of Agriculture, Faisalabad, Punjab, Pakistan. Water leachates of allelopathic crops as sorghum, sunflower, brassica rice and a tree as mulberry were used as foliar sprays. These water leachates were also used with reduced doses of the herbicides. Allelopathic crops as sorghum (dwarf), sunflower, moongbean, soybean and sesame were intercropped with maize or cotton crops. In rotation, sorghum and berseem were included. Weed control with water leachates by 50-75% was achieved. Similarly, reduction of herbicide(s) dose by 50-70% with allelopathic extracts was recorded. Intercropping and rotation studies revealed 70-80% weed control. Results of some experiments conducted in recent years will be presented and discussed.

440. The Allelopathic Potential of Rye Grass and Rotational Crops in the Winter Rainfall Area of the Western Cape. Michael Ferreira¹, Carl Reinhardt²; ¹Agriculture Western Cape, Elsenburg, Western Cape, South Africa; ²University of Pretoria, Pretoria, Gauteng, South Africa

The widespread use of herbicides has created new weed problems, in terms of a shift in the weed population and the evolution of herbicide resistant rye grass, as has happened in Western Cape grain producing areas. As a result, there is increasing interest in integrated weed management strategies based on a wide range of control options, like allelopathic activity. Therefore, chemical interference (allelopathy) was evaluated on rotational crops and rye grass in laboratory and glasshouse experiments. The plant series used consisted of *Hordeum vulgare* L. v. Clipper (barley), *Brassica napus* L. v. ATR Hyden (canola), *Triticum aestivum* v. SST 88 (wheat), *Lupinus albus* L. v. Tanjil (lupins), *Medicago sativa* L. v. SA standard (lucerne), *Medicago truncatula* Gaertn. v. Parabinga (medics) and *Lolium multiflorum* Lam. v. Energa (rye grass). Experiments in the laboratory observed

the effect of seed and seedling leachates on the germination process and the growth of seedlings. For the determination of allelopathic effects from root leachate, pots planted to each plant type were over-irrigated three times a week to provide for sufficient drainage per pot. Root leachates from lucern and medics reduced barley height at both three and five weeks after planting. The radicle length of wheat was reduced by seed leachates from barley, wheat and lupins. Lupins seed leachate also reduced wheat cumulative germination. The radicle length of rye grass was inhibited by seed leachates from wheat and lupins. This growth-inhibiting effect from lupin seed and seedling leachates, was also evident in rye grass radicle length and cumulative germination percentage. Crop choice may be a valuable management option for minimizing the negative effects of crop or rye grass residues. Finally, allelopathic activity from lupins could play a role in integrated weed resistance management.

441. Can Drought Resistance be the Driving Force for Weed Management through Allelopathy?. Garyfallia Economou¹, Andreas Papastavrou¹, Georgios Livanos¹; ¹Agricultural University of Athens, Athens, Greece

Global effect has severe consequences on field crops especially in arid and semi-arid counties. Drought resistance constitutes an important issue to consider from crops and weeds part. Certain field crops like cereals demonstrate significant allelopathic action when subjected to abiotic stress by exuding growth inhibitors in rhizosphere. This phenomenon broadens the horizons in integrated weed management since the cultivation of drought resistant crops may control the weeds populations. The objective of this study was to evaluate two factors: A) drought tolerance of four wheat Greek landraces: two hard wheat (Kontopouli 17 and *Ntopia Heracliou*) and two bread wheat (*Atheras Kerkiras* and *Zoulitsa Arkadias*) and B) the allelopathic potential imposed by these landraces on the growth of *Chenopodium album*, a global weed with a severe spread in semi arid regions. Four gradual irrigated levels (from a well irrigated up to deficient irrigated level) were applied in order to assess the factor A. In order to evaluate factor B the following procedure was followed: *C. album* plants were grown under greenhouse conditions in pots filled with perlite. The plants were watered with a solution originating from the landraces root exudates of the deficient irrigated level, whereas the solution with root exudates from the well irrigated level was used as reference solution. Each solution consisted of 200 gr. of the roots diluted in 1 lt of water. Watering was applied twice a week with 100 ml of each solution and started from the stage of the 1st leaf appearance. The experiment lasted six weeks and four replicates were used. The inhibitory effect of cereal root exudates on *C. album* growth was evaluated by measuring the total height and the dry weight of the plants. Results

indicated that all four landraces exhibited significant tolerance to the deficient irrigated level. In addition, all four drought resistant wheat landraces produced inhibitory substances under the deficient irrigation conditions. In particular, the wheat landraces root exudates reduced *C. album* height from 25% to 52 % and the dry weight from 28% to 50% compared to the control (well irrigated level). The order of the four landraces according to their demonstrated inhibitory action was: Kontopouli 17, *Atheras Kerkiras*, *Ntopia Heracliou* and *Zoulitsa Kerkiras*. The aforementioned data confirm the allelopathic potential of the wheat Greek landraces under water stress conditions, giving emphasis on the fact that domestic genetic resources constitute an unexploited treasure that wait for scientists to reveal its secrets.

442. Introduction of Optimized Herbicide Dosages (MLHD System) in China. Corné Kempenaar¹, Hongjun Zhang², Ye Jiming², Liu Xue², Harm Brinks³, Herman Krebbers³, Andries Rosema⁴, Roel Groeneveld¹, Bastiaan Bink⁵, Wu Xiao Bo⁵; ¹Wageningen University & Research Centre, Wageningen, Gelderland, Netherlands; ²ICAMA, Beijing, China (Peoples Republic of); ³DLV Plant, Wageningen, Gelderland, Netherlands; ⁴EARS, Delft, Netherlands; ⁵Hofung, Beijing, China (Peoples Republic of)

MLHD is a decision support system for applying minimum effective herbicide dosages. It was developed some ten years ago in the Netherlands originally for photosynthesis inhibiting herbicides. Later on, herbicides with other modes of action were added (www.mlhd.nl). MLHD makes choices in low dosage systems more rational. MLHD supplies information on sensitivity and minimum effective dosages of contact herbicides in look-up tables, and uses sensor technology (plant photosynthesis meter) to predict effects of these herbicides on weeds and crop shortly after application. The predictions are then used in next weed management decisions.

In 2004 a 4-year Sino-Dutch project was started to explore the potential of the MLHD system in arable crops (maize, soybean and winter wheat) in China (www.cmhd.cn). Weed control in these crops in China is mainly done by lance sprayer applied soil herbicides.

Results in maize were most promising and are summarized in this abstract. In 48 plots, herbicide use according to MLHD was compared with Normal Practice (NP). Plots were at least three by ten meters in size. Herbicides used in MLHD were atrazin, bentazon and nicosulfuron (used post-emergence of weeds in ca 4-leaf stage) while NP was acetochlor plus atrazin (pre-emergence application). Key parameters on herbicide use, number of herbicide applications, efficacy and crop yield were determined.

MLHD gave a reduction of 49 % in herbicide use (gram a.s. per ha) while efficacy of control and maize yields (+ 6.7 % compared to NP) increased significantly. The reduction in environmental effects by MLHD was even

larger than 50 % because of a use of herbicides which are on average less persistent. The demonstrated plant photosynthesis meter (PPM) played an important role in the project. Good relations between PPM-measurements and herbicide efficacy were demonstrated. Such measurements increase adoption of optimized dosages.

We concluded that MLHD can help Chinese agriculture to make the important step from weed control by traditional soil herbicides to use of optimized dosages of contact herbicides.

443. Absorption, Translocation, and Metabolism of Glufosinate Confer Various Levels of Tolerance in Crop and Weed Species. Wesley Everman¹, Scott Clewis², Alan York², John Wilcut²; ¹Michigan State University, East Lansing, MI, United States of America; ²North Carolina State University, Raleigh, NC, United States of America

Glufosinate is considered a non-selective herbicide; however weed species show various degrees of sensitivity and control. Differences in levels of tolerance to glufosinate have been attributed several factors including temperature, humidity, growth stage, application rate or timing, and variations in level of absorption and translocation. Although low levels of glufosinate metabolism have been observed in several species, metabolism has not been regarded as a factor in differential tolerance of weed species to glufosinate. The objectives of this study were to determine the basis of observed *Eleusine indica*, *Digitaria sanguinalis*, and *Amaranthus palmeri* tolerance to glufosinate through comparisons to glufosinate-resistant (GR) *Gossypium hirsutum* and *Zea mays* and the highly susceptible weed species *Ipomoea lacunosa* and *Senna obtusifolia*.

Crop and weed seeds were planted in 10-cm pots containing a commercial potting medium and thinned to one plant pot⁻¹ upon emergence. Plants were grown in a plastic greenhouse maintained at 25 + 2 C constant temperature.

Glufosinate at 470 g ai ha⁻¹ was applied POST to each. Immediately after spraying, 14C-glufosinate was applied to the adaxial surface of the first fully expanded leaf of each weed and crop species. Plants were harvested at 1, 6, 24, 48, and 72 HAT. All plants were divided into four regions: 1) treated leaf (TL), 2) above treated leaf (ATL), 3) below treated leaf (BTL), and 4) roots (R). Plant parts were dried for 48 h at 40 C, weighed, and combusted with a biological sample oxidizer. Radioactivity in the oxidized samples was quantified by LSS.

Plants in the metabolism study were partitioned and immediately stored at -20 C until further analysis. Glufosinate metabolism was determined using a method adapted from Mersey et al. (1990) and Pline et al. (1999b). 14C-Glufosinate and metabolites were separated by thin-layer chromatography (TLC), utilizing a silica-gel solid phase TLC plates. The study was arranged in a random-

ized completed block with three replications of treatments and repeated in time. Treatments were separated by Fisher's Protected LSD test at P = 0.05.

Absorption of 14C-glufosinate was >85% 24 HAT in *Amaranthus palmeri* and *Senna obtusifolia*, and was <30% at all harvest intervals for GR *Gossypium hirsutum*, GR *Zea mays*, non-transgenic *Gossypium hirsutum*, and *Ipomoea lacunosa*. Elevated levels of translocation were observed in GR *Zea mays* and *Amaranthus palmeri*. 14C-glufosinate was translocated to ATL and R 41 and 27% in GR *Zea mays*, respectively, and 49 and 15% to ATL and BTL, respectively, in *Amaranthus palmeri*. Metabolites of 14C-glufosinate were detected in all crop and weed species. Metabolism of 14C-glufosinate was < 20% in non-transgenic *Gossypium hirsutum* and *Ipomoea lacunosa*, however metabolism rates were >70% in GR *Gossypium hirsutum* and *Digitaria sanguinalis* 72 HAT. Intermediate rates of metabolism were observed for *Amaranthus palmeri*, *Senna obtusifolia*, *Eleusine indica*, and GR *Zea mays*, with metabolites comprising >30% of detectable radioactivity.

444. Cocklebur Control in Soybean. Nader Soltani¹, Chris Kramer¹, Joshua Vyn¹, Christy Shropshire¹, Peter Sikkeema¹; ¹University of Guelph Ridgetown Campus, Ridgetown, Ontario, Canada

Field trials were conducted in 2006 and 2007 on three Ontario farms with heavy infestations of cocklebur to determine the effectiveness of various PRE- and POST-emergence herbicides for the control of cocklebur in soybean. There was minimal injury (2% or less) to soybean at 7, 14, and 28 days after emergence from the PRE-emergence and POST-emergence herbicides evaluated. Cloransulam-methyl applied PRE provided up to 98% visible control, reduced density 93%, and reduced dry weight of cocklebur 96%. Linuron, metribuzin, imazethapyr, and clomazone applied PRE provided 4-77% visible control and reduced density and dry weight of cocklebur minimally (54% or less) compared to the weedy check. Cloransulam-methyl applied POST provided as much as 98% visible control, reduced density up to 96%, and reduced dry weight of cocklebur as much as 98%. Chlorimuron-ethyl, imazethapyr, imazethapyr plus bentazon, and glyphosate applied POST provided 49-90% visible control, reduced density 67-89%, and reduced dry weight of cocklebur 69-92%. Acifluorfen, fomesafen, bentazon, and thifensulfuron-methyl applied POST provided 1-51% visible control, reduced density 0-80%, and reduced dry weight 21-88% compared to the weedy check. Soybean yield increased as much as 79% with cloransulam-methyl applied PRE or POST compared to the weedy check. Based on these results, cloransulam-methyl applied PRE or POST-emergence provides excellent control of cocklebur in soybean. Chlorimuron-ethyl, imazethapyr, imazethapyr plus bentazon, and glyphosate applied POST

have some potential for cocklebur control in soybean. Linuron, metribuzin, imazethapyr, and clomazone applied PRE and acifluorfen, fomesafen, bentazon, and thifensulfuron-methyl applied POST do not provide adequate control of cocklebur in soybean at the rates evaluated.

445. Effect of Crop Density and Weeding Times of Broad Leaf Weeds on Competitiveness Ability and Yield of Cotton (*Gossypium hirsutum*). Sara Bahrami¹, Gholam Reza Zamani¹, Sohrab Mahmoodi¹; ¹University of Birjand, Birjand, South Khorasan, Iran

Broadleaf weeds are one of the most important factors in cotton production. They caused important yield losses in Iran with an average of 20%. Therefore weeding is an important management practices for cotton production that should be carried out to insure optimum yield. In order to study the effect of crop density and weeding times of board leaf weeds on competitiveness ability and yield of cotton, a field experiment was performed at research station of Birjand University in 2006. The experimental design was factorial based on randomized complete block with 3 replications. Treatments were chosen to provide three different cotton densities (6, 9 and 12 plant m⁻¹) and five weeding times (0, 1, 2, 3 times of weeding with a weed free cotton as control). Results showed that crop density had significant effects on seed cotton yield and competitiveness ability of cotton ($p < 0.05$). There was significant interaction between crop density and weeding times of board leaf when studying cottonseed yield, lint yield and lint percentage of cotton. Cotton yield increased with adding crop density and increase of weeding times. High crop density could increase competitiveness ability of cotton against weeds. In low crop density, more weeding times was necessary to obtain the same crop yield. 0, 1, 2 and 3 times of weeding could decreased seed cotton yield 47%, 28%, 0% and 16% relative to weed free cotton in low density respectively. But these decreases were 73%, 0.09%, 0.1% and 0.04% in high cotton density. This indicated that high plant density (12 plant m⁻¹) can be used as an effective tool to diminish the negative effects of weeds in cotton production.

446. Effect of Crop-Weed Density on Common Lambs Quarters (*Chenopodium album* L.) Competition with Cotton (*Gossypium hirsutum* L.) in Birjand. Gholam Reza Zamani¹, Mojtaba Velayati¹, Majid Jami Alahmadi¹, Rahele Abedini¹; ¹The University of Birjand, Birjand, South Khorasan, Iran

Common lambs quarters is one of the main annual weed in cotton weed in Birjand region. In order to evaluate the effect of density on competition between cotton (*Gossypium hirsutum*) and common lams quarters (*Chenopodium album*), a field experiment was conducted in the

agricultural research station in Birjand University, Iran. The experiment was carried out in a complete block design, as factorial, with three replications. Treatments were common lambs quarters densities (0, 6, 9, 12 plant/m²) and cotton densities (6, 9, 12 plant/m²). Three pure stand of common lambs quarters densities (6, 9, 12 plant/m²) was added to each block. Results showed that as weed density increased, total dry matter, LAI and height of cotton were significantly decreased. The rate of cotton total dry weight decrease in weed densities (6, 9, 12 plant/m²) were 35, 42 and 48% respectively. As weed densities increased from 6 to 9 and 12p/m², LAI of cotton decreased 33, 44 and 55% respectively. These decreases in height and light interception were 15, 14, 21% and 8, 2, 14% respectively. Also result showed that there was a significant decrease in yield and yield components of cotton by weed densities. 6 plant/m² of weed caused 15% decrease in seed cotton and increase of weed density up to 9 and 12plant/m² caused further decrease in seed cotton. Weed densities, (6, 9 and 12plant/m²) caused 16, 30 and 45% decrease in cotton seed respectively. As weed density increased from 6 to 9 and 12 plant/m² lint yield decreased 13, 24 and 42% respectively. In this experiment, increasing cotton density could decrease the negative impact due to increasing weed density. Control of weeds would help to improve cotton yield, so increasing crop density results as a good implement in weed management in cotton.

447. Effects of Jimson Weed (*Datura stramonium* L.) Competition on Growth, Yield and Yield Components of Chitti Bean (*Phaseolus vulgaris* L.). Sohrab Mahmoodi¹, Mohsen Khanjani¹, Majid Jami-Al-Ahmadi¹, Ali Akbar Ghanbari²; ¹University of Birjand, Birjand, Southern Khorasan, Iran; ²Bean National Research Station, Khomein, Markazi, Iran

Jimson weed (*Datura stramonium* L.) is a major weed of bean (*Phaseolus vulgaris* L.) fields in Iran. It can reduce Iranian bean field yield up to 70% and made problems on bean harvest. In order to evaluate the effects of Jimson weed competition on growth, yield and yield components of Chitti bean (the most common variety of bean in Iran) a field study based on factorial experiment with three replications was conducted two times in farm at Bean Research National Station in Khomein in 2006. Treatments were chosen to provide four different weed densities (4, 8, 12 and 16 plant m⁻¹) and three relative times of weed emergence (with crop emergence, in first trifoliolate leaf stage and third trifoliolate leaf stage of bean) with a weed free treatment as control. The results showed that the effect of Jimson weed interference on vegetative and reproductive growth of bean was significant ($P < 0.05$). The height, LAI and aboveground biomass of Chitti bean were significantly reduced when weed density increased or relative time of weed emergence decreased. The interaction of weed density and relative time of weed emergence on

most vegetative and reproductive growth characteristics of bean was significant ($P < 0.05$). The effects of weed density on bean biomass was not significant when Jimson weed emerged at third time. Bean aboveground biomass reduction due to Jimson weed competition were 31%, 29% and 14% in 1st, 2nd and 3rd time of weed emergence respectively. The time of weed emergence was more important than weed density when studying the bean yield. Bean yield loss due to Jimson weed competition was 52.6%, 41.2% and 23% in 1st, 2nd and 3rd time of weed emergence respectively. The pod number, shoot number and 100-seeds weight of bean were reduced as the weed density increased at the 1st, 2nd time of weed emergence but dose not affected by weed density at 3rd time. The number of seeds per pods was not affected by Jimson weed interference. As conclusion the results indicated that relative time of Jimson weed emergence in Chitti bean had more important effects than weed density on growth characteristics and yield of crop.

448. Simultaneous Competition of Redroot Pigweed (*Amaranthus retroflexus* L.) and Jimsonweed (*Datura stramonium*) in Corn/Soybean Intercropping. Faezeh Zaefarian¹, Majid Aghaalikhani¹, Hamid Rahimian Mashhadi², Eskandar Zand³, Mohammad Rezvani⁴; ¹Tarbiat Modares University, Tehran, Iran; ²Tehran University, Karaj, Tehran, Iran; ³Plant Pest and Diseases Research Institute, Tehran, Iran; ⁴Islamic Azad University, Ghaemshahr Branch., Ghaemshahr, Mazandaran, Iran

In order to investigate the role of corn/soybean intercropping in resources use efficiency and suppressing the weeds, a field experiment was carried out in research farm of agriculture faculty of Tehran university in 2006. Treatments were arranged in factorial experiment based on Randomized Complete Blocks with three replications. The treatments were 5 different mixing ratios of corn (*Zea mays* L.) and soybean (*Glycine max* L.) consist of: 100% corn : 0% soybean (P1), 75% corn : 25% soybean (P2), 50% corn : 50% soybean (P3), 25% corn : 75% soybean (P4) and 0% corn : 100% soybean (P5) and 4 levels of weed contamination consist of: weed free (W1), presence of redroot pigweed (*Amaranthus retroflexus* L.) (W2), presence of jimsonweed (*Datura stramonium*) (W3) and simultaneous presence of redroot pigweed and jimsonweed (W4). The density of the weeds were 15 plant per meter of row. The results showed that the highest yield of corn (9627.8 Kg/ha) was obtain in P2W1, and the lowest one (3916.7 kg/ha) in P2W4. But the highest yield of soybean (5050.00 Kg/ha) was seen in P5W1 and the lowest one (731.33 Kg/ha) in P2W4. The highest amount for some yield components of corn such as number of grain row, number of grain in row, 1000 grain weight were seen in P4W1, but the highest rate of harvest Index (0.45) was observed in P2W4 and the lowest rate (0.20) in P4W4. But the highest amount of some yield components of soybean

such as pod number per plant, grain number per pod, 1000 grain weight was seen in monoculture of soybean and weed free. Also, the highest amount of harvest index was seen in P5W1. It means that by decreasing corn population, the corn and soybean yield components increased. The highest weed biomass was seen in monoculture of soybean with two weed (376.73 g m²). There was a significant reduction in weed biomass of intercropping system over both monocultures.

449. The Effect of Corn Density and Planting Arrangement on its Grain Yield and Growth Indices under Competition of *Amaranthus retroflexus* L. Alireza Yadavi¹, Majid Aghaalikhani², Amir Ghalavand², Eskandar Zand³; ¹Yasuj University, Yasuj, Kohgiluyeh va Boyer Ahmad Province, Iran; ²Tarbiat Modares University, Tehran, Tehran Province, Iran; ³Weed Research Division, Plant Pest and Disease Research Institute, Tehran, Tehran Province, Iran

In order to study the effect of planting arrangement and plant density on yield and growth indices of grain corn (*Zea mays* L. cult. three way cross 647 hybrid) under competition of *Amaranthus retroflexus* L. (redroot pigweed) a field experiment was carried out at Kabotar Abad experimental station, agricultural research center of Esfahan in 2003. Treatments were arranged in a factorial split experiment based on RCBD with three replications. Factorial arrangement of corn densities (74000 and 111000 plant/ha) and planting patterns (single row, rectangular twin row and zigzag twin row) formed the main plots. Subplots referred to pigweed densities (0, 4, 8 and 12 plant per m of row). The result showed that leaf area index (LAI), total dry matter accumulation (TDM), crop growth rate (CGR), net assimilation rate (NAR) and grain yield of corn were decreased by presence of *A. retroflexus*. Whole of variables except of NAR and RGR in higher corn density were more than low corn density and reduction of LAI, TDM, CGR and grain yield of corn under competition of *A. retroflexus* decreased with increasing of corn density. Between different corn arrangement, twin row planting and especially zigzag twin row increased total attributes of corn except of RGR and NAR, in such a manner twin row planting arrangement decreased the *A. retroflexus* competition effect on these traits.

450. A Summary of Studies Comparing Nozzle Types, Application Volumes, and Spray Pressures on Postemergence Weed Control. Robert Wolf¹, Dallas Peterson¹; ¹Kansas State University, Manhattan, Kansas, United States of America

The introduction of several new postemergence herbicides and the presence of Roundup Ready crops have placed a renewed interest in the need to determine the operating parameters that optimize the spray deposition

on the target weeds while minimizing drift. When making foliar applications the herbicides are not always distributed uniformly, do not completely penetrate into the lower parts of the plant canopy, may not provide adequate coverage on the target, and a portion may drift from the target field into sensitive areas.

Recent nozzle technology is placing an increased emphasis on achieving optimum efficacy while keeping the drift potential at a minimum. One such nozzle design is the venturi style nozzle. The adoption of this nozzle type is widespread and without adequate knowledge of performance or good operating parameters. Venturi nozzles can produce very coarse sprays that could result in reduced target coverage under some conditions. More information about how to use the latest nozzle technologies to apply herbicides for postemergence control of grasses and broadleaves is paramount for achieving optimum weed control.

Multiple field studies were conducted in Kansas, USA over several years to measure herbicide efficacy comparing various nozzle types (extended range flat-fans, turbo flat-fans, air induction/venturi flat-fans), application volumes (47 and 94 L/ha), and spray pressures (ranging from 137 to 483 kPa). Orifice sizes were selected to deliver desired application volumes at given pressures when application speeds were 9.6 km/h. Various plant species representing broadleaf and grass type weeds were treated with glyphosate and paraquat at sublethal herbicide rates to accentuate efficacy differences. Typically, ammonium sulfate at 2% w/w was added to the glyphosate treatments and NIS at 0.25% v/v was added to the paraquat treatments.

Summarized results indicate that weed control is not sacrificed while minimizing water requirements utilizing low spray volumes using venturi and chamber style nozzles that produce much larger droplet sizes with potentially less coverage than conventional flat fan spray nozzles. It was also found that using higher pressure for venturi style nozzles improved coverage and efficacy potential while still minimizing drift potential when compared to conventional nozzles at lower pressures. Results also reflect improved efficacy with venturi style nozzles in the presence of higher temperature and lower humidity. This result is possibly due to the increased evaporation potential from the smaller droplet sizes associated with conventional nozzle types. There was very little measured difference in how the two herbicides responded to the different nozzle types and application variables.

From these studies it is recommended that applicators should consider using drift reduction nozzle technology to make applications when conditions are conducive to spray drift. However, to achieve the best results it is recommended that venturi nozzle types be used at higher pressures to generate a droplet size consistent with improved coverage and minimized drift. Results may differ with application parameters outside the scope of this research.

451. Activity of Fenoxaprop-p-ethyl 10% EC in Rice-Wheat Double Cropping System as Influenced by Rates and Application Time. Ramesh Singh¹, Ram Singh¹; ¹Institute of Agri. Sci. Banaras Hindu University, Varanasi, Uttar Pradesh, India

Rice-Wheat crop sequence occupies 10.4 million ha area in Indo-Gangetic plains of India and ensures food and nutritional securities of the region. Grassy weeds such as *Echinochloa colona* L. (Jungle rice) and *Cyperus* sp. (Nut-sedge) and *Phalaris minor* Retz. (Little seed canary grass) are major weeds in rice and wheat respectively. Treatments consisted of three rates of fenoxaprop (45, 55 and 65g ai/ ha) applied at 10 and 15 days after sowing (DAS) in direct seeded rice and four rates of fenoxaprop (100, 120, 240 & 480g ai/ha) applied at 30 DAS, in wheat. The application rate of 65g/ha at 10 DAS significantly reduced the population and dry weight of nut sedge and jungle rice in rice crop. This treatment had maximum grain yield (2830 kg/ha) of rice. In wheat, application rate of 480 g/ha, though at par to 240g/ha, was found most effective against little seed canary grass and had wheat grain yield (3210 kg/ha) comparable to maximum wheat yield (3310 kg/ha) obtained in weed free treatment.

452. Allelopathic Effects of Sunflower (*Helianthus annuus*) on Germination and Initial Growth of Redroot Pigweed (*Amaranthus retroflexus*) and Common Lambsquarter (*Chenopodium album*). Reza Ghorbani¹, Kobra Orooji¹, Mohammad Rashed¹, Hamid Khazaei¹, Majid Azizi¹; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan, Iran

Allelopathic effects of sunflower on redroot pigweed and common lambsquarter in two series of laboratory and greenhouse experiments were studied. Under laboratory conditions, leaf, stem and root aqueous extracts of sunflower at 0%, 2.5%, 5%, 7.5 % and 10% (m/v) concentrations were applied to determine their effect on redroot pigweed and common lambsquarter seed germination and initial growth under laboratory conditions. The results indicated that germination and mean daily germination were reduced 43% and 50%, respectively. The effects of leaf and stem extracts on germination were more allelopathic than root extracts of sunflower. The percentage and quality of germination were decreased by increasing the concentration of extracts. The root length and shoot length were reduced by 80% following application of sunflower extracts. The results of this study suggest that sunflower have severe allelopathic potential for redroot pigweed and common lambsquarter. In greenhouse experiments, to study the role of decomposition plant debris on release of allelochemicals, stem, root and leaf residues of sunflower were incorporated with pot soil by 5% (w/w) and set under the mist system in greenhouse for 8 weeks. Fresh residues of sunflower were

also mixed with soil. After preparing pots, weed seeds were sown and then were irrigated with tap water as needed. Redroot pigweed and common lambsquarter were grown and samples were taken in five growth stages (2, 4, 6, 8 leaf and mature plant) and dry weight, leaf area and height of weeds were determined. The results of greenhouse experiments indicated that incorporation of sunflower residues in the soil (fresh or decomposed residues) reduced growth of redroot pigweed and common lambsquarter. The difference between fresh and decomposed residues was not significant. Inhibitory effects of sunflower residues on weed in this study, apparently, were depended on weed age, weed species, sunflower organel and degree of decomposition residues.

453. Bioavailability of Diuron, Imazapic and Isoxaflutole in Soils of Contrasting Textures. Rubem Oliveira Jr.¹, Miriam Inoue², Jamil Constantin¹, Diego Alonso¹, Cássio Tormena¹; ¹State University of Maringá, Maringá, Paraná, Brazil; ²UNEMAT, Tangará da Serra, Mato Grosso, Brazil

Most available recommendations suggest that the modulation of herbicide rates applied as pre-emergence should take into account the soil texture and/or contents of organic matter in soil, usually by assuming that the highest rates are for clay and/or soils rich in organic matter. Research carried out elsewhere indicate that other soil characteristics such as mineral components of clay fraction, specific surface area and pH can also influence the main mechanisms controlling the final destination of the herbicides in the environment. Diuron, imazapic and isoxaflutole are soil-applied herbicides commonly used in sugarcane in Brazil due to their relatively long residual activity in soil. This research was aimed at understanding the dynamics of the herbicides diuron, imazapic and isoxaflutole in two soils of different physico-chemical properties. To accomplish such intent, several greenhouse experiments were run. The residual activity of diuron (applied at rates of 0; 1.6 and 3.2 kg/ha), imazapic (0; 98 and 122.5 g/ha) and isoxaflutole (0; 35 and 70 g/ha) was measured in samples from a sandy loam soil (pH H₂O = 5.4; C = 5.19 g/dm; clay = 10%; sand = 88%) and a clay soil (pH H₂O = 5.6; C = 15.96 g/dm; clay = 56%; sand = 35%), by sowing a bioindicator (*Brachiaria decumbens*), at 0, 25, 50, 75 and 100 days after herbicides application (DAA). Diuron was very stable in clay soil; for the highest rate, control was higher than 92% up to 100 DAA. No differential effect was observed in sandy loam soil, even when 2x labeled rate were applied. Bioavailability (residual activity) of diuron was linked to the increased sorption and lower degradation rate in soils with higher clay and/or organic matter contents. Results achieved in this research support the idea that the elevation of diuron rates in sandy soils does not imply in the increase of residual activity for such soils. Imazapic provided a short bioavailability in relation to *B. decumbens*, independent of rates

applied. Poor control of *B. decumbens* by imazapic was related to leaching to deeper soil layers due to the simulated precipitation. The persistence of isoxaflutole was longer in clay soil than in the sandy loam soil. Soil texture influences the persistence of bioavailability of herbicides in this study. Bioavailability in sandy loam soil did not vary significantly with applied rates for all herbicides. For diuron and isoxaflutole, the bioavailability was longer in clay soil. For imazapic, on the contrary, the bioavailability was shorter, probably because of higher leaching due to high pH of clay soil.

454. Chemical Weed Control in Canola. Ijaz Ahmad Khan¹; ¹NWFP Agricultural University, Peshawar, NWFP Pakistan

To study the efficacy of different herbicides for controlling weeds in canola, an experiment was conducted at Agricultural Research Farm Malakandher, NWFP Agricultural University, Peshawar during 2000-2001 using RCB design, having four replications. Variety Dunkled of canola in plot size of 6x3m² was planted during the last week of October, 2000. The data were recorded on weed density m², days to 50% flowering, number of branches/plant, number of siliquae/plant, siliqua length (cm), days to maturity, plant height at maturity (cm), number of seeds/siliqua, 1000 seed weight (g) and seed yield (kg/ha). None of the herbicides except Sencor WP70 had a phytotoxic effect on the crop. All the parameters were significantly affected by different herbicidal treatments. Minimum weeds m² (3.20) were observed in plots to which Treflan 4EC was applied. Maximum weeds m² (18.83) were observed in weedy check plots. Number of branches (15.00), number of siliquae/plant (609.9), siliqua length (7.90 cm), number of seeds/siliqua (29.00), 1000 seed weight (3.68 g) and seed yield (1568 kg/ha) were maximum for plots to which Treflan 4EC was applied as pre-emergence herbicide.

455. Chemical Weed Control in Dry Lentil Field (*Lens culinaris* Medik.) in Yasuj, Iran. Sirous Amiri¹, Mohammad Reza Tareghyan¹, Seyed Karim Mousavi; ¹University of Birjand, Birjand, South Khorasan, Iran

Lentil is a legume with a poor competitive ability and has serious problem with different weed population. In order to assess the efficacy of herbicides for weed control in this crop, a field experiment was conducted at the Yasuj Agricultural and Natural Resources Research Center, Iran, in early spring, 2007. Treatments were consisted of preplant soil incorporated applications of pendimethalin (1000, 1160 and 1323 g a.i. ha-1), pre-emergence applications of imazethapyr (40, 50, and 60 g a.i. ha-1), simazine (640, 1200 and 1600 g a.i. ha-1), Imazethapyr plus pendimethalin (21.2 310, 36.7 545 and 52.5 776 g a.i. ha-

1 respectively) and post-emergence applications of bentazon (960, 1200 and 1440 g a.i. ha⁻¹) at 4- to 6- leaf stage of weeds. Results showed that both pre-emergence applications of imazethapyr plus pendimethalin (36.7 545 and 52.5 776 g a.i. ha⁻¹ respectively) reduced weed density and dry weight significantly, while the total crop biomass and seed yields were increased by 77 percent, compared with the unweeded control. Bentazon was toxic to lentil at all application rates. However unrestricted weed growth in the unweeded treatment, was accounted for up to 78 percent crop yield loss compared with weed free.

456. Chemical Weed Management in Wheat Intercropped with Sugarcane. Bakhtiar Gul¹, Khan Marwat¹; ¹NWFP Agricultural University Peshawar, Peshawar, North West Frontier Province, Pakistan

To assess the effect of various herbicides to control weeds in wheat intercropped with sugarcane, a field trial was conducted at Sugar Crops Research Institute, Mardan during rabi season 2003 and 2004, using randomized complete block (RCB) design having four replications. The experiment consisted of eight treatments viz; seven herbicides and a weedy check. The herbicides included were; terbutryn + triasulfuron @ 0.16 kg, 2,4-D @ 0.7 kg, fenoxaprop-p-ethyl @ 0.93 kg, clodinafop @ 0.05 kg, bromoxynil + MCPA @ 0.49 kg, carfentrazone-ethyl @ 0.02 kg and isoproturon @ 1.0 kg a.i./ha. The data were recorded on weeds kill percentage, fresh weed biomass, plant height, spike length, number of spikes m², number of grains/spike, 1000 grain weight, biological yield, grain yield and harvest index. Parameters like weed kill percentage, weed biomass, number of spikes m² and grain yield were significantly affected by the herbicides. Maximum weed kill percentage (96.2%) and minimum weed biomass (179 kg/ha) were recorded in terbutryn + triasulfuron as compared to weedy check having values of 0 % and 1381 kg/ha, respectively. Similarly spike length (12.6 cm), number of spikes (490 m²), number of grains/spike (52.25), 1000 grain weight (44.8 g), biological yield (18240 kg/ha), grain yield (4453 kg/ha) and harvest Index (29.3%) were the highest in terbutryn + triasulfuron treatments as compared to weedy check having (11.0 cm), (342 m²), (41.0), (40.23 g), (16260 kg), (3575 kg/ha) and (24.3 %), respectively.

457. Comparing Flamer, Trifluralin, and Their Combination, to Control *Sinapis arvensis* L. and Other Weeds in Canola Fields. Parviz Shimi¹; ¹Iranian Research Institute of Plant Protection, Tehran, Iran

Weeds are one of the most limiting factors in canola fields in Iran. Wild mustard (*Sinapis arvensis*), is not controlled well by the recommended herbicides. Genetically modified canola varieties are prohibited. It was,

therefore, decided to investigate the efficacy of flamer, and its combination with trifluralin, on the control of wild mustard and other weeds in canola fields.

A two-year trial was performed in Tehran Province during 2002-2003. The experiment was Randomized Complete Block Design with 9 treatments and 4 replications. Treatments included fast (2km/h) pre plant flamer (ff), slow (1 km/h) pre plant flamer (sf), trifluralin 48% EC at 2 L/ha pre plant incorporated (t), ff + t, sf + t, t + ff, t + sf, weedy and weed free checks. Results showed that sf + t could control wild mustard by 63%. Treatments sf, and t + ff controlled wild mustard by about 40%. Other broad-leaf weeds were not controlled very well in any of the treatments. However, Gramineae weeds were controlled best at 88% by t + ff. Treatment t controlled grass weeds by 53%. Highest canola yield occurred in treatments t, and sf + t in both years. General results indicate potential for flamer use in canola weed control.

458. Competition of Wild Mustard (*Sinapis arvensis* L) Densities with Rapeseed (*Brassica napus* L.) under Different Levels of Nitrogen Fertilizer. Hossein Ghadiri¹, Ruhollah Naderi Kharaji¹; ¹College of Agriculture, Shiraz University, Shiraz, Fars, Iran

Rapeseed is increasingly becoming a popular oilseed crop in Iran, including Fars province, due to its high oil and protein content. Wild mustard is a dominant weed in rapeseed fields of Iran which can cause major yield losses. In order to evaluate the competitive effects of wild mustard densities on rapeseed under different nitrogen rates, a two year (2004-2005) field experiment was carried out at the Kushkak experimental station of the college of agriculture, Shiraz University. Treatments were various wild mustard densities (0, 10, 20, 30, and 40 plant m²) and nitrogen rates (0, 50, 100, 150, and 200 kg N/ha). The factorial set of treatments was arranged within a randomized complete block with four replicates. Commercial rapeseed seeds cultivar Talaye were planted at 8 kg/ha. Results indicated that in both years rapeseed yield and yield components decreased as wild mustard density per unit area increased. Rapeseed grain yield increased by increasing nitrogen rates, but there was no significant difference between 150 and 200 kg N/ha. With 0 and 10 wild mustard plants m², increase in nitrogen fertilizer to 150 kg/ha caused a significant increase in grain yield, whereas with 20, 30, and 40 wild mustard plants m² the increase in nitrogen fertilizer to 100 kg/ha led to significant increase in grain yield. These results indicate that increase in nitrogen not only cannot diminish the effect of weed competition, but also provides a more suitable situation for weed competition with the crop. In addition, in all wild mustard densities, by increasing nitrogen fertilizer from 50 to 150 kg N/ha, rapeseed grain oil decreased significantly. Also, by increasing nitrogen fertilizer to 150 kg N/ha, grain protein increased.

459. **Control of the Field Dodder on Sowings of Sugar Beet and Alfalfa.** Aijan Jusupova¹, Shaken Zharasov², Gulnaz Mombekova²; ¹al-Farabi Kazakh National University, Almaty, Kazakhstan; ²Kazakh Research Institute of Plant Protection, Almaty, Kazakhstan

Among 19 species of dodders in Kazakhstan the most wide spread and harmful in southern part is the field dodder (*Cuscuta campestris* Juncker). Its seed productivity on one plant of alfalfa - 29.0, sugar beet - 56.0 thousand of seeds. Decline in raw weight of crop connected with the parasitic activity of the field dodder after one month is in average on alfalfa - 54.2, sugar beet - 62.7%, comparing with control non affected plants.

Different herbicides, usually applied before and after appearance of the field dodder shoots, were tested in order to clarify their efficacy. For sugar beet additionally some agrotechnical measures were applied. Calculation of infestation with weed was conducted according to generally used methodic of all-Union Institute of Plant Protection (1981). Phenological observations on growth and development of the field dodder and cultivars were conducted according to the methodic of Balashov L.L. (1959).

During the experiments it was shown that application of harrowing before and after appearance of dodder shoots on fields of sugar beet infested by dodder leads to destruction of the latter on 72.6%. Application of two harrowings before sowing, and also before and after appearance of shoots provides decrease of infestation with dodder by 89.3%. But, even under application of such agrotechnical measures 30-100 weeds on 1 m² are left in shelter belt of row, which reduce yield of sugar beet edible roots on 100-190 c/ha. That is why for the complete removing of weeds from sowings of sugar beet not only agrotechnical, but also chemical measures of control are essential.

On sowings of sugar beet, under presence of 3.8 weeds/m² of dodder pesthole, the most efficient was kerb (6 kg/ha), which lead to 100% collapse of this weed. At that the amount of saved crop made up 48.5 c/ha, sacharinity of sugar beet edible roots increased on 1.0%. If applying mixture of kerb (3 kg/ha) and bethanal-progress AM (3 l/ha) biological efficacy is significantly reduced and comes to 90.9%.

On alfalfa, grown for green, highly infested with the field dodder, where 350 weeds/m² of dodder pesthole were indicated to be, biological efficacy of used herbicides came to 92.4-99.1%, and economical (the amount of saved crop) to 31-82 c/ha. Under application on after-grass of pivot (0.8 l/ha), hurricane (1.5 l/ha), kerb (4 kg/ha) yield of alfalfa equaled 115, 122 and 125 c/ha, correspondingly, comparing to the yield in control of 42 c/ha. Collapse of the field dodder made up 98.3-99.1%.

Observations have shown that maximal effect of herbicides is to be in those cases, when stems of the dodder are wet, i.e. after rainfall or vegetation watering.

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460. **Control of Weedy Rice and Growth Response for Rice by Benzobicyclon.** Il-Bin Im¹, Seng Hyen Ahn¹, Sun Kim¹; ¹Honam Agricultural Research Institute, NICS, RDA, Iksan, Jeonbuk, Korea, South

The weedy rice is restricting the direct sowing cultivation of the rice plant in Korea. There are weedy rice of indica type of long grain and japonica type of short grain. This research conducted to search the selective control possibility of weedy rice consequently in the rice (*Oryza sativa* L.) cultivation paddy field, to study the safety for direct seeding rice plant. The herbicide tested to these studies was benzobicyclon (3-(2-chloro-4-mesybenzoyl)-2-phenylthio-bicyclo[3.2.1]oct-2-en-4-one), and the dose of which was 140 g/ha, and the application time was 0, 1 and 2 leaves stage. 50% growth suppression dose of the weedy rice due to the use of the benzobicyclon was about 22 g/ha in case of long grain type but 1032 g/ha very high in case of short grain type. The growth of long grain weedy rice was suppressed by 140 g/ha applications of benzobicyclon 50~100% on 14th day after application, but the growth of short grain weedy rice was suppressed by the same applications 0~30%. The growth of japonica rice was suppressed by 140 g/ha applications of the benzobicyclon 0~55%, but the growth of hybrid rice of indica and japonica was suppressed by the same applications more than 80%. Consequently the benzobicyclon will be able to use for the control of indica weedy rice of long grain types, but it is impossible to use to the cultivation paddy field of indica rice.

461. **Control of Wild Barley in Wheat Fields of Iran.** Mohammad Ali Baghestani¹, Eskandar Zand¹, Alireza Atri¹, Fariba Maighani¹; ¹Iranian Plant Protection Research Institute, Tehran, Iran

In order to investigate wheat yield response and control of volnuteer barley (*Hordeum vulgare* L.), wild barley (*H. spontaneum* Koch.), two-rowed barley (*H. disticum* L.), and hare barley (*H. murinum* Am. Auctt.) with sulfosulfuron WG 75%, field and greenhouse experiments were conducted in 2004-2005 and 2005-2006. Field experiments were conducted at five locations in which pre- and post-emergence sulfosulfuron at 0, 27, 41, 54, 68, 81 and 95 g/ha were studied in a randomized complete block design with four replications. Greenhouse experiments further evaluated the effect of these treatments on different barley species. Results indicated that herbicide treatments did not cause any visual damage on wheat and different barley species. The best treatments in terms of wild barley control were post-emergence application of sulfosulfuron at 54 g/ha and pre-emergence application of sulfosulfuron at 68 g/

ha. Sulfosulfuron at 68 g/ha either applied pre- or post-emergence resulted in highest damage on common barley. Two-row barley was satisfactorily controlled by post-emergence application of sulfosulfuron at 54 g/ha. However, pre-emergence application of sulfosulfuron at 41 g/ha could acceptably control mouse barley. Overall, sulfosulfuron acted better on mouse barley and common barley especially where applied as pre-emergence herbicide.

462. Corn Yield and Weed Control as Affected by Method and Rate of Eradicane. Eshagh Keshtkar¹, Hassan Alizadeh¹, Fariborz Abbasi¹, Mohsen Mesgaran¹; ¹University of Tehran, Karaj, Tehran, Iran

Applying herbicide through irrigation water (Herbigation) is practiced widely by farmers in corn fields of Iran, however, the efficacy of this method has not been warranted. Thus, a field study was conducted in 2006 at Research Fields of University of Tehran (Karaj) to compare the conventional method of herbicide application (spraying) with different herbigation treatments. Eradicane, a commonly used herbicide in corn fields, was selected as a test herbicide in this experiment. Eradicane was applied at 5.5 (labeled rate), 3.85 or 7.15 L/ha using four application methods. Methods were the conventional spraying (CS), herbigation via the first irrigation (HRB1), herbigation via the second irrigation (HRB2) and applying eradicane through both the first and second irrigations at half dose of a single application (HRB3). The experiment design was a randomized complete block with three replications. Treatments were arranged in a 4 by 3 factorial with three controls (i.e. weed infested, weed free and atrazine plus alachlor (at 1 Kg/ha 5 L/ha)). The results showed that the application methods and eradicane doses affected significantly the corn yield and yield components ($P < 0.01$) with exception of 100 seed weight. The highest grain yield (10.62 t/ha) was observed with CS method, however, did not differ from the HRB2 treatment. Eradicane applied at either rates of 5.5 and 7.15 L/ha resulted in the highest grain yields. There were also no significant differences between CS and HRB2 for other yield components as well as weed biomass or population reductions. No eradicane treatment was found to be as effective as atrazine plus alachlor in increasing corn yield and growth parameters. The results of this experiment suggested that CS method has a better performance than herbigation, but if farmers are about to apply eradicane through furrow irrigation, a herbigation via the second irrigation at the maximum rate of 7.15 L/ha could be recommended.

463. Development of Herbicide Applied in Corn Field and its Application in China. Gui Li¹, Jing Wu¹; ¹Jiangsu

Academy of Agricultural Sciences, Nanjing, Jiangsu Province, China (Peoples Republic of)

Recently, 20 years of development of chemical herbicide industry promotes the continuously advancement of weed chemical control technology in corn field. But the traditional herbicide is still dominating the present herbicide varieties applied in the corn field. The herbicide innovated in the future will possess the characteristics of higher activity, better selectivity, no disadvantage to non-target organisms, appropriate effective duration and environmental compatibility. Besides speed-up in the nonselective herbicide production and application with expansion of transgenic herbicide-tolerance corn, discovery of new action target, separation of enantiomer with herbicidal activity and introduction of F (N) atom or heterocyclic structure into some compounds are the trends of development of herbicide applied in corn field. Now, the main herbicides used in Chinese corn field are atrazine, metribuzin, alachlor, acetochlor, metolachlor, propisochlor, thifensulfuron, nicosulfuron, trifluralin, 2,4-D and so on, and among them, atrazine is used in about 15 percent of corn sown area. Because its long residue threaten the safety production of some succeeding crops seriously, the short residue herbicides and post-emergence herbicides need developed urgently in order to increase flexibility and choice in corn weed chemical management. On the basis of introduction of novel herbicide varieties suited to Chinese corn planting mode, herbicide mixture and its applied technique should be emphasized. In addition, adaptable and environmental compatible herbicide synergist and herbicide safener should be researched intensively on their mechanism and application. Herbicide formulations need also to be diversity to change the current situation of simplistic formulation.

464. Effect of Sulfosulfuron Application Rate on Wild Barley (*Hordeum spontaneum* C.Koch.) Control in Wheat Field. Iraj Nosratti¹, Mouna Dastouri¹, Hassan Alizadeh¹, Muhammad Baghestani²; ¹University of Tehran, Tehran, Iran; ²Institute of Plant Pest and Disease, Tehran, Iran

Wild barley (*Hordeum spontaneum* C.Koch.) is an annual grass weed species which is one of most important factor reducing yield of wheat-production areas of Fars province, southern of Iran. One of the most important problems is lack of appropriate herbicides controlling wild barley. Therefore finding effective herbicides as well as the non chemical methods in order to continuing wheat production in this region is very critical. Sulfosulfuron (Apyros 75 WG®) is a newly introduced selective herbicide in Iran of capability of controlling both grasses and broadleaf weeds in wheat fields. Application rate of this herbicide is low (26.6 g ha⁻¹). In addition, the range of application timing in wheat is wide. Applying 26.6 g ha⁻¹ of Sulfosulfuron has no effect on wild barley (Baghestani et

al., 2003). Several studies have showed that increasing Sulfosulfuron rate by 100 g ha⁻¹ have no decreasing effect on yield of wheat (Parish, 1995). The objective of this study was to (1) evaluation of the efficiency of various doses of Sulfosulfuron on wild barley control and (2) determination of the visual injury caused by herbicide on wheat plant.

Materials and Methods

This experiment was conducted in Zarghan Agriculture Research Center which is located in Fars province in southern of Iran in 2006. Before sowing wheat (*Triticum aestivum* vr shiraz) wild barley seeds were dispersed on the site of study. The experimental design was completely randomized block with four replications. Treatments included application of various doses of Sulfosulfuron at rate of 0.0, 27, 41, 54, 68, 81, 95 g ha⁻¹ from Apyros 75 WG® on four-leaf wild barley at the initial of wheat tillering stage. A non ionic surfactant was added to the spray solution. Visual injury caused by herbicide on wheat and weed plants was determined during time from herbicide application timing until four wk after treatment (WAT) according to the European Weed Research Committee (EWRC) standard method. The number of wild barley as well other broadleaf weed species were counted in stable quadratic frames before herbicide application, at two and four WAT and at half-flowering wheat. At harvest, wheat dry matter, height and yield components as well as wild barley and other broadleaf weed species dry matter were measured. Data obtained from study were subjected to ANOVA and means were separated by LSD.

Results and Discussion

Results of this study showed that applying 95 g ha⁻¹ of Sulfosulfuron was most effective in reducing wild barley density. In general, using herbicide after flowering stage of wheat had no visual injury. Sulfosulfuron. Efficacy of Sulfosulfuron on other weed species was not considerable

465. Effect of Water Shortage, Dosage and Time of Herbicide Application on Phytotoxicity of Herbicides in Paddy Fields of Iran. Bijan Yaghoubi¹, Hasan Alizade¹; ¹University of Tehran, Karaj, Tehran, Iran

Delayed Phytotoxicity (DP) of herbicides is a physiological disorder that affects the normal seedling growth, tillering, flowering and maturity of rice. In Iran this problem emerged during the last ten years in some soils and has been considered as a mysterious disorder for one decade. Field observations during the last five years clearly suggested that the herbicides, time of herbicide application or water shortage have something to do with DP. Therefore, a one year elaborate greenhouse study in 2005 and two years field experiment during 2006-2007 were conducted based on the preliminary field observations on two popularly used herbicides i.e. Butachlor and Thio-bencarb (TB) on Hashemi rice variety. The experiment was

laid out in split-split plot design with two herbicides. Main plots, were time of application i.e. pre and post transplanting; and sub plots were the water levels i.e. inundated and saturated while the sub-sub plots were herbicide dosage levels i.e. (TB 1, 1.5, 3, 4.5 & 6 and Butachlor 1.2, 2.4, 3.6, 4.2 & 6 kg-ai/ha) at Rice Research Institute of Iran. The results showed that the application of both herbicides before transplanting decreased the seedling growth indices rate more in comparison to their application after transplanting. The severity of phytotoxicity was observed more in saturated soil condition as compared to inundated field conditions. Interestingly, the typical rice DP syndrome was observed for treatment with pre-transplanting application of TB under saturated field conditions that had a direct correlation with increasing herbicide dosage levels and soil organic carbon contents. Typical symptoms of DP in rice plants including green dark colour of leaves, excessive tillering, curvature or fish hooking of tillers, brittleness of leaves and panicles, slow vegetative growth, high infertile grains and delay in maturity were observed in plots treated with TB. We found a strong interaction between the dosage, time of application and water level both in greenhouse and field experiment. Application of TB after transplanting especially in inundated plots not only did not cause any phytotoxicity on rice but also showed better control of weeds. In this paper we report for the first time that the DP symptoms in rice is much prevalent in the paddy heartland of Iran as a result of improper usage of herbicide TB and irrigation management at the time of herbicide application.

466. Effect of Weed Management Methods at Various Growth Stages on Yield and Weed Density of Wheat. Khalid Nawab¹, Muhammad Arif¹, Muhammad Zafar-ullah Khan¹; ¹NWFP Agricultural University, Peshawar, NWFP, Pakistan

One of the main reasons for low production is weed infestation of the wheat crop thus resulting in failure to get maximum advantage of resources. To study the effect of weed management at various growth stages on yield and weed density of wheat, an experiment conducted at Agricultural Research Farm, NWFP Agricultural University, Peshawar, Pakistan during winter 2005-2006. The experiment was carried out in RCB design with split plot arrangement and four replications. The weeds control methods were moving, hoeing, inter-cultivation and chemical while growth stages of wheat were two to five leaf stage, four leaf to boot stage, boot to flowering stage and soft dough grain to maturity stage. The growth stages were kept in the main plots while weed control methods were assigned to the sub plots. Tillers m⁻² was not significantly affected by weed management methods and stage of growth while their interaction was significant. Maximum grains spike⁻¹ was recorded when weeds were

controlled at four leaf to boot stages. Highest number of grains spike-1 was noted when weeds were controlled at soft dough grain to maturity stage by moving method. Methods of weeds control and stages of weed management significantly increased thousand grain weight. Higher grain yield was recorded when weeds were controlled at 2-5 leaf stage in wheat crop. Highest reduction in the number of weeds was achieved with chemical method of weeds control. It was concluded that chemical weed control method resulted in better control of weeds when applied in the early growth stages of wheat.

467. Effect of Wild Oat (*Avena fatua* L.) Densities and Nitrogen on Morphophysiological Traits of Several Iranian Wheat (*Triticum aestivum* L.) Cultivars. Hossein Ghadiri¹, Meysam Ebrahimi¹, Eskandar Zand²; ¹College of Agriculture, Shiraz University, Shiraz, Fars, Iran; ²Institute of Plant Protection, Tehran, Iran

In order to investigate the competitive effects of different densities of wild oat (*Avena fatua* L.) with winter wheat (*Triticum aestivum*) under different levels of nitrogen fertilizer, a two year experiment was conducted in the Karaj research field of weed research department of Plant Protection Institute during 2004-2005. The first year experiment consisted of 2 factors, 8 wheat cultivars and 2 weed densities with randomized complete block design using four replications. Weed density was considered constant (80 plants m²) for weedy plots and none for weed free plots. The eight wheat cultivars that were utilized were: Tabasi, Roushan, Karaj 2, Azadi, Niknejad, Mahdavi, Shiraz and Pishtaz. At the end of first year experiment, two wheat cultivars, Roushan and Shiraz, were introduced into the second year experiment as the least competitive and most competitive cultivars, respectively, in order to perform complementary studies. In second year experiment, the additive competition of wild oat with winter wheat was studied. Analysis of variance was conducted for each measured variable as a split factorial design for three factors of cultivar (Roushan and Shiraz), nitrogen (0, 100, 200 and 300 kg N/ha), and wild oat densities (0, 80, 160 and 240 plants m²). The results of second year investigation indicated that, in all densities of wild oat, by increasing nitrogen fertilizer to 100 kg/ha, grain yield, biological yield, spike length, fertile spikelet per spike and wheat mean kernel weight increased significantly. However, further increase in nitrogen to 200 kg/ha in the infested plots decreased the mentioned traits significantly. For some traits like wheat tiller per meter square, plant height, and wild oat biomass, the increasing trend continued at higher nitrogen levels. Also the harvest index showed a negative correlation with nitrogen increase. Wheat grain yield, harvest index, fertile spikelet per spike and kernel number per spike decreased as wild oat density per unit area increased.

468. Efficacy of Different Herbicides for Controlling Weeds in Onion at Higher Altitudes. Muhammad Saeed¹, Muhammad Saeed¹, Khan Marwat¹; ¹Dept. of Weed Science, NWFP Agricultural University, Peshawar, NWFP, Pakistan

To study the efficacy of different herbicides for controlling weeds in onion (variety Swat-1), an experiment was conducted at Agriculture Research Station (North), Mingora during rabi 2003?04, using Randomized Complete Block (RCB) design, having eight treatments and four replications. The treatments were seven herbicides including pendimethalin @ 1.32, trifluralin @ 1.2, s-metolachlor @ 1.92 kg ha⁻¹ used as pre-emergence, while post-emergence herbicides were 2,4-D @ 1.13, bromoxynil + MCPA @ 1.3, clodinafop @ 0.05 kg ha⁻¹ and terbutryn + triasulfuron @ 0.3 kg a.i ha⁻¹ and a weedy check. The effect of all these herbicides was studied on weeds kill percentage, fresh weed biomass (kg ha⁻¹), size of onion bulbs (ml), onion bulbs m-2, plant height (cm), onion diameter (cm), onion yield (kg ha⁻¹) and cost-benefit ratio. The parameters that significantly affected by different herbicides were weed kill percentage, size of onion bulbs (ml), onion diameter (cm) and onion yield (kg ha⁻¹). Maximum weeds kill percentage (88.6 %), size of onion bulbs (78.25 ml), onion diameter (5.49 cm) and onion yield (29950 kg ha⁻¹) were recorded in pendimethalin treatment as compared to weedy check 00.0 %, 47.75 ml, 4.06 cm and 13700 kg ha⁻¹, respectively. The cost-benefit ratio was also highest (1:29.81) in pendimethalin followed by s-metolachlor (1:19.32) and trifluralin (1:17.05) while, it was the lowest was in terbutryn + triasulfuron (1:3.90). It is concluded that the performance of pendimethalin was the best among all the herbicidal treatments followed by s-metolachlor. Therefore, pendimethalin is recommended @ 1.32 kg a.i ha⁻¹ for significantly reducing the weeds population and enhancing the bulb yield in onion.

469. Efficacy of Post-Emergence Herbicides on Control of Annual Grassy Weeds in *Arachis hypogaea* L. and their Residual Effect on Succeeding *Zea mays* L. in Peanut-Maize Sequence Cropping System. Lokanath Malligawad¹; ¹University of Agricultural Sciences, Dharwad, Karnataka State, India

Arachis hypogaea L. (Peanut) is important oilseed crop of India. It is mainly grown during rainy season in Karnataka state. Weeds pose serious problem and weeds alone account for one-third of the total losses due to pests. Slow growth habit of peanut in early growth stages encourages rapid growth of weeds and results in severe crop-weed competition and reduced yield. Pre-emergence (Pre-em) herbicides have certain limitations in their applications and are being used indiscriminately and injudiciously without due consideration of specific weed

species prevailed under specific field situations. With the changing scenario of weed management, farmers in a need of effective post-emergence (Post-em) herbicides for control of annual grass weeds. Therefore, field studies on medium Vertisols during 2005 and 2006 were carried out at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (Karnataka State, India) to evaluate the efficacy of three Post-em and two Pre-em herbicides on control of annual grass weeds in peanut(-Spanish bunch) during rainy season (June-October) and their residual effect on succeeding *Zea mays* L. (Maize) crop during Post-rainy/Summer season (October-April). Rainfall during the crop growth periods of peanut during 2005 and 2006 was 625.3 mm (50 RD) and 430.3 mm (49 RD), respectively.

Results indicated that annual grass weeds (*Digitaria* Spp. *Eleusine indica* L., *Dinebra retroflexa* Panz., *Echinochloa colonum* L., *Panicum* Spp and *Setaria* Spp.) were completely controlled by the Post-em application (20 to 25 days after sowing) of either propaquizafop 10 EC (AGIL) @ 50, 75, 100 and 200 g a.i./ha or quizalofop ethyl 5 EC (TARGA SUPER) @ 37.5, 50 and 100 g a.i./ha and fenaxy-p-ethyl 9 EC (Whip Super) @ 100 g a.i./ha. All the annual grass weeds showed phytotoxicity symptoms within 4-5 days of application. The efficacy of propaquizafop and quizalofop was similar at different rates of their application. Post-em herbicides did not control broad leaved (dicot) weeds. Post-em herbicides did not show any phytotoxicity symptoms on peanut. Pre-em application of oxyfluorfen 23.5 EC @ 150 g a.i./ha or pendimethalin @ 1000 g a.i./ha effectively controlled both annual grass and dicot weeds. Post-em application of either propaquizafop or quizalofop or fenaxy-p-ethyl although very much effective against annual grass weeds in peanut during rainy season, they did not show any residual toxicity (scorching/leaf injury, wilting, vein clearing, epinasty and hyponasty) on succeeding maize grown 110 to 119 days after Post-em herbicide application. Both Pre-em and Post-em herbicides did not control sedges and *Cynodon* Spp.

470. Efficacy of Propaquizafop 10 EC (AGIL) – A Post-Emergence Herbicide on Control of Annual Grassy Weeds in *Arachis hypogaea* L. and *Vigna mungo* (L.) Hepper During Rainy Season Under Rainfed Farming Situations. Lokanath Malligawad¹; ¹University of Agricultural Sciences, Krishinagar, Dharwad, Karnataka State, India

Arachis hypogaea L. (Peanut) and *Vigna mungo* (L.) Hepper (Black gram) are important food legumes in India. These crops are generally grown as sole crop during rainy season (June to October) in Southern India under rainfed situation and in rice fallows in summer (January to April). Slow growth habit of peanut in early growth stages encourages rapid growth of weeds and results in severe crop-weed competition and reduced yield. Weeds pose serious problem and weeds alone cause 17 to 84 % and 50

to 60 % yield losses in peanut and black gram, respectively. Pre-emergence (Pre-em) herbicides have certain limitations in their applications and are being used indiscriminately and in-judiciously without due consideration of specific weed species prevailed under specific field situations. With the changing scenario of weed management, farmers in a need of effective post-emergence (Post-em) herbicides for control of annual grassy weeds in peanut and black gram. Therefore, field studies with two trials were carried out on medium Vertisols during rainy seasons (June-October) (2002 to 2005) under rainfed farming situations at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (Karnataka State, India) to evaluate the efficacy of Propaquizafop 10 EC (AGIL), a post-em herbicide, on control of annual grassy weeds in peanut (Spanish bunch) and black gram (TAU 1). Rainfall during the crop growth periods of peanut during 2002 and 2003 was 109.3 mm (13 RD) and 61.1 mm (06 RD), respectively. Rainfall during the crop growth periods of black gram during 2004 and 2005 was 194.9 mm (16 RD) and 598.7 mm (46 RD), respectively. Results of the trials indicated that post-em application (20 to 25 days after sowing) of Propaquizafop 10 EC (AGIL) applied @ 25 or 50 or 200 g a.i./ha effectively controlled annual grassy weeds (*Digitaria* Spp. *Eleusine indica* L., *Dinebra retroflexa* Panz., *Echinochloa colonum* L., *Panicum* Spp and *Setaria* Spp.) in both the crops. All the annual grassy weeds showed phytotoxicity symptoms within 4-5 days of application. The efficacy of Propaquizafop in killing annual grassy weeds was higher at higher rates of application. Propaquizafop did not control broad-leaved (dicot) weeds in both the crops. Greater weed control efficiency (during 2005) with post-em application of Propaquizafop was observed only when it was applied on lush green (succulent) annual grassy weeds. The weed control efficiency in black gram tended to decrease with a decrease in succulence in weeds. Under moisture stress situations with weeds showing wilting symptoms, efficacy of Propaquizafop was greatly reduced due to non-absorption of applied herbicide.

471. Efficacy of Quizalofop Ethyl 5 EC (TARGA SUPER) - a Post-Emergence Herbicide on Control of Annual Grassy Weeds in *Arachis hypogaea* L. (Peanut) and its Interaction with Quinalphos, Mancozeb and Urea. Lokanath Malligawad¹; ¹University of Agricultural Sciences, Krishinagar, Dharwad, Karnataka State, India

Arachis hypogaea L. (Peanut) is an important oilseed crop of India. Weeds pose serious problem during rainy season. Weeds alone account for one-third of the total yield losses due to pests. Earlier studies at Dharwad indicated that peanut yields were reduced by 17 to 84 % due to weed (both grassy and broad-leaved) competition, and annual grassy weeds alone contribute nearly 48 to 65 per cent of total weeds. Most grasses have found to pose

severe competition right from early stage of crop growth and affect the crop vigor severely. Pre-emergence herbicides have certain limitations in their applications and are being used indiscriminately and in-judiciously without due consideration of specific weed species prevailed under specific field situations. In previous studies at Dharwad, it is observed that post emergence (Post-em) application of Quizalofop ethyl 5 EC (TARGA SUPER) @ 37.5 or 50 or 100 g a.i./ha effectively controlled the annual grassy weeds in peanut. Quinalphos (insecticide) and Mancozeb (fungicide) are commonly used in peanut for the control of defoliators and rust, respectively. Under heavy rainfall situations urea is being used as foliar spray to reduce the N-deficiency in peanut. Herbicides and insecticides or fungicides or fertilizers are often applied simultaneously or serially to peanut within a short period. Insecticides, fungicides, fertilizers are not harmful when they are used as per the recommended practices. The tolerance of peanut to a herbicide may be altered in the presence of either insecticide or fungicide or fertilizer nutrients and vice versa. Therefore, field studies on medium Vertisols during two consecutive rainy seasons (June-October) of 2005 and 2006 were carried out at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (Karnataka State, India) to evaluate the efficacy of Quizalofop ethyl 5 EC (TARGA SUPER) (50 and 100 g a.i./ha) applied in combination either with Quinalphos 25 EC @ 0.02 % or with Mancozeb 75 WP @ 0.02 % or with Urea (46.0 % N) @ 1.00 % on control of annual grassy weeds in peanut (Spanish bunch). Rainfall during the crop growth periods of peanut during 2005 and 2006 was 625.3 mm (50 RD) and 430.3 mm (49 RD), respectively. The results of the trial indicated that Post-em application of TARGA SUPER applied either @ 50 or 100 g a.i./ha effectively controlled annual grassy weeds. Post-em application of TARGA SUPER at 50 or 100 g a.i./ha rate, in addition, to either Quinalphos or Mancozeb or Urea did not cause any phytotoxicity symptoms on peanut and did not alter the efficacy of TARGA SUPER in controlling the annual grassy weeds under rainfed farming situations.

472. Enhanced Herbicidal Activity against Grass Weeds through Mixture of Cyhalofop-Butyl with Metamifop and its Physiological Basis. Jin-Seog Kim¹, Jung-Sup Choi¹, Jong Yeong Pyon²; ¹Korea Research Institute of Chemical Technology, Yuseong, Daejeon, Korea, South; ²Chungnam National University, Yuseong, Daejeon, Korea, South

Objectives

Cyhalofop-butyl and metamifop are herbicides of aryloxyphenoxypropionate type developed for the control of grass weeds in rice. These herbicides, however, show differences in herbicidal symptoms; shoot growth inhibition as well as chlorosis, wilting, and desiccation of leaf.

The objectives of this study were to assess herbicidal effects of mixture of cyhalofop-butyl and metamifop and to examine its physiological basis.

Materials and Methods

To characterize the herbicidal interaction of mixture of cyhalofop-butyl and metamifop (97% purity), sets of experiments i.e., herbicidal activity against several grass weeds under the different application conditions, changes in herbicidal efficacy by mixing ratios, and herbicidal responses when applied at different leaf stages of barnyardgrass were conducted. To determine physiological basis of synergistic effect of two herbicides, phytotoxicity and symptoms appeared after herbicide application on specific leaves, and re-growth patterns of the herbicide-treated barnyardgrass were investigated

Results

Significant synergistic interactions were observed depending on the mixing rates of the herbicides when the mixtures of cyhalofop-butyl and metamifop were treated to grass weeds grown under the upland condition or on the water-surface under the submerged paddy conditions. Synergistic effects were significant at 4 to 6 days after application in barnyardgrass. The required times for 40% herbicidal activity to barnyardgrass were 13.5, 10, and 4.2 days at 20 g/ha cyhalofop-butyl, 20 g/ha metamifop, and its mixture of both herbicides, respectively. When the total amount of active ingredient in the mixture of cyhalofop-butyl and metamifop was fixed, the mixture ratio of 1:1 or 1:2 showed remarkably higher herbicidal efficacy. The application rates required to control barnyardgrass completely at 6 leaf stage were approximately 125 g/ha in metamifop and 60 g/ha in cyhalofop-butyl + metamifop (1:1 or 1:2).

The physiological basis of synergistic effect of two herbicides might be due to a complementary nature of a rapid growth inhibition by cyhalofop-butyl and the leaf chlorosis/desiccation caused by metamifop, which might be induced by the differences in translocation and metabolism of the herbicides.

Conclusion

The mixture of cyhalofop-butyl and metamifop had a synergistic interaction in herbicidal efficacy and controlled barnyardgrass more rapidly. Thus, the findings of this study indicated that the mixture herbicide could be used more effectively for grass weed control in rice.

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473. Evaluation Efficacy of Two Herbicides from Imidazolinone Group on Rapeseed Weeds Control from Cruciferae family in Mazandaran Province, Iran. Afshin Esmaeilifar¹, Ali Zaman Mirabadi², Rezapour Mehdi Alamdarlou²; ¹Islamic Azad University, Arak, Markazi Province, Iran;

²Oilseeds Research and Development Co., Saari, Mazandaran Province, Iran

In order to investigate the efficacy of Pulsar 40® and Intervix® herbicides from Imidazolinone group on rapeseed weed control from cruciferae family an experiment was performed in Mazandaran (Juibar) during 2007. Experiment was in split-plot design with three replications and treatments included dosages 1, 1.25, 2.5 L/ha of each herbicide and control. Spraying of herbicides was done as post-emergence in stage B4-5 of rapeseed. The rapeseed variety was tolerant to these herbicides (Clearfield). The weeds in the field included *Sinapis arvensis* (wild mustard), *Senecio vulgaris* (groundsel), *Silybum marianum* (milk thistle), *Rumex* sp. (sorrel), *Veronica persica* (Bird's eye), *Avena* sp. (oat) and *Phalaris* sp. (canary grass). Results of experiment indicated that these herbicides had complete effect on wild mustard, bird's eye, oat and canary grass and destroyed them. They had no effect on sorrel and for other weeds caused growth reduction and about six weeks later these weeds started to grow again. There wasn't significant difference among the efficacy of the herbicides or different doses. There wasn't any phytotoxicity or growth reduction from the herbicides on rapeseed planted variety.

474. Evaluation of the Time of Weed Removal and Land Preparation Methods on Weed Composition, Crop Quality and Performance of Okra (*Abelmoschus esculentus* L. Moench). Adeyemi Raphael¹, Smith Kenzie², Ojeniyi O²; ¹Obafemi Awolowo University, Ondo, Nigeria; ²Federal University of Technology, Akure, Ondo, Nigeria

Justification for the Research:

Quite a large proportion of okra produced in South-Western Nigeria is produced by the local farmers under the traditional system of land preparation - heap, mounds and ridge. However the improved high yielding dwarf okra cultivar NHAE-47 has failed to give high yield on the farmer's field because the farmers are unable to provide the necessary weed control when they are grown under the traditional tillage systems.

Objective of the Study:

The objective of this study was to determine the combined effect of tillage and weed control on the weed composition and nutritional quality of hybrid okra.

Methods:

The field experiments were carried out in the early and late seasons of 2004. Six treatment combinations involving two tillage methods, zero tillage and ridging with post planting treatments of weeding at 4 weeks after planting (WAP), keeping the crop weed free and weeding throughout crop life cycle were evaluated in a randomized complete block design and replicated four times. Weeds were identified in a diagonal transect. Data were collected

on the weed flora composition, okra growth and yield as well as proximate composition.

A total of 10 weed families were observed in the early season while 8 weed families were observed in the late season. The predominant families in the early season include: Asteraceae (23.5 %, 4 species), Poaceae (17.6%, 3 species) and Cyperaceae (11.8%, 2 species) while the most predominant in the late season were the Asteraceae (35.7%, 5 species), Poaceaceae (21.4%, 3 species) and Cyperaceae (14.29%, 2 species).

Better vegetative growth of okra were observed in the early season than the late season irrespective of the time of weed removal while the converse was true for the yield of okra in both seasons due to greater weed biomass in the former. Combination of ridging and regular weed control most enhanced okra leaf N, P, K, and Ca status. Combination of ridging with weed free or weeding at 4 WAP gave better fat and crude protein than zero tillage combined with either of the weeding regimes.

Conclusion:

A single timed weeding at 4 WAP combined with ridged tillage method can be adopted in management of weed in okra farming system in the rain forest area of Nigeria.

475. Fall vs Spring Applied Sulfentrazone for Weed Management in Chickpea (*Cicer arietinum*). Eric Johnson¹, Robert Blackshaw¹, Ken Sapsford², Frederick Holm²; ¹Agriculture and Agri-Food Canada, Scott, SK, Canada; ²University of Saskatchewan, Saskatoon, SK, Canada

Sulfentrazone is a Group 14 herbicide that inhibits the protoporphyrinogen oxidase (PPO) enzyme. It is not currently registered in Canada but registration is being sought in chickpea, field pea, flax, and sunflower. Sulfentrazone is a soil-applied herbicide that requires soil moisture for activation and root uptake. Initial studies conducted in Western Canada indicated inconsistent weed control, particularly when applied in spring seasons that received below normal rainfall. Also, control of wild mustard (*Sinapis arvensis* L.) and other Brassica species was variable. The hypothesis was that late fall application may improve the consistency of weed control since the spring snow-melt would move the sulfentrazone into the rooting zone allowing activation to occur. Eight site-years of field studies were conducted from 2003-2008 at Scott, SK and from 2004 to 2007 at Lethbridge, AB, Canada. Sulfentrazone was applied at rates ranging from 0 to 840 g ai ha⁻¹ in late October and in early spring (3 days after seeding desi chickpea). Application timing had no effect on the control of kochia (*Kochia scoparia* L.) with rates of 140 g ai ha⁻¹ providing greater than 80% control with either fall or spring application. Spring applied sulfentrazone was superior in controlling wild mustard and volunteer canola (*Brassica napus* L.); however, spring application rates of > 420 g ai ha⁻¹ were required to provide control. This rate

would likely injure subsequent crops based on re-cropping studies. Chickpea yields were higher with spring application than fall application in three of the eight site-years, with similar yields occurring in the other five site-years. Ongoing studies are examining tank mixtures of sulfentrazone at 70 to 280 g ha⁻¹ with isoxaflutole to attain broad spectrum weed control in chickpea without herbicide carryover concerns in following crops.

476. Glyphosate Tolerant Sugar Beet (*Beta vulgaris* L.) Weed Control with Glyphosate Tank Mixtures. Don Morishita¹, J. Daniel Henningsen¹, Donald Shouse¹; ¹University of Idaho, Twin Falls, Idaho, United States of America

Weed control in glyphosate-tolerant soybean (*Glycine max* (L.) Merr.), corn (*Zea mays* L.), or cotton (*Gossypium hirsutum* L.) has shown little or no interaction when glyphosate is tank mixed with other herbicides, insecticides or fungicides. Glyphosate tolerant sugar beet was approved nearly 10 years ago, but due to industrial customer concerns, sugar beet processors have not accepted them for processing. 2008 marks the first year of widespread glyphosate tolerant sugar beet production in the USA. Currently, the glyphosate label does not list any approved tank mixtures with any pesticides used in sugar beet. It does offer this precaution: tank mixtures of this product with herbicides, insecticides or fungicides may result in crop injury or reduced weed control. Based on this label information, we determined there was need for information on the compatibility of glyphosate with other pesticides for use on glyphosate-tolerant sugar beets. Field studies were conducted from 2003 to 2007 to evaluate herbicide tank mixtures and to begin investigating potential interactions with insecticides and fungicides tank mixed with glyphosate for use on glyphosate-tolerant sugar beet. Seven studies looked at glyphosate tank mixtures with other herbicides and another study evaluated three insecticides and two fungicides tank mixed with glyphosate applied to glyphosate-tolerant sugar beets. Herbicides tank mixed with glyphosate included clethodim, clopyralid, cycloate, desmedipham, dimethenamid-P, EPTC, ethofumesate, phenmedipham, pyrazon, quizalofop, sethoxydim, trifluralin, and triflurosulfuron. Insecticides applied with glyphosate were esfenvalerate, chlorpyrifos, and cypermethrin-S and fungicides tank mixed with glyphosate were trifloxystrobin and azoxystrobin. No crop injury, reduced weed control, or reduced sugar beet yield was observed with any of the herbicide tank mixtures, with the exception of pyrazon. Common lambsquarters control was reduced with glyphosate pyrazon, although sugar beet yield was not affected. With limited evaluations of insecticide and fungicide tank mixtures with glyphosate, very little negative effect was observed. The only exception was early season common lambsquarters control with trifloxystrobin and azoxystrobin. However, common

lambsquarters control was equal to glyphosate alone at the later evaluation date. There was no difference in root yield or recoverable sugar among any of the pesticide tank mixtures indicating no negative interaction between glyphosate and the herbicides, insecticides, or fungicides. Growers and crop advisors however, are anxious for the pesticide manufacturers to label these tank mixtures to help assure them no potential problems exist with glyphosate tank mixtures.

477. Herbicide Application Timing Affects Blackberry Control in Florida Pastures. Brandon Fast¹, Jason Ferrell¹, Brent Sellers¹; ¹University of Florida, Gainesville, FL, United States of America

Blackberry (*Rubus* spp.) is a woody perennial shrub that forms dense thickets in Florida pastures and reduces forage yield, quality, and accessibility. Additionally, blackberry stems are densely covered with sharp prickles that frequently injure livestock. According to current recommendations, herbicides labeled for blackberry control should be applied in the spring (at or prior to bloom) or in the fall (after fruit drop); however, pasture herbicides are typically applied during the summer months, and blackberry control is often inconsistent and/or unsatisfactory. The objective of this research was to determine if herbicide application timing affects blackberry control. Experiments were conducted in 2005 and 2006, and treatments included triclopyr (1.1 kg ae/ha), triclopyr + fluroxypyr (0.8 + 0.3 kg ae/ha), fluroxypyr + picloram (0.5 + 0.7 kg ae/ha), and metsulfuron (0.02 kg ai/ha) applied in the spring (April) and fall (October). Blackberry control was visually rated on a percentage scale of 0 (no control) to 100 (complete control) 12 months after treatment. Application timing did not significantly affect blackberry control in 2005; furthermore, control achieved by metsulfuron (89%), fluroxypyr + picloram (86%), and triclopyr + fluroxypyr (81%) was significantly greater than that achieved by triclopyr (69%). In 2006 herbicides provided significantly greater blackberry control when applied in the fall compared to the spring. Blackberry control provided by metsulfuron in both fall (93%) and spring (85%) was significantly greater than that provided by all other treatments. Blackberry control achieved by metsulfuron was the highest or among the highest of all treatments both years. In 2005 favorable growing conditions were present at both herbicide application timings, and in 2006 unfavorable (dry) growing conditions were present at both application timings. Based on these results, we have concluded that if herbicides are applied when conditions are favorable for plant growth, blackberry control is not affected by herbicide application timing. Furthermore, we have concluded that if herbicides are applied when conditions are unfavorable for plant growth, herbicides will provide better blackberry control when applied in the fall compared to the spring.

478. **Impact of *Conyza canadensis* on the Yield Character of Oilseed Rape and its Economic Threshold.** Zhu Wenda¹, Wei Shouhui², Yu Dazhao¹; ¹Hubei Academy of Agricultural Sciences, Wuhan, Hubei, China (Peoples Republic of); ²Chinese Academy of Agricultural Sciences, Haidian, Beijing, China (Peoples Republic of)

Additive series experiment and curve fit were adopted to study the change of yield characters of oilseed rape under different density of *Conyza canadensis*. The results showed that with the interference of *Conyza canadensis*, the pod number, seed number, yield and yield loss of oilseed rape decreased gradually as the weed density increased, but the 1000-grain weight showed no significant change. The logarithmic regression model was better for describing the relationship between *Conyza canadensis* density and rape pod number ($y = -72.543\ln x + 624.954$, $P < 0.001$), seed number ($y = -0.935\ln x + 26.682$, $P < 0.001$), yield ($y = -311.994\ln x + 3167.996$, $P < 0.001$) and yield loss ($y = 10.838\ln x - 10.046$, $P < 0.001$). When manual weeding was adopted for control of *Conyza canadensis* in oilseed rape fields, the economic infestation level for *Conyza canadensis* was 7.99% and the economic threshold was about 5.28 plant/m².

479. **Impacts of Grazing and Mechanical Defoliation on Weed Frequency and Biomass in Berseem Clover (*Trifolium alexandrinum*) Pasture.** Ershad Tavakol¹, Mohammad Reza Chaichi², Parastoo Hoseinzadeh³; ¹Mahabghodss Consulting Engineering, Tehran, Iran; ²College of Agriculture California Polytechnic State University, Poma, California, United States of America; ³Yekom Consulting Engineers, Tehran, Iran

Method of defoliation can affect weed frequency, population and biomass during the growth period of forage crops. In this research, the effects of two defoliation methods (mechanical and grazing by sheep) with different harvest intensities and sowing densities of Berseem clover were assessed and evaluated. Berseem clover was sown on April 15th 2006 in 3 densities (10, 20 and 40 kg.ha⁻¹) and 3 harvest intensities were applied of (3, 6 and 9 cm from ground level) in order to evaluate the weed competition with the main plant during the plant growth period. During the research, the dry matter variation of 12 most common weed species was measured in each plot. The least weed biomass and frequency occurred in mechanical harvest treatment with sowing density of 40 kg.ha⁻¹ and cutting height of 3 cm from ground level. Implementing of grazing method at the highest intensity with sowing density of 40 kg.ha⁻¹ decreased the weed population and biomass compared to control treatment (no defoliation). Results showed that mechanical harvest is more advantageous in reduction of weed frequency and biomass compared to grazing system.

480. **Influence of Different Durations of Weed Interference on Grain Yield Loss in Three *Brassica napus* L. (Winter Oilseed Rape) Cultivars.** Adel Dabbagh Mohammadi Nassab¹, Javad Hamzei¹, Farrakh Rahim Zade Khoie¹, Aziz Javanshir¹, Mohammad Moghaddam¹; ¹Tabriz University, Tabriz, East Azarbaijan, Iran

In order to determine the amount of grain yield loss of winter oilseed rape cultivars under weed interference condition, an experiment was carried out in 2004-2005 at Agricultural Research Station, Faculty of Agriculture, University of Tabriz. Three winter oilseed rape cultivars (OKAPI, LICORD & SLM046) with 12 weed interference durations were evaluated in a factorial complete block design with three replications. The experiment consisted of two sets of treatments based on different growth stages of oilseed rape. In the first set, the crop was kept weed-free until the following growth stages: four-leaf; eight-leaf; stem elongation; flowering; and pod formation. In the second set, weeds were permitted to grow in the crop until the growth stages: four-leaf; eight-leaf; stem elongation; flowering; and pod formation. Weedy and weed-free checks were also included in the study for comparison. Regression models were used to describe the amount of grain yield loss. Cultivars and different weed interference durations significantly affected grain yield. Grain yield loss increased as weed interference duration increased. Therefore, minimum values of grain yield was observed by the full period of weed-infestation and maximum values for that was seen for the weed free control and SLM046. Grain yield loss in SLM046 cultivar was smaller than Okapi and Licord cultivars. Regression models showed that preventing >10% grain yield loss, winter oilseed rape must be kept weed free between the six-leaf stage and initial flowering(47-110 DAE).

481. **Inhibitory Effects of Common Lambs Quarters (*Chenopodium album*) Seeds on Germination of Maize (*Zea mays*) and Sorghum (*Sorghum bicolor*) Seeds.** Gholam Reza Zamani¹, Mojtaba Velayati¹, Majid Jami Alahmadi¹; ¹The University of Birjand, Birjand, South Khorasan, Iran

Most of allelopathic studies have demonstrated the importance of live and dead plant tissues as source of allelochemicals. Seeds of several species also have inhibitory effects on germination of the same or other species. In order to determine the allelopathic effects of common lambs quarters (*Chenopodium album*) seeds, a study was conducted under controlled conditions in Birjand University, IRAN. The laboratory experiments were carried out in a completely randomized block design with 6 replications. four treatments of each crop species were consisted of 15 seeds of sorghum (*Sorghum bicolor*) and/or 10 seeds of maize (*Zea mays*) with 0, 200, 400 and 600 seeds of common lambs quarters that were equally distributed around seeds of both crop species. Results indicated as the

number of weed seeds increased, the crop germination percentage was decreased significantly. There were significant effects of neighboring weed seeds on coleoptile and radicle length, number of secondary and adventitious roots and length of secondary and adventitious roots of crop species.

482. Investigation of the Effects of Planting Date, Seed Density and Weed Management on the Seed Yield of Wheat (Tajan cultivar). Yahia Abtali¹, Mehdi Abtali², Esmaeil Yasari³; ¹Agriculture and Natural Resources Researches Center of Mazandaran, Iran, Sari, Mazandaran, Iran; ²Agricultural Products Insurance Office of Mazandaran, Iran, Sari, Mazandaran, Iran; ³Payam Nour University, Mazandaran, Iran, Sari, Mazandaran, Iran

In order to investigate the effects of different planting dates, seed density and weed management in wheat field (Tajan cultivar) an experiment was carried out in two consecutive cropping seasons 2003-2004 and 2004-2005. A split-split plot experimental design based on randomized completely blocks design (RCBD) in three replications was performed in this study. The main plot was planting date in three different levels consisting of: Nov 11th, Dec 1st and Dec 21st (as factors a1, a2 and a3), respectively. The sub plots comprising three levels of seed application: 140, 160 and 180 kg/ha (as factors b1, b2 and b3), respectively and the sub-sub plots were three different approaches of weed management: mixed application of the herbicides clodinafop propargyl and tribenuron-methyl in recommended doses, single application of these two herbicides with interval time, along with a non weeding control plot (as factors c1, c2 and c3), respectively.

The investigations were including the determination of monocot weeds density, determination of biomasses of monocot as well as dicot weeds, singly and together, determination of wheat stands density, wheat biomass and seed yield in different plots receiving different treatments.

Analysis of variation was done by using MSTAT-C statistical software and mean comparison of the treatments was performed following Duncan's multiple range test (DMRT). The graphs also were drawn using excel software.

The results revealed significant differences in the number of weed plant stands and seed yield at different planting dates, while different levels of seed density did not show significant differences and all three treatments were ranged in the same statistical group. Among different weed control treatments, herbicide application treatments differed from no herbicide application control plot. Statistical assessments also showed significant differences among the interaction of different factors, where the treatment a1c1 with an average seed yield of 5658 kg/ha produced highest seed yield and the treatment a2c3 with an average of 4355 kg/ha seed yield was the lowest one. Interaction of the three studied factors, a1b1c1 resulted in 5903 kg/ha the

maximum seed yield while a1b2c3 produced 4142 kg/ha seed yield, minimum seed yield among all the treatments.

483. New Methodologies for the Management of Associating Weeds in Crop Maize in the South-Western Region of Poland. Hanna Golebiowska¹; ¹Institute of Soil Science and Plant Cultivation, State Research Institute, Wroclaw, Lower Silesia, Poland

The majority of arable land, covering 59% of the area is situated on different soil stands: Cambisols and Podzols the south-western region of Poland, while 33% belong to fertile Chernozems and Alluvisols occurring in river valleys. As far as monocotyledonous species are concerned, all soil stands were dominated by *Echinochloa crus-galli*, *Chenopodium album* and *Amaranthus retroflexus*. They were often accompanied by late germinating species *Aethusa cynapium*, *Setaria* spp., *Solanum nigrum* featuring short growing period as well as those remaining in cultivated plants till harvesting. For many years high efficiency of weed control had been provided by triazine herbicides withdrawn from the market in 2007. Effectiveness of recommended sulfonylurea herbicides for majority of weeds growing in maize plantation is not satisfactory and, therefore, to maintain maize free from weeds they should be applied in combination with other herbicides. Identification of the state and abundance of weed infestation on different soil was conducted and evaluation of herbicide efficacy used at the lowered doses for control was tested. The weed management should be integrated to the farm production system to reduce the occurrence of weeds. Maize is crop that use high level of herbicide consumption, due its efficiency and fastness of work performance of chemical control.

The purpose of experiments undertaken in 2004-2006 was the assessment of weed occurrence intensity in maize as influenced by the changes in agrotechnical measures, as well as establishing of effectiveness of weed control. The following results were obtained in performed experiments:

1. Assessment of weeds present in maize crop cultivated on black soil revealed high infestation with weeds *Echinochloa crus-galli*, *C. album*, *A. retroflexus* and *S. nigrum*, and occurring with increasing frequency *Aethusa cynapium* and *Hyoscyamus niger*. A high effectiveness of controlling those weeds is achieved after the application of herbicide mixture: foramsulfuron + jodosulfuron metylosodowy + florasulam + 2,4 D.

2. On brown soil was observed high intensity of the occurrence of *E. crus-galli* + *Setaria* ssp, *C. album*, and Polygonaceae family; *Galium aparine* and perennial species *Artemisia vulgaris* are also becoming troublesome. Those species were most effectively controlled with a mixture of herbicides: mezo-trione + rimsulfuron.

3. The weed community occurring on podsollic soil was composed mainly of *E. crus-galli*, *Elymus. repens*, *C. album*, *Viola arvensis*, *Capsella bursa-pastoris*, *Galinsoga*

parviflora. The efficacy of control of that weed community was the highest in case of a mixture: rimsulfuron + dicamba

484. Performance of Pre and Post-Emergence Herbicide Doses on *Asphodelus tenuifolius* CAV in Chickpea Field. Muhammad Khan¹, Gul Hassan¹, Imtiaz Khan¹; ¹North West Frontier Province, (NWFP) Agricultural University Peshawar Pakistan, Peshawar, NWFP, Pakistan

A study was conducted to assess the phytotoxicity of residues of *Croton bonplandianum* Baill, a noxious weed, towards the growth of crops (*Brassica oleracea* var. botrytis L. and *Brassica rapa* L. and weeds (*Melilotus alba* Medik and *Medicago polymorpha* L.). The early growth of both (crops and weeds), measured in terms of root length, shoot length and dry weight, was significantly reduced when grown in soil amended with varying amount of *Croton* residues. A direct relationship was observed between the amount of residue incorporated in the soil and growth reduction. In order to test this, aqueous extract concentrations (0.5, 1, 2 and 4%) of residue were prepared. In a laboratory bioassay it was observed that, these extracts severely reduced the early growth of weed and crop plants. A significant amount of the phenolics (the largest group of secondary metabolites usually implicated in Allelopathy), was estimated in residues extracts, as well as in residue incorporated soil. The phenolic content increased with increasing residue concentration, thereby showing their direct involvement in the observed growth inhibitions. Therefore, the study establishes that *Croton* residue exert an allelopathic influence on the early growth of weeds and crops by releasing water-soluble phenolics into the soil.

485. Promotion by 5-Aminolevulinic Acid of Seedling Growth and Antioxidant System of Oilseed Rape (*Brassica napus*) under Herbicide Toxicity Stress. Weijun Zhou¹, Wenfang Zhang¹, Fan Zhang¹, Zonglai Jin¹, Qing-fu Ye¹, R. Raziuddin¹; ¹Zhejiang University, Hangzhou, Zhejiang, China (Peoples Republic of)

Weeds are one of the major constraints in the production of oilseed rape (*Brassica napus* L.), one of the world's major oilseed crops. Use of effective herbicides to control weeds in the fields is one of the main objectives of agronomists. In order to improve weed control efficacy and minimize the application costs, complex combinations of 5-aminolevulinic acid (ALA) and new post-emergence herbicide ZJ0273 (propyl 4-(2-(4,6-dimethoxypyrimidin-2-yl)oxy)benzylamino)benzoate) were used to investigate their combined effects in relation to seedling growth and development of oilseed rape (*Brassica napus* cv. ZS 758). *Brassica* seeds were treated with different concentrations of ZJ0273 [viz., 100 (normal dose for rape), 200, 500 and

1000 mg/l] and ALA (viz., 0.1, 1, 10 and 50 mg/l). ALA was applied as pre- and post-treatment alone and in combination with ZJ0273. We found that ZJ0273 stress imposed negative effects on rape seedling growth. Shoot fresh weight, shoot length and root fresh weight was inhibited significantly under ZJ0273 stress and the rate of decline was consistently increased with the increase in ZJ0273 concentration. Root oxidizability was also inhibited significantly under ZJ0273 stress conditions and the higher concentration of the ZJ0273 herbicide, the lower the oxidizability. Herbicide ZJ0273 treatment produced a gradual decrease in antioxidant enzymes (peroxidase (POD), superoxide dismutase (SOD) and ascorbate peroxidase (APX) activities) and increase in peroxidation substance (malondialdehyde (MDA) accumulation). The increase and decrease were consistent with the ZJ0273 dosages. Our results indicated that pre- and post-treatments with lower dosage of ALA (1 mg/l) improved the rape seedling growth and root oxidizability parameters while the higher concentration of ALA (50 mg/l) depressed the growth. We also found that the plant treated by 1 mg/l ALA produced the highest shoot fresh weight, shoot length, root fresh weight and root oxidizability when the seeds were treated with different concentrations of ZJ0273. Lower dosages of ALA improved the activities of antioxidant enzymes whereas the highest dosage of ALA increased the accumulation of peroxidation substance. These results indicate that ALA has promotive effects in the recovery of growth and development of rape seedlings under herbicide ZJ0273 toxicity stress.

486. Prospects of Wheat as a Dual Purpose Crop. Muhammad Arif¹, Muhammad Azim Khan¹, Muhammad Waqas¹, Fazal Munsif²; ¹NWFP Agricultural University Peshawar, Pakistan, Peshawar, NWFP, Pakistan; ²NWFP, Agricultural Research Institute, Tarnab, Peshawar, Peshawar, NWFP, Pakistan

The use of wheat as a forage and grain (dual purpose) crop is aimed at reducing competition between area devoted to grain and forage crops. The income stability of this system is higher because both livestock and wheat commodities are available for market. Field experiments were conducted at Agricultural Research Farm, NWFP Agricultural University, Peshawar, Pakistan during winter 2005-2006 and 2006-2007. The experiments were laid out in randomized complete block design with split plot arrangements having three replications. Wheat variety Saleem-2000 was sown with the help of a hand hoe in a plot size of 2.5 x 5 m² with row to row distance of 30 cm. A cut was given to the respective plots about 60 days after sowing. At the time of cut, the crop was ready to be used as fodder. Weed density was recorded about 30 days after each cutting and about 60 days after sowing in non cut plots. During the first year, a simple experiment was conducted to look into the potential use of wheat as a

dual-purpose crop and its effect on associated weeds. Perusal of the data indicated that non-cut plots produced significantly more spikes m⁻², grains spike⁻¹, grain weight, grain yield and biological yield. Similarly, no-cut plots suppressed weeds. However, economic analysis indicated that income of the cut plots was at par with the income of the non-cut plots. Keeping these results in view, the second year experiment was designed to study the effect sowing date and seed rate on grain yield, weed density and economic analysis of dual purpose wheat. Sowing dates (15 October, 1 November, 15 November and 1 December) were kept in the main plot, while combinations of three seed rates (100, 150 and 200 kg ha⁻¹) and cutting treatment (Cut and No-cut) were kept in the sub-plot. Higher grain yield was recorded for early sowing in mid October followed by sowing on 1st November which were statistically at par with each other. The effect of seed rate on grain yield was not significant. Amazingly, cutting of wheat crop improved grain yield. The sowing date (SD) x seed rate (SR) x cutting (C) interaction for grain yield was significant. Maximum weed density was noted in plots sown on 15th November while minimum weed density was recorded in plots sown on 1st December. Imposition of cutting on wheat crop significantly improved weed density as compared to non-cut plots. The SD x C and SR x C interactions for weed density were significant. It was concluded that wheat can be used as a dual-purpose crop to provide sufficient feed to the starving livestock in Pakistan however weeds problem need to be addressed.

487. Pyroxsulam: A New Postemergence Herbicide for Wheat. Roger Gast¹, James Breuninger¹, Monte Weimer¹, Dominique Larelle¹, Brett Oemichen¹; ¹Dow AgroSciences, Indianapolis, IN, United States of America

Pyroxsulam is a new triazolopyrimidine sulfonamide herbicide that provides broad spectrum postemergence weed control in wheat. The control spectrum includes key annual grasses occurring in global cereal markets such as *Alopecurus* sp., *Apera spica-venti*, *Avena* sp., *Bromus* sp., *Lolium* sp. and *Phalaris* sp., and many broadleaf species. Herbicidal activity with pyroxsulam is achieved through ALS inhibition at low use rates ranging from 9 - 18.75 g ai ha⁻¹ depending upon timing and target weed species. At these rates it provides some level of residual weed control; however it quickly degrades allowing rotation to most crops the following season. When combined with the safener cloquintocet-mexyl, pyroxsulam is selective in winter and spring wheat varieties (including durum), winter rye and winter triticale over a wide application window. Product offerings will consist of pyroxsulam formulated alone and premixed with other broadleaf herbicides tailored to provide complete weed control and meet needs of local geographies. Lead commercial formulations include a 7.5% WG for winter wheat and 30 g ai/L oil dispersion (OD) formulation for spring wheat

markets. Field evaluations have shown that pyroxsulam can be tank mixed with a wide range of broadleaf herbicides for one-pass grass and broadleaf weed control. Overall, pyroxsulam has a very favorable environmental and toxicological profile. It undergoes rapid aerobic microbial soil degradation with an average laboratory soil half-life of 3 days. In studies conducted in western Canada the median field soil half life was 13 days. No degradates of concern were produced in any studies. Pyroxsulam exhibits very low acute and chronic toxicity (practically nontoxic) to mammals, birds, fish and aquatic invertebrates. Studies have shown it not to be carcinogenic, teratogenic, mutagenic, neurotoxic or a reproductive hazard. Pyroxsulam is currently registered in Canada, United States and Chile, and under review in the Australia, Argentina and several European Union countries. Dow AgroSciences is seeking to widely register pyroxsulam for use in all major cereal producing countries with first commercial launches in 2008.

488. Reducing Wild Mustard (*Sinapis arvensis* L.) Seed Bank in the Soil. Himeira Salimi¹, Parviz Shimi¹, Saeed Samavat²; ¹Iranian Research Institute of Plant Protection, Tehran, Iran; ²Water and Soil Research Institute, Tehran, Iran

Wild mustard (*Sinapis arvensis* L.) is the most noxious weed in Iranian canola fields. The use of genetically modified seeds is prohibited, and there are no effective enough herbicides to control this weed. One way of controlling wild mustard is reducing its seed bank in the soil by destroying the seeds on the soil surface. With this hypothesis in mind, a two-year trial was carried out in Tehran province during the year 2005-2006. After harvesting a canola field uniformly infested with wild mustard when planted, an experiment was conducted in randomized complete block design with 4 replications and the following 8 treatments: five treatments with canola stubble (about 20 cm high) including flaming in dry and wet (after irrigation) soil conditions, burning stubble (by setting on fire) in dry and wet soil conditions and no treatment check. Three treatments without canola stubble (surface cut) included flaming in dry and wet soil and no treatment check. Results indicated that all treatments reduced viable wild mustard seeds on soil surface. Highest control of wild mustard seeds was 43% which belonged to the treatment under wet conditions with stubble. Flaming did not have any serious effect on soil microorganisms or on its physicochemical aspects. However, dry soil treatments proved safest.

489. Responses of Corn to Preemergence and Postemergence Applications of Saflufenacil. Nader Soltani¹, Christy Shropshire¹, Peter Sikkema¹; ¹University of Guelph Ridgetown Campus, Ridgetown, Ontario, Canada

Saflufenacil (provisionally approved by ISO) is a new herbicide being developed by BASF for preemergence (PRE) broadleaf weed control in corn. Field studies were conducted at two Ontario locations in 2006 and 2007 to evaluate responses of field corn to PRE and postemergence (POST; spike and 2-3 leaf stage) applications of saflufenacil at 50, 100 and 200 g ai/ha with and without an adjuvant. A wettable granule (WG) formulation of BAS 800H was used for the studies. Saflufenacil at 100 g/ha applied PRE caused no visible injury in corn and there was no decrease in corn height or yield. Saflufenacil at 100 g/ha applied POST at the spike stage caused up to 3% visible injury in corn but there was no decrease in corn height or yield. Saflufenacil at 100 g/ha applied POST at the 2-3 leaf stage caused up to 6% visible injury and 4% decrease in height, but no decrease in yield. The addition of the adjuvant, Merge at 1% v/v resulted in up to 5 and 80% visible injury and a decrease in height of 9 and 59% when applied at the spike and 2-3 leaf stage, respectively. Generally, injury decreased over time but was greater with the high rate. These results confirm that saflufenacil applied PRE can be safely used in corn at rates up to 200 g/ha. While POST applications of saflufenacil plus Merge at the spike and 2-3 leaf stage result in unacceptable injury and yield loss in field corn, POST (spike and 2-3 leaf stage) applications at the rate of 50 or 100 g/ha without adjuvant demonstrated acceptable corn tolerance and may allow use beyond the proposed PRE use pattern.

490. Responses of Spring Cereals to Preemergence and Postemergence Applications of Saflufenacil. Nader Soltani¹, Christy Shropshire¹, Peter Sikkema¹; ¹University of Guelph Ridgetown Campus, Ridgetown, Ontario, Canada

Saflufenacil (provisionally approved by ISO) is a new herbicide being developed by BASF for broadleaf weed control in corn and other crops prior to crop emergence. Three field studies were conducted in Ontario, Canada over a two year period (2006 and 2007) to evaluate responses of spring cereals (barley, oats, and wheat) to preemergence and postemergence applications of saflufenacil 50 and 100 g ai/ha. Saflufenacil applied preemergence caused minimal visible injury (4% or less) at 3, 7, 14 and 28 days after emergence and had no adverse effect on height and yield of barley, oats, and wheat. Saflufenacil plus Merge (1% v/v) applied postemergence caused as much as 80, 72, and 75% visible injury in barley, oats, and wheat, respectively. Injury decreased over time but was greater with the high rate. Saflufenacil applied postemergence reduced plant height as much as 17, 13, and 21% and reduced yield as much as 29, 8, and 19% in barley, oats and wheat, respectively. Based on these results, saflufenacil applied preemergence at the proposed rate can be safely used in spring planted barley, oats and wheat; however, the postemergence application of saflufenacil results in unacceptable injury and yield loss. These results are

consistent with the proposed preemergence burndown use pattern for saflufenacil.

491. Selection of Barley Breeding Lines and Varieties Tolerant to the Herbicide Imazamox. Bianca Martins¹, Alejandro Perez-Jones², Elena Sanchez², Patrick Hayes², Pedro Christoffoleti¹, Carol Mallory-Smith²; ¹University of Sao Paulo, Piracicaba, Sao Paulo, Brazil; ²Oregon State University, Corvallis, Oregon, United States of America

The use of the imidazolinone herbicide imazamox in the herbicide-resistant Clearfield® wheat provides control of some difficult to manage weeds. However, the residual activity from imazamox can injure barley which is an important crop in the United States. Therefore, a greenhouse dose-response experiment was conducted to evaluate the tolerance of select barley varieties and / or breeding lines to imazamox. The imazamox rates tested were 0.0, 0.011, 0.022, and 0.044 kg ai ha⁻¹ applied to 2-leaf barley lines or varieties (88Ab536, Strider, Hundred, Stab113, Orca, Merlin, Doyce, Steptoe, Morex) and Clearfield® wheat which was used as the control. Plant height increase and above ground biomass were determined 21 d after imazamox treatment. The experimental data were submitted to analysis of variance, and means were compared using Tukey's test at the 5% probability level. Most of the lines or varieties were affected, to some degree, when evaluated at 21 d after spraying. Plant height increase at the field rate of 0.044 kg ai ha⁻¹ was greatest for Steptoe, Morex and Clearfield® wheat and was equal to the control for all three cultivars. At 0.044 kg ai ha⁻¹, Steptoe produced the greatest biomass, and there was no statistical difference among lines Strider, Hundred, Orca, Doyce, Morex and Clearfield®. Analyzing how each line or variety responded to the increasing imazamox doses related to growth and above ground biomass at the end of the experiment, we concluded that the most tolerant lines to imazamox were Steptoe and Morex, followed by Lines 88Ab536, Stab113 and Orca. Future studies will be conducted to compare the ALS (acetolactate synthase) enzyme response of the barley lines and varieties to imazamox.

492. Soil Seed Incorporation and Management of *Brachiaria ruziziensis* and *Pennisetum glaucum* as Cover Crop in the Brazilian savannah Soils Cultivated with Soybean under no Till Cropping Systems. Pedro Christoffoleti¹, Roberto Torres², Carlo Boer², Aroldo Marochi², Andre Figueiredo², Antonio Galli², Saul Carvalho¹, Marcelo Nicolai¹; ¹University of Sao Paulo, Piracicaba, Sao Paulo, Brazil; ²Monsanto, Sao Paulo, Brazil

In the no till cropping system the influence of plant residues left on the soil surface from different species of cover crops on soil conservation and in the stability of the

crop productivity has been well studied. However, in the Savannah areas of Brazil new technologies are necessary in order to optimize the no till system since the tropical climate facilitate the rapid decomposition of cover crop plant residues, and the success of the soil mulching depend on the crop species tolerance to water stress, great biomass yield and planting method, among other characteristics. *Brachiaria ruziziensis* and *Pennisetum glaucum* has been tested and used by growers with great potential as cover crop in the central part of Brazil, in the Savannah areas, however the seeding system and the effect on the crop followed the desiccation of the cover crop still need some scientific information. Therefore, this research had the objective of evaluating the dry biomass yield of *Pennisetum glaucum* L. var. comum and *Brachiaria ruziziensis* as a cover crop prior to soybean planting, the best method of seed incorporation of the cover crops, and the interference on the soybean yield in an area of the Brazilian Savannahs. The experiment was installed in Campo Verde, MT, Brazil, in April of 2004, when the cover crop were seeded in an experimental design of randomized complete blocks, using sub-plots and five replications, being the main plots the two species of cover crop and the sub-plots three methods of seed incorporation to the soil (in row, broadcast incorporation of seeds and broadcast incorporation of seeds by heavy chain tractor powered). At 195 days after cover crop seeding desiccation was done using glyphosate at 1,440 g a.e. ha⁻¹. Soybean was seeded 21 days later and harvested 126 days later being evaluated the final stand, plant height, grain humidity and yield. The dry biomass of the cover crops were evaluated eight days after soybean seeding and two days prior to harvest. *Brachiaria ruziziensis* presented higher dry biomass yield at the first sampling and two days prior soybean harvest, when compared to *Pennisetum glaucum*. The volume of dry biomass yielded by *Pennisetum glaucum* and *Brachiaria ruziziensis* was not dependent on the seeding methods. The soybean grain yield and height were higher when it was cultivated in the system of no till using the cover crop *Brachiaria ruziziensis*.

493. Studies on the Persistence of Propaquizafop 10% EC Formulation on Black Gram and Soil under W.B Field Condition. Anjan Bhattacharyya¹, Dipak Hazra¹, M Sarkar²; ¹Bidhan Chandra Krshi Viswavidyalaya(bckv), Mohanpur, West Bengal, India; ²Indofil Chemicals Company, Mumbai, Maharashtra, India

Field and laboratory study was carried out for consecutive two seasons to study the persistence/dissipation nature on Black gram pod and soil of an herbicide propaquizafop 10% EC in 2004-05. The study was under taken to generate a systematic residue data base with this particular formulation on Black gram crop in West Bengal condition. Three treatments are given @ 50 g a.i./ha, 100 g a.i./ha and 200 g a.i./ha during 15-20 DAT. For

dissipation study, paddy water, soil & plant samples were collected at different days interval from each treatment plot replication wise along with control plot. Soil cropped with Black gram, plant and grain samples were collected at harvest Propaquizafop residue from soil/plant/ Grain samples was extracted with acetonitrile by shaking in a mechanical shaker. The extract concentrated and partitioned with hexane. The acetonitrile layer was concentrated & chromatographed over aluminium oxide (10 g) & propaquizafop residue was eluted with 20% ethyl acetate in n-hexane and subsequently evaporated to near dryness in a rotary vacuum evaporator and reconstituted in methanol and finally analysed by HPLC. Shimadzu High Performance Liquid Chromatograph (Model no. SPD M 10A) equipped with PDA-10A detector connected to CBM-101 module using CR LC10 software was used for quantification of propaquizafop in different substrates. The other HPLC parameters were as follows: Column = Phenomenex RP-18 (25 cm length x 4 mm i.d.); λ_{max} = 235nm; Mobile phase = Acetonitrile: Water (8: 2); Flow rate = 1.5 ml/ min; Retention time = 5.37 min; Limit of Quantification (LOQ) = 0.05 ppm; Limit of Detection (LOD) = 0.02 ppm). The study revealed that the dissipation of propaquizafop in field soil was followed first order kinetics irrespective of doses and season. The half-life values were calculated in the range 15.05- 27.37 days for soil irrespective of the treatment and season. No residue was detected in soil samples as well as in grain and plant samples at harvest for all doses. In plant, only residue was found on first day for the highest dosage (200 g a.i./ha). So It may be concluded that Propaquizafop will not create any hazards from environmental point of view.

494. Study the Effect of Wild Oat on Wheat in Dry Land Farming. Omid Massoudifar¹; ¹Agriculture and Environment Org., Tehran, Iran

In order to the competitive ability of wild oat (*Avena fatua*) on wheat (*Triticum aestivum*) in dry land conditions, this experiment designed. Wild oat is one of the important weeds in fields. The experiment was arranged as randomized complete blocks design (statistical method) with three replications. The treatments included (from the factorial combination) four wheat seed value (250, 300, 350 & 400 seed per m²) and wild oat density (15, 35, 55 & 70 plant per m²). Results showed the leaf area, stem length, protein accumulation, spike per m², HI (harvest index) decreased with increase wild oat plant density. Correlation between root and shoot dry weight (wheat) and wild oat number was positive and significant. The density of 350 seed per m² wheat had maximum of yield.

495. Sugar Beet Root Yield and Sugar Content in Response to Field Dodder Competition. Joel Felix¹, Joey Ishida¹;

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A survey of grower fields planted to sugar beets (*Beta vulgaris* L.) was conducted during October 2007 to determine the effect of field dodder competition on harvestable root yield and sugar content of parasitized and non-parasitized plants in Eastern Oregon. Sugar beets parasitization by dodder could be related to weed management programs used by growers in Eastern Oregon, but can also be attributed to continuous emergence throughout summer. Surveyed fields were chosen randomly, and were representative of dodder infestation in the area. Weed control in sampled fields was based on the micro-rate program of phenmedipham plus desmedipham plus ethofumesate + triflurosulfuron methyl + dimethenamid at 150g + 5.8 g + 35 g ai/ha, respectively, plus methylated oil at 1.5% V/V. A total of 10 samples (with 8 sugar beets each) were randomly harvested at crop maturity from two rows covering approximately 1 m² each in areas with and without dodder parasitization. Sample weight was recorded before transporting the samples for commercial sugar content determination. Sugar beet root yield and percent sugar content were significantly reduced for parasitized samples compared to dodder-free areas. Root yield for parasitized samples ranged between 42 and 78 T/ha with an average of 65 T/ha compared to 76 and 112 T/ha with an average of 95 T/ha for non-parasitized samples. The average sugar content for parasitized samples was 13% compared to 16% for non-parasitized roots. As a consequence, the gross sugar content ha⁻¹ was reduced 43% for parasitized areas. Grower loss from dodder parasitization is great since both root yield and percent sugar content are used to determine payments.

496. Susceptibility of *Hordeum vulgare* (Barley) to Sulfonylurea Herbicides. Amalia Rios¹, Ana Ines Carriquiri, Alejandro García¹; ¹INIA Uruguay, Colonia, Uruguay

In Uruguay, studies carried out for over 25 years have shown the control efficiency of sulfonylureas in winter crops. They achieve an excellent control of the most important winter weeds and also present a good residuality which diminishes the incidence of late emergence weeds. Throughout these years it has been observed that it is necessary to apply at least twice the recommended dose to stress a *Triticum aestivum* (wheat) and *Hordeum vulgare* (barley) crop. The scope of this trial was to study sulfonylurea induced alterations in *Hordeum vulgare* through its ecophysiological response, and its effects on its growth and development. Considering that the recommended dose for chlorsulfuron is between 7.5 and 15 g a.i./ha and for the mix with metsulfuron methyl (62.5% + 12.5%) is 6.2+1.2 to 12.5+2.5 g a.i./ha of chlorsulfuron and metsulfuron respectively; the treatments in Z22 were:

chlorsulfuron alone at 7,5; 15; 22,5 and 30 g a.i./ha and the mix with metsulfuron methyl at 6,2+,12; 12,5+2,5; 18,7+3,6 and 25+5 g a.i./ha. Determinations began 12 days after the application, harvesting plants from a linear meter every 14 days between 40 and 144 days after emergence. The treatment with chlorsulfuron 30 g a.i./ha presented a slight effect on foliar area growth per plant; observed only 12 days after applications. Possibly, in response to this dose, the biggest root growth rate observed meant more root weight and significantly less aerial part:root system ratio. Except this treatment, in each of the seven harvests carried out, no differences were detected in: plant number; stem number; stem with expanded flag leaf; total phytomass; aerial, leaf and root mass; net assimilation rate; aerial part:root system and foliar area:total mass ratio; specific foliar area and grain yield. These results probably suggest that a way of escaping from this chemical stress induced on the foliar system is increasing photoassimilates in the flow towards the root system. Aerial part and roots system growth interact, and as plants develop, their activity ends up in higher growing rates; and during reproductive stages, both assimilation rates are similar and finally crop yield is similar too.

497. Tausch's Goatgrass, a Worst Grass Weed, Is Spreading in Wheat Fields in Northern China. Chao-xian Zhang¹, Hong Huang¹, Shou Wei¹, Xiang Li¹, Qui Wang², Di Liang³; ¹Institute of Plant Protection, CAAS, Beijing, China (Peoples Republic of); ²Institute of Oil Crop, Hebei Academy of Agricultural Sciences, Shijiazhuang, Hebei, China (Peoples Republic of); ³National Agricultural Technology Extension Service Centre, Ministry of Agriculture, Beijing, China (Peoples Republic of)

In the past 2 decades, farming system have changed in China, and agricultural management has been simplified with increased and more intensive herbicide use. In the meantime, the weed flora has changed, and some previously unimportant annual weeds are becoming increasing problems to Chinese crop growers. To understand weed flora change in wheat, field survey was conducted. Tausch's goatgrass (*Aegilops tauschii* Coss.) was filed in as a worst grass species in Hebei, Henan, Shanxi and Shanxi Provinces, 0.33 M ha of wheat fields in these provinces were infested, infestation is expanding rapidly. The goatgrass density was 10-50 heads/m² in average wheat fields, and was as high as 500-1200 heads/m² in some seriously infested wheat fields, resulted in 10-50% crop yield loss, and wheat production and food safety are threatened. High similarity with wheat varieties made the grass very difficult to control, high tillering and reproduction abilities of the goatgrass, trans-regional machinery harvest, and long time chemical control for broad leaved weeds in the region may be accounted for its heavy infestation and fast spreading. Effective measures

must be taken to impede the grass further distribution, to contain its damage and safeguard wheat production. Based on field weed survey and understanding of the grass, control measures, including plant quarantine, cultural and chemical methods were proposed.

498. Tebuthiuron Behavior in Sugar Cane Soil Using Modified Drainage Lysimeter. Evandro Correa¹, Luiz FOLONI¹, Pedro Christoffoleti², José Teixeira Filho¹; ¹University of Campinas, Campinas, Sao Paulo, Brazil; ²University of Sao Paulo - ESALQ, Piracicaba, Sao Paulo, Brazil

Tebuthiuron is one of the most used herbicides in the sugar cane crop, in São Paulo State, Brazil, being sprayed in pre-emergence conditions of the crop. Since it is a herbicide that is considered as long term persistent product and the active ingredient is highly soluble in water it is important to know the herbicide behavior in the environment, specially related to its leaching potential. Several researches, from theoretical and mathematical models, had been presented in the literature, describing the susceptibility of ground contamination by the herbicide tebuthiuron. Furthermore, under tropical conditions researches were conducted in laboratory and field condition in the Brazilian soils and climatic conditions indicating that there is a low leaching potential of this herbicide in the soil, however these researches are not definitively conclusive since methodology used and specific conditions were applied. Therefore the aim of this research was to evaluate the vertical movement of the tebuthiuron herbicide in field conditions of a Clay Distroferric Red Soil in Campinas, São Paulo State, Brazil, a typical soil grown with sugarcane in Brazil, in a field experiment, simulating real conditions of the crop. The tested hypothesis was based on the low vertical mobility and small potential of groundwater contamination by tebuthiuron. The trial was carried out at the Experimental Field College of Agricultural Engineering UNICAMP, in a climate classified as Cwa and Cfa, according to Köppen classification. The experiment was installed in a modified drainage lysimeter of 2 m of diameter and 3 m of depth, with 10 vertical points where drainage water samples were collected. Sugarcane was planted in February 15 of 2006 and tebuthiuron was sprayed at 2.4 or 1.2 kg a.i./ha. Irrigation of 255 mm was simulated in the area and soil samples were collected periodically after experiment installation. The samples were submitted to High Performance Liquid Chromatography (HPLC) for analysis of the tebuthiuron level, using standard level analysis. The data indicated a reduction in the concentration of the herbicide in the soil through time: March to August, 2006: sample 1: 0.020 g a.i. (5.3%); 2: 0.016 g a.i. (4.3%); 3: 0.015 g a.i. (4.0%); 4: 0.014 g a.i. (3.7%); 5: 0.014 g a.i. (3.7%); 6: 0.007 g a.i. (1.9%); 7: 0.002 g a.i. (0.5%); 8: 0.001 g a.i. (0.3%) total applied in lysimeter area (0.3768 g a.i.), confirming the hypothesis

that the tebuthiuron vertical mobility is low in Clay Distroferric Red Soil, clay texture, indicating small potential of groundwater contamination on this soil under Brazilian conditions of sugarcane cultivation.

499. The Impact of Planting Date and Crop Density of Common Dry Bean (*Phaseolus vulgaris*) on Weeds Growth Characteristics. Reza Ghorbani¹, Zaynab Avarseji¹, Mohammad Rashed Mohasel¹, Ahmad Nezami¹; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan, Iran

In order to study the effectiveness of different planting dates and crop densities on weed growth characteristics, a field experiment was conducted in Ferdowsi University of Mashhad, Research Station of College of Agriculture, during 2006. The experiment was arranged as a split plot based on a Completely Randomized Block Design with 3 replications. Different planting dates (April, 25th, May, 10th and May, 24th) were placed in the main plots and various crop density (10, 20, and 30 plant/m²) in the sub plots. The results indicated that planting date of April 25th, caused minimum weed dry matter and weed growth rate. The maximum yield and dry matter of common bean were obtained in crop density of 30 plants/m². However, weed growth rate and dry matter weights in plots with 30 plants/m² were minimum.

500. The Improvement of Oxyfluorfen Application Techniques. Lou Yuanlai¹, Xue Guang¹; ¹Jiangsu Suke Agricultural Chemical Co, Ltd., Nanjing, Jiangsu, China (Peoples Republic of)

This study was carried out during 1999 and 2007 in China based on the field trials and demonstration practice in south part of the Yangtze River of China. The field trials on improvement of oxyfluorfen application techniques were conducted in rice, cotton, garlic, peanut, onion, ginger, tobacco, sugarcane and turf. The results of this study showed that the improvement of oxyfluorfen application covers the application rate in different crops, application time, application method and the mixture with other chemicals. After the improvement, the rate of oxyfluorfen was 35.2g a.i./ha in transplanted rice (over 35 days seedlings), 105.6g a.i./ha in dry sown rice, 42.2g a.i./ha in cotton nursery (123g a.i./ha in direct sown cotton), 126.7g a.i./ha in peanut, 140.8g a.i./ha in garlic and ginger, 70.4 g a.i./ha in onion, 123.2g a.i./ha in transplanted tobacco, 105.6 g a.i./ha in sugarcane and 211.2 g a.i./ha in Zoysiagrass. The application time and method of oxyfluorfen improved was 1 day before transplanting in rice with sand broadcasting, 2-3 leave stage of crop in garlic and onion with spraying, 2-3 days after seeding in peanut, ginger and sugarcane with spraying, 2-3 days before transplanting in tobacco and in winter time in dormant in Zoysia turf with spraying. The mixture chemicals

included pendimethalin, butachlor, bensulfuron, acetochlor and trifluralin. The rate of rate for mixing was decided according to the region weed species in different climate zones to fit the objective of increasing the weed control and reducing the costs for all user after the mixture application.

501. The Safety of Mesotrione and Nicosulfuron to the Different Varieties of Maize. Zhang Hongjun¹, Liu Xue¹, Cui Hailan²; ¹ICAMA, Beijing, China (Peoples Republic of); ²China Academy of Agricultural Science, Beijing, China (Peoples Republic of)

The trials were carried out during 2005-2006 in the field of Beijing to evaluate the safety of mesotrione and nicosulfuron to summer maize. There were two factors. The treatment with herbicide was the first factor, and the treatments were 300 g a.i./ha mesotrione, 120 g a.i./ha nicosulfuron, and no treatment. The second factor was the different varieties of the maize, and there were 46 varieties which were cultivated in Beijing, Hebei, Shandong and Henan province. The herbicides were applied at the 4-5 leaf stage for maize, and spray volume was 450 L/ha. The treatments were repeated 4 times. The visual injury was observed after treatment, and the plant height were measured after treatment 5 days, 10 days, and 15 days. The maize were harvested, and the data were measured, for instance, shoot dry weight, leaf number, the dry weight of ears, the length of ears, the seed weight. The visual injuries were different for the herbicide with different mechanisms. The beaching on the leaf was observed 4 days after the mesotrione treatment, and the young leaf turned yellow 5 days after the nicosulfuron treatment. The plant heights were significant inhibited after treatment 5 days, and they could not refresh after 15 days after treatment. With the data analysis of the harvest maize, especially shoot dry weight for the crossing crop, mesotrione was safe to the maize, and nicosulfuron was not. The yield or growth were reduced by 20-50% for some varieties. Some other varieties were killed. The designed dose of the herbicide was two times larger than the highest registered rate. With this high dose, the mesotrione was safe to the maize, and nicosulfuron was not to the sweet maize, even to some common maize. It was very necessary to apply nicosulfuron at accurate dose on appropriate stage of the maize; otherwise, there would be some injury cases.

502. Tolerance of Winter Wheat to Preplant and Preemergence Herbicide Tankmixes. Nader Soltani¹, Christy Shropshire¹, Peter Sikkema¹; ¹University of Guelph Ridgetown Campus, Ridgetown, Ontario, Canada

Field experiments were established at the Huron Research Station and at University of Guelph Ridgetown Campus in the fall of 2004 and 2005 to evaluate the

tolerance of winter wheat to tankmixes of glyphosate plus either amitrole, dicamba, dicamba/diflufenzopyr, 2,4-D amine, 2,4-D ester, chlorimuron-ethyl or thifensulfuron-methyl/tribenuron-methyl applied preplant (PP) and pre-emergence (PRE). Contrasts comparing PP vs PRE treatments showed no difference in visible injury, plant height and yield between application timings. The tankmix of glyphosate (1800 g/ha) plus either amitrole (1155 g/ha), dicamba (300 g/ha), 2,4-D amine (700 g/ha), 2,4-D ester (700 g/ha) or thifensulfuron-methyl/tribenuron-methyl (15 g/ha) caused minimal (less than 5%) and transient visible injury in winter wheat (Table 1). In addition, these tankmixes had no effect on plant height and yield. The tankmix of glyphosate (1800 g/ha) with dicamba/diflufenzopyr (200 g/ha) or chlorimuron-ethyl (9 g/ha) caused as much as 8 and 18% visible injury in winter wheat, respectively (Table 1). Glyphosate (1800 g/ha) plus dicamba/diflufenzopyr (200 g/ha) did not affect plant height but glyphosate plus chlorimuron-ethyl reduced plant height 11%. Yield was reduced 15% when glyphosate was tankmixed with dicamba/diflufenzopyr and 26% when glyphosate was tankmixed with chlorimuron-ethyl. Based on these results, the PP and PRE application of glyphosate tankmixes with dicamba/diflufenzopyr or chlorimuron-ethyl resulted in unacceptable injury in winter wheat at the rates evaluated. The PP and PRE application of glyphosate tankmixes with amitrole, dicamba, 2,4-D amine, 2,4-D ester and thifensulfuron-methyl/tribenuron-methyl at the rates evaluated had an adequate margin of crop safety for weed management in winter wheat under Ontario growing conditions.

503. Weed Control Efficacy of Pre Emergence Herbicides in Maize. Anees Amin¹; ¹NWFP Agricultural University, Peshawar, NWFP, Pakistan

A field study was conducted at Agricultural Research Farm, Pakistan Academy for Rural Development Peshawar, during summer 2007 to evaluate efficacy of different pre emergence herbicides in maize variety 'Azam'. Randomized complete block design, having four replications was used in the experiment. The treatments were; 1) Stomp 330 EC (pendimethalin), 2) Dual Gold 960 EC (s-metolachlor), 3) Primextra Gold 720 SC (s-metolachlor + atrazine), 4) Atrazine 38 SC (atrazine), 5) Hand Weeding, 6) and Weedy check. The major weeds infesting the experimental field were *Cyperus rotundus*, *Sorghum halepense*, *Echinochloa crus-galli*, *Digitaria sanguinalis*, *Portulaca oleracea* and *Digeria muricata*. The data were recorded on the weed density m⁻² 25 and 75 days after sowing (DAS), dry biomass of weeds m⁻² 25 and 75 days after sowing (DAS), plant height (cm), cob length (cm), number of plants at harvest, biological yield (t ha⁻¹), number of grains cob⁻¹, 500 grain weight (g), grain yield (t ha⁻¹), harvest index (%), economics of different herbicides. Analysis of the data showed that all the parameters

studied were significantly affected by the treatments except number of plants at harvest, biological yield and harvest index. Primextra greatly suppressed weeds and their dry biomass both 25 and 75 DAS and proved to be the best in weed control efficiency. Maximum grain yield (2.84 t ha⁻¹) was recorded in Primextra Gold 720 SC while minimum grain yield (1.94 t ha⁻¹) was recorded in weedy check where no herbicide was applied. Increased weed control significantly increased the grain yield and other yield related traits of maize. However Primextra proved to be the more effective against weeds and favored crop. Stomp was not effective against *C. rotundus* therefore Primextra application is recommended for higher yield of maize.

504. Weed Control in Maize (*Zea mays* L.) using Triazolinone and Sulfonylurea Herbicides. Eskandar Zand¹, Mohammad Ali Baghestani¹, Saeid Soufizadeh², Ali Eskandari³, Reza Deihimfard³, Reza Pourazar¹, Farrokhdin Ghezeli¹, Peyman Sabeti¹, Hekmat Esfandiari¹, Fatemeh Etemadi⁴; ¹Plant Protection Institute, Tehran, Iran; ²Shahid Beheshti University, Tehran, Iran; ³Ferdowsi University of Mashhad, Mashhad, Khorasan, Iran; ⁴Tarbiat Modares University, Tehran, Iran

In order to investigate the efficacy of different new and old herbicide options for weed control in maize, six field experiments were conducted in 2006 in Iran. Treatments consisted of pre- and post-emergence applications of amicarbazone at 350, 525, and 700 g ai ha⁻¹, post-emergence applications of nicosulfuron at 60 g ai ha⁻¹, foramsulfuron at 450 g ai ha⁻¹, rimsulfuron at 10, 11.25, and 12.5 g ai ha⁻¹ plus ionic surfactant at 0.2% (v/v), nicosulfuron plus rimsulfuron at 26.25, 30 and 33.75 g ai ha⁻¹ plus non-ionic surfactant at 0.5% (v/v), 2,4-D plus MCPA at 1080 g ai ha⁻¹, and pre-plant applications of atrazine plus allachlor at 800 + 2400 g ai ha⁻¹, respectively, and EPTC at 4920 g ai ha⁻¹. A full season weed-infested control was also included in the experiments. Post-emergence applications of herbicides were made at three- to six-leaf stage of maize. Results achieved at different locations showed that nicosulfuron, and rimsulfuron at the two highest doses were the most efficient herbicides for satisfactory control of weeds. Current herbicide EPTC also acted well in this respect. Application of these herbicides also led to high grain yield of maize. Foramsulfuron treated plot also resulted in high grain yield. New herbicide amicarbazone applied pre- and post-emergence, however, did not show a consistent response at different locations although it could be regarded as an option to be used in herbicide application programs.

505. Bio-Efficacy of some Promising Herbicides in Transplanted Kharif Rice and their Influence on Soil Micro Flora. Ratikanta Ghosh¹; ¹Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Calcutta, West Bengal, India

RATIONALE:

Weeds are considered as a major pest and serious constrains of rice, which cause 41.6% reduction in yield resulting low productivity. In transplanted condition the yield loss is varied 18-20 %. To sustain the productivity growth without endangering the natural resources, appropriate technology which is economically viable, socially just and environmentally safe should be adopted.

OBJECTIVES:

To evaluate the bio-efficacy of different promising herbicides for environmentally safe and economically viable weed control measure

To evaluate the phytotoxicity in rice plants

To study the effect of herbicides on soil micro flora

METHODS:

Field experiments were conducted in Gangetic Inceptisol at the Viswavidyalaya Farm, Kalyani during Kharif 2006 with 9 treatments viz. Ethoxysulfuron 60 WG @ 15, 17.50, 20 & 40 g/ha, Ethoxysulfuron 15 WP @ 18.75 g/ha, Almix 20 WP @ 4g/ha and 2,4-DEE 38 EC @ 400 g/ha at 20 DAT along with twice hand weeding at 20 & 40 DAT and the unweeded control. The treatments were replicated thrice in a RBD design. The economics of the treatments were also recorded.

The enumeration of microbial population was done on agar plates containing appropriate media following serial dilution technique and pour plate method incubating at 30°C. The counts were taken at 5th day of incubation for each observation viz. at initial, and at 10 and 30 days after application of the chemicals.

RESULTS:

Predominant weeds were *Echinochloa crusgalli*, *Echinochloa colon*, *Echinochloa formosensis*, *Cyperus iria*, *Cyperus difformis*, *Fimbristylis littoralis*, *Alternanthera philoxeroides*, *Lindernia ciliate*, *Stellaria media*, *Luwigia parviflora*, *Ammania baccifera* and *Marsilea quardifolia*.

Results revealed that hand weeding twice gave the highest grain yield (5.08 t/ha) and this treatment did not differ significantly with Almix 20WP @ 4g/ha (5.01 t/ha) and the two higher doses (20 & 40 g/ha) of Ethoxysulfuron. Weed control efficiency of Almix 20 WP @ 4g/ha at 60 DAT was highest (90.44%) among the tested herbicides.

Regarding benefit: Cost ratio, highest value (1.41) was obtained with Almix 20 WP @ 4g/ha among the herbicides used in this experiment. No phytotoxic effect on the crop was observed. The soil micro flora study showed that all the herbicides tested had no detrimental effect after 30 DAA though population in the initial stage showed slightly decreased in all fungi, actinomycetes and total bacteria.

CONCLUSION:

From this experiment it can be concluded that Almix 20 WP @ 4 g/ha or the higher two doses of Ethoxysulfuron 60 WG as post emergence can profitably and safely be replaced the tedious time consuming and expensive hand weeding practice in this Gangetic Inceptisol.

506. **Weed Management in Canola in Swat-Pakistan.** Muhammad Saeed¹, Khan Marwat¹; ¹Dept. of Weed Science NWFP Agricultural University, Peshawar, NWFP, Pakistan

To evaluate the effect of different pre and post-emergence herbicides for controlling weeds in rapeseed (variety Oskar), an experiment was conducted at Agriculture Research Station, Mingora during rabi season 2005/06, using randomized complete block (RCB) design, keeping four replications. The experiment was sown in mid-October, having eight treatments, viz; seven herbicides, a hand weeding and a weedy check. Each treatment consisted of 4 rows 75 cm apart and 4 m long thus giving a total size of 4m x 3m. The pre-emergence herbicides included; s-metolachlor @ 1.92 kg, pendimethalin @ 1.32 kg and trifluralin @ 1.2 kg, while the post-emergence herbicides were fenoxaprop-P-ethyl @ 0.75 kg, clodinafop @ 0.05 kg, oxadiazon @ 0.36 kg and propaquizafop @ 0.02 kg a.i ha⁻¹. The data were recorded on weeds density m⁻², fresh weed biomass (kg ha⁻¹), number of branches plant⁻¹, number of siliquae plant⁻¹, siliqua length (cm), plant height at maturity (cm), number of seeds siliqua⁻¹, 1000 seeds weight (g), seed yield (kg ha⁻¹) and cost-benefit ratio. The data recorded on weeds density m⁻², fresh weeds biomass (kg ha⁻¹) and seed yield (kg ha⁻¹) were significantly affected by the different herbicidal treatments. Pendimethalin treatment exhibited the best performance, with minimum weeds m⁻² (13.5) and fresh weeds biomass (257.9 kg ha⁻¹) as compared to weedy check (38 m⁻²) and (806 kg ha⁻¹), respectively. Similarly, maximum number of branches plant⁻¹ (6.89), number of siliquae plant⁻¹ (301), siliqua length (6.8 cm), number of seeds siliqua⁻¹ (25.8), 1000 seeds weight (3.99 g), seed yield (1692 kg ha⁻¹) and cost-benefit ratio (1:7.47) were recorded in pendimethalin treated plots as compared to weedy check having (5.69), (216), (6.3 cm), (21.6), (3.62 g) and (1119 kg ha⁻¹), respectively.

507. **Damages of Occurrence of Ruderal Weed Populations of Spring Rape Fields in Qinghai & Countermeasures to be Taken.** Qingyun Guo¹, Liangzhi Guo¹, Youhai Wei¹, Liang Cheng¹, Cunyue Xin¹, Hua Weng¹; ¹Qinghai Academy of Agriculture & Forestry, Xining, Qinghai, China (Peoples Republic of)

Rape plant is an important oil-yielding crop in China and its cultivation area covers an area of 6,667,000 ha. and spring rape crop covers an area of appropriately 667,000 ha. And the spring rape crop is mainly distributed in Qinghai, Gansu, Inner Mongolian Autonomous Region, Xinjiang Uygur Autonomous Region, Tibetan Autonomous Region, Northeastern Plain and western Sichuan. Therefore, it is apparent that Qinghai is an essential spring production area of the spring rape crop in China, about 1,855,000 ha.

The types of weeds from the spring rape fields are multifold with their complicated coenotypes and severe damages and they have become a constraint to the local rape crop production. Therefore, in order to find out the occurrence rate and damage changes of the major ruderal weed populations of the rape crop fields in recent twenty years in Qinghai and based on the previous survey area in 1986, some representative natural villages were selected in 23 townships of 9 different counties and additional 7 state farms as well from 2004 to 2005 to have 378 example plots ranging from 0.1 to 0.3 ha. to be surveyed. All the weeds in the sample plots were recorded and damage rates were measured along with their succession tendency being studied and control countermeasures were recommended accordingly in accordance with the Five Damage Standard established by the State Weed Damage Survey Team.

The survey result has shown that the damage rates of *Elsholtzia densa*, *Avena fatua*, *Daucus carota*, *Leprodiclis holosteoides*, *Potentilla anserina* are 59.8%, 48.1%, 19.3%, 29.4%, 21.4% respectively and they are 30.3%, 19.1%, 35.3%, 22.9%, 24.6% lower than their percentages 20 years ago. In the meantime, the damage rates of *Sonchus brachyotus*, *Chenopodium album*, *Galium aparine*, *Cephalanoplos setosum*, *Polygonum sibiricum*, *Polygonum aviculare*, *Hypericum leptocarpum* are 56.3%, 81.2%, 37.8%, 28.3%, 17.7%, 51.9%, 51.1% respectively and they have increased by 19.9%, 14.3%, 12.1%, 3.1%, 3.0%, 2.9%, 0.4% than their percentages 20 years ago. Major ruderal weed components from the rape crop fields: In the irrigated area are mainly *S. brachyotus* + *Convolvulus arvensis* + *S. brachyotus* + *Phragmites communis* + *P. sibiricum*, *E. densa* + *Thlaspi arvense* + *L. holosteoides* + *Polygonum nepalense* + *S. brachyotus* + *Galium aparine*. In the farm area are *E. densa* + *S. brachyotus* + *S. brachyotus* + *D. carota* + *A. fatua* + *P. anserina*. Based on the different ecological regions, the succession tendency analysis of major ruderal weed populations with their min. 3 level have been undertaken and the result has shown that *S. brachyotus*, *P. sibiricum*, *P. sibiricum*, *Equisetum arvense*, *C. arvensis*, *S. brachyotus*, etc. have become predominant populations in the irrigated rape crop fields and their damage rates are 5.17%, 5.17%, 1.72%, 1.72%, 3.45%, 3.45% respectively and they have increased by 3.81%, 3.81%, 1.72%, 1.72%, 0.75%, 2.09% respectively compared with their percentages 20 years ago. Similarly, the ruderal weeds like *S. brachyotus*, *T. arvense*, *P. nepalense*, *E. densa*, etc. have become predominant populations with their damage rates being 4.47%, 3.66%, 0.81%, 8.94% respectively and they have increased by 4.87%, 0.84%, 0.41%, 0.07% respectively than their percentages 20 years ago while the damage rates of *L. holosteoides*, *G. aparine* have decreased compared with their percentages 20 years ago. However, they're still predominant. *E. densa*, *D. carota*, *P. anserina*. *A. fatua* are still the predominant ruderal weeds from the sate farm rape crop fields with their damage rates being 29.5%, 69%, 34% and 10% respectively and they have decreased

compared with their percentage rates 20 years ago while the damage rates of *S. brachyotus*, *S. brachyotus* have become 8.72%, 6.71% respectively and they have increased by 0.82%, 0.27% accordingly compared with their percentages 20 years ago.

It is recommended to control the ruderal weed populations in the irrigated rape crop fields through comprehensive control techniques with the prioritized chemical treatment along with adjuvant weeding and deep ploughing (Referring to the mechanical deep tillage immediately after the fall harvest and pulling out the undersoil rootstalk of ruderal weed). It is recommended to control the ruderal weed in the rape crop dryland through the combined control method of weeding between the crop rotations and chemical treatment. However, it is still recommended to control the ruderal weed in state farmland through a comprehensive control package of prioritized chemical treatment with an adjuvant rake-weeding at a very early stage.

508. Weed Communities Related to No-Tillage Systems in the Crop Belt on the North Coast of Uruguay. Amalia Rios¹, Gabriela San Román, Virginia Mailhos, Alejandro García¹; ¹INIA Uruguay, Colonia, Uruguay

During the past six years Uruguay has been experiencing a strong and growing expansion of the agricultural sector associated mainly with an increase in the area of glyphosate-resistant crops. This leads to a major dependence on the use of this agrochemical, causing an eventual flora modification process and a risk of weed resistance development. This issue could affect not only crop productivity, but also the economics of farming. Weed population composition and density generally reflects the continuing agronomic practices, crop rotation, its productivity and intrinsic competitive characteristics of each species. Fields having information about crop rotation, no-tillage years, number and frequency of glyphosate applications were evaluated, in order to understand and characterize eventual changes in weed communities associated with these systems in the country. A photographic survey was carried out in fields located in the crop belt on the north coast of the country. The number of fields studied was 70, totalling 3760 hectares. Based on the pictures, the species were identified and the number of plants of each species was quantified. Presence, frequency and number of weeds per square meter were calculated. Possible associations between weed species and the following variables were analyzed: number of years under no-tillage and number of glyphosate applications. The average period of time that these fields were under no-tillage was three years, with a minimum of two years and a maximum of eight. The total amount of glyphosate used during this period of time for each field turned out to be of 26 L/ha, and 8,6 L/ha/year, with a minimum of 4,12 and a maximum of 13,76 liters. The total number of species

evaluated was 75. The species with the most presence was *Digitaria sanguinalis*. 30 families were identified, being the Asteraceae family the most numerous one with 14 species, outstanding in presence *Carduus* sp. (37,1%), *Conyza* sp. (17,1%), and *Bidens* sp. and *Senecio* sp., both with 15,7%. They were followed by the family of Poaceae and Fabaceae with 10 and 7 species respectively. After analyzing these results it is to be concluded that for presence and frequency, as well as weeds/m², the following species were presented in order of importance: *D. sanguinalis*, *Sida rhombifolia*, *Tragia* sp. and *Trifolium repens*. It seems important to point out that concerning weeds/m², *Echinochloa* sp. was included in third place.

509. Weed Communities Related to No-Tillage Systems in Agricultural Center Area of Uruguay. Amalia Rios¹, Amalia Belgeri, Pia Caullin, Alejandro García¹; ¹INIA Uruguay, Colonia, Uruguay

In Uruguay, crops production has traditionally developed in a system that rotates beef cattle and crops. However, in the last few years these systems have experienced a development process of agriculture with a tendency to separate, in a farm level, the areas dedicated to beef cattle and crops production. The strong dependence to use herbicides, the introduction of glyphosate-tolerant crops and its quick spread, have increased the treatments frequency causing a high selection pressure, favoring the more tolerant weed species populations. In this situation, and considering the experience in other countries, the weeds dynamics shifts can be a short term problem. The risk of the appearance of resistant weed biotypes to herbicides, mainly glyphosate, is probably a long-term problem, which could compromise not only the productivity and the economic equation of the crops but also the viability of the technology. In order to recognize and characterize eventual shifts in the weed communities associated to the no-tillage systems in the country, a photographic fallow report was carried out in the traditional agricultural center area, whose results are presented in this work. 77 fallows were analyzed, coming up to a total of 4617 hectares, having selected all those inside the region with no-tillage history and those that counted with crop rotation information, years without tillage, frequency of the treatment applications and quantity of glyphosate used. Species were identified from the pictures and the number of individuals was quantified by species, having determined presence, frequency and plants per square meter. Results were analyzed in an effort to find associations between different managements and presence of species. The average time for no-tillage fallows was 6.12 years; the total glyphosate used by hectare in the no-tillage period for each fallow was 40.8 liters on average and for the total hectare-year of 6.6 liters. A total of 94 species were found, with a minimum of 6 species and a maximum of 24 by fallow. The species with more presence,

frequency and plants per square meter was *Digitaria sanguinalis*. 32 families were determined, being Poaceae and Asteraceae the most numerous with 11 species each, standing out *Echinochloa* spp.(69%), *Setaria geniculata* (46%), *Gnaphalium* sp.(24%) and *Carduus* sp.(23%) with more presence, followed by the families Leguminosae and Apiceae with 7 and 4 species each. The results of the associations between presence of species and different managements showed *D. sanguinalis* as the species with more presence, whatever the situation was. In systems with more than 6 years of no-tillage and 38 liters of glyphosate, *Portulaca oleracea* has the same presence as *D. sanguinalis*. In the same way, *Amaranthus quitensis* and *Tragia volubilis* also increase their presence. Regardless of the years without tillage, the crops rotation and the management carried out, the richness of weed communities was preserved. The results of this work point out the necessity to continue with this kind of studies in order to predict eventual weed shifts and the appearance of resistant weed biotypes. Due to the advantages of no-tillage and glyphosate resistant crops, it is expected that the adoption of these technologies will continue, but their sustainability should be preserved by considering the concepts of integrated weed management.

510. Evaluation Efficacy of some New Herbicide on Wheat and Broadleaf Weeds. Mohammad Mehdi Khayami Rad¹;
¹Plant Protection Institute, Tehran, Iran

In order to study the efficiency of some new herbicides to control broad leaved weeds in wheat, two experiments were conducted as a randomized complete block design with 15 treatments and 4 replications in 2004-2005 growing season at Karaj and Varamin. Treatments were diflufenican plus MCPA at 0.5, 1, and 1.5 L/ha, clopyralid plus 2,4-D at 1.5, 2, and 2.5 L/ha, and fluroxypyr at 1.5, 2, and 2.5 L/ha, as new herbicides, and tribenuron methyl at 20 g/ha, 2,4-D plus MCPA at 1.5 L/ha, bromoxynil plus MCPA at 1.5 L/ha, and dichloprop-p plus mecoprop-p plus MCPA at 2.5 L/ha, as old herbicides and full-season weed free and weed infested checks. Herbicides were applied at wheat tillering stage. Results showed that bromoxynil plus MCPA at 1.5 L/ha and clopyralid plus MCPA at 2.5 L/ha could satisfactorily control weeds at Karaj and Varamin respectively. On the other hand fluroxypyr at 1.5 and 2 L/ha, and diflufenican plus MCPA at 1 L/ha were the poorest treatments in terms of weed control at Karaj and Varamin, respectively. Grain yield was significantly affected by herbicide treatments. At Karaj and Varamin, the highest grain yield was obtained in diflufenican plus MCPA at 0.5 L/ha treated plot (7428 kg/ha) and clopyralid plus MCPA at 2.5 L/ha treated plot (9225 kg/ha), respectively. Among different traits measured at harvest, number of spikes/m², number of fertile spikelets/m², number of grains/m², plant height, grain weight and biological yield were affected by herbicide treatments only.

511. Influence of *Alternanthera philoxeroides* on the Growth of Garlic and its Economic Threshold. Wei Shouhui¹, Zhu Wenda², Zhang Chaoxian¹, Huang Hongjuan¹, Yu Dazhao²; ¹Chinese Academy of Agricultural Sciences, Haidian, Beijing, China (Peoples Republic of); ²Hubei Academy of Agricultural Sciences, Wuhan, Hubei, China (Peoples Republic of)

Alternanthera philoxeroides is a noxious exotic weed species, the occurrence and infestation of *Alternanthera philoxeroides* in garlic fields constitutes a major threat in garlic production. To determine the influence of *Alternanthera philoxeroides* on the growth of garlic and its economic infestation level, additive series experiment and curve fit were adopted to study the change of yield characters of garlic under different density of *Alternanthera philoxeroides*. The results showed that with the interference of *Alternanthera philoxeroides*, the plant height, bulb number, root number, light penetration rate, yield of garlic bolts and cloves decreased gradually as the weed density increased. The logarithmic regression model was relatively better for describing the relationship between *Alternanthera philoxeroides* density and yield loss of garlic cloves ($y = 6.039\text{Ln}x + 0.977$, $P < 0.001$). When manual weeding was adopted for control of *Alternanthera philoxeroides* in garlic fields, the economic infestation level for *Alternanthera philoxeroides* was 5.21% and the economic threshold was about 4.02 plant/m².

512. Weed Interference on Transplanted and Direct Sowed Red Beet. Robinson Pitelli¹, Leonardo Carvalho¹, Arthur Cecilio Filho¹, Silvano Bianco¹; ¹Sao Paulo State University, Jaboticabal, Sao Paulo, Brazil

Weed interference is an important issue in the red beet production. Horticultural areas receive frequent soil disturbance, high fertilization and irrigation, providing suitable conditions to ruderal weeds colonization. These weeds have dense soil banks and quick growth, competing strongly with red beet and promoting losses in the root quality and productivity. Aiming to evaluate the effects of weedy or weed-free periods on the red beet root production, two field trials were set up in a randomized block design with three replications. In the first experiment, the red beet was direct sowed and the periods were considered after 75% of the beet emergence. In the second one, 5-leaf beet seedlings were transplanted in the field and the periods were considered after the transplanting. The treatments consisted of weekly increasing periods which the crop was maintained weedy and weed-free from the emergence or the transplanting. In the crop harvest, the marketable root production (diameter >4 cm) was evaluated. The main weeds in both experiments were *Amaranthus viridis*, *Coronopus didymus*, *Galinsoga parviflora*, *Nicandra physalodes* and *Solanum americanum*. In the weed-free treatment, the root yield of the direct sowed

and the transplanted beets areas were 3,667.08 and 4,413.63 g/m², respectively. So, the production was around 17% higher in the transplanted beet. In the weedy treatment, those yields were 106.57 and 1,185.23 g/m², respectively, showing that the yield losses of the direct sowed beet reached more than 97%, while the losses of transplanted beet was around 73%. The period from the emergence or the transplanting until the maximum time without any effect on the root production is designed as period before the weed interference (PBI), and their extensions were 2 and 6 weeks for the direct sowed or the transplanted beet, respectively. The minimum period maintained weed-free, from the emergence or the transplanting, which provide conditions to the beet shows its productive potential is designed by total period for prevention of the weed interference in the root productivity (PTPI), and their values were 6 and 7 weeks for the direct sowed or the transplanted beet, respectively. The results indicate that the weed interference reduced drastically the root production for both systems of red beet crop implantation and the interference was stronger in the direct sowed.

513. Halosulfuron Tolerance of Four Melon (*Cucumis melo* L.) Types. Robin Gomez¹, Franklin Herrera²; ¹Iowa State University, Ames, Iowa, United States of America; ²University of Costa Rica, San Jose, Costa Rica

Weed control in melon has traditionally been achieved through the use of soil fumigants, principally methylbromide, a known contributor to ozone layer depletion. Alternatives to its use have been proposed for temperate regions, but because there are many melon types created depending on the production zone and final market, it is necessary to evaluate the effect of these alternative strategies on tropical cultivars as well. The herbicide halosulfuron can give excellent control of sedge weeds such as *Cyperus rotundus*, which is one of the world's most aggressive weeds, and which has great impact in melon production in the tropics. To determine the suitability of halosulfuron for weed control in tropical melon we conducted greenhouse experiments in the Fabio Baudrit Experimental Station, Alajuela, Costa Rica, from March to May of 2004. The selectivity of four halosulfuron postemergence rates (0.000, 0.050, 0.075 and 0.100 kg a.i. / ha) was evaluated for four melon types (Cantaloupe, Dorado, Piel de Sapo and Honeydew) at three growth stages (2 leaves, 3 to 4 leaves and vines). Additionally, we evaluated the selectivity of three halosulfuron rates (0.050, 0.075 and 0.100 kg a.i. /ha) applied to the soil 3, 5, 7, and 9 days before the transplant of the same melon types. All the postemergent applications caused phytotoxicity symptoms in all the melon types, which increased with the herbicide rate, but a late recovery of the plants was observed in all the treatments and their final biomass didn't differ from the control. For these applications the rate applied had a

stronger influence on phytotoxicity than did the growth stage at the time of the application, with the exception of Piel de Sapo melon, which was more susceptible at the two-leaf growth stage. On the other hand, dose and time between application and transplanting mainly affected Dorado and Cantaloupe melons in pre-transplant applications. The least severe effects were observed when transplanting occurred 3 and 5 days after the application of the 0.050 kg/ha rate, respectively. Piel de Sapo and Honeydew melons were only affected by the highest rate applied. Of the four cultivars, only Honeydew plants developed less biomass than the control. These experiments showed that halosulfuron rate and time of application must be determined depending on the melon type that will be planted.

514. Economic Responses of Different Weed Management Practices on Yield and Quality of Ginger. Apurba Bandyopadhyay¹, Muktar Sarker², Samir Samanta¹, Jayanta Tarafdar¹; ¹Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, India; ²Indofil Chemicals Company, Mumbai, Kolkata, West Bengal, India

Field and laboratory study was carried out to evaluate the economic aspects of different weed management practices with oxyfluorfen in ginger cultivation and its effect on different yield and quality parameters. Two formulations (oxyfluorfen 23.5% EC and oxyfluorfen 5 %ME) of the selected different dosages are tested and observed that both the formulations are very effective for controlling the broad leaf weeds and moderately effective against grasses but unable to control sedges. Between the two formulations, 5 % ME is found equally effective with lower a.i. as compared to 23.5% EC formulation. Quality parameters of fresh ginger, were evaluated and result showed no variation among the practices followed. In addition better yield was achieved in effective herbicide treated plots.

515. Cover Cropping as a Weed Control Measure in Orchards. Mohammad Bazoobandi¹, Amir Abdollahzadeh Gonabadi, Alireza Koochaki², Mehdi Nassiri Mahalati¹; ¹Azad University of Mashhad-Golbahar, Mashhad, Khorasan Razavi, Iran; ²Ferdowsi University of Mashhad, Mashhad, Khorasan Razavi, Iran

Orchards are the most important horticultural crops in Iran. However these distinct agro- ecosystems suffer from weed interferences and should be managed. The present study was conducted during 2004-2005 at the orchard yards of Khorasan Agricultural Research Center to evaluate effects of different cover crops on weed biomass and population, nitrogen and organic matter content of soil. The experiment was laid out in randomized complete block design with three replications. Treatments included

factorial combinations of three cover crop species i.e. rye (*Secale cereale*), hairy vetch (*Vicia villosa*) and grass pea (*Lathyrus sativus*) with four management systems i.e. cover crop mowing, cover crop incorporated with soil, non lethal dose of herbicide sprayed and green mulch. Results showed that rye with the highest LAI, CGR and biomass was the most effective crop in significant reduction of weed biomass and population. Among different cover crop management systems, green mulch and herbicide sprayed cover crops significantly reduced weed biomass and population. Legume cover crops and soil incorporating cover crops increased nitrogen content of soil compared to the control, rye and green mulch treatments. Organic matter of soil was highest in the rye, green mulch and soil incorporated cover crop and lowest with mower and herbicidal treatments. Therefore, it may be concluded that adopting any sort of cover crop can improve orchard soil nutritional conditions as well as satisfying weed management.

516. Influence of Selected Environmental Factors on Seed Germination and Emergence of Major Weed Species in Coconut Plantations of Sri Lanka. Sri Haren Sumith Senarathne¹, Ravi Sangakkara²; ¹Coconut Research Institute, Lunuwila, Sri Lanka, Lunuwila, North western, Sri Lanka; ²Faculty of Agriculture, University of Peradeniya, Sri Lanka, Peradeniya, Central, Sri Lanka

Weeds are a perennial problem in coconut plantations which causes significant losses in crop yields. The occurrence of a wide range of weeds also causes problems of eradication. The ecology of these species which are diverse and persistent has not been clearly identified. Thus, field, laboratory and green house studies evaluated the effect of three different environmental factors on the seed germination, emergence and survival of two major weed species in coconut plantations, namely *Mimosa pudica*, *Ureana lobata* *Panicum maximum* and *Pennisitum polystachyon*.

Germination percentage of all the weed species was very high in the absence of moisture stress (0.0MPa) and it was significantly reduced with increasing soil moisture stress, no germination was observed at -0.9MPa. Germination of both grass seeds ranged from 8% to 25% and 10% to 45% as moisture stress decreased from -0.4MPa to 0MPa (distilled water) respectively. In contrast, seeds of *M. pudica*, and *U. lobata* were moderately tolerant to soil moisture stress. All the weed species seeds germinated over a wide range of soil pH values with the highest germination occurring at pH 6. However, *P. maximum* prefers neutral to slightly acidic soil conditions and seeds germinate of this specie in a narrow range pH (4-7), indicating that pH may be a limiting factor for germination in most soils. In all the species, seedlings emergence was very high when placed on the soil surface (0.5cm) and declined rapidly with increasing depth with the exception

of *U. lobata*, where *P. maximum* seed germination was lower than that of *P. polystachyon*. The studies illustrate the adaptability of these persistent weeds to different environmental conditions which would enable the development of management strategies to reduce their populations below economic threshold levels in coconut plantations.

517. Tolerance to Glyphosate in Leguminosae Used as Plant Covers in Citrus Orchards. Hugo Enrique Cruz-Hipólito¹, Jose Alfredo Domínguez-Valenzuela², Juan Lorenzo Medina-Pitalúa², María Dolores Osuna³, Rafael De Prado¹; ¹Universidad de Córdoba, Córdoba, Spain; ²Universidad Autónoma Chapingo, Texcoco, Mexico; ³Finca La Orden, Badajoz, España, Spain

In large areas of citrus orchards in the Mexican tropics, leguminosae have traditionally been used as cover crops. Among the main advantages of these crops as plant covers can be highlighted: a) weed control, as the vigorous growth of the plant prevents the entry of light, which limits weed development; b) there is an increase in levels of organic matter in the soil; c) the fixation of atmospheric nitrogen to which plant cover use contributes up to 231 Kg N ha⁻¹; d) plant cover controls erosion and maintains moisture levels in the soil.

Glyphosate has become the leading postemergence, systemic, non-selective, broad-spectrum herbicide for the control of annual and perennial weeds. Today, glyphosate is used as a non-crop, plantation crop herbicide and in cover crops on spring time.

The objective of this research was to investigate the mechanism of tolerance to glyphosate present in *Mucuna pruriens* var. *utilis*, *Neonotonia wightii*, *Clitoria ternatea* and one *Amaranthus hybridus* population susceptible to this compound.

The studies, carried out on whole plants in a controlled growth chamber, showed a high degree of tolerance in the three species of leguminosae: *M. pruriens* (ED50 403.78 g a.i. ha⁻¹), *N. wightii* (ED50 308.65 g a.i. ha⁻¹), *C. ternatea* (ED50 541.24 g a.i. ha⁻¹) while *A. hybridus* (ED50 64,260 g a.i. ha⁻¹) displayed a great susceptibility to the herbicide. The absorption and translocation studies of ¹⁴C-Glyphosate, made on these species showed that, after 24 h of foliar application, *A. hybridus* absorbed 30% more than the leguminosae. The great tolerance of the leguminosae to glyphosate was determined by a low penetration and lesser translocation of the herbicide towards the growing apical areas, in which there was an important activity of the enzyme EPSPS, and thus a lesser inhibition of the latter. Also studied were the epicuticular waxes, in which differences in their morphology and distribution on the leaf surface were observed.

518. Effects of Weedy Periods on Transplanted Onion Productivity. Robinson Pitelli¹, Leonardo Carvalho¹, Cesar Scheide¹; ¹Sao Paulo State University, Jaboticabal, Sao Paulo, Brazil

Onion is one of the most susceptible crops to weed interference and the evaluation of the factors affecting the weed-crop relationship is essential for better understanding of this process and the development of suitable weed management programs. The objective of this research was to evaluate the changes in the phytosociological index and biomass accumulation of the weed community and evaluate the effects on the onion bulb productivity after different weedy periods. The treatments consisted of increasing weedy periods since the transplanting until 14, 28, 42, 56, 70, 84 and 98 days after. The dry matter accumulation for weed community was slow at the beginning of the crop cycle, in both years. The relative importance (RI) of the weed populations changed during the onion cycle, so that species like *Amaranthus viridis* and *Nycandra physaloides* have higher RI when the weed competition began became expressive to onion productivity. The period from the transplanting until the maximum time without any effect on the bulb production is designed as period before the interference (PBI). The quick dry matter accumulation occurred from 42 to 84 DAT in both years. In 2001, the dry matter accumulation showed tendency to stabilization after this period, however in 2002 the weed community accumulated high quantity of dry matter until the onion harvesting. Considering acceptable losses of 5% in the onion bulb production, the weed community of the cultivar Granex-33, in 2001, promoted a PBI of 23 DAT; while the weed community of the cultivar Baia Periforme, in 2002, promoted a PBI of 44 DAT.

519. Phenyl Isothiocyanate: A Potential Alternative of Methyl Bromide for Weed Control in Tomato and Bell Pepper Production Systems. Sanjeev Bangarwa¹, Jason Norsworthy¹, Griff Griffith¹; ¹University of Arkansas, Fayetteville, Arkansas, United States of America

Methyl bromide (MeBr) is widely used for weed control in *Lycopersicon esculentum* (tomato) and *Capsicum annuum* (bell pepper) production. With the impending ban of MeBr in the USA, an effective alternative is needed. Greenhouse experiments were conducted to: 1) determine the effect of phenyl isothiocyanate (PITC) concentration and exposure period on yellow nutsedge sprouting and 2) compare the persistence of PITC in soil under low density polyethylene (LDPE) and Virtual Impermeable Film (VIF) mulches. Additionally, field experiments were conducted in 2006 and 2007 to evaluate tomato and bell pepper tolerance and effectiveness of PITC against *Cyperus esculentus* (yellow nutsedge), *Amaranthus palmeri* (Palmer amaranth), and *Digitaria sanguinalis* (large crabgrass). Greenhouse exper-

iments were organized in a completely randomized design with 3 replications. Soil containing yellow nutsedge tubers was treated with PITC at 500 and 5000 nmol g⁻¹ dry soil and placed in closed glass jars from 0 to 21 d after treatment. Tubers were evaluated for sprouting for 21 d following each exposure concentration and duration. Persistence of PITC applied to soil at 5000 nmol g⁻¹ dry soil in glass jars which were covered with LDPE or VIF mulches from 0 to 21 d after treatment were compared. Phenyl ITC was extracted from two 25g sub-samples of treated soil from each jar and analyzed by gas chromatography. Field experiments were organized in a randomized complete block design with 2 mulch types (LDPE and VIF) and 6 rates of PITC (15, 75, 150, 750, 1500 kg ha⁻¹), replicated 4 times. PITC was applied to the soil and immediately incorporated using a roto-tiller. Raised beds were prepared after PITC incorporation and covered with LDPE or VIF mulch. Tomato and bell pepper were transplanted 3 wk after applying the plastic mulch. Observations were taken on crop injury, weed control, and crop yield. Data were subjected to ANOVA, and means were separated using Fisher's protected LSD (P=0.05). Regression curves were fitted for rate response to weed control and crop injury after double square-root transforming the PITC rate.

A PITC concentration of 5000 nmol g⁻¹ soil for 3 d in a closed environment reduced yellow nutsedge sprouting by 98%. PITC persists longer under VIF mulch compared with LDPE mulch. In field experiments, higher crop injury was observed in 2006 than in 2007. The difference in injury was due to the timing of punching holes in the mulch, which were 0 and 48 h prior to transplanting in 2006 and 2007, respectively. Unacceptable crop injury occurred in tomato and bell pepper at the highest PITC rate of 1500 kg ha⁻¹. PITC at 750 kg ha⁻¹ provided effective control of yellow nutsedge (82%), Palmer amaranth (95%), and large crabgrass (85%) through 4 wk after transplanting. Overall, VIF mulch improved weed suppression over the LDPE mulch. Moreover, tomato and bell pepper fruit yields were equivalent to that of MeBr when PITC was applied at 750 kg ha⁻¹ in 2007. Therefore, it is concluded that PITC at 750 kg ha⁻¹ can be a potential alternative of MeBr in tomato and bell pepper production when it is applied under a VIF mulch and beds are allowed to aerate 48 h prior to transplanting.

520. Hexazinone and Hexazinone + Diuron for Weed Management in Tea in North Bengal. Ratikanta Ghosh¹, Manab Roy¹; ¹Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Calcutta, West Bengal, India

RATIONALE:

Tea (*Camellia sinensis* L.), cultivated around 0.45 mha and producing around 500 mkg per annum and engaging around more than 1.25 million people, is the one of the most important cash crops in India but the losses in

production and degradation of the quality of the tea due to interference of weeds now poses threats to the tea growers.

OBJECTIVE:

To find out the bio efficacy of new herbicide molecule Hexazinone 75 DF and Velpar K 4 60 WP at different doses on tea weed flora

To find out the bio efficacy of new herbicide molecule Hexazinone 75 DF with or without non ionic surfactant and Velpar K4 60 WP on tea weed flora

To record the phytotoxicity effect of these two testing herbicides on tea plants

METHODS:

The field experiment was conducted at Kamalpur Tea Estate locating at Bagdogra of Siliguri, area, district Darjeeling in West Bengal during Summer and Kharif seasons of 2007. The experiment was carried out in randomized block design (RBD) with eleven treatments replicated thrice. The treatments comprised of six doses of the testing herbicide Hexazinone 75 DF (300, 400, 500, & 600 g/ha without surfactant) and two with non ionic surfactant (300 & 400 g/ha), three doses of Velpar K4 60 WP (800, 1000 & 1200 g/ha) and the standard market available Glyphosate 41 % SL applied @ 2500 g/ha besides the weedy check. The herbicides were applied on second week of March and September 2007 with a knapsack sprayer fitted with flat jet deflector nozzle with a spray volume of 500 l/ha. The density and dry weight of the grass, sedge and broadleaf weeds were recorded besides observations on the percent control of weed plants at two different dates at 10 and 30 days after application (DAA) of herbicides, the resurgence of weed flora at 45 and 60 DAA and the phytotoxicity effect of these testing herbicides on the tea plants at 7, 15 and 30 DAA.

RESULTS:

The major weed flora observed in the experimental field were *Cynodon dactylon*, *Digitaria ciliaris*, *Eleusine indica*, *Oplismenus compositus*, *Paspalum conjugatum*, *Panicum repens*, *Paspalum distichum*, *Cyperus rotundus*, *Cyperus compressus*, *Cyperus mucronatus*, *Cyperus iria*, *Cyperus aromaticus*, *Fimbristylis littoralis* among monocots whereas *Muehlenbeckia platyclada*, *Borreria hispida*, *Ageratum conyzoides*, *Blainvillea latifolia*, *Oldenlandia corymbosa*, *Ludwigia purviflora*, *Cyanotis auxilaris*, *Scoparia dulcis*, *Pouzolzia indica*, *Crassocephalum crepidioides*, and *Convolvulus arvensis* were common among broadleaf dicot weeds. All the herbicide treatments showed better weed control efficacy than the weedy check.

Hexazinone 75 DF applied @ 600 g /ha followed by its lower dose 500 g/ha were recorded full control of weeds within 10 DAA whereas Velpar K4 60 WP @ 1200 g/ha followed by its lower dose 1000 g/ha showed better weed control (within 12 DAA) than the standard herbicide used in this experiment or its lower dose 800 g/ha. Hexazinone 75 DF applied @ 300 or 400 g/ha with non ionic surfactant recorded better efficacy in controlling all types of weed flora (within 15 DAA) in comparison to the same doses of this herbicide using without surfactant (within 20 DAA).

The weed flora like *Cynodon dactylon*, *Cyperus rotundus*, *Crassocephalum crepidioides*, *Convolvulus arvensis* *Borreria hispida*, *Muehlenbeckia platyclada* because of presence of tuber, stolon or deep rooted and hardy in nature showed resurgence after 45 DAA in case of the lower two doses of the testing herbicides Hexazinone 75 DF @ 300 and 400 g/ha without surfactant, Velpar K4 60 WP @ 800 g/ha & Glyphosate 41 % SL applied @ 2500 g/ha and after 60 DAA in case of higher two doses of both these two testing herbicides without the non ionic surfactant along with Hexazinone 75 DF @ 400 g/ha with non ionic surfactant.

The tea plants did not show any phytotoxicity as against the application of any doses of either the testing Hexazinone 75 DF with or without non ionic surfactant or Velpar K4 60 WP and thus looked safer as like as the standard herbicide Glyphosate 41% SL.

CONCLUSION:

The experimental results thus, revealed that both the testing herbicides Hexazinone 75 DF or Velpar K 4 60 WP at their higher two doses without the non ionic surfactant or Hexazinone 75 DF @ 400 g/ha with the non ionic surfactant could be used as a replacement of the standard Glyphosate 41% SL

521. Evaluation of Triasulfuron for Weed Management in Tea. Ratikanta Ghosh¹; ¹Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Calcutta, West Bengal, India

Tea (*Camellia sinensis* L.) is the most important plantation crop cultivated throughout the India. In around 500 M kg tea is produced per annum from an area of 0.45 m ha. More than 1.25 million people are directly depended for their livelihood in tea sectors. India earns a huge amount of foreign money per annum by exporting a good quality tea. But now-a-days the quality is degraded due to the interference of some twinner and climber weeds.

The objectives of this experiment are to find out the bio efficacy of Triasulfuron (Logran 20 WG) on tea weed flora including their resurgence and to record the phytotoxicity effect of this molecule on tea plants.

The experiment was conducted at Kamalpur Tea Estate of Darjeeling district in West Bengal during summer and kharif seasons of 2007 in randomized block design (RBD) having seven treatments with three replication. The treatments comprised five different doses of the testing molecule Triasulfuron (15,17.5, 20, 22.5 and 25. g a.i./ha) along with standard Glyphosate applied @ 2.5 kg a.i./ha besides the weedy check. The herbicides were applied on third week of March and September with a knapsack sprayer fitted with flat jet deflector nozzle with a spray volume of 500 l/ha. The density and dry weight of different categories of weeds were recorded along with the phytotoxicity effect of these testing herbicides on the tea plants at 5, 7, 15, 30 and 45 DAA. The percent control of weed flora at 10 and 30 DAA were also recorded along with their resurgence at 45 and 60 DAA.

The dominant broadleaf weeds found in the tea garden were *Borreria hispida*, *Ageratum conyzoides*, *Muehlenbeckia platyclada*, *Cyanotis auxilaris*, *Blainvillea latifolia*, *Ludwigia purviflora*, *Oldenlandia corymbosa*, *Pouzolzia indica*, *Convolvulus arvensis*, *Crassocephalum crepidioides*, and *Evolvulus numularis*. Beside these some grassy weeds like *Digitaria ciliaris*, *Paspalum distichum*, *Eleusine indica*, *Oplismenus compositus*, and sedge weeds viz. *Cyperus rotundus*, *Fimbristylis littoralis*, *Cyperus compressus*, *Cyperus aromaticus* were also observed. Triasulfuron @ 25 g a.i./ha showed highest weed control efficiency at 20 DAA followed by its lower doses. All the broadleaf weeds were completely managed by Triasulfuron used @ 20, 22.5 and 25 g a.i./ha. In controlling the dicot weeds the lower two doses (15 & 17.5 g a.i./ha) showed at par with Glyphosate applied @ 2.5 kg a.i./ha.

All the treatments showed significantly higher control of weeds than untreated control. The Weed Control Efficiency is gradually decreased after 60 DAA for the highest dose of Triasulfuron (25 g a.i./ha) and after 45 DAA for all the other doses. This is mainly due to the resurgence of the perennial broadleaf weeds having corm, tuber, rhizome and deep rooted system. Both the testing Triasulfuron and the standard Glyphosate did not show any phytotoxicity on the tea plants at any doses.

From this experiment it can be concluded that Triasulfuron (Logran 20 WG) could be used @ 22.5 or 25 g a.i./ha for controlling all types of weed flora in tea as a replacement of traditional Glyphosate, and this not only help to increase the production but also improve quality of tea.

522. Evaluation of Effective Weed Management Practices in Young Tea Plantation of Terai Climate of West Bengal, India. Samir Kumar Samanta¹, Mukter Ahmed Sarkar²; ¹Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, India; ²Indofil Chemicals Company, Kolkata, West Bengal, India

Weed management for the sustainable and economic tea production is the major challenge to all the planters and scientific communities. Uprooting of less productive section and replanting is the established practice but maintaining the weeds in the young tea section is a great economic constraint. Apart from plant-weed nutrient competition, few weeds pose serious threat as the alternative host of pests, diseases and allergenic to the daily workers. To combat the problem, field studies were carried out to find out the effective method of weed management practices in young tea (0-1 yr.) in Terai climatic condition of Darjeeling districts of West Bengal, India. Field trials were conducted in a Randomized Block design with three replications at Kamalpur Tea Estate, Bagdogra, Darjeeling, W.B. Plot size were taken as 5m x 5m. Four herbicides i.e oxyfluorfen 23.5 EC, glyphosate 41 SL, 2, 4 D (sodium salt) 80 WP and paraquat 24

SC were applied in one-year old tea plantation (mixed Assam clone variety).

All the plots were affected by both broad leaf and grassy weeds. The molecules were applied on standing weeds with a WFN-40 nozzle except oxyfluorfen which was applied after cleaning all weeds by spade. Hand weeding was given at an interval of 15 days. Both the paraquat and 2,4 D treated (all dosages) plots were found highly phytotoxic to the tea plantation (wilting, leaf burning, leaf curling, yellowing). No phytotoxicity was observed in oxyfluorfen and glyphosate treated plots. Broad leaf weeds were controlled for 60 days with oxyfluorfen @ 235 g a.i./ha and grasses for 30 days. Glyphosate @ 820 g a.i./ha controlled grasses for 30 days and broad leaves for 20-25 days. 2, 4 D controlled only broad leaves for 15-20 days and paraquat controlled only grasses for 15 days. During this experiment one application of oxyfluorfen @ 235 g a.i./ha along with one handweeding at 40 days after application provided satisfactory control upto 60 days. Glyphosate controlled grassy weeds very satisfactorily but control of broad leaf weeds (*A.conijoids* which is a major problem) was not satisfactory. So considering the weed spectrum and performance of the chemicals, oxyfluorfen followed by one hand weeding was found most effective.

Glyphosate a popular herbicide was found economically less effective than oxyfluorfen in this study. Oxyfluorfen 23.5 EC was found the best treatment @ 235 g a.i./ha.

523. Soil Management Systems in Olive Orchards of Southern Italy: A Qualitative Evaluation of the Weed Flora. Mariano Fracchiolla¹, Cesare Lasorella¹, Domenico Caramia¹, Pasquale Viggiani², Pasquale Montemurro¹; ¹Università di Bari, Bari, Italy; ²Università di Bologna, Bologna, Italy

Soil management has an important role in sustainable agriculture, affecting flora community, soil fertility and crop growth.

In this paper we show preliminary results about the effects on weed flora of different soil management strategies in olive orchards:

1. Cover crop sowing (*Vicia villosa*) on alternate years. In the first year soil was tilled only for vetch sowing and suppressing at the beginning of spring. In the following year weeds were mechanically controlled (mowing)

2. Chemical control with a mixture of glyphosate and oxyfluorfen

3. Chemical control with glyphosate

4. Mechanical control (mowing)

The trial was carried out in Savellettri (Apulia Region) in 2006 and 2007. A randomized block design with four replicates was used.

Surveys were done both in spring and in autumn 2006 and 2007. Collected data were used to calculate the following parameters for each species:

-Frequency: number of replications in which species was found/4 x 100

-Abundance: expressed as covering index according to Brown-Blanquet scale

-Importance Index: calculated as average between frequency and abundance

Moreover, in order to give a different weight to the species found in the plots, each species was rated according to some features, chosen among those affecting most crop growth, soil structure and fertility (root apparatus, habit, life cycle, competitive ability with crop). For each feature, index ranged from 1 (bad) to 3 (very good).

Based on their average indexes, species were divided into three groups (<2; =2 and >2). This grouping allowed the calculation of the Incidence Index determined as the ratio between the sum of Importance Indexes of the species belonging to the group and the sum of Importance Indexes of all species.

This value was used as overall parameter of the 'quality' of weed flora resulting from each of the compared strategies.

During the spring 2006 and 2007, species having index >2 had the lowest incidence index in the plots treated with oxyfluorfen. Differences between treatments were lower during autumn surveys, but still present. In the autumn 2007, no species belonging to the group <2 were found in the plots of the strategy 1.

Due to the short period of observation, it is not yet possible to give predictive data about flora shifting in the time. Nevertheless, these first results show that different strategies are able to affect strongly flora composition. Moreover, the method of analysis turned out to be appropriate to describe flora community not only from a quantitative point of view, but above all to investigate its qualitative features. It could be considered a good guideline to carefully evaluate the effects of different soil management techniques.

524. Differential Effect of Organic and Plastic Mulches on *Cyperus rotundus* Suppression and *Citrullus lanatus* (Watermelon) Fruit Yield. Jose Pablo Morales-Payan¹, Pedro Marquez-Mendez¹, Yasser Shabana², Raghavan Charudattan², Erin Roskopf³, Waldemar Klassen⁴; ¹University of Puerto Rico-Mayaguez, Mayaguez, Puerto Rico, United States of America; ²University of Florida-Gainesville, Gainesville, FL, United States of America; ³USDA/ARS, Fort Pierce, FL, United States of America; ⁴University of Florida, Tropical REC, Homestead, FL, United States of America

Cyperus rotundus (Purple nutsedge) [PN] is commonly referred to as one of the worst weeds of the world. In Puerto Rico, PN is among the most troublesome weeds in

production systems where synthetic herbicides are not utilized. Alternative methods for PN management, such as mulching, may be valuable tools for organic production in PN-infested soils. Field research was conducted in Isabela, PR, to assess PN suppression by black and IRT plastic mulches and eight organic mulches and its impact on *Citrullus lanatus* (watermelon) yield in a production system managed according to organic regulations. The organic mulches were hays of *Paspalum notatum* (Bahia grass), *Imperata cylindrica* (cogongrass), *Vigna unguiculata* (cowpea), *Pennisetum glaucum* (millet), *Cyperus rotundus* (purple nutsedge), *Sorghum bicolor* (sorghum), *Crotalaria juncea* (sunhemp), and *Secale cereale* (rye). Mulches were placed on the soil beds the same day *Citrullus lanatus* (watermelon) cv Crimson Sweet was planted. The original PN density was 100 tubers per m². The crop was managed using organic production practices. PN able to grow through the mulches grew unchecked until crop harvesting. Plastic mulches suppressed PN almost completely, but also caused drastic suppression of crop growth and yield. PN biomass was suppressed by as much as 20% in *Crotalaria*- and *Vigna*-mulched plots, resulting in significant crop yield loss as compared to the weed-free crop. *Imperata cylindrica* and *Cyperus rotundus* mulches reduced PN shoot biomass by as much as 80%, resulting in higher crop yields than in PN-infested plots. These results confirm the importance of PN management in this organic crop and the differential suppression efficacy of the mulches tested.

525. Preparation and Application of Isotopically Modified Compounds of a Novel Rape Herbicide, ZJ0273. Tang Qinghong¹, Zhengmin Yang¹, Qingfu Ye², Long Lu¹; ¹Chinese Academy of Science, Shanghai, China (Peoples Republic of); ²Zhejiang University, Hangzhou, Zhejiang Province, China (Peoples Republic of)

ZJ0273, propyl 4-(2-(4,6-dimethoxypyrimidin-2-yloxy)-benzylamino)benzoate, is an active ingredient used in rape field which obtained temporary registration in China in 2003. It is formulated as herbicide under the trade name of Youli (EC) and Youli No.2 (SC) for field use. In order to study its mechanism of action, metabolism and environmental behaviors, we prepared twelve corresponding isotopically modified compounds of ZJ0273: (?T) Two isotopically substituted compounds, propyl 4-(2-(4,6-dimethoxypyrimidin-2-yloxy) (phenyl-3,4,5,6-2H4)benzylamino)benzoate (1) and propyl 4-(2-(4,6-di(2H3) methoxypyrimidin-2-yloxy)benzylamino)benzoate (2), were synthesized from (2H6)phenol with a 4 step-yield of 44% and from (2H6)methanol with a 3 step-yield of 42%, respectively. (?U) Starting with 4-amino[phenyl-U-14C6]benzoic acid, 4,6-dichloro-2-methylthio[4,6-14C2]pyrimidine, [U-14C6]phenol and [phenyl-2,3,4,5,6-3H5]phenol, four specifically monolabeled compounds, propyl 4-(2-(4,6-dimethoxypyrimidin-2-yloxy)benzylami-

no)[phenyl-U-14C6] benzoate (3), propyl 4-(2-(4,6-dimethoxy[4,6-14C2]pyrimidin-2-yloxy)benzylamino)benzoate (4), propyl 4-(2-(4,6-dimethoxypyrimidin-2-yloxy)[phenyl-U-14C6]benzylamino)benzoate (5) and propyl 4-(2-(4,6-dimethoxypyrimidin-2-yloxy)[phenyl-3,4,5,6-3H4]benzylamino) benzoate (6), were synthesized through esterification, condensation, reduction and substitution reactions and purified by RP-PHPLC. Their structures were identified by HPLC-MS (ESI), ¹H NMR and MS (EI). HPLC analysis showed their chemical purities exceeded 98%. HPLC-LSC and TLC-IIA measurements demonstrated that their radiochemical purities were over 98%. Their specific activities were 1.110, 1.024, 1.025 and 4.590 mCi/mmol, respectively. (V) Two specifically durallabeled compounds, propyl 4-(2-(4,6-dimethoxy[4,6-14C2]pyrimidin-2-yloxy)[phenyl-3,4,5,6-3H4]benzylamino)benzoate (7) and propyl 4-(2-(4,6-dimethoxypyrimidin-2-yloxy)[phenyl-3,4,5,6-3H4]benzylamino) [phenyl-U-14C6]benzoate (8), were prepared by homogeneously mixing the relevant specifically monolabeled compounds (4, 5) with (6), respectively. (W) Four specifically trilabeled compounds were prepared by homogeneously mixing the durallabeled compounds (7, 8) with deuterium-substituted ZJ0273 (1, 2), respectively. The application of these isotopically modified compounds of ZJ0273 which were used as isotopic tracer in our present studies was discussed.

526. Dissipation of Pendimethalin in Water. Indu Bainsla¹, Anil Duhan¹, Beena Kumari¹; ¹CCS Haryana Agricultural University Hisar (India), Hisar, Haryana, India

Pesticide use pattern in the present day situations has led to resistance build up by pests and pesticide residues which demands newer and safer pesticides with different modes of action. Thus there is a need to evaluate pesticides no or lesser residues in the commodity as well as in the environment. Keeping this in mind studies had been done to investigate dissipation of pendimethalin (Stomp 30EC) in water under laboratory conditions. Pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitroaniline], a selective herbicide, was applied at two doses @ 1 (T1) and 2 (T2) kg ai/ha to the canal water collected in brown bottles except the control. Water samples were periodically collected and processed on 0 (1h after application), 1, 3, 7, 15, 30, 60, and 90 days after treatment. Samples were partitioned thrice with 15 % dichloromethane in hexane after addition of 10-15g of NaCl. Residues were analyzed by gas liquid chromatography (GLC) fitted with electron capture detector. Per cent recovery varied from 98.8 to 99.1 at 0.20 and 0.50 µg/g. Pendimethalin degradation followed a first order kinetics. The observed half lives were 13.37 and 15.12 days at T1 and T2 doses.

527. Sensitivity of Soil Borne Plant Pathogenic and Beneficial Fungi to Two Formulations of Oxyfluorfen and

its Impact on Chromosomal Behavior and Proteomics in Onion (*Allium cepa*) and tomato (*Lycopersicon esculentum*). Jayanta Tarafdar¹, Amrita Banerjee¹, Somnath Roy¹, Mukter Ahmed Sarkar², Samir Samanta¹; ¹Bidhan Chandra Krishi Viswavidyalaya (State Agricultural University), Kalyani, West Bengal, India; ²Indofil Chemicals Company, Mumbai, Maharashtra, India

Oxyfluorfen is a protoporphyrinogen oxidase (PPO) inhibitor herbicide currently being used for controlling wide-spectrum of weeds in various crops including tea. Oxyfluorfen was also reported to reduce disease severity of Sclerotinia stem rot (white mold) on soybean, which stimulated production of antimicrobial compounds (phytoalexins) in leaf tissue. Our present study aimed to investigate the impact of two formulations of Oxyfluorfen (Oxyfluorfen 23.5EC and Oxyfluorfen 5ME) on the most aggressive soil borne fungus *Sclerotium rolfsii* and biocontrol agent *Trichoderma viridae* and its interaction with tomato subject to application of Oxyfluorfen in vitro and in vivo condition. The sensitivity of Oxyfluorfen on mitotic index, phase distribution and mutagenic potentialities for onion (*Allium cepa*) root cells was examined. The chromosomal behavior and cell division for root cells of *Allium cepa* was examined at 24, 48 and 72 hours after exposure to at different concentrations of two formulations of Oxyfluorfen. The protein profile of the onion and tomato plants exposed to Oxyfluorfen was also studied. Four concentrations for each formulated product were assayed by poison food technique and dual culture method of the fungi. The obtained results indicated that the cell division in onion root tip was not affected when exposed to Oxyfluorfen 5ME but divisional stage was restricted to Metaphase at initial hours after exposure to Oxyfluorfen 23.5EC. All the mitotic steps were found but few abnormalities like Anaphase Bridge and stickiness of chromosomes were occurred in Oxyfluorfen 5ME treated root cells of onion depending upon the concentrations. The stem rot pathogen, *S. rolfsii* was more sensitive to both formulations of Oxyfluorfen than *T. viridae*, determined by the colony diameter of both the fungi individually. A complete inhibition of growth of *S. rolfsii* was noticed with increase of concentration Oxyfluorfen 23.5EC and Oxyfluorfen 5ME and inhibition percentage was found higher in *S. rolfsii* than *T. viridae*. In dual culture, *T. viridae* showed antagonistic effect on *S. rolfsii* in the media fortified with Oxyfluorfen 5ME than Oxyfluorfen 23.5EC. The protein profiles of tomato and onion artificially inoculated by the fungi before and after spraying of Oxyfluorfen were compared with untreated control. The results suggest that Oxyfluorfen might not directly affect the process in mitosis but inhibit particular phases of the life cycle which is self-repairable. Both the formulations of Oxyfluorfen showed differentially sensitive to onion and tomato under laboratory condition which might be due to differential uptake or the metabolism of each species.

528. **Families: Current Mistakes and Suggested Substitutes.** Abed Forouzesh¹, Eskandar Zand², Saeid Soufizadeh³, Sadegh Samadi Foroushani¹; ¹College of Aburaihan, University of Tehran, Pakdasht, Tehran, Iran; ²Plant Protection Research Institute, Tehran, Iran; ³Environmental Sciences Research Institute Shahid Beheshti University, Tehran, Iran

One of the main methods of classification of herbicides is based on their chemical family. Chemical families have been nominating based on using their herbicide active ingredient and chemical structure of the compound. The present study has shown that there are many mistakes in nominated literatures of current herbicide families. These literatures include papers in peer-reviewed journals, books and other herbicide-related sources. So, it is necessary to do a revision on the current methodology of nominating herbicide families. Many of these mistakes have been found in popular scientific resources relating to herbicide and weed sciences. Some examples of these scientific resources are as follows: a) 30 mistakes in Herbicide Handbook (2002) published by Weed Science Society of America; b) 41 mistakes in The Pesticide Manual (2004) published by British Crop Protection Council; c) 19 mistakes in Crop Protection Handbook (2006) published by Meister Publishing Company; d) 49 mistakes in Herbicide Resistance Action Committee (2005); and e) 30 mistakes in Mallory-Smith, C.A. and E.J. Retzinger (2003), Weed Technology, 17: 605-619. Corrections to the chemical family names have been made according to the chemistry rules governing the nomination of a chemical compound. Some of the wrong family names which have been used in at least three of the above resources are: Aryloxyphenoxy propionate (clodinafop-propargyl, fluaizifop-butyl, and haloxyfop-methyl to pyridinyloxyphenoxy propionate family), Cyclohexanedione (butoxydim, clethodim, sethoxydim, tepraloxym, and tralkoxydim to hydroxycyclohexenone family), Triazinone (hexazinone to triazinedione family), Benzothiadiazole or Benzothiadiazinone (bentazon to benzothiadiazinanone family), N-phenylphthalimide (flumiclorac to N-phenylcyclohexenedicarboximide family), Thiadiazole (fluthiacet-methyl to thiadiazolidinone family), Oxadiazole (oxadiargyl, and oxadiazon to oxadiazolone family), Acetamide (napropamide to propionamide family), and Benzofuran (ethofumesate to dihydrobenzofuran family), respectively.

529. **Dissipation of Pendimethalin in Soil.** Indu Bainsla¹, Beena Kumari¹; ¹CCS Haryana Agricultural University Hisar (India), Hisar, Haryana, India

Intensive use of agrochemicals mainly pesticides in natural environments have become a major concern and have stimulated scientists to develop reliable methods to assess the potential effects of these anthropogenic chemicals on soil quality, the maintenance of which constitutes

considerable intervention in the research agenda. Keeping this in mind field studies of dinitroaniline herbicide, pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitroaniline] in soil under wheat (Variety C-306) crop at different doses were carried out to investigate dissipation behavior of the herbicide. The studies were carried out at Research Farm of CCS Haryana Agricultural University in randomized block design (RBD) during 2006-07. Pendimethalin (Stomp 25EC) was applied @ 1 (T1) and 2 (T2) kg a.i. / ha in the soil along with sowing. Soil samples were periodically collected on 0 (1h after application), 1, 3, 7, 15, 30, 60, 90 and 150 (harvest) days after treatment at the depth of 5-20 cm. Soil samples were extracted by open column chromatography using Florisil and activated charcoal as adsorbents and hexane acetone as eluent. Residues were analyzed by gas liquid chromatography (GLC) fitted with electron capture detector. Percent recovery varied from 94.09 to 95.47 at 0.25 and 0.50 µg/g. Initial residues of pendimethalin, 3.609 and 10.473 µg/g dissipated to 0.002 and 0.00238 µg/g in 150 days after treatment at T1 and T2 doses. Pendimethalin degradation followed a first order kinetics. The observed half lives were 13.68 and 11.99 days at T1 and T2 doses.

530. **Simultaneous Estimation of Clodinafop and Metsulfuron Methyl in Soil, Wheat Grain and Straw by HPLC.** Ramesh Kumari¹, Beena Kumari¹, R Malik¹, Ashok Yadav¹; ¹CCS Haryana Agricultural University Hisar (India), Hisar, Haryana, India

Possible bioaccumulation of pesticide in crop produce may cause ailing effect on animal and human. Thus there is a need to evaluate these chemicals in the soil and crop produce at harvest. Sulfonylureas are being used largely in India due to low application rates and high degree of weed selectivity. Clodinafop propargyl, a herbicide from aryloxyphenoxy propionate group (Topic), is a post-emergence herbicide used at very low rate to control a wide range of grass weed species at various growth stage. It is a successful herbicide for control of grassy weeds. Metsulfuron methyl is also used for selective post-emergence control of broadleaf weeds in wheat, and for annual and perennial grasses in corn *Phalaris minor* and *Avena ludoviciana* often infest wheat crop with many broad-leaved weeds. Due to effective control of *P. minor* with alternate herbicides a number of broad leaf weeds are becoming predominant in the rice wheat cropping system. The problem of complex weed flora is being solved by sequential application of sulfosulfuron, fenoxaprop and clodinafop at 30-35 days after sowing followed by metsulfuron methyl after a week. But sequential application needs two separate sprays amounting to the cost of application in terms of time and labour. Ready mix formulation of sulfosulfuron and metsulfuron methyl is available but phytotoxicity to succeeding crop maize and sorghum has been reported from several parts putting a

question mark to the acceptability. Clodinafop followed by metsulfuron methyl looks to be a suitable solution for the complex weed flora of wheat. Readymix formulation of CIL-H/406 was applied at the rate of 60 g a.i./ha (single dose) and 120 g a.i./ha (double dose) after 35 days of sowing of wheat crop and its persistence was studied in soil, grain and straw at harvest. In view of environment and food safety a HPLC method has been used for the simultaneous estimation of residue of clodinafop and metsulfuron methyl in soil, wheat grains and wheat straw. Samples of soil, grain and straw along with control were collected at harvest.

531. Weed Diversity Loss due to Farmland Homogenisation. Santiago Poggio¹, Claudio Ghersa¹; ¹Facultad de Agronomía - Universidad de Buenos Aires, Buenos Aires, Ciudad Autónoma de Buenos Aires, Argentina

Farmland biodiversity has declined as agriculture intensification increased in the last decades. Consequently, homogenous rural landscapes would sustain lower plant diversity than more complex landscapes comprising different types of habitats. Therefore, we tested the hypothesis that weed species diversity and annual crop percent of farmland are negatively associated at both field and landscape scales. Plant diversity was sampled in fields cropped with cool- (wheat and pea) and warm-season crops (maize and soybean). Surveys were carried out in fencerows, edges, and centres of fields. Percent of cropland in the landscape (Acropland) was chosen as a straightforward indicator of heterogeneity. Species diversity was additively partitioned into its α -, β -, and γ -diversity components, calculating β -diversity as the difference between γ -diversity and mean α -diversity. Then, the relationships between either α -, β -, and γ -diversity and Acropland were studied. Plant diversity decreased in most field habitats as Acropland increased, but there were no significant decline for fencerow α -diversity. Fencerows sustain the highest plant diversity, despite of their low areal proportion in both landscapes and fields. Although field edge weeds are intensely controlled, field edge diversity was higher than that of field centres, which suggests that mass effects from fencerows may be involved in sustaining the weed richness of field edges. Maintaining non-cropped habitats in farmland, such as fencerows, may promote diverse arable plant communities by providing suitable habitats for both common and rare species and promoting spatial mass effects, which in turn preserve both wildlife habitats and ecological services in agro-ecosystems.

532. Arable Weeds as Indicators of Agricultural Sustainability. Terho Hyvonen¹, Erja Huusela-Veistola¹; ¹MTT Agrifood Research Finland, Jokioinen, Finland

Monitoring of the populations of organisms associated with farmland provide information on the sustainability of cropping measures. Recently, interest in the application of arable weeds as an indicator group has grown. This study aimed at developing an indicator based on trophic interactions among common arable weeds and animals associated with weeds for the sustainability of cropping measures.

The relative importance of 25 weed species for farmland birds, pollinators (wild bees), phytophagous insects and pests was explored by recording the number of linkages between weed species and each animal group found from the literature. Each weed species was weighted based on the number of reported linkages with each animal group. These weights were applied to exploring the ecological consequences of long-term changes in weed populations in Finland. Data were used from weed surveys of Finnish spring cereal fields conducted in the 1960s, 1980s and 1990s.

The relative importance of weed species varied according to animal groups. Annual weed species able to produce numerous seeds (e.g. *Chenopodium album*, *Polygonum aviculare*) were important for the farmland birds and some perennial weed species (e.g. *Achillea* species, *Cirsium arvense* and *Sonchus arvensis*) were important for the pollinators. The highest number of linkages was established between weed species and phytophagous insects. The number of harmful pest species associated with broad-leaved weeds was low for all species. The general pattern of changes in values of indices over recent decades was similar: there was a marked decline in the values between the 1960s and the 1980s, and a slight increase between the 1980s and the 1990s. These changes were regarded as being a consequence of changes in the intensity of agricultural practices. The slowest recovery of the values was for pollinators.

The results suggest that the ecological consequences of changes in the intensity of agriculture can be explored with the aid of a biodiversity indicator based on species interactions. Owing to the differences in the importance of weed species for different animal groups, maintaining weed species richness is necessary to ensure ecosystem services are provided for the higher trophic levels in farmland.

533. How Can Weed Management Support the Development of a More Multifunctional Agriculture?. Jonathan Storkey¹, Peter Lutman¹; ¹Rothamsted Research, Harpenden, Herts, United Kingdom

Over the last 50 years arable agriculture has focussed strongly on increasing crop yields. Whilst this has been very successful it has had negative environmental effects and it is now realised that agriculture needs to be more multifunctional, delivering not only adequate food but also a healthy environment.

It is clear from many research projects, especially in Western Europe, that intensive agriculture has caused declines in plants, invertebrates and vertebrates adapted to the farmed landscape. One of the key ecological causes of these species declines is the intensity of weed management which has caused a reduction in the provision of primary resource in arable ecosystems leading to impacts higher up the food chain, on invertebrates, birds and mammals.

How can this be redressed? Arable ecosystems could be enhanced by allowing more wild plants (weeds!) to grow within crops, thus providing more resources for higher trophic groups. Alternatively farmers could continue to farm intensively within the main field areas but deliver enhance diversity by planting new habitats around the margins of the cropped fields (which would have to be managed). Two projects are presented to compare the relative merits and challenges associated with these contrasting approaches.

One of the two projects is aimed at exploring the impact of enhancing plant diversity on un-cropped areas of farms. Blocks of 100ha have been identified in 28 arable farms in the south of England. The habitats present in these blocks have been surveyed and the plant, invertebrate and bird species present assessed. A range of new habitats have been established on some farms and their impact on overall biodiversity is being monitored. So far, it appears that the more diverse the range of plant habitats present the greater the plant species diversity. There are also indications that greater plant species diversity is linked to more invertebrate species. The alternative approach of reducing herbicide inputs in fields so as to retain more weed species within crops, known to provide food for invertebrates and birds, has also been explored in a second project. Reduced intensity weed management in winter cereals is possible but the retention of forb species that do not threaten crop yields, whilst at the same time avoiding build up of grass weeds, poses severe challenges to weed management. This approach is also less popular with farmers and may only be appropriate for fields with a low grass weed burden as part of subsidised agri-environment schemes.

Thus, the delivery of a more multifunctional agriculture will pose increasing questions for weed management that will have to be addressed. These two projects are beginning to provide some answers.

534. Demanding Weeds in Arable Fields – is it a Feasible Approach? Baerbel Gerowitt¹, Lena Ulber², Horst-Henning Steinmann²; ¹University of Rostock, Rostock, Mecklenburg-Vorpommern, Germany; ²University of Goettingen, Goettingen, Niedersachsen, Germany

In European countries agri-environmental schemes were introduced to reduce negative side effects of agriculture and to promote biodiversity. However, these schemes are often reviewed as ineffective because measures are not regional adjusted and incentives for farmers are scarce.

People, not involved in the agricultural sector, argue whether subsidies are justified. Therefore concepts are needed to develop new schemes with a focus on achievements rather than a focus on measures.

Plants can be seen as elements of biodiversity and as well as indicators for biodiversity, since fauna benefits from plant diversity in several ways. An approach for a regional outcome-based system for rewarding ecological services of agriculture was developed by an interdisciplinary working group.

The approach is based on the principle of demand and supply. Thus, demand need to be expressed and supply need to be possible. In arable situations, the approach focuses on weeds.

Via a tender procedure, a set of ecological services is announced. These services are represented by different levels of species richness. Farmers are asked to fulfill these services on parts of their land. Farmers who are willing and able to participate have to describe the level of species richness they aim at. Additionally they have to mention the price to compensate for. A regional board as the steering committee of the concept defines details of the demand. By this way, local preferences and scarcity of diversity can be considered. Principles of market economy are introduced. The procedure for weeds in arable fields will be described based on a regional example in Germany.

535. Initial Results from Studies of the Role of Habitat Diversity on Arable Farms on the Diversity of Plants and Invertebrates. Peter Lutman¹, Jonathan Storkey¹, John Holland², Jim Orson³, Dan Chamberlain⁴; ¹Rothamsted Research, Harpenden, Herts, United Kingdom; ²Game Conservancy & Wildlife Trust, Fordingbridge, Hampshire, United Kingdom; ³The Arable Group, Morley, Norfolk, United Kingdom; ⁴British Trust for Ornithology, Thetford, Norfolk, United Kingdom

Agriculture in the 21st Century needs to be multifunctional, delivering both food and environmental value. In Europe the issue of how to reduce the environmental impact of agriculture is of increasing importance and the challenge of reconciling profitable crop production with biodiversity is high on the research agenda. One option that is popular with farmers is to spatially separate crop production from the provision of habitat for wildlife. The rationale for this approach is that most intensively managed crops contain little biodiversity (only crops and a few weeds) and so field centres can be dedicated to production, leaving field margins and other un-cropped land as refuges for wildlife. This paper reports on the preliminary results of a project started in 2006 exploring the potential for optimising the value of un-cropped land for invertebrates, birds and mammals. The delivery of increased abundance of these higher trophic groups depends on providing adequate plant resources. This needs to be balanced with the risk of encouraging

populations of pernicious arable weeds. Plant communities were surveyed in crops and a range of contrasting types of un-cropped land across 28 farms in Southern England. Sampling areas included crops, farmer managed field margins and areas sown with prescribed seed mixes to provide habitat for invertebrates or birds. There was large variation between farms in plant species richness and this was reflected in differences in the numbers of bee and butterfly species recorded. Cropped areas made a relatively small contribution to farm scale plant species richness. The distribution of arable weeds between different habitat types varied between species. Annual ruderal species, including *Stellaria media*, *Viola arvensis* and *Senecio vulgaris* were only found in crops and in un-cropped land that had recently been cultivated. Other, more competitive species, including *Cirsium arvense*, *Galium aparine* and *Anisantha sterilis* were found in a wider range of habitats. While the occurrence of arable weeds on un-cropped land may be a concern in terms of the risk of invasion into neighbouring crops, some of these species may also be providing valuable resources for higher trophic groups. Understanding the contrasting response of weeds to the management of un-cropped land and the extent of their contribution to farm scale biodiversity will be valuable for reconciling crop production with conservation.

536. Influence of Crop Rotation Intensity and Weed Control on Weed Species Richness and Composition in Winter Wheat Fields. Lena Ulber¹, Horst-Henning Steinmann¹; ¹Georg-August-University of Goettingen, Goettingen, Niedersachsen, Germany

There is considerable evidence that increased weed diversity may enhance stability of agro-ecosystems. Since weed communities are influenced by the crop rotation system, an enhanced temporal diversification of crops in a rotation may facilitate increased weed species diversity.

The study aims to investigate the effect of crop rotation at three intensity levels (organic, conventional diverse, conventional short rotation) as well as weed control treatment (treated vs. non-treated) on species richness, cover and composition of weeds in winter wheat.

During an on-farm trial in Germany, 24 winter wheat fields were surveyed. Fields were grouped into eight triplets each consisting of three fields assigned to one of the following crop rotation intensities:

- (1) organic crop rotation with 3-7 different crops (O);
- (2) conventional short crop rotation with ≤ 3 different winter crops (CS);
- (3) conventional diverse crop rotation with $\geq 3-5$ different summer and winter crops (CD).

Within each field, two paired plots (each 10 m x 10 m) were installed in the field centre of which one plot received no weed control treatment (NT) whereas the other was treated (T) with herbicides or mechanical weed control.

During a vegetation survey, weed species were identified and percentage cover was determined.

To compare weed species richness and cover between the different treatments levels, a linear mixed model was fitted using restricted maximum likelihood. Differences in weed species composition and treatment-species associations were analysed by means of canonical discriminant analysis (CDA).

A total of 98 weed species was identified during the survey. Total species number was higher in O than in CD and CS (77 species compared to 70 and 54, respectively). At plot level, species richness was significantly influenced by crop rotation intensity but no significant difference in species richness between CD and CS was found for both T- and NT-plots. The effect of weed control treatments on species richness was significant in CD and CS but not in O.

Crop rotation intensity had no significant effect on weed cover. Weed control treatments significantly reduced weed cover in CD and CS but had no effect in fields of O. Significant interactions between crop rotation intensity and weed control treatment indicated no differences in cover between both O-NT and O-T and CD-NT and CS-NT. Treated plots in CD and CS differed significantly from all other treatments.

In the CDA analysis, three main clusters of treatment groups were distinguished. The first axis separated conventional from organic crop rotations. The second axis segregated between conventional plots with and without weed control treatment. For organic fields, O-T and O-NT were grouped together and associated with most of the species included in the CDA.

Crop rotation intensity and weed control treatment were found to be important determinants of weed communities. However, to further investigate the influence of crop rotation intensity on weed vegetation in conventional systems, other factors such tillage, planting date and management history will be incorporated in future analyses.

537. A Weedy Rice Workshop: Towards the Development and Establishment of a Global Weedy Rice Initiative. Bernal Valverde¹; ¹Investigación y Desarrollo en Agricultura Tropical, S.A., Alajuela, Costa Rica

Weedy *Oryza* species, particularly *O. sativa* (feral forms of the cultivated species) infest rice fields throughout the world and cause severe yield and quality losses. Being taxonomically identical or very closely related to the crop, weedy rice is extremely difficult to control by conventional means and is on the increase as more land is transformed from transplanting to direct seeding. New technologies, particularly the development and commercial introduction of herbicide-resistant varieties, offer new opportunities to selectively manage weedy rice but pose the risk of aggravating the problem through the movement and establishment of the resistance genes in weedy rice by

gene flow and introgression. This workshop provides an opportunity to discuss new developments about weedy rice and to determine how to launch a Global Weedy Rice Initiative. The Initiative will develop an effective network for the systematic and coordinated study of weedy rice, the dissemination of information, sharing of biological material, and a discussion forum to better understand and manage this important weed in the most relevant human food crop.

538. Weedy Rice (*Oryza sativa* L.) Evolution in Japan as a Model for Comparative International Studies of Weedy Rice. Jun Ushiki¹, Maiko Akasaka¹, Hiroaki Watanabe¹, Duncan Vaughan²; ¹National Agricultural Research Center, Tsukuba, Ibaraki, Japan; ²National Institute of Agrobiological Sciences, Tsukuba, Ibaraki, Japan

Rice first evolved in China and from there was introduced into Japan more than 2000 years ago gradually spreading across Japan from the south to the north. Red japonica rice was cultivated in Japan in the 7th and 8th century. In the 14th and 15th century red indica rice was introduced from China. But towards the end of the 19th century most red rice disappeared, except as speciality rice or weedy rice. Indica rice ceased to be cultivated in Japan until recently when it was introduced briefly in a limited area for forage use.

Two prefectures in Japan where weedy rice occurs have been studied in detail, Nagano and Okayama, and will be discussed. In Nagano the evolution of weedy red rice biotypes has been studied over 40 years. Weedy rice has spread from a restricted area in one valley in the north of the prefecture where dry direct seeding was practiced to areas where wet direct seeding has become common. During this 40 years period the predominant biotype of weedy rice changed from late heading, longer culmed biotypes to earlier flowering, shorter culmed biotypes. In addition, dormancy of weedy rice increased. The recently evolved predominant weedy rice, that is difficult to distinguish from the main cultivated variety until its seeds shatter, escapes hand weeding the main method to control weedy rice. Consequently now biotypes of Nagano weedy red rice can survive even in a transplanted system.

In contrast to Nagano, Okayama weedy rice has a white pericarp. Weedy rice has a long history and is widely distributed in Okayama, a prefecture that still grows varieties bred before the 1950s. Presence of weedy rice in Okayama probably reflects the dry seeded rice culture that has been practiced there on a large scale since the 1940s. Morpho-physiological and genetic characterization of Okayama weedy rice reveals most japonica weedy rice has the same genetic profile as two old japonica varieties, Akebono and Asahi. In addition, in the past Okayama grew indica varieties for forage and today in restricted areas indica weedy rice can be found.

Analysis of weedy rice from Okayama and Nagano reveals they have the non-shattering allele of *sh4*, the main non-shattering allele, but the shattering allele of *qSH1* that distinguishes between the degree of shattering of indica and japonica varieties. It seems that the genetics of shattering in weedy rice is complex and that the cloning of other QTLs associated with shattering would enhance our understanding of de-domestication of rice.

Dormancy in weedy rice is highly variable both within and among biotypes. Many individuals of japonica weedy rice plants from one district of Okayama had no germination after 200 days. However, all individual weedy rice from other areas in Okayama and Nagano germinated after 200 days and many have no dormancy.

Weedy rice can be categorised on two axes; indica/japonica differentiation and wild/cultivated characteristics. Japanese weedy rice shows a trend towards japonica/wild characteristics. Weedy rice from other regions of the world shows different trends. Comparing seed propagation characteristics of weedy rice most Japanese weedy rice has less dormancy than weedy rice from Brazil and the US. This may reflect indica and japonica characteristics of weedy rice and/or different cultural practices such as continuous cropping in Japan rather than rotation in the US and Brazil.

These studies provide a basis for international comparison of weedy rice evolution. Weedy rice evolves locally in response to different sets of selection pressures. Developing, internationally agreed, standard descriptors and procedures for studying weedy rice the principal characteristics of weedy rice that will enable their appropriate control can be elucidated. With good data sets computer modelling may also provide tools to predict if and what type of weedy rice will emerge and assist in preventive measures.

539. Genetics of Weedy Rice Traits: Seed Dormancy and Red Pericarp Color. Xing-You Gu¹, Jie-Qiong Lou¹, Michael Foley²; ¹South Dakota State University, Brookings, SD, United States of America; ²USDA-ARS, Fargo, ND, United States of America

Seed dormancy contributes to persistence of weeds in agro-ecosystems by distributing germination over time. We developed weedy rice (*Oryza sativa*) as a model system to elucidate genetic, evolutionary, and molecular mechanisms regulating seed dormancy. Weedy rice (including red rice) evolved divergently from cultivated rice (*O. sativa* and *O. glaberrima*) for the dormancy trait in human disturbed environments. Seed dormancy in our system associates with the seed shattering, awn, black hull color, and red pericarp color characters and the associations contribute to the divergence. Seven and eight quantitative trait loci (QTLs) controlling seed dormancy were identified from a tropical and a temperate weedy rice accession, respectively. These QTLs interacted with each other (epistasis) or with

environmental factors during seed development to regulate variation in seed dormancy. Many dormancy loci are identical in genomic position, but different in phenotypic effect between the two types of weedy rice. Most of the QTLs link with the QTLs for the associated characters and linkages could not be separated by phenotypic selection for seed dormancy over several generations. One major QTL (qPC7) that was identified for red pericarp color, mapped to the same position as the red pericarp color gene Rc, and tightly linked to the dormancy loci qSD7-1. Fine mapping of the qSD7-1 to qPC7 region narrowed these two QTLs to the Os07g11020 gene locus, which provided the first evidence that association between seed dormancy and red pericarp color is caused by pleiotropy, rather than linkage, in weedy red rice. This dormancy gene also has a pleiotropic effect on seed weight. We map-based cloned the qSD7-1 dormancy gene and the genomic sequence is annotated as a predicted bHLH transcription factor, with a 14-bp deletion in exon 7 accounting for the natural variation in the aforementioned traits. We are using microarray analysis to determine if the qSD7-1 dormancy gene regulates the pleiotropic effects on dormancy and red pericarp color through same or different physiological pathways.

540. Hybridization and Introgression between Cultivated and Weedy Rices: its Environmental Consequences. Bao-Rong Lu¹; ¹School of Life Sciences, Fudan University, Shanghai, China (Peoples Republic of)

Weedy rice (*Oryza sativa* f. *spontanea*) infests rice fields in both tropic and temperate rice cultivation regions worldwide. It becomes the third or fourth most noxious weeds in paddy fields, particularly in regions where direct seeding or no-till is replacing rice transplanting practices. Weedy rice successfully thrives and extends in paddy fields, which, to a great extent, is owing to its excellent adaptation to the agronomic practices and ecological conditions, in addition to its heavy seed shattering and intense seed dormancy, through which it can survive chronically in soil seed banks. Weedy rice can mimic morphological and physiological characteristics of cultivated rice (*Oryza sativa*) grown in the same field. This makes the control of weedy rice extremely difficult once it infests a rice field, causing problems of rice yield and quality reduction. The rapid adaptive evolution of weedy rice may have played an essential role in its successful invasion to the managed agro-ecosystems. In theory, hybridization and introgression with the concomitant rice varieties may closely associate with the rapid adaptive evolution of weedy rice, and through the recurrent hybridization and introgression, elite crop genes can be continuously incorporated into weedy rice populations. It is proven that weedy rice can easily hybridize and introgress with cultivated rice because of its conspecific status with cultivated rice. There is a general concern that

gene flow from genetically modified (GM) rice through outcrossing may complicate the adaptive evolutionary process of weedy rice owing to the novel and unique function of transgene(s), e.g. herbicide and insect resistance from GM rice. The unexpected change of evolutionary potential and process may largely increase the difficulty of controlling a weedy rice population that picks up transgenes resistant to biotic and abiotic stresses, causing unwanted environmental consequences. Therefore, assessment of environmental consequences caused by (trans)gene flow to weedy rice is important for sustainable agriculture. Spontaneous gene flow between cultivated and weedy rices has been reported in a number of locations with a considerable frequency. Our experiment aimed to measure the mating system of weedy rice populations occurring in different rice fields indicated variable outcrossing rates between 0.4~12%, indicating the inevitability of transgene flow to weedy rice. Comparative analysis of artificial hybrids and progenies of weedy rice with insect resistant GM rice showed obvious fitness benefit for some traits e.g., number of seeds per plant and 1000-seed weight with insect pressure but fitness cost for the same traits without insect pressure. Further fitness studies of hybrids and progenies with or without a transgene under different environments will shed meaningful light for understanding the role of hybridization and introgression in weedy rice adaptive evolution determining environmental consequences.

541. Evolution of Herbicide Resistance in U.S.A. Weedy Rice: A Confluence of Genetic, Ecological, Agronomic and Economic Forces. Nilda Burgos¹, Vinod Shivrain¹, David Gealy², Robert Scott¹, Yong Kuk³, Marites Sales¹, Kenneth Smith¹; ¹University of Arkansas, Fayetteville, Arkansas, United States of America; ²USDA-ARS, Dale Bumpers National Rice Research Center, Stuttgart, Arkansas, United States of America; ³Suncheon National University, Suncheon, Jeonnam, Korea, South

Weedy rice costs U.S. rice growers about \$300/ha losses annually. About 60% of rice fields are infested with weedy rice. Herbicide-resistant rice technology, Clearfield (CL) rice, was commercialized in 2002 to help manage weedy rice. It was predicted that the technology will be overcome by weedy rice in 5 - 8 yrs because of two concurrent events: (1) gene flow from cultivated rice and (2) selection of naturally tolerant individuals in the population due to the resulting intensive use of ALS inhibitors in rice areas. We are at the threshold of the predicted life span of the technology, yet the acreage of CL rice continues to increase. Significant problems of herbicide-resistant (HR) weedy rice had not yet occurred. This paper aims to present salient findings from field and gene sequencing experiments in relation to the current status of herbicide resistance evolution in weedy rice. A weedy rice survey and experiments on gene flow, reciprocal crosses, herbicide

response, and ALS gene sequencing were conducted at several locations in the Arkansas Delta and the Main Agricultural Research Center, Fayetteville, Arkansas between 2003 and 2007. The risk of detectable gene flow from CL161 rice to weedy rice ranges from 0 to 1.89% in commercial fields and 0 to 0.25% in miniplots. Gene flow hinges primarily on synchronization of flowering between the crop and weed, which in turn is dependent on the phenology of rice and weedy rice as well as sowing dates. HR-hybrid rice triples the risk of gene flow. These relatively low outcrossing rates should still result in a few thousand resistant weedy rice in fields after a few seasons. However, the evolution of HR weedy rice from gene flow is mitigated by: (1) reduced fitness in the weedy rice crosses, including delayed flowering and reduced fecundity; (2) the intervening winter period when several weed seeds perish by deterioration or fowl predation; (3) the growers' attempts at preventing further seed production of outcrosses; and (4) the favorable commodity price of soybean. Rotation with upland crops is the best cultural tool for weedy rice management. Profit margin determines what growers do. Intensive use of imidazolinone herbicides (ALS inhibitors), have selected for resistant weed populations in as early as 4 yrs. Polymorphisms exist at the nucleotide level in the ALS gene of weedy rice populations. The majority of these mutations are inconsequential for resistance, but two accessions were tolerant to the commercial rate of imazethapyr. These harbor a Gly654-Glu mutation, which confers resistance to ALS inhibitors. Increased rice acreage intensifies selection of these mutation events.

542. Innovative Approaches to Manage Weedy Rice: Prospects and Speculations. Jonathan Gressel¹; ¹Assif Strategies Ltd., Yakum, Israel

The simplest method to control weedy/feral rice is herbicide resistant rice bearing a gene not found in weedy rice. This has been achieved by both mutagenesis of the ALS gene to obtain imidazolinone resistant rice or by transforming rice with genes conferring resistance to glyphosate or glufosinate. Alas, experience with the ALS-R rice has educated us that gene flow is rapid to the weedy form, rendering the technology ineffective. Gene flow can theoretically be mitigated by transforming the herbicide resistance gene in a tandem construct where it is flanked by genes conferring low stature (e.g. RNAi or antisense of the gibberellic acid biosynthesis pathway or the GA receptor), RNAi or antisense of the major shattering gene, and/or RNAi or antisense of the major gene controlling secondary dormancy. Thus, hybrids with the weedy/wild forms would have herbicide resistance tightly genetically linked with crop traits, assuring harvesting and not remaining in the field. Additionally, the herbicide resistance construct could contain RNAi or antisense of a gene in the anthocyanin pathway under a

seed specific pathway ensuring lack of color, precluding dockage due to colored seed.

Other more novel concepts could be tested: 1. The same anti-weediness genes described above could be cloned into a multi-copy transposon and transformed into rice or weedy rice, and planted in the field. Genes in multi-copy transposons appear in all F2 and backcross progeny, (unlike chromosomally inherited genes), and thus become dispersed throughout the population, turning the weed into crop rice; 2. The same anti-weediness genes can be cloned into an attenuated virus pathogen of rice. If the crop is herbicide resistant, virus DNA-coated abrasive could be added to the herbicide in post-emergence treatments. Any weedy rice or its hybrids with rice that previously introgressed the herbicide resistance gene would be transformed by the virus to a harvestable, crop-like form, and eliminated from the field or rendered non-competitive. As more genomic differences between rice and its feral/weedy form become known, they too could be utilized in mitigator, transposon, and virus technologies to assure that the weedy feral material remains a small part of the field population.

543. Integrated Weed Management, Integrated Pest Management or Integrated Crop Management? Robert Norris¹; ¹University of California, Davis, California, United States of America

The term Integrated Weed Management, abbreviated to IWM, has been used by weed scientists for about three decades. The concept states that IWM combines cultural, mechanical, biological and chemical weed control tactics into an economically and ecologically acceptable framework. These tactics are essentially the same as those utilized within the framework of Integrated Pest Management, universally known as IPM. Integrated control, which evolved into IPM, was originally proposed nearly 50 years ago. The major difference between IWM and IPM is that the former specifically addresses problems related to weed control, whereas IPM integrates management of organisms in all pest categories. Integrated Weed Management is therefore a subset of the more inclusive IPM. The term IPM has become universally accepted, and is understood by many people. IWM has been used exclusively by weed scientists and is essentially an unknown term outside weed science. Although much of current IPM is restricted to management of one type of pest, often an insect, its goal is to integrate management of organisms belonging to all pest categories. To this end a continuum of IPM integration has been proposed. Use of a single tactic for pest control, such as pesticide application on a strictly schedule basis, is not considered to be an IPM approach. Level I IPM includes monitoring of pest populations prior to initiating management actions, and includes integration of non-chemical methods into the management strategy. Level I IPM is typically targeted

against a single pest, or pest category, and represents most current IPM programs. IWM is at this level. IPM at level II attempts to integrate management of organisms in all pest categories into a single cohesive program. At IPM level II there are situations where use of IWM conducted without considering other pests can be counter-productive in relation to IPM, such as management of certain beneficial insects. Level III IPM attempts to place pest management into the context of wide scale ecological processes; current IPM programs probably do not achieve this level of integration. Because IWM makes no attempt to integrate management of pests other than weeds, its use should be discontinued. The IPM concept is sufficiently robust that the weed science community should work to further the use weed management within the framework of IPM. Integrated Pest Management, and IWM, recognizes cultural management tactics as a component of pest management, such as alteration of planting date, choice of varieties, fertilizer use, irrigation scheduling and adjustment of harvesting schedules. Integration of such practices into IPM programs argues for use of the even broader concept defined by Integrated Crop Management (ICM).

544. Advances in Integrated Weed Management Systems for Cereal Crops. Robert Blackshaw¹, John O'Donovan¹, Ken Harker¹, Hugh Beckie¹; ¹Agriculture and Agri-Food Canada, Lethbridge, Alberta, Canada

Herbicides have been hailed as one of the most important advances in agriculture and they now typically comprise 20 to 30% of input costs in many cropping systems. Despite herbicides providing unparalleled control of weeds there has been an over reliance on their use at the expense of other useful methods of weed management. Farmers cite low and volatile commodity prices, crop injury and herbicide carryover concerns, the increasing incidence of herbicide resistant weeds, and public concern about the environmental and human health effects of pesticides as issues forcing them to reconsider how they manage weeds. Many producers are interested in alternative methods of weed management but are concerned about the risk of adopting such practices when current profit margins are slim and/or the family food supply is dependent on adequate production. Successful long-term weed management requires a shift from simply controlling problem weeds with in-crop herbicides to agricultural production systems that are redesigned to manage weeds at all stages of their life cycle. Such systems should restrict weed emergence, reduce weed growth and reproduction, and minimize weed competition with crops. Research in the last decade has documented that management practices such as reduced tillage, diverse crop rotations, competitive cultivars, higher crop seed rates, altered seed dates, specific fertilizer placement and timing, intercropping, silage crops, and green manure or cover crops can effectively manage

weed populations, especially when used in conjunction with targeted but limited herbicide use. Research has also clearly indicated that the effectiveness and consistency of these non-herbicide weed management practices greatly increases when three or more of these practices are simultaneously employed. For example, a western Canadian study found that the combination of early seed date, higher crop seed rate and subsurface-banded fertilizer within a zero tillage cropping system resulted in a highly effective integrated weed management (IWM) program for wheat and barley. It was noteworthy that the weed seedbank was not greater after four continuous years of using 50% herbicide rates within this IWM system. Similar results have been attained with corn in the USA. Weed suppression was six fold greater when narrow row spacing, higher corn populations, and banded nitrogen fertilizer were combined as compared with any single cultural practice utilized alone. Once these IWM systems are implemented herbicides can then be used in a more targeted and sustainable manner, preserving their usefulness for decades to come. Producers are gaining confidence in the merits of these agronomic practices in terms of sustainable weed management and are gradually adopting these integrated systems on their farms. Further research and extension efforts are required to ensure that these IWM systems are biologically and economically robust to facilitate greater adoption at the farm level.

545. Weed Science Research on Integration for Improving Weed Management. Ze Pu Zhang¹; ¹Chinese Academy of Agricultural Sciences, Beijing, China (Peoples Republic of)

More than 30 species are the important weeds infesting in rice wheat, maize, soybeans and cotton fields which account for about 80% of the 123 million hectares of the total cultivated area in China, about 40 million hectares of cropland are heavily infested by weeds. The herbicide application area has been steadily enlarged up to more than 60 million hectares. Chemical weed control has retained high crop yields but it has caused some crop and environmental problems, for maintaining favorable ecological conditions, integrated weed management are adopted. For preventing weed occurrence or alleviating weed damages, studies on improving and exploring innovation of utilizing agricultural technical measures to weed management are enhanced. The studies are carried on: integrating chemical control with tillage under an intensification; enhancing crop competitiveness through planting crop cultivar relatively at high seeding rates for reducing the impact of weeds on crop yield; approaching the weed-economic threshold to provide information to make long-term management decision for better weed control and use various options in herbicide application for saving operating costs; improving herbicide application techniques through defining minimal dosage, critical application time, good type of herbicide and its formula-

tion and improving spray implements for raising application quality and raising spray efficacy for economizing the costs in crop production; monitoring the herbicide residues in the agricultural regions to propose a system for controlling the risk of environmental pollution; attaching importance to the new cultivation technologies adopting the methods of crop rotation and cropping system; using allelopathy as a tool for integrated weed management; using biotechnology for improving weed management, inducing into herbicide resistant crops to extend the areas to be applied with herbicides; identifying and regulating the techniques of gene configuration and evaluating the effect on non-target objectives, environmental safety as well as economic benefits; preventing and delaying the development of herbicide resistant weeds, proceeding research on the level of weed resistance to the herbicides, the relationships between agronomic practices and the development of herbicide resistance, and the mode of action of herbicides and screening new effective herbicides for controlling resistant weeds.

546. Agroecological Approaches to Managing Weeds in Eggplant using the Stale-Seedbed Technique. Aurora Baltazar¹, Jhoana Opena¹; ¹University of the Philippines, Los Banos, Laguna, Philippines

Farmers in the Philippines control weeds in their vegetable fields by handweeding from three to as much as 15 times (weekly) in a cropping season, increasing weed control inputs up to 20% of production costs. A cheaper agroecological approach to reduce weed populations as well as reduce production costs is through the stale-seedbed technique. Consisting of two extra harrowings after land preparation, this method allows weed seedlings to emerge which are then killed with a second harrowing. It flushes out and depletes weed seed populations in the soil, reducing the amount of weed growth and the number of handweedings required to provide season-long weed control. Studies were conducted in five farmers' fields in Batangas province, Philippines from May to September 2006 to compare efficacy of stale-seedbed technique with farmers' practice of weekly handweeding against weeds in five eggplant cultivars. Weed density and fresh weight, time spent in handweeding, cost of weed control inputs, and crop yield at harvest were recorded. The most dominant species in all five fields were *Cyperus rotundus*, *Amaranthus spinosus* and *Echinochloa colona*. Yields of the five cultivars from stale-seedbed plots were similar to or higher than those of cultivars treated with weekly handweeding. Although yields did not differ much between the two treatments, weed control costs in the stale-seedbed plots were 56% lower and total production costs 30% lower than those in plots with weekly handweeding. This increased net profits in the stale-seedbed plots by two- to four-fold higher than net profits in the farmers' practice plots. Our data suggest that two

harrowings prior to planting followed by two handweedings during the cropping season controlled weeds as efficiently as the farmers' intensive weekly handweedings throughout the season, which reduced weed control costs and resulted in net profits two to four times higher than that of the farmers' practice. Our data also indicate that farmers do not have to keep their fields weed-free to obtain high yields and net profits.

547. Winter Annual Weeds as Alternative Hosts for Soybean Cyst Nematode. William Johnson¹, Earl Creech², Valerie Mock¹; ¹Purdue University, W. Lafayette, Indiana, United States of America; ²University of Nevada, Fallon, Nevada, United States of America

Soybean cyst nematode (*Heterodera glycines* Ichinohe; SCN) has been reported to be the most detrimental plant pathogen in U.S. soybean production and it has the ability to parasitize a broad-range of host plants, encompassing nearly 150 legume and non-legume genera representing 22 plant families. Several SCN host species are common winter annual weeds in U.S. soybean production fields and include purple deadnettle (*Lamium purpureum* L.), henbit (*Lamium amplexicaule* L.), field pennycress (*Thlaspi arvense* L.), shepherds-purse [*Capsella bursa-pastoris* (L.) Medik], common chickweed [*Stellaria media* (L.) Vill.] and smallflowered bittercress (*Cardamine parviflora* L.). Challenges associated with managing SCN are its ability to survive in the absence of a host, to adapt to SCN-resistant soybean varieties and weed hosts, and to reproduce under a wide range of environmental conditions. Management systems for SCN include rotation to a non-host crop and use of SCN resistant soybean varieties but fail to address winter annual weed management. Failure to manage winter annual weeds has provided a niche for SCN reproduction and population density increase in the absence of soybean. Weather station data from the Midwestern U.S. indicate that temperatures are adequate for SCN to complete a life cycle in the fall and/or spring on compatible winter annual weeds when soybean is not present in the field. We have shown that in the field, SCN can reproduce on purple deadnettle and henbit in the fall after soybean is harvested and as a composite, winter weed hosts of SCN were found in 93% of SCN-infested fields at an average density of 151 plants/m². A subsequent field survey of production fields in Indiana, Illinois, and Ohio showed that all growth stages of SCN were found to be associated with henbit and purple deadnettle at both fall and spring sample timings. SCN juveniles were generally found at highest abundance in the spring. SCN cyst and egg production was also widespread and occurred to a much higher degree during the fall than the spring developmental period. These results indicate that management tactics designed to minimize the impact of winter weeds on SCN population density would probably be most effective if conducted in the fall, where the majority of

SCN reproduction occurred. However, spring populations of winter annual weeds that are harboring SCN juveniles may result in additional SCN reproduction and population increase if the weeds are not controlled in a timely manner prior to planting. Indeed, we have shown that after hatching, SCN juveniles can survive for at least 20 days at 0 degrees C inside the roots of a winter annual weed host and continue development when transferred to warmer temperatures. Therefore, in a field environment where the fall or spring alone may not be sufficient for SCN to complete a reproductive cycle on winter annual weeds, the nematode may be able to reproduce by combining the fall and spring developmental periods. Limited research has been conducted to address the effects of winter weed management tactics on SCN dynamics and reproduction in the field. We have shown that in fields with relatively low henbit and purple deadnettle densities (less than 75 plants/m²), SCN population density was reduced by crop rotation and use of an SCN-resistant soybean cultivar, however, SCN density was not influenced by winter annual weed management when winter weed management operations were conducted in mid to late October. However, the results generated from this research and other studies suggested that the timing of winter annual weed removal will play an important role in influencing SCN population density and requires further research.

548. An Integrated Strategy for Perpetual Management of *Nassella trichotoma*. Aaron Simmons¹, David Kemp¹, Warwick Badgery², David Michalk²; ¹Charles Sturt University, Orange, NSW, Australia; ²NSW Department of Primary Industries, Orange, NSW, Australia

Control of *N. trichotoma* in Australian native pastures is particularly difficult due to limitations imposed by low site productivity, limiting opportunities to generate incomes, steep and rocky slopes, and the adverse effects of herbicides on valuable grass species. This weed species now ranges over 1m ha in south-eastern Australia, seed is widely dispersed and without careful management new infestations are to be expected. Research findings are enabling the framework of a strategy for long-term management of *N. trichotoma* in native pastures to be developed. The framework focuses on the strategic grazing of pastures that can increase the perennial grasses content of the pasture and provide competition against seedlings trying to survive their first summer. This competition can be effective by maintaining as little as 0.5t DM/ha of perennial grass biomass over summer, this level will depend upon site characteristics and in some instances 1.5t DM/ha may be more appropriate. Increasing content of desirable perennial grasses (to >60% of total biomass) reduces the bare ground in Autumn limiting opportunities for *N. trichotoma* seedlings to establish.

The discriminate use of herbicides is also a feature of the framework. Broad acre use of both flupropanate and

glyphosate has to be questioned because of the collateral damage they inflict on valuable grass species. Eradicating existing valuable grasses results in more bare ground that allows seeds to germinate and the absence of competition provides ideal conditions for seedlings to survive. In native grass areas over-sowing with competitive pastures is uneconomic. Typically the broad acre use of herbicides needs to be repeated every 3 to 5 years, forever. Spot spraying with either herbicide is preferred as it minimizes collateral damage, however high labor costs make it uneconomical for the use of spot spraying to control large and/or dense infestations.

Gaps in knowledge currently exist and research to address this is currently being done and will be discussed. Limiting seedling recruitment through plant competition is reasonably advanced, but ways of killing mature plants ecologically are not yet well understood. Novel methods to better manage the biology of the system to limit *N. trichotoma* are being explored. Ultimately any useful methods are likely to require continual maintenance.

549. Management of *Striga hermonthica* (Del) Benth in *Zea mays* with *Sesamum indicum* and *Glycine max* as Intercrops and Nitrogen Fertilization in Benue State, Nigeria. Rosemary Ahom¹, Okoronkwo Okereke¹, David Chikoye¹; ¹University of Agriculture Makurdi, Makurdi, Benue State, Nigeria

Zea mays ranks second after *Oriza sativa* in importance in Benue State, Nigeria. *Striga hermonthica* Del. Benth is a noxious weed which is the most serious constraint to *Z. mays* production in West Africa. Yield losses due to *S. hermonthica* in *Z. mays* may reach 100 % (total crop failure) for heavily infested fields and this can be very devastating to the small-scale low income farmers. Manual weeding is the only *S. hermonthica* control method practiced by farmers in Benue State. This method may reduce *S. hermonthica* stands/unit area but crop yield advantages are not significant. Use of tolerant/resistant crop varieties, trap and intercropping, fertilizer application can reduce *S. hermonthica* damage and fit easily into the cropping system of the low- input farmers. However, these methods have not been clearly tested in combination (Integrated Striga Management = ISM) to attract the attention of farmers in Benue State and therefore adoption of these techniques is not widespread.

The objectives of this study were:1. to determine the susceptibility or tolerance of two *Z. mays* varieties intercropped with *Sesamum indicum*(sesame) or *Glycine max*(soybean) to *S. hermonthica* infestation.

2. to determine the effect of nitrogen fertilization on the growth of *S. hermonthica* in *Z. mays* intercropped with *S. indicum* or *G. max*.

Field trials were conducted on a naturally heavily Striga hermonthica- infested field in Benue State, Nigeria to determine the effect of intercropping and nitrogen (N)

fertilization on *S. hermonthica* infestation on two varieties of *Zea mays* (P.Ex.Y and 9022-13STR) intercropped with either *G. max* or *S. indicum* at three levels of N application (0, 60, 120/KgNha). The layout was a factorial in Randomized Complete Block Design (RCBD) with three replications. It was observed that the height of *Z. mays* was significantly ($P=0.05$) higher in sole *Z. mays* than in the intercrops and at 120/KgNha compared to 0/KgNha and 60/KgNha. Intercropping *Z. mays* with either *G. max* or *S. indicum* delayed emergence, flowering and fruit maturity in *S. hermonthica*. Subsequently the severity of *S. hermonthica* infestation was also significantly ($P=0.05$) reduced in the intercropped plots. *Z. mays* grain yield was increased with *Z. mays*/*G. max* intercrop but not with *Z. mays*/*S. indicum* intercrop. *S. indicum* suppressed *S. hermonthica* more than *G. max* but at the same time depressed *Z. mays* grain yields. *Z. mays* grain yield (0.59tonnes/ha) was higher at 120/KgNha compared with the yield at 0/KgNha and 60/KgNha (0.34tonnes/ha and 0.43tonnes/ha, respectively).

In conclusion, the advantage of using an ISM package to reduce the severity of *S. hermonthica* infestation was successfully demonstrated to farmers where *Z. mays* was intercropped with *G. max*. Because *S. indicum* which was more efficient than *G. max* in suppressing *S. hermonthica* also depressed *Z. mays* yields, it was recommended that farmers in Benue State use *S. indicum* as a preceding crop to help clean up the field before planting *Z. mays*. It was also recommended that farmers apply up to 120/KgNha (if available and affordable.) to reduce *S. hermonthica* damage in *Z. mays*.

550. Effect of Rice Establishment with Drumseeder on Growth of Weeds and Yield of Rice. Anuruddhika Abeysekara¹; ¹National Rice Research and Development Institute, Kurunegala, North Westernpro, Sri Lanka

Weed management is one of the major constraints of rice growers in Sri Lanka and yield losses of 40% - 50% of the yield losses are not uncommon. Ninety percent of the rice area grown in Sri Lanka is sown with pre-germinated seeds manually broadcast on to puddled soils. In efforts to achieve good crop establishment and suppress weeds farmers use to a high rice seed rate of 200-400 kg/ha and herbicides. With the aim of reducing costs and losses to weeds experiments were conducted at the Rice Research and Development Institute, Sri Lanka during 2006-2007 to evaluate the drum seeder for row seeding of pre-germinated seed and alternative weed management options. Treatments compared row seeding with drum seeder and manual broadcasting and three weed control methods, viz. no weeding, hand weeding and use of herbicides, and treatment combinations were compared to row seeding together with mechanical weeding. Except weed control all the other management practices followed the recommendation of department of agriculture. The results show that

weeds were effectively controlled by herbicides in both establishment methods, as did the rotary weeder in the row seeded treatment. Least grain yield and highest weed numbers and biomass were recorded from the no weeding plots. Irrespective of the weed control methods grain yields were significantly greater with row seeding than with drum seeder. The principal weed species did not differ between establishment methods. However, the higher number and biomass of broad leaf weeds were obtained in row seeded establishment in no weeding treatments. The drum seeder had the advantages of enabling a lower seed rate (70 kg/ha) compared to recommended rate for manual broadcasting (100 kg/ha) and it also allowed mechanical weeding which helps reduce reliance on herbicide. Based on these results, drum seeders appear to be an attractive alternative to broadcasting seed for rice farmers in Sri Lanka.

551. Herbicide Resistant Weeds: Global Scale and Impact. Ian Heap¹; ¹WeedSmart LLC, Corvallis, Oregon, United States of America

The International Survey of Herbicide-Resistant Weeds currently lists 316 herbicide resistant weed biotypes. The majority of these cases are weeds resistant to one or more of seven herbicide modes of action; ALS inhibitors (95), Photosystem II inhibitors (66), ACCase inhibitors (35), Synthetic Auxins (26), Bipyrillidiums (23), Ureas and amides (21), Glycines (13), and Dinitroanilines (10). Weeds with resistance to PSII inhibitors, Synthetic Auxins, and Bipyrillidiums are common but in general of little economic significance at present. ALS inhibitor and ACCase inhibitor-resistant weeds are the most widespread and have the greatest economic impact on crop production globally. The most serious herbicide-resistant weed situations are in rice production in Asia and South America and wheat production in Australia and Canada. *Echinochloa* spp. with resistance to ALS inhibitors, chloroacetamides, ureas and amines, thiocarbamates, and ACCase inhibitors present the greatest economic threat in rice. In addition many broadleaf weeds have evolved resistance to most of the rice herbicides, particularly the ALS inhibitors, leaving growers with few alternatives. Unless companies develop new herbicides for rice the situation will become dire over the next 10 years. *Lolium* spp., *Avena* spp., *Foxtail* spp., *Phalaris* spp., and *Alopecurus myosuroides* have evolved resistance in cereals to most grass herbicides (esp. ACCase and ALS inhibitors) over large acreages in over 25 countries, including Australia, Canada, the USA, and European countries. The boom in soybean production in Brazil over the last 10 years has been reliant on intensive herbicide use. With 22 herbicide-resistant weed biotypes Brazil has more resistant weeds than any other South American country. ALS inhibitor-resistant weeds are of considerable economic importance, including *Bidens pilosa*, *Bidens subalternans*, *Cyperus difformis*, *Euphorbia heterophylla*, *Fimbristylis miliacea*, *Parthenium hysteropho-*

rus, *Raphanus sativus*, and *Sagittaria montevidensis*. *Euphorbia heterophylla* is of particular concern as it has also evolved resistance to glyphosate and PPO inhibitors. With the recent introduction of glyphosate-resistant soybean (officially 2005, illegally since 2000) the concern for selection of glyphosate-resistant weeds is similar to that of US soybean growers. At present there are four glyphosate-resistant weeds in Brazil. *Lolium multiflorum*, *Coryza bonariensis*, *Coryza Canadensis* and *Euphorbia heterophylla* have all evolved resistance to glyphosate in soybean in Brazil. *Euphorbia heterophylla* is presently the most important, but none cover great acreage or are of great economic importance.

The introduction of glyphosate-resistant crops in 1996 changed crop production in the USA. The first glyphosate-resistant weed found in a glyphosate-resistant crop is *Coryza canadensis* which first appeared in 2000 and now infests more than 300,000 ha. The appearance of glyphosate-resistant *Amaranthus palmeri*, *Amaranthus rudis*, *Ambrosia artemisiifolia* and *Ambrosia trifida* present the current greatest economic threat to corn, soybean and cotton production in the USA. The decline in discovery and registration of new herbicide modes of action over the past 15 years is of great concern to all dealing with herbicide-resistant weeds. To get precise information for each weed and country go to <http://www.weedscience.org>.

552. Comparison of Pinoxaden's Resistance Profile with other ACCase Inhibitors. Shiv Kaundun¹, Richard Dale¹, Amy Lycett¹; ¹Syngenta, Bracknell, Berkshire, United Kingdom

The options for the chemical control of grass weeds in small grain cereals crops are limited and strongly rely on modern post-emergence herbicides inhibiting acetolactosynthase and acetyl coA carboxylase. Due to their high efficacy and long term extensive use, resistance has evolved to both modes of action in key grass weeds, mainly via enhanced metabolism and/or target site insensitivity. In spite of resistance evolution, these post emergence herbicides remain very effective on a vast majority of populations worldwide. Understanding the mechanisms of resistance and subsequent development of robust methodologies for the early detection and tackling of resistance is paramount for their long term sustainable use. In this respect we have investigated the resistance profile of Syngenta's new phenylpyrazolin ACCase inhibitor, pinoxaden (Axial[®]) and compared it with existing aryloxyphenoxypropionates (FOP) and cyclohexanedione (DIM) ACCase herbicides.

The study was based on 36 resistant *Lolium* sp. populations (Australia) and 14 *Avena* sp. populations (UK). The efficacy of five different ACCase inhibitors was studied under glasshouse conditions and the ACCase target gene from individual resistant and sensitive plants was also sequenced and/or fingerprinted with dCAPS

methodology for mutations causing resistance to ACCase herbicides. Nineteen of the 36 *Lolium* populations contained the broad resistance I1781L mutation and this affected the efficacy of pinoxaden. On the other hand pinoxaden provided excellent levels of control on the standard metabolic resistant biotype AUS97 as well as other populations not containing known strong FOP-DIM mutations. Overall and based on a principal component analysis of 36 weed populations and 5 ACCase inhibitors, pinoxaden aligned more closely to the DIM herbicides than the FOPs. Out of the 13 resistant *Avena* populations tested, all showed resistance to clodinafop and five to tralkoxydim, yet all were totally controlled with pinoxaden. Seven of the *Avena* populations contained FOP-specific mutations at ACCase positions 2027, 2041 and 2096. Resistance to clodinafop in the other populations appears to be due to metabolism affecting tralkoxydim also. In conclusion based on the *Lolium* and *Avena* populations studied, pinoxaden showed a resistance profile closely resembling a strong DIM such as sethoxydim and cycloxydim rather than a cereal safe FOP or tralkoxydim. Being safe for use in cereals it constitutes a herbicide of choice for the control of certain types of resistant grasses. Having determined its resistance profile, DNA based methods have been established to quickly identify mutations affecting pinoxaden and thus ensure its long term sustainable use in small grain cereal crops.

553. Modelling Proactive Glyphosate Resistance Management in US Cropping Systems with Glyphosate-Resistant Crops. Paul Neve¹, Jason Norsworthy², Kenneth Smith², Chuck Foresman³, Les Glasgow³, Ian Zelaya³; ¹University of Warwick, Wellesbourne, Warwickshire, United Kingdom; ²University of Arkansas, Fayetteville, Arkansas, United States of America; ³Syngenta Crop Protection, Greensboro, North Carolina, United States of America

Since 2000, glyphosate resistance has evolved in five weed species growing in US cropping systems with intensive use of glyphosate-resistant crops. Simulation models have previously been demonstrated as a useful tool for understanding the major biological and management factors that drive evolution of glyphosate resistance in agroecosystems. These models also enable assessment of the relative effectiveness of proactive management strategies for reducing the risk of evolved resistance. Results will be presented from a new study to adapt existing models of glyphosate resistance evolution to US cropping systems.

A case study will be presented which explored management options to reduce risks of glyphosate resistance evolution in *Amaranthus palmeri* (Palmer amaranth) in southern US cotton-based cropping systems. This cropping system has almost exclusive use of glyphosate-resistant cotton varieties and crop rotation is rare. Evolved resistance to glyphosate in populations of Palmer amaranth was first confirmed in 2005 in Georgia and the

number of suspected and confirmed new cases is rapidly increasing. Palmer amaranth is highly competitive with a single female plant capable of producing in excess of 500,000 seeds. Palmer amaranth is also capable of germinating and emerging throughout the growing season. With this combination of cropping system and biological parameters, the model predicted resistance to evolve in many Palmer amaranth populations within 4-5 years in weed management programs heavily reliant on glyphosate. Introduction of additional herbicide modes of action with season-long residual control of Palmer amaranth significantly reduced the risk of evolved resistance, even when intensive use of glyphosate-resistant cotton was maintained. Delays in crop sowing and the use of herbicides with other modes of action for burndown weed control reduced the proportion of the Palmer amaranth population that was exposed to glyphosate, further reducing risks of resistance evolution.

In addition to the Palmer amaranth case study, this paper will consider in more general terms the ways in which simulation models can be used to investigate which particular population and life cycle characteristics predispose weed species to evolution of glyphosate resistance. We will demonstrate that modelling glyphosate resistance in species where resistance has already evolved is just one application for resistance models. Perhaps more importantly, these models can be employed in the future to highlight combinations of operational (cropping system) and biological (species) factors that are particularly prone to glyphosate resistance evolution. In this way, situations where glyphosate resistance is a particular threat can be identified early and proactive management strategies put in place to mitigate the evolution of resistance.

554. Multiple Resistance to Glyphosate and ALS- Inhibitors in *Euphorbia heterophylla* L. from Brazil. Hugo Enrique Cruz-Hipólito¹, Ribas Vidal², M.M. Trezz², Daniel Gil¹, Javid Gherekhloo¹, Juan Pedro Ruíz-Santaela¹, Rafael De Prado¹; ¹Universidad de Córdoba, Córdoba, Spain; ²Federal University at Rio Grande do Sul, Porto Alegre, Brazil

Euphorbia heterophylla (wild poinsettia, EPHHL) is a weed species native from Brazil and has a long history of herbicide resistance selection. The objective of this work was to evaluate multiple resistance to glyphosate and to acetolactate synthase (ALS) inhibitors in a biotype collected from Rio Grande do Sul, Brazil. In the field, treatments consisted of glyphosate at 960 g acid equivalent (a.e.) ha⁻¹ either alone or in mixture with chlorimuron, cloransulam, imazethapyr (all ALS inhibitors), or lactofen. Additional treatments of glyphosate at 1920 g ha⁻¹ and an untreated control were also used for comparisons. For experiments conducted in the growth-chamber, ten-leaf plants of an EPHHL biotype suspected of multiple resistance to the compounds and a known susceptible

biotype were sprayed with several rates of glyphosate or imazethapyr. In the lab, classical methods for ALS inhibition assay and shikimate accumulation were conducted using both biotypes. Field results confirm limited EPHHL control (<50%) with all treatments containing glyphosate alone or in mixtures with ALS inhibitors. Adequate (>85%) EPHHL control was attained with lactofen. Resistance factor (RF) from plants growing in the greenhouse were 4 and >>12 for glyphosate and imazethapyr, respectively. ALS enzyme assay yielded a RF = 25 for imazethapyr, confirming this biotype is resistant to ALS inhibitors due to an insensitive ALS. More shikimate accumulated on the susceptible biotype than on the resistant biotype. These results indicates multiple resistance to glyphosate and ALS inhibitors is present in this *E. heterophylla* biotype from Southern Brazil.

555. Resistance to Glyphosate in *Echinochloa colona* in Australia. Chris Preston¹, Peter Boutsalis¹, Jenna Malone¹, Fleur Dolman¹, Andrew Storrie²; ¹University of Adelaide, Glen Osmond, SA, Australia; ²NSW Department of Primary Industries, Tamworth, NSW, Australia

Echinochloa colona (L.) Link is one of two *Echinochloa* species that are important weeds of summer cropping systems in Australia. Glyphosate resistance has evolved in two populations of *E. colona* in northern NSW. These glyphosate-resistant populations occurred in fields with a long history of winter cropping with summer fallow control entirely with glyphosate.

Dose response studies demonstrated the suspect populations were resistant to glyphosate compared with the response of a local susceptible population of the same species. It took 5 times as much glyphosate to control the resistant population compared with the susceptible population.

Experiments to examine the mechanism of glyphosate resistance in this species have shown only slight variations in glyphosate absorption between the resistant and susceptible plants. Glyphosate was absorbed only slowly by both resistant and susceptible plants with less than 60% of the applied glyphosate absorbed over 48 h. Up to 50% of the absorbed glyphosate was translocated out of the treated leaf accumulating in the roots and the rest of the shoot for both resistant and susceptible plants. Slightly less glyphosate was translocated from the treated leaf of resistant plants compared with susceptible plants.

Shikimate accumulation following application of glyphosate was greater in susceptible plants than in resistant plants. This shows that the absorbed glyphosate does not inhibit 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase as readily in the resistant plants compared with the susceptible plants. A conserved region of the EPSP synthase gene in both resistant and susceptible plants has been sequenced to determine the presence of amino acid

substitutions in the protein that may be responsible for resistance to glyphosate.

The evolution of glyphosate resistance in *E. colona* represents a significant threat to fallow weed management in cropping systems in northern NSW, as there are few alternative effective management strategies for this weed in this situation.

556. Glyphosate-Resistant Populations of *Amaranthus palmeri* Prove Difficult to Control in the Southern United States. Robert Nichols¹, Stanley Culpepper², Christopher Main³, Mike Marshall⁴, Thomas Mueller³, Jason Norsworthy⁵, Robert Scott⁵, Kenneth Smith⁵, Larry Steckel³, Alan York⁶; ¹Cotton Incorporated, Cary, NC, United States of America; ²University of Georgia, Tifton, GA, United States of America; ³University of Tennessee, Jackson, TN, United States of America; ⁴Clemson University, Blackville, SC, United States of America; ⁵University of Arkansas, Fayetteville, AR, United States of America; ⁶North Carolina State University, Raleigh, NC, United States of America

Over the past 20 years, Palmer amaranth (*Amaranthus palmeri*) has become more common and difficult to manage in the southern United States (US). In the past decade, management of Palmer amaranth in the U.S. improved substantially through use of the postemergence herbicide, glyphosate (N-phosphonomethyl glycine), in conjunction with transgenic, glyphosate-resistant soybean (*Glycine max*) and cotton (*Gossypium hirsutum*) cultivars. Such cultivars comprised over 90% of the soybean and cotton hectares in 2007 and glyphosate-resistant corn (*Zea mays*) cultivars also cover significant hectares. Thus, glyphosate may be used continuously on many hectares without rotation, even when the crops are rotated. Moreover, glyphosate may be applied multiple times per season. Repeated treatments of a single mode of herbicide action to a common, prolifically reproducing weed over such an extensive area (> 60 million ha) clearly created a high risk of resistance.

Confirmed field failures of labeled rates of glyphosate have occurred in 5 U.S. states. Resistant populations of Palmer amaranth are found in at least 13 and 11 counties in Georgia and North Carolina, respectively. The Tennessee (TN)-Arkansas (AR) populations were first observed in contiguous counties on opposite sides of the Mississippi River, but the levels of resistance in the AR populations appear to be greater than those in the TN populations. Glyphosate-resistant Palmer amaranth populations are now found in 3 TN counties and at least 8 counties in AR; in South Carolina they are found in at least 3 counties.

A disturbing aspect of the emergence of glyphosate resistance in Palmer amaranth is its potential for adverse impact on cotton production. Weed control tends to be more difficult in cotton than in other row crops. Cotton requires 8 weeks of weed-free growth to produce maximum

yields. The TN population requires repeated treatments with glyphosate to achieve satisfactory control, and glyphosate is wholly ineffective against the GA, NC, and some of the AR and SC populations. Numerous programs have been tested to manage glyphosate-resistant Palmer amaranth with inconsistent success. The management programs are expensive and rely in part on soil-applied herbicides that may not be activated by moisture on the coarse-textured soils common in the Southeastern Coastal Plain. Moreover, Palmer amaranth is difficult to control in part because of wide-spread resistance to the aceto-lactate synthase (ALS) mode of action. The recent successful management of Palmer amaranth was achieved largely by use of glyphosate.

557. Molecular Genetics of Glyphosate Resistance and Gene Flow in *Amaranthus palmeri*. Todd Gaines¹, Philip Westra¹, Christopher Preston², Dale Shaner³, Bekir Bukun¹, Stephen Chisholm¹, Sarah Ward¹, Jan Leach¹, Stanley Culpepper⁴, Timothy Gray⁴, Ted Webster³, William Vencill⁴, Patrick Tranel⁵; ¹Colorado State University, Fort Collins, CO, United States of America; ²University of Adelaide, Adelaide, SA, Australia; ³USDA-ARS, Fort Collins, CO, United States of America; ⁴University of Georgia, Tifton, GA, United States of America; ⁵University of Illinois, Urbana, IL, United States of America

Glyphosate resistance has recently been reported in *Amaranthus palmeri* (Palmer amaranth) populations from Georgia. The molecular resistance mechanism and potential for pollen-mediated gene transfer to other *Amaranthus* species are unknown. Resistant and susceptible plants were screened with an in-vivo shikimate accumulation assay. Using a range of glyphosate concentrations from 0 to 10,000 μM , susceptible plant leaf discs accumulated shikimate in 15 μM glyphosate while resistant plant leaf discs accumulated shikimate only in concentrations higher than 1,000 μM glyphosate. Resistant and susceptible leaf discs had equal uptake of ¹⁴C-labeled glyphosate at a 250 μM concentration. Putative hybrid plants between *Amaranthus palmeri* and *Amaranthus spinosus*, *Amaranthus hybridus*, and *Amaranthus powellii* were produced under greenhouse and field pollinating conditions and inherited the resistance trait. Candidate resistance mechanisms under investigation include mutations in the target site enzyme 5-enolpyruvylshikimate 3-phosphate synthase (EPSPS) and over-expression of EPSPS. Gene sequences have been obtained for 1,661 base pairs of EPSPS from resistant and susceptible plants. The only mutation found in all resistant plant sequences causes an amino acid change from arginine to lysine in exon 6 at position 316 of the mature EPSPS enzyme. Residues at this position in available plant EPSPS sequences include arginine, lysine, and methionine. Several species have lysine at position 316 and are not glyphosate resistant. We consider this

mutation unlikely to be the cause of glyphosate resistance. Based on semi-quantitative RT-PCR using a 1 Kb EPSPS fragment and 18S rRNA as a control gene, EPSPS is expressed at an approximately three-fold higher level in resistant plants. The exact mechanism of glyphosate resistance in *Amaranthus palmeri* has not yet been determined.

558. Gene Flow from Transgenic *Agrostis stolonifera* L. via Pollen Evaluated at a Landscape Level. Maria Zapiola¹, Carol Mallory-Smith¹; ¹Oregon State University, Corvallis, Oregon, United States of America

Gene flow to feral populations and compatible relatives is one of the main issues for the deregulation of genetically engineered (GE) crops. Transgenic glyphosate-resistant (GR) *Agrostis stolonifera* L. (creeping bentgrass) has been developed but is still under regulated status in the USA, and therefore, cannot be sold commercially. However, in 2002, 160 ha were planted to GR *A. stolonifera* within a 4,500 ha seed production control area in Oregon, USA. *Agrostis stolonifera* is an outcrossing, perennial turf grass that propagates through seeds and stolons and has compatible relatives in the area. The introduction of GR *A. stolonifera* in the area presented a unique opportunity to study transgene flow via pollen from a perennial outcrossing species at a landscape level. For four years, 2003 to 2006, we collected panicles from non-GR *A. stolonifera*, *A. gigantea* Roth. (redtop), and *Polypogon monspeliensis* (L.) Desfontaines (rabbitfoot grass). Panicles were hand-threshed and seeds were planted in the greenhouse. At the two-leaf stage, seedlings were counted and sprayed with glyphosate at 1.68 kg a.e. ha⁻¹. Two weeks after application, surviving seedlings were counted and resprayed with the same rate of glyphosate. A final count was performed three weeks after the second application and surviving seedlings were tested with lateral flow test strips to confirm the expression of the glyphosate resistance transgene. Gene flow via pollen was found in all four years. Of the approximately 16,000 seedlings tested in 2003, 0.36% was GR. The percentage of GR seedlings was 0.032, 0.047 and 0.005% of the approximately 207,000, 34,000 and 115,000 tested in 2004, 2005 and 2006, respectively. The GR seedlings resulted from panicles collected from 7, 6, 4, and 3 plants in 2003, 2004, 2005, and 2006, respectively. The percentage of in situ sampled plants that produced GR seedlings averaged 28% for 2003 and ranged from 1.75 to 6.12% in the following years. Because the area sampled was not the same for each year, direct comparison of results from different years is not possible. We did not find any GR *P. monspeliensis* seedlings, but we did find GR seedlings originating from *A. gigantea* plants and GR seedlings originating from *A. stolonifera* plants. We also found resistant seedlings originating from other *Agrostis* spp. or potential hybrids. Consequently, even though the GR fields were removed after harvest in 2003,

there is still enough pollen carrying the transgene in the area to allow its persistence and perpetuation in the environment. However, gene flow via pollen does not seem to account for the 62% of GR *A. stolonifera* plants we found in situ during the 2006 survey, implying that there are other means of gene flow, either seeds or vegetative propagules, that play a role in perpetuating the transgene. Results of this study should be used in the decision making process for authorization of field trials and deregulation of GE crops.

559. An Australian Farmer's Experience Living with Herbicide Resistance. Murray Scholz¹; ¹B. J. Scholz & Co, Culcairn, New South Wales, Australia

My family and I farm in south-eastern Australia. We were early adopters of minimum tillage in the 1970s and have continuously cropped with no-till since the 1980s. Herbicide resistance is now a major issue for us due to a resultant high dependence on selective herbicides for wild oats (*Avena fatua*) and annual ryegrass (*Lolium rigidum*). Herbicide resistance, no-till and our variable climate have a major impact on our management and profitability.

My presentation will show how we live with and manage the problem using an integrated weed management strategy. The plan is proactive, trying to minimise weed numbers using multiple techniques including chemical, physical and cultural strategies. This has allowed us to remain in a continuous cropping system without reverting to cultivation or a traditional long pasture phase. We are also trying to prevent ryegrass from developing resistance to other herbicide groups as well as development of herbicide resistance in other weed species.

I am undertaking a Nuffield Australia Scholarship, which enables me to study worldwide current and potential IWM techniques, including herbicide tolerant GM crops, new technologies and non-chemical organic farming techniques.

560. Can Resistant Cereals Solve the Striga Weed Problem in Africa. Julie Scholes¹; ¹University of Sheffield, Sheffield, S. Yorkshire, United Kingdom

Striga hermonthica and *S. asiatica* are root parasitic weeds that severely constrain crop yields in Africa. They infect staple cereal crops including maize, sorghum, millet and upland rice resulting in stunting of the plant and yield losses that range from 30-100%. The UN has estimated that over 40% of cereal producing regions of Africa are infested with Striga seed, directly affecting the lives of over 100 million of the poorest subsistence farmers. Farmers use a range of control strategies to try to keep the parasite in check including hand weeding, crop rotations, trap cropping, improving soil fertility and the use of tolerant cultivars. However, success has been elusive as Striga

affects host growth and development shortly after attaching to the root. By the time the parasite emerges above ground much of the damage to the crop has already occurred and is irreversible. Some promising new control strategies are emerging including the use of *Desmodium uncinatum* as an intercrop and the development of herbicide coating on seeds of herbicide resistant maize. These strategies partially alleviate the impacts of *Striga* as both prevent parasite attachment. The mechanisms underlying these control strategies will be highlighted. It is clear however, that additional control strategies are urgently required. Resistant host cultivars could have a major impact in reducing crop losses due to *Striga* but the paucity of resistant host germplasm, the polygenic nature of resistance and insufficient knowledge of parasite race structure, impede progress. In this talk I will review our current understanding of mechanisms underlying resistance to *Striga* species, our knowledge of parasite race structure and diversity and consider the implications and challenges for breeding cereal cultivars resistant to *Striga*.

Identifying host genotypes that possess resistance is a major focus of *Striga* research. There are a few cultivated and some wild sorghums that exhibit partial resistance to either *S. hermonthica* or *S. asiatica* but little evidence of complete immunity. The phenotype of the resistance response varies from hypersensitive-like death of the parasite to mechanical resistance within the host root. The range of resistance phenotypes is encouraging as an understanding of the molecular genetic basis of these traits may open the way for pyramiding of resistance genes in cultivars. We have screened rice germplasm for resistance to different ecotypes of *S. hermonthica* and *S. asiatica* and have identified cultivars that range from completely susceptible to highly resistant. The cultivar Nipponbare is particularly interesting as it exhibits very good resistance to one ecotype of *S. hermonthica*; more than 95% of parasites that attach to the roots die. The resistance phenotype includes host cell necrosis at the site of attachment and an inability to penetrate the endodermis. The discovery of resistance in rice to *Striga* is highly significant as it is the best model cereal for molecular genetic studies. Analysis of changes in gene expression in susceptible and resistant cultivars using rice microarrays has revealed that many of the genes up regulated in Nipponbare are those classically associated with defence responses to microbial pathogens e.g. Pathogenesis Related genes, cytochrome P450s and WRKY transcription factors. To begin the identification of the genetic basis of resistance in Nipponbare we carried out a QTL analysis using a mapping population of Backcross Inbred Lines derived from a cross between Nipponbare and Kasalath. QTL explaining a large proportion of resistance were discovered on five chromosomes; 4 alleles providing resistance from Nipponbare and 1 allele from Kasalath. Recently there has been much interest in combining gene expression data and QTL analysis for the identification of putative genes underlying the trait of interest. We have

used this approach and have identified three genes located at the peak of the largest QTL on the Nipponbare genome that are highly up regulated only during a resistance response.

In order to breed resistance to *Striga* knowledge of parasite diversity and race structure is essential but little is known about the genetic structure of *S. asiatica* (an inbreeder) or *S. hermonthica* (an outbreeder) in relation to host specificity. We have carried out a study using Amplified Fragment Length Polymorphism (AFLP) to genotype individual parasites growing on three different cultivars of rice that range from very susceptible to highly resistant to test the hypotheses that (1) the population of *S. hermonthica* seed collected from a field in Kibos, Kenya is highly genetically variable and (2) that the rice cultivars are infected with genetically distinct sub populations of the parasite. The *S. hermonthica* ecotype was highly genetically variable consistent with the outbreeding nature of this species. In addition, there was clear genetic differentiation between the subpopulations of *Striga* attached to the different rice cultivars which explains why a very few individual parasites were able to infect Nipponbare i.e. they possessed the virulence genes that enabled them to overcome the resistance in this cultivar. Further study of these virulence loci and their response to selection by host cultivars will reveal new ways to breed parasite resistance into host crop plants

561. Photoresponse Analysis of Phytochrome A in a Non-Photosynthetic Parasitic Plant, *Orobancha minor* Sm. Kazuteru Takagi¹, Atsushi Okazawa¹, Yu Wada¹, Chitra Trakunaleamsai¹, Eiichiro Fukusaki¹, Koichi Yoneyama², Yasutomo Takeuchi², Akio Kobayashi¹; ¹Osaka University, Suita, Osaka, Japan; ²Utsunomiya University, Utsunomiya, Tochigi, Japan

Light induces various morphological responses. Photoreceptors are involved in these responses. Among photoreceptors, phytochromes are red and far-red light photoreceptors. After light perception, phytochromes localize from cytoplasm to nucleus and control the expression of downstream genes. The entire network of light signaling has not yet been clear, because of its complexity. We focused on phytochromes in a non-photosynthetic parasitic plant, *Orobancha minor*. This plant cannot photosynthesize, and acquires energy from their host plants. Therefore, it is thought that *O. minor* has a light signaling system containing altered parts that are related to photosynthesis control, but retaining the function necessary to regulate morphogenesis. Amino acid sequence of phytochrome A (phyA) from *O. minor* (*OmphyA*) was compared to that of phytochrome A from *Arabidopsis thaliana* (*AtphyA*). The result revealed that *OmphyA* has 71% sequence identity and 26 amino acid substitutions which cannot be found in other photosynthetic plants. These substitutions are largely located in/

around functional domains. For further analysis, we compared the light responses of *O. minor* with photosynthetic plants to find functional differences between *OmphyA* and other phyAs.

First we confirmed intracellular localization and gene expression pattern of *OmphyA* under various light conditions. As a result, it was revealed that at the molecular level *OmphyA* behave as other phyAs. Next we tested photoresponses of *O. minor* in germination, anthocyanin accumulation and stem elongation under several light conditions. Interestingly red light had no effect but far-red light inhibited the stem elongation indicating red light high-irradiance responses should be lacked during this stage in *O. minor*. Lastly we compared the gene expression involved in phyA signaling between *OmphyA* and *AtphyA* transfected *A. thaliana* protoplasts using qRT-PCR. It was revealed that the expression levels of genes involved in phyA signaling were different in *OmphyA* and *AtphyA* transfected protoplasts.

These results suggest that *OmphyA* function is different from that of *AtphyA*, and these differences may attribute to amino acid substitutions of *OmphyA*. Transcriptome and metabolome analyses are in progress using *OmPHYA* introduced *phyA* mutant of *A. thaliana*.

562. Gene Silencing of Mannose 6-Phosphate Reductase in the Parasitic Weed *Orobanche aegyptiaca*. Radi Aly¹, Hela Cholakh¹, Anna Eykalis¹, Danny Joel¹, Benny Steinitz², Aharon Zelcer², Amit Gal-On²; ¹ARO, Newe-Yaar Research Center, Ramat Yeshai, Israel; ²ARO, Bet Dagan, Israel

Orobanche spp. (broomrape) is a root parasite which subsets on roots of a wide range of crops, causing severe losses in yield quality and quantity. This parasite accumulates high amounts of mannitol during its development which is regulated by Mannose 6-Phosphate Reductase (M6PR), an essential process to broomrape for water and nutrient uptake from the host.

Small interfering RNAs (siRNAs) are short double-stranded RNA molecules that facilitate potent and sequence-specific gene suppression by degradation of mRNA sequences to which they are homologous, thereby silencing the target gene. In our study, we used the inverted repeat technique for gene silencing of the M6PR gene in order to provide the host plant with resistance against the parasite.

A gene construct containing the 35S promoter followed by the silencing fragment (a specific PCR fragment - 286 bp from *O. aegyptiaca* M6PR-mRNA, in a form of inverted-repeat), was transformed into tomato host plants. By PCR, RT-PCR and Southern blot analysis, transgenic plants were proved to have the silencing fragment. Our results indicated that introducing of short double-stranded RNA molecules of the M6PR gene into *O. aegyptiaca* tubercles grown on tomato plants, facilitate suppression

and degradation of the native M6PR mRNA, thereby reduction of total soluble solids (sugars) in the treated tubercles. Quantitative Real-Time RT-PCR analysis showed that the endogenous M6PR- mRNA of *O. aegyptiaca* tubercles or shoots grown on transgenic tomato plants harboring the M6PR silencing construct was reduced by 60-80%. Additionally, Orobanche dead tubercles were increased significantly on transgenic plants as compared with the control plants indicating an efficient target gene silencing.

563. How Mineral Nutrients Affect the Exudation of Strigolactones, Germination Stimulants for Root Parasitic Weeds. Kaori Yoneyama¹, Hitoshi Sekimoto¹, Yasutomu Takeuchi¹, Koichi Yoneyama¹; ¹Utsunomiya University, Utsunomiya, Tochigi-ken, Japan

Strigolactones including orobanchol, orobanchyl acetate and 5-deoxystrigol, which are released from plant roots induce germination of root parasitic weeds, Orobanche and Striga, and hyphal branching of symbiotic arbuscular mycorrhizal fungi. Our previous study demonstrated that nutrient deficiencies affect strigolactone exudation: in *Trifolium pratense*, phosphorus (P) deficiency significantly promoted orobanchol exudation, while, in *Sorghum bicolor*, nitrogen (N) deficiency as well as P deficiency enhanced 5-deoxystrigol exudation. To clarify the effects of mineral nutrients on strigolactone exudation in detail, the amounts of strigolactones exuded by several plant species grown hydroponically were quantified by using LC/MS/MS. In the leguminous *Medicago sativa*, P deficiency promoted orobanchol and orobanchyl acetate exudation as in the case of orobanchol exudation by *T. pratense*. By contrast, in the leguminous *Astragalus sinicus*, not only P deficiency but also N deficiency significantly enhanced orobanchol and 5-deoxystrigol exudation. From these results, the response of strigolactone exudation to nutrient supply appears to vary with plant species but not with strigolactones. Effects of mineral nutrients on strigolactone exudation by important crops, *Solanum lycopersicum*, and *Zea mays*, host of Orobanche and Striga, respectively, will be presented.

564. Developing a Decision Support System (DSS) for *Orobanche aegyptiaca* Control in Tomato. Hanan Eizenberg¹, Jhonathan Ephrath, Tal Lande¹, Gay Achdari¹, Evgeny Smirnov¹, Joseph Hershenhorn¹; ¹ARO, Ramat Yishay, Israel

Broomrapes (*Orobanche* spp.) are chlorophyll-lacking root parasites that cause severe damage to vegetable and field crops worldwide. Egyptian broomrape (*O. aegyptiaca*) is common throughout Israel where it parasitizes a wide range of crops. Its economical impact endangers the future existence of the processing tomato industry in

Israel. Numerous studies under controlled conditions and field experiments were conducted in the last ten years in Israel and produced excellent results in *O. aegyptiaca* control in tomato using sulfosulfuron and imazapic. The efficacy of *Orobanche* control is highly correlated with the infestation level and rate and timing of herbicide application. A decision support system (DSS, named 'Pick-It'), for rational control of the parasite in processing tomato was developed. The DSS is based on: a) Risk assessment based on crop rotation, field history, geographical information system (GIS), and other relevant information that assist in predicting the severity of *Orobanche* infestation in the field. (b) A predictive model for *Orobanche* development based on growing degree days. c) Optimizing the herbicide rate sub-model allowing defining *Orobanche* developmental stage which is the most sensitive to low herbicide rates. The two later sub-models were validated under field conditions using a minirhizotron® camera. The alpha version of 'Pick-It' DSS is currently being evaluated in commercial tomato fields.

565. Introgression of Quantitative Trait Loci (QTL) for Striga Resistance into Adapted Sorghum Landraces through Marker Assisted Backcrossing in Sub-Saharan Africa.

Heiko Parzies¹, Dan Kiambi², Rolf Folkertsma², C. Hash², Fred Rattunde², Santie de Villiers², Hartwig Geiger¹, Ismail Rabbi¹, Netra Bhandari¹, James Gethi³, Acar Touré⁴, Ousmane Koita⁵, Abdalla Mohamed⁶, Abraha Tesfamichael⁷, Ben Kanyenji³, Bettina Haussmann², Dave Hoisington²; ¹University of Hohenheim, Stuttgart, BW, Germany; ²ICRISAT, Nairobi, Kenya; ³KARI, Nairobi, Kenya; ⁴IER, Bamako, Mali; ⁵University of Bamako, Bamako, Mali; ⁶ARC, Wad Medani, Wad Medani, Sudan; ⁷NARI/CoA, Hamelmalo, Eritrea

The parasitic weed *Striga hermonthica* is a major biotic constraint to sorghum production particularly in semi-arid regions of Africa where it can cause up to 100% yield losses. Five genomic regions (QTL) associated with striga resistance from a resistant durra line (N13) were initially identified from multi-location field trials in Mali and Kenya. The QTL explain between 14 and 44% of the total phenotypic variation observed for striga resistance. In a subsequent project, flanking SSR markers to the QTL have been employed in marker-assisted backcrossing (MAB) to develop near-isogenic farmer preferred sorghum varieties (FPSVs) carrying up to three striga resistance QTLs. A total of seven FPSVs from Kenya, Eritrea, Sudan and Mali were selfed twice following two backcross generations (BC2S2) and resulted in numerous lines with up to four striga resistance QTL. These lines are presently being evaluated in multi-location field trials in the participating countries. Preliminary results show striga resistance in some of the BC2S2 lines is as good as that of the donor line N13 in Kenya, Sudan and Mali. Additionally, seed system, gene flow and outcrossing rates of

selected FPSVs were investigated to estimate the risk of long-term loss of resistances under farmers diverse seed management. The study revealed large variation of outcrossing rates in FPSVs (4?20%) and a 99% dispersal of pollen within 40 m of the pollen source. Simultaneous analysis of landraces from two contrasting agro-ecosystems, Kenya and Sudan, revealed the impact of different seed systems and farming practices on the genetic structure of sorghum landraces. The project has been very successful in producing locally adapted striga-resistant sorghum materials for direct use by farmers, knowledge about seed-systems and stability of improved materials for clear management recommendations as well as implementing successfully biotechnological methods in developing countries.

566. Combining an Herbicide Resistance Gene with Natural Polygenic Resistance to Control *Striga hermonthica* (Del.) Benth in Maize. Abebe Menkir¹, David Chikoye¹, Lum Fontem¹; ¹International Institute of Tropical Agriculture, Ibadan, Oyo State, Nigeria

Farmers in the savannas of West and Central Africa have been battling with the parasitic weed known as *S. hermonthica*, which is destructive to their cereal crop. Maize is a staple food crop in this region and susceptible cultivars can sustain up to 100% yield loss under severe field infestation in marginal production areas. One of the options currently pursued to control *S. hermonthica* is the use of seed treatment with low doses of ALS-inhibiting herbicides, such as imazapyr and nicosulfuron. As these herbicides kill both *S. hermonthica* and maize, maize cultivars targeted for seed treatment should possess a resistance gene to this group of herbicides. As an outcrossing species with enormous seed output and propensity to generate new populations, *S. hermonthica* can evolve resistance to the ALS-inhibiting herbicides fairly quickly. In order to minimize the potential risk of yield loss associated with the emergence of such herbicide resistant *S. hermonthica* populations, an imazapyr resistance (IR) gene has been incorporated into maize inbred lines that already have good levels of polygenic resistance to this parasite. Inbred lines and experimental hybrids that combine the IR gene with polygenic resistance to *S. hermonthica* have been developed. In a field trial conducted at two locations, most of the herbicide resistant hybrids were competitive to a commercial hybrid check in yield potential in Striga-free plots. The best six herbicide resistant hybrids yielded 4742 to 5700 kg per ha grain with seed treatment and 3572 to 4656 kg per ha grain without seed treatment in Striga infested plots. On the other hand, the susceptible hybrid check included in this trial produced 538 kg per ha grain in infested plots and sustained a yield loss of 86% due to *S. hermonthica*. These hybrids may be planted without seed treatment in infested

fields in alternate years to delay the emergence of ALS-inhibiting herbicide resistant *S. hermonthica* populations.

567. Co-delivering of Striga-Mycoherbicides with Fungicides Using Seed Treatment Technology: Compatibility, Field Efficacy and Implication. Abuelgasim Elzein¹, Juergen Kroschel², Beed Fen³, Adolphe Avocanh³, Paul Marley⁴, Gearg Cadisch¹; ¹University of Hohenheim (380), Stuttgart, BW, Germany; ²International Potato Center (CIP), Lima, Peru; ³IITA, Tri Postal, Cotonou, Benin; ⁴Ahmadu Bello University, Samaru, Zaria, Nigeria

Root parasitic weeds of the genus *Striga* and fungal diseases constitute a major biotic constraint to staple food production in Africa, and consequently aggravate hunger and poverty. With the aim of improving sorghum and maize performance and yield, an investigation on the possibility of delivering *Striga*-mycoherbicides (*Fusarium oxysporum* f. sp. *strigae*, isolates Foxy 2 & PSM197) and selected fungicides using seed treatment technology to control simultaneously *Striga hermonthica* and sorghum and maize fungal diseases was made. Film-coated seeds of sorghum with different application rates of Apron XL[®] and Ridomil Gold[®] in combination with the mycoherbicides Foxy 2 and PSM197 and different coating adhesives were used. The effects of Apron XL[®] and Ridomil Gold[®] fungicides on growth and sporulation of the two isolates was examined by growing the film-coated sorghum seeds on PDA media. Delivering of the fungicides Apron XL[®] and Ridomil[®] with *Striga*-mycoherbicides Foxy 2 and PSM197 using seed treatment technology did not interfere with the seed coating process nor with the initial survival of fungal isolates on coated sorghum seeds. Apron XL[®] clearly enhanced the growth, sporulation and viability of both isolates, indicating strong compatibility with *Striga*-mycoherbicides. However, Ridomil Gold[®] was not compatible on PDA medium. Under field conditions of West Africa, the integration of fungicide Apron XL[®] (at a rate of 0.8 ml/kg of seeds) with *Striga*-mycoherbicides (Foxy2 & PSM197) and resistant maize cultivars using seed treatment technology and Arabic gum as adhesive showed significant reduction in *Striga* emergence by 82% and 90% compared to the respective resistant and susceptible controls. The respective reductions when the two isolates integrated alone without fungicide with the resistant maize were 82%, and 89%. Improved performance of maize treated with *Striga*-mycoherbicides and fungicide by 300% was further recorded. The compatibility between *Striga*-mycoherbicides and Apron XL[®] fungicide has significant implication for controlling simultaneously *Striga* and sorghum and maize fungal diseases and improving crop performance and yield.

568. Field Applications of *F. oxysporum* f.sp. Orthoceras for the Control of *Orobanche cumana* Wallr. Dorette

Müller-Stöver¹, Rossitza Batchvarova², Joachim Sauerborn³; ¹University of Copenhagen, Taastrup, Copenhagen, Denmark; ²AgroBioInstitute, Sofia, Bulgaria; ³University of Hohenheim, Stuttgart, Germany

Chlorophyll-lacking parasitic weeds of the genus *Orobanche* (broomrapes) are currently regarded as one of the most serious threats to modern agricultural practice mainly in warm-temperate and subtropical regions. The most destructive broomrape species on a world basis is *Orobanche cumana* Wallr. which is an important constraint of sunflower production, especially in Southern Europe and the Black Sea region. The fungus *Fusarium oxysporum* Schlecht. f. sp. *orthoceras* (Appel & Wollenw.) Bilai was found to be an effective antagonist against all developmental stages of the parasitic weed under greenhouse conditions, reducing *Orobanche* emergence by up to 80%. In a first field trial carried out in Israel, control efficacy was lower compared to the pot experiments and the soil population of the fungus strongly decreased during the season. However, a better biocontrol efficacy could be achieved in field experiments under different environmental conditions in Bulgaria. The application of the fungus in two consecutive seasons led to a reduction of the number of *Orobanche* shoots by 66 % and more than 90 %. The results emphasize the variability of biocontrol efficacy under natural conditions that is influenced by a complex of biotic and abiotic factors. Our current and future research focuses on identifying the key elements within these intricate interactions.

569. The Influence of Herbicide Resistant Cropping Systems on the Soil Environment in Canada. Clarence Swanton¹, Robert Gulden², Jeff Powell¹, Rachel Campbell¹, Miranda Hart¹, David Levy-Booth¹, Kari Dunfield¹, Peter Pauls¹, Jack Trevors¹, John Klironomos¹; ¹University of Guelph, Guelph, Ontario, Canada; ²University of Manitoba, Winnipeg, Manitoba, Canada

Herbicide-resistant (HR) crops and in particular, genotypes resistant to glyphosate, have been well accepted by Canadian producers since their introduction in the mid-1990s. Over the past four years we conducted both field and greenhouse experiments, where we investigated the effects of a glyphosate-resistant corn and soybean cropping system on the soil environment. We explored the effects of genotype and herbicide (glyphosate) on the cycling of plant DNA in soil, plant litter decomposition, the soil food web, soil bacteria functioning, and symbiotic associations between microbes and plants. To date, our results show that the behaviour of recombinant DNA (rDNA) is similar to that of indigenous plant DNA. A small amount of DNA persists over the winter and persistence is primarily influenced by environment (year and location). In our field experiments, rDNA was found in leachate water and was detected on soil microarthro-

Pods and nematodes. We found transient effects of genotype and glyphosate on soil bacteria, fungal, protozoan, and nematode biomass. Crop litter decomposition of glyphosate-resistant and glyphosate treated genotypes was reduced compared to conventional genotypes. Neither glyphosate nor genotype had an impact on denitrifying bacteria in the rhizosphere. In a greenhouse study, genotype specific differences in colonization of roots by rhizobia and mycorrhizal fungi were observed among soybean genotypes; however these effects were not linked to the genetic modification. Many of the genotype and herbicide effects that have been observed in our studies appear to be transient in nature with no apparent long-term influence on the structure and functioning of the soil environment.

570. Impact of Glyphosate-Resistant Soybean Production on Biological Activity in the Soil and Rhizosphere Environment. Robert Kremer¹; ¹USDA-ARS, Columbia, Missouri, United States of America

Widespread use of glyphosate-resistant crops represents a major advancement in effective weed management. Consequences of 'Roundup Ready [RR] Systems' include alterations in microbial ecology and biology in crop rhizospheres. Affected functions include nutrient cycling and plant availability; phytopathogen-antagonist interactions; and beneficial microbial activities. Objectives were to identify impacts of genetically-modified (GM) crops on soil biology; define mechanisms responsible for observed effects; and determine strategies to overcome detrimental interactions limiting plant growth. *Fusarium* spp. indicate potential impacts of RR soybean by responding to alterations in rhizospheres. However, because the rhizosphere is a complex system, more comprehensive analyses of structure and function of entire microbial communities were devised for a complete assessment of potential effects of RR soybean. 'Indicator microbial groups' and specific microbial activities sensitive to ecosystem changes and relevant to RR production systems were selected for assessment. A 'polyphasic' microbial analysis targeted the broad impact on microbial communities, thus, providing a more reliable view of GM effects than individual techniques. Current assessment of potential GM crop effects is an evolving framework based on previous observations plus descriptions of specific rhizosphere communities and associated activities. Specific analyses include fungal root colonization, Mn-transforming bacteria, symbiotic nitrogen-fixing bacteria, and pseudomonads. Interactive components explain linkages of microbial community shifts with functional alterations. Ratios of Mn-reducers to oxidizers were consistently lower in RR soybean, especially with glyphosate, suggesting potential low Mn availability. Fluorescent pseudomonads were higher in conventional soybean rhizospheres relative to RR and negatively correlated with *Fusarium* root coloni-

zation, demonstrating a microbial imbalance due to RR soybean cropping. The framework for examining multiple key indicators in rhizospheres efficiently detected impacts of RR soybean. Understanding complex rhizosphere factors (root exudation, glyphosate release, microbial activities) interacting with root-associated microorganisms is essential for 'managing' rhizosphere environments to reduce/eliminate adverse effects of GM crops in crop management systems.

571. Is Management Effective? The Results of an Adaptive Experimental Management Program to Determine Best Practice Chemical Control on *Cytisus scoparius* and Impacts on Native Vegetation. Lynise Wearne¹, Cathy Allan², Marie Keatley², Paula Dower²; ¹CSIRO, Townsville, Queensland, Australia; ²Parks Victoria, Omeo, Victoria, Australia

Management of invasive plant species is often done in the absence of appropriate evaluation to determine the effectiveness on the target species/community or the off-target damage to other species.

Adaptive experimental management, however, considers management actions as experimental treatments and employs approaches such as replication and control. This allows alternative management strategies to be compared simultaneously. Parks Victoria has used this approach in one of its largest pest control programs.

English Broom (*Cytisus scoparius*) has been a high priority weed for control in the Alpine National Park, Australia, for over fifteen years, but managers have little evidence of the outcomes of extensive weed control efforts. Following the bushfires in 2003, which burnt extensive stands of *C.scoparius* in the Alpine National Park, Parks Victoria established a series of one hectare trial plots to address the effectiveness, efficiency and environmental outcomes of best-practice chemical control strategies.

The effects of three best-practice herbicides (360 g L-1 glyphosate, 300g,L-1 triclopyr with 100 g L-1 picloram, 600g L-1 triclopyr) applied during Autumn or Spring on one-hectare plots were compared with non-treatment plots at each of three sites. After 3 years results indicate substantial differences in rates of damage to *C.scoparius* stands, however, no herbicide resulted in a 100% kill rate. Herbicide type and timing of application were important factors. There were significant changes to native vegetation across all sites after 3 years, in both treated and control plots. Herbaceous species were the most susceptible growth-form to increasing *C.scoparius* and herbicide application, with decreasing cover and richness across all treatments and control plots. Grass cover decreased across all treatments and control plots except where 300 g L-1 triclopyr with 100 g L-1 picloram was used, here cover increased. Mortality of canopy trees was greater across all treated plots in comparison to control plots, hence suggesting direct impacts from herbicide application. The

implications for management and future management directions as a result of these findings will be discussed.

572. An Advanced Test Design to Evaluate Reversible Side Effects of Herbicides and their Active Ingredients on Terrestrial Non-Target Plants. Roland Kubiak¹, Sandra Siemoneit-Gast¹, Andreas Höllrigl-Rosta², Stephan Reuter¹, Guido Velten¹; ¹RLP AgroScience GmbH, Neustadt Weinstr., Rhineland Palatinate, Germany; ²Federal Environmental Agency, Dessau, Saxony-Anhalt, Germany

Regulatory assessment of the risk of herbicides and their active ingredients to terrestrial non-target plants is based on standard tests in which the natural vegetation of field boundaries is mainly represented by crop monocultures. Current assessment schemes are deficient in guidance to alleviate uncertainties emerging with respect to extrapolation from a single surrogate species tested under laboratory/greenhouse conditions to a plant community in a natural field situation. Due to the lack of interspecific competition and short test duration complex ecological traits such as the plants potential for compensation and recovery from negative effects cannot be reliably assessed. We aimed for a more realistic yet standardized test design that includes relevant wild plant species under competitive conditions. In a first step, we selected representative wild plant species of field margins, which seemed appropriate for use in a multi-species test. A total of 231 (mainly perennial) wild plant species was screened with respect to germination and growth rates to allow for standardized test conditions. We then configured artificial communities and developed an evaluation scheme to assess competition and recovery effects which was eventually applied in two trials with herbicides of different modes of action. The herbicides were applied to species communities synchronized to the 2 to 4 leaf growth stage (BBCH 12 to 14). Subsequently, plant growth was three times assessed in two weeks intervals and compared to results from concurrent single-species tests. The observed effect rates (e.g. ER50) demonstrate the influence of competition on the potential of plants to recover from negative effects over time. In a competitive environment the recovery process was either stimulated or inhibited. Our results provide evidence that the proposed test design allows for simulation of reversibility of short-term effects in the framework of standardized regulatory testing. The introduced methodological approach suggests a supplement test to assess the risk for terrestrial non-target plants exposed to plant protection products and their active ingredients. This multi-species test complies with the trend towards increasing consideration of realistic scenarios in risk assessment, with concomitant simplification and better standardization compared to field studies.

573. Atrazine-Degrading Microbial Populations in Soils. Thomas Mueller¹, Krishnakali Roy¹, Dhritiman Ghosh¹, Mark Radosevich¹; ¹University of Tennessee, Knoxville, TN, United States of America

Using Bio-Sep[®] beads containing varying concentrations of atrazine, we were able to monitor shifts in microbial community structure due to in situ enrichment using atrazine as a substrate in agricultural soils that varied in their atrazine exposure history. Fluorescent in situ hybridization (FISH) with 16S rDNA-based phylogenetic probes and 16S rDNA denaturing gradient gel electrophoresis (DGGE) were used to assess the community composition of bacteria that colonized the beads. Atrazine dissipation in soil in which the beads were deployed was rapid indicating that atrazine-degrading bacteria responsive to atrazine additions were present in the soils selected for bead deployment. DGGE analysis revealed that the soil and bead communities were distinctly different. Atrazine concentration within the beads appeared to influence the community composition to a greater extent than the prior atrazine treatment history to the soils in which the beads were buried. Eubacterial biomass increased by approximately 5-40 fold in atrazine containing beads relative to atrazine-free beads suggesting an enrichment in atrazine-degrading bacteria within the baited beads. The phylogenetic distribution within the bead communities varied depending upon i) atrazine concentration and ii) the prior history of atrazine application to the soil in which the beads were buried. In beads buried in soil with a recent history of atrazine application, the abundance of Actinobacteria increased approximately 80 fold in beads containing 20 mg atrazine kg⁻¹ of beads. In the beads from non-history soil, Actinobacteria were enriched by only 10 fold while the greatest enrichment was observed for the gamma-Proteobacteria and Planctomycetes which increased by 60 and 25 fold respectively. While a number of atrazine-degrading bacteria classified within the gamma-Proteobacteria have been isolated, no such bacteria have been described within the Planctomycetes. In enrichment cultures derived from soil incubated Bio-Sep beads, bacteria from this phylum were detected and we hypothesize that the growth of these bacteria in atrazine-degrading enrichment cultures is supported by oxidation of alkylamines released during the degradation of atrazine by other members of the consortia. Attempts to isolate these bacteria to date have been unsuccessful. At the higher atrazine concentration (200 mg atrazine kg⁻¹ of beads) the gamma Proteobacteria were enriched by 120 and 230 fold in the beads buried in history and non-history soil, respectively. The alpha-Proteobacteria were enriched to a much lesser extent; 10 and 20 fold in the history and non-history beads, respectively. Interestingly, the relative enrichment of Actinobacteria and Planctomycetes that were observed at the lower atrazine concentration did not occur in beads

containing the higher atrazine concentration of 200 mg atrazine kg⁻¹ of beads.

The results demonstrate that BioSep beads are a suitable matrix for recruiting a highly diverse subset of the bacterial community involved in atrazine degradation and have the potential for isolation of other novel soil bacteria.

574. Microbial Ecology of Herbicide Degradation – Potential and Limitations of Nucleic Acid Based Stable Isotope Probing. Gerald Sims¹; ¹USDA-ARS, Urbana, IL, United States of America

The use of stable isotopes to label phylogenetically informative biomolecules (phospholipid fatty acids, DNA, or RNA), is often referred to as stable isotope probing (SIP). The approach has potential for demonstrating that a detected microbial population is active in a particular process, if that process results in assimilation of C or N into the biomass of the population in question. SIP is one of the few techniques available that can be used for this purpose effectively in soils, however the approach has important limitations. Since nucleic acid based SIP requires a very high rate of label incorporation (approximately 20%) to separate active from inactive populations, very high label rates and relatively high substrate concentrations are required. Since nucleic acids contain more C than N, labeling with C provides a larger separation between active and inactive populations and thus greater sensitivity. Many substrates are subject to sorption in soil, and introduction of a labeled test substance throughout soil pore space is not instantaneous. Bioavailability limitations may thus preclude accumulating sufficient label to achieve centrifugal separation of enriched from un-enriched nucleic acids. Herein we report experiments on the potential for use of N labels in DNA-based SIP to study herbicide-degrading populations in soil. We demonstrate the utility of C labeling for DNA-SIP for the herbicide 2,4-dichlorophenoxy acetic acid, and present evidence for limited bioavailability in the degradation of herbicides and resulting limitations for DNA-SIP.

575. Persistence and Phytotoxicity of Sulfosulfuron Residues and its Major Secondary Metabolites under Wheat Based Cropping System. Shobha Sondhia¹; ¹National Research Centre for Weed Science, Jabalpur, M.P., India

Any persisting herbicide residues can damage the succeeding sensitive crops and affect human and animal health due to bioaccumulation of residues in crop produce. This problem may further intensify with the rain, irrigation and deep ploughing and thus residues may contaminate ground water. Nowadays, due to introduction of herbicide resistance crop, the use of herbicides is likely to increase beyond normal rates. Thus it becomes essential to study fate, persistence and phytotoxicity of sulfosulfuron resi-

dues in surface and subsurface soil under normal and higher doses. Thus an experiment was conducted in wheat with the objectives (i) to evaluate the persistence of sulfosulfuron residues and its major metabolites in surface and subsurface soil and (ii) cause of phytotoxicity of sulfosulfuron residues and its major metabolites on succeeding crops viz. sorghum and maize, grown in kharif 2006 and pea and lentil grown in Rabi 2006. Sulfosulfuron was applied as post-emergence at 25, 50 and 100 g/ha in wheat crop in Rabi 2005.

Soil samples from surface and subsurface were collected at 0, 5, 10, 30, 50, 100, 150, 200, 250, 300, 365 and 400 days after application of sulfosulfuron and analyzed by HPLC.

Sulfosulfuron residues were found below the detection limit (<0.001 µg/g) after 150 days in the soil in those plots which were treated with 25 and 50 g/ha doses. However, in case of 100 g/ha treated plots, sulfosulfuron residues were not detected after 200 days. Confirmation of soil samples after 100 days with LC-MS/MS in ESI () mode revealed that sulfosulfuron was present upto 100 days in the surface and sub-surface depths in higher treatments. However, its metabolites viz sulfonamide and aminopyrimidine were present in toxic level in the surface and subsurface soil in 50 and 100 g/ha treatments which also caused severe phytotoxic effect on pea and lentil causing delay/ poor germination, delay in pod formation and reduction in grain yield. However, where sulfosulfuron was applied at 25 g/ha did not indicate any adverse effect on germination and yield of pea and lentil at P=0.05 level, while yield in 50 and 100 g/ha treatments was found higher as compared to control and 25 g/ha treated plots but this may be due to presence of less number of weed in these plots due to presence of sulfosulfuron residues as compared to control and 25 g/ha treated plots. Phytotoxic effect was not significant after 150 days at P=0.05 level. Among the various sensitive crops evaluated field pea was found more sensitive followed by lentil, maize and sorghum.

In the present study sulfosulfuron residues persisted in the subsurface soil depth upto six months with a half life of 17 to 25 days. Results also indicate that sulfosulfuron can move from the surface soil to subsurface soil profile with irrigation water under field conditions and offer risk of ground water contamination. Thus potential risk of phytotoxic effects on sensitive succeeding crops and leaching of sulfosulfuron residues from surface to subsurface can not be overruled which is matter of concern to all as respects to groundwater contamination.

576. Validation of a Leaching Model with the Herbicide Picloran in Clay Soils under *Brachiaria decumbens* Vegetation. Edemir Mantovani¹, Luiz Foloni¹, Pedro Christofoleti²; ¹University of Campinas, Campinas, Sao Paulo, Brazil; ²University of Sao Paulo - ESALQ, Piracicaba, Sao Paulo, Brazil

Picloran is one of the most used herbicides for weed control in pastures, especially for those hard to kill weeds. Several reports exist about water wells and springs contamination with herbicides residues as a result of deep leaching into the ground. Due to the lack of knowledge and available data on the destination of the picloran in the Brazilian soils, researches are necessary in the site conditions of soils and climate, in order to evaluate the potential of underground water contamination with residues of picloran. With the objective of evaluating the simulation of a vertical movement of picloran in the field conditions using a simulator, an experiment was conducted to test the hypothesis that picloran, in controlled environment and through results of a mathematical simulator, is adsorbed to soil constituents, and so presenting low vertical mobility and low potential of underground water contamination. The research was conducted in the Experimental Field Area of UNICAMP, Brazil, located in Campinas SP, Brazil. For collecting sample of the soil solution at 10 different depths, it was constructed a draining modified lysimeter, 2.0 m of diameter per 3.0 m of depth, with 10 vertical points of collection in the profile spaced in 30 cm among them. These points of water drained collection from the simulated rain were set by placing a PVC pipe. The samples were collected one day after the simulated rain, monthly from October 2006 to March 2007. After collecting the samples were submitted to Gas Chromatography (GC) Analysis in order to analyze picloran and metabolites content. The mathematical model MACRO 5.1 was used to simulate picloran leaching into the soil profile, and results from the simulation were compared for validation to the results obtained in the GC analysis. The results from the simulation model and GC analysis indicated that there is a decreasing in the presence of picloran as the depth of the drained water from the simulated rain is collected, confirming the hypothesis of low vertical mobility of this herbicide. Even though, picloran is a very water soluble herbicide; its application in the field conditions, at recommended rate, does not represents risks for springs and water well contamination. The simulator MACRO 5.1 is a valuable tool for prediction of picloran and possibly to other herbicides leaching in the soil profiles.

577. Buffer Strip Effect on Terbutylazine Runoff in Light Level Soil. Marco Milan¹, Francesco Vidotto¹, Franco Tesio¹, Michèle Nègre², Serenella Piano¹, Aldo Ferrero¹; ¹AGROSELVITER, Università di Torino, Grugliasco, To, Italy; ²DIVAPRA, Università di Torino, Grugliasco, To, Italy

Pre-emergence herbicides are frequently reported to be responsible of watercourses pollution because of their runoff on the treated fields. Terbutylazine is a pre-emergence herbicide largely applied to control most

annual broad-leaved weeds in maize. The study was aimed to assess the effect of an untreated strip located on the downhill field border on the mitigation of the runoff of the herbicide after its application. The study was carried out in 2007 on a sandy soil of the Po valley (Northern Italy), characterized by a slope of 0.5% in the direction of the field length, to favor removal of the waters in excess and runoff of those used for irrigation. Two adjoining plots of 2100 m² (14 m x 150 m) each, both cultivated with maize were considered. One plot (Control), had no buffer strip, while the other was characterized by the presence of a 6 m wide strip located on the downhill field border. The plot with the buffer strip was divided in two sub-plots; one with the untreated buffer strip planted with maize (Maize Buffer) and the other with the untreated buffer strip planted with Italian ryegrass (Ryegrass Buffer). Terbutylazine was applied at 750 g a.i./ha in pre-emergence with conventional farm equipment on the entire plot area, with the only exception of the buffer strips. Over the growing season both plots were subjected to a total of 380 mm of water out of which 220 provided by rainfall and the balance by 3 sprinkling irrigations. Concentrations of terbutylazine and its main metabolite desethyl-terbutylazine were assessed in runoff water, collected at the downstream head of the field border, and in soil samples (2 cm depth), collected both in the treated area and across transects 1m-spaced in the untreated strips. Determination of both chemicals in water and soil samples was performed by HPLC, adopting a methodology with a detection limit of 0.05 µg/L and 0.6 µg/kg, respectively.

Highest concentrations of terbutylazine and desethyl-terbutylazine (136.18 and 43.55 µg/L, respectively) in runoff water were recorded in Control 23 days after treatment (DAT), immediately after a heavy rain. At that time the concentrations of terbutylazine and desethyl-terbutylazine assessed in runoff water collected from Maize Buffer were 0.94 and 1.13 µg/L, respectively and from Ryegrass Buffer 0.06 and 1.10 µg/L, respectively. Runoff samples collected 120 DAT from Control showed a content of 0.74 µg/L of terbutylazine and 1.12 µg/L of its metabolite. Terbutylazine concentrations in the soil of the untreated strips varied remarkably over the time from the herbicide application and through the strips.

578. Better Weed Management: What Advice do Farmers Need? Stephen Moss¹; ¹Rothamsted Research, Harpenden, Herts, United Kingdom

For effective weed management, a farmer or advisor needs to predict the likely outcome of different strategies so that rational decisions can be made. Critically, weed management advice needs to be tailored to the individual field situation because weed infestations vary substantially both within, and between, fields. While weed research has improved our ability to provide advice on the impact and control of weeds at the generic level, it is questionable what

real advances have been made at the individual field level. In the UK, most arable farmers use a crop consultant, who typically advises on 4,000 to 10,000 ha of arable crops and charges US \$20 per ha. Consultants in the UK typically visit each field about 15 times per season and, even if an advisor allocates 1000 hours a year to advice on weeds, that equates to an average of only about 1 minute/ha per visit. Consequently, the amount of time that can be spent, cost effectively, on any individual field is very limited. The situation may differ, of course, in other countries with different farm size and agronomic systems, and where 'free' advice is still available.

The question needs to be asked; how far can we go in refining weed management advice to make it more applicable at the individual field scale? This is a real challenge as, while it is relatively easy to gather reasonably accurate information on the average effect of weeds on crop yields, emergence patterns, seed persistence etc, (by conducting a series of field trials for example), it is much more difficult to predict what will happen in any specific field in a given year. Improvement may be achieved by more intensive field monitoring and sampling, but the costs involved are often not recognised by researchers. How often are the costs of travelling to each field and collating and analysing the data included in economic appraisals of weed management? Such costs are nearly always ignored, but their omission raises serious questions about the economic validity of such studies.

Is weed modelling the answer? Holst et al., (2007) stated that 'Whereas the best control tactics in the short term can be explored by multifactorial field experiments, the assessment of long-term management strategies necessitates a model description, whereby the system can be explored mathematically, in conjunction with empirical observation'. As the stated purpose of many models is to support practical weed management, a fair question to ask is how successful models have been at achieving this objective. The excellent review by Holst et al. (2007), covered models of the population dynamics of 60 weed species in 40 crops. The most frequently stipulated justification for the models they reviewed was either as theoretical approaches for investigating new concepts or for providing guidelines for practical weed management. However they never found any empirical assessment of the practical impact of models with the claimed purpose of providing guidelines for practical weed management. That seems a staggering statement and one that could be construed as a damning indictment of much weed modelling. Whether weed management decision models will be adopted widely is still far from certain (Wilkerson et al., 2002).

There is a risk of diminishing marginal returns in many modelling studies, where additional refinement delivers little or no benefit in terms of better weed management. If models are to be truly useful in weed management, much more emphasis needs to be given to applicability at the individual field scale, as in the RIM model by Pannell et al.

(2004). If models are used to evaluate longer term weed management strategies for different farms and conditions at a more general level, one does need to justify the validity of complex models when so many factors cannot be predicted with any degree of precision (e.g. seedbank distribution, cultivation efficiency, environmental factors).

In my opinion, simple models are very useful, and perfectly adequate as educational aids, but over complexity is counter productive. It might be better to recognise some of the practical limitations, and not pursue a policy of trying to achieve unrealistic precision. There needs to be more emphasis on demonstrating that modelling really can deliver better practical weed management advice at the individual field level, rather than contributing to impressive publications that rate highly on scientific impact but deliver little of practical relevance.

579. Have Models Contributed to Weed Management?
Bruce Maxwell¹; ¹Montana State University, Bozeman, Montana, United States of America

Models can be defined in a range of ways that can strongly influence an assessment of their value in impacting management decisions. Narrowly defining models as algorithms used to predict management outcomes would sharply decrease the number of cases where models could be considered as directly contributing to management decisions. Some examples of directly applied models maybe application of the herbicide dose response relationship to choose herbicide rates, the hydrothermal time emergence models to determine the most effective time of herbicide application or mechanical practice, and the rectangularity relationship used to maximize competitiveness of crops by adjusting distance between crop rows and within-row crop seeding rates. A more broad definition of models may include conceptual relationships or algorithms often incorporated into decision support software that indirectly contribute to management decisions. Many more cases can be listed as contributing to management decisions with this more broad definition of models. Examples, may include the probability of occurrence models, the climate envelope models, the weed dispersal functions and the weed impact functions incorporated into decision support systems. A serious constraint on application of models to practical weed management decisions is the requirement of an understanding of the spatial and temporal variation in model parameter values. I propose that direct application of models is more constrained by the need for temporal site-specific data the more that they rely upon characterization of biological processes rather than response to inputs. Response to inputs (e.g. herbicides) may have greater spatial and temporal generalization because the response is assessed at the extreme end of the process, i.e. mortality. If weed management decisions involving herbicides were based on the degree of injury required to

increase crop yield to maximize annualized net economic return, then site-specific data would also be required. The uncertainty associated with predicting weed population or community dynamics over multiple interacting biological processes, even in a single environment, is a daunting task that seems to doom the direct application of models in weed science. I suggest that the use of models will increase under two scenarios that involve change in perspective. The first is for weed scientists to concentrate on novel ways that will allow weed managers to collect site-specific data that can accumulate over time as part of their standard management operations and allow local parameterization of the models. The second is to change our expectations and formulation of models from tools of prediction to tools that convey general principles upon which to base weed management.

580. Economic and Environmental Tradeoff Analysis for Site-Specific Weed Management under Risk. Eihab Fathelrahman¹, L. Wiles¹, J. Ascough II¹; ¹USDA-ARS-NPA, Fort Collins, CO, United States of America

Site-specific weed management is the strategy of varying weed management within a field to match the variation in the density and composition of the weed population. The motivation for site-specific management has been reducing herbicide use, with a research focus on patch spraying. In most cases, site-specific weed management involves economic and environmental tradeoffs that vary from field to field because the outcomes of site-specific weed management depend on the spatial distribution and composition of the weed population within a field. Observing the weed population to predict the outcomes before site-specific weed management is not practical, so choosing if, or how, to implement site-specific weed management in a field is decision subject to uncertainty and risk. The overall objective of this study is to investigate and analyze economic and environmental tradeoffs in site-specific weed management strategies under this risk of variation in outcomes among fields and imperfect knowledge of the outcome in particular field due to effect of the spatial distribution and composition of the weed population. We explicitly evaluate differences (across strategies) in gross margin (e.g., revenue minus operational cost), yield loss, amount of herbicide used, and number of weed escapes using stochastic efficiency with respect to a function (SERF) methodology (a type of stochastic dominance technique) and data collected from 16 fields in eastern Colorado to rank four weed management strategies: 1) uniform application using one herbicide (UN); 2) patch spraying with one herbicide (P1); 3) patch spraying with two herbicides (P2); and 4) patch spraying with unlimited herbicides (PX). The SERF method was developed to analyze, screen, rank, and evaluate alternatives at different levels of risk (e.g., risk preferring to risk neutral to risk averse) using cumulative distribution function (CDF)

input information. Unlike traditional stochastic dominance approaches, SERF uses the concepts of certainty equivalents and risk premiums to rank and evaluate set of risk-efficient alternatives instead of finding a subset of dominated alternatives. In addition to using SERF to rank the four management strategies, we also conduct economic and environmental tradeoff analyses, specifically gross margin versus herbicide use and number of weed escapes, and the tradeoff between herbicide use and number of weed escapes. The results of the study include tabulation and illustration of the certainty equivalent and risk premium calculations for each of the tradeoff scenarios using a new spreadsheet software tool called the Risk Screening and Tradeoff Analysis Toolbox (RSTAT). Preliminary SERF results for gross margin show that the patch spraying with unlimited herbicides (PX) strategy is the preferred alternative across a risk neutral to extremely risk averse preference range. However, the SERF gross margin rankings are very close, with a risk premium of less than ten dollars per hectare between the PX strategy and the uniform application strategy (UN), the least preferred of the four strategies.

581. Using Models to Guide Weed Management Strategies. Matt Liebman¹, Adam Davis², Paula Westerman³; ¹Iowa State University, Ames, Iowa, United States of America; ²USDA Agricultural Research Service, Urbana, Illinois, United States of America; ³Universitat de Lleida, Lleida, Spain

Recent growth in market demand for organic products and on-going concerns over environmental and human health risks associated with agrichemicals have catalyzed increased interest in organic and low-external-input (LEI) farming systems by producers, consumers, scientists, and other groups. Though substantial advances have been made during the last decade in weed control machinery and knowledge of weed ecology, both producers and researchers continue to identify weed management as a key problem in organic and LEI systems. Numerous investigators have concluded that improvements in weed management strategies that are minimally reliant on herbicides require the integration of multiple weed suppression tactics. However, the most cost-effective and efficacious ways to choose and combine tactics remain unclear. Here we suggest that the selection, deployment, and assessment of weed suppression tactics for organic and LEI systems would be aided by supplementing empirical studies with models of weed population dynamics. Such models are particularly valuable for evaluating the likely impacts of various sets of tactics on weed populations five to ten years into the future. We illustrate the utility of joining empirical and theoretical approaches with results from our recent work, which include the following predictions: (1) Reduced weed seedling recruitment, effected through the use of mulches and allelopathic cover

crops, and reduced weed fecundity, achieved through the use of crop cultivars, densities, and spatial arrangements that increase crop competitive ability, should reduce weed population growth rates and costs of weed control. (2) Controlling weed seed production in the stubble of a harvested crop through timely mowing, selective herbicide application, or surface tillage should have strong positive effects on weed control in subsequent crops. (3) Perennial forage crops are effective at reducing densities of annual weeds, but minimal gains in weed control should occur after two years of forage production. (4) Weed seed predation should play a critical role in suppressing weed population growth in systems managed with little or no herbicide, especially when tillage is delayed to retain weed seeds on the soil surface, and a diversity of crops is grown to provide continuous cover for seed predators. (5) Increased investment for several years in weed suppression through cultivation and hand weeding should result in lower cumulative weed control costs over the longer term. Whereas no model can be simultaneously general, realistic, and precise (Levins, 1966), models of weed population dynamics in organic and LEI systems have the potential to help direct scarce research resources and management time to where they are likely to be most beneficial.

582. The Ethics of Technology and Education in Weed Science. Robert Zimdahl¹; ¹Colorado State University, Fort Collins, CO, United States of America

This paper is intended to make three points. The first involves assumptions that we all make, including ethical assumptions. Some areas of truth do not yield to scientific inquiry. Truth must be sought in dialogue where it is obtained from a variety of points of view, none of which may be grounded in science. It is a messy process that questions assumptions, which is uncomfortable because most don't want assumptions questioned, they want to use them. The second point discusses problems in developed country agriculture that lead to the claim that agriculture, including weed science, needs a new ethic. Today's farmers must increase size to obtain market share and link with agribusiness to produce and market commodities. Is one of agriculture's problems that we give lip service to family farms and food quality but that we don't really care? Do we care what structure agriculture has? Is the price of food all we care about? Do we assume that someone will take care of the land because someone always has? Do we care that farmers are becoming low wage employees on their own land? The third point considers what is risked by trying to create an appropriate ethical standard for agriculture. All societies and all cultures, including the scientific culture, have created a system of values. It arises from collective beliefs and motivations gained through an understanding of and assumptions about the natural world, their fellow human beings, and the transcendent. Dominant cultures, including the scientific culture, have

always claimed the universality of their beliefs and values. The scientific culture has ignored making its values explicit and thereby ignored the ethical foundation of its work and its effects.

583. A Mental Model of Ohio Grain and Produce Farmers' Perceptions and Beliefs about Weed Management. Douglas Doohan¹, Robyn Wilson¹, Mark Tucker², Neal Hooker¹, Jeff LeJeune¹; ¹The Ohio State University, Wooster, OH, United States of America; ²Purdue University, West Lafayette, IN, United States of America

Experts have sought to understand the weak adoption by farmers of integrated weed management approaches and more recently, herbicide resistance strategies. Attempts to increase adoption of these strategies have relied largely on the innovation adoption methodology that assumes a significant number of non-adopters. Research has shown this methodology to be less than adequate for these contexts. In order to increase the effectiveness of engagement efforts there is a need for a more circular process of communication, which incorporates the perceptions, values, and existing beliefs of the target audience. A better understanding of the underlying drivers for decision making in these contexts will allow future efforts to more effectively communicate the need for integrated and preventive tactics. The objective of the research reported here was to probe the mental model (conceptual map) of farmers for weed management in an attempt to establish a baseline understanding of the key factors that drive their decision making. Thirty Ohio farmers participated in an in-depth interview where they were asked to reflect on how weeds are introduced and spread, what risks and benefits they pose, and what management strategies they are familiar with and which they prefer. Their responses were mapped, coded and analyzed for dominant beliefs and major decision making influences. The results indicate that farmers largely attribute the introduction and movement of problematic weeds to factors outside their control (e.g., the environment, specific plant characteristics). They do believe in diverse and integrated management, but their focus is on control as opposed to prevention. In general, they tend to receive messages about integrated and preventive approaches, but do not always put them into practice due to underlying beliefs about the inevitability of new weeds being introduced and spread on their farm.

584. Weed Science Education and Technology Transfer Systems in Brazil. Ricardo Filho¹; ¹Universidade de Sao Paula - ESALQ, Piracicaba, Sao Paulo, Brazil

Agricultural business in Brazil is very important corresponding to about 27% of the total economy. Weed control remains a major limiting factor to efficient crop

production in the developing countries. Actually about 160 courses in agronomy are offered in Brazil. It is important to have weed training and educated professionals. To develop a competitive weed production system, the first undergraduate course of weed science was established in 1969 at ESALQ/ USP-SP. The Brazilian Weed Science Society was created in 1963, and the official journal of the Brazilian Society was published in 1978 (Planta Daninha). At the university there are several important groups involved in conducting weed science programs (MS and PhD). Some of the most common weed management training opportunities for students and farmers in Brazil are seminars and workshops offered by university and/or industry specialists. The use of herbicides represents about 40% of the total agrochemicals used in Brazil. Integrated weed management systems are promoted through a wide range of bulletins, books, videos and other publications as a means of managing herbicide resistance weeds and/or delaying resistance development. A survey was carried out to know how the weed science was established as a course in most college and universities. At this moment the Ministry of Education and Culture is establishing the curriculum of the agronomy courses. The weed control technology transfer is sustained by the agricultural research and extension based on universities, research institutions (EMBRAPA) and a strong private sector. However, it is important to improve the communication as a way to have a better county extension agents, private agricultural consultants and agricultural product representatives. Other valuable training tools are the internet, videos, web sites and online education (long distance instructions). It is important to say that some aspects of technical themes such as biology, ecology, biological control from the integrated weed management systems need to be improved. Politicians at local and state level are becoming aware of the importance of allocating money for research.

585. Solving the Weed Problem in Africa would Increase Food Production and Improve the Lives of Women and Children. Leonard Gianessi¹; ¹CropLife Foundation, Washington, DC, United States of America

One of the greatest hindrances to improving crop production in Africa is inadequate control of weeds. Uncontrolled weeds lower crop yields by 25% in Sub-Saharan Africa. Many fields are not harvested because of severe weed infestations. Most smallholder farmers rely on handweeding by family members and hired workers. The availability of rural labor is declining as young people migrate to cities and due to the death toll of AIDS. Most of the weeding is done by women and children who spend about half of their lives pulling weeds. Much of the weeding is done too late to prevent yield loss. The parasitic weed *Striga* cannot be removed by hand and significantly reduces crop production. Numerous experiments have

shown that herbicides could be used by smallholders to control weeds effectively without the need for so much handweeding. The widespread adoption of herbicides in Sub-Saharan Africa would not only increase crop production but would also free millions of people from the drudgery of handweeding making it possible for them to pursue other productive activities and schooling. The first step toward increasing herbicide use in Sub-Saharan Africa is to make the public, the press, government agencies, and the international policy community aware of their potential.

586. Achieving High Adoption of IWM in Direct-Seeded Rice in the Philippines. Sally Marsh¹, Madonna Casimero², Rick Llewellyn³, Jesusa Beltran¹, Leylani Juliano²; ¹University of Western Australia, Crawley, Western Australia, Australia; ²Philippines Rice Research Institute, Maligaya, Nueva Ecija, Philippines; ³CSIRO Sustainable Ecosystems, Urrbrae, South Australia, Australia

A number of economic and environmental forces such as reduced water availability and increased labour costs are driving changes in rice planting techniques and weed management in the Philippines and Asia generally. Both flooding and manual weeding have been traditionally important for weed management in transplanted rice, but with direct seeding of rice there is less use of these methods and an increased reliance on herbicides, potentially leading to an increased likelihood of the development of herbicide resistance.

Here we describe and reflect on research work which involves farmers in the Philippines, and researchers in Australia and the Philippines with expertise in the areas of weed science, farming systems and agricultural economics. On-farm trials and farmer/researcher learning took place over a three-year timeframe, with the aim of testing and adapting an Integrated Weed Management (IWM) system that will be both profitable and practical for farmers growing direct-seeded rice. The approach used was village-level integration: a form of farmer participatory research which takes account of traditional or best farming practices of farmers and also involves the active participation of farmers in managing simple experiments on-farm.

An initial survey was conducted with 400 farm households in Iloilo and Nueva Ecija provinces to identify weed types in direct-seeded rice and assess farmers' current weed management practices. This informed participatory processes in four districts where local weed and rice production issues were scoped, and six seasons of on-farm trials were conducted with over 80 farmer cooperators. Measurements taken from the trials, which compared IWM with local Farmers' Practice, included weed density, weed weights, productive tillers, crop yield and economic results. Post-season evaluation meetings with farmers were used to assess the trial results and plan adaptations to the

IWM techniques being used. After two years, a survey was used to assess the uptake of the IWM techniques among farmer cooperators and neighbouring villagers.

A key insight from this research work was that learning on weed management techniques is more meaningful for farmers when encompassed within a broader farming systems framework. The on-farm trials indicated that IWM resulted in better weed management; higher crop yields, especially in the dry season; and higher net incomes for farmers. The IWM system had to be adapted to the reliability of the local irrigation system, which affects the ability to use longer land preparation and intermittent irrigation. A challenge to herbicide use was confirmed by the project's finding of herbicide resistance in *Echinochloa crus-galli* to products containing butachlor, propanil and pretilachlor. IWM is being adopted rapidly by the farmer cooperators (with 75% of them using all the IWM components on the rest of their farms) but more slowly by neighbouring farmers. Work with farmers to develop an effective and practical IWM system needs to be on-going, and consideration should be given as to how farmer knowledge and concerns can be cost-effectively incorporated into the development and extension of IWM systems.

587. Mass-Production of Insect Agents for Strategic Use in Classical Weed Biological Control. Rosemarie De Clerck-Floate¹; ¹Agriculture and Agri-Food Canada, Lethbridge, Alberta, Canada

Classical weed biological control, which involves the use of exotic organisms to control invasive alien plants, typically aims to establish thriving and self-spreading populations of the control agents following one or a few introductions into the new environment. Although there are notable examples of success using the classical approach, it often takes many years to achieve the level of agent establishment and population increase required for weed control to occur. Recent attempts to increase both the speed and predictability of biocontrol are leading to a more strategic approach to agent use, whereby practitioners strive to release the optimum number of agents to achieve desired outcomes as quickly as possible. However, once an effective strategy is developed for agent use, it can be hampered by a lack of available agents for release. Hence, the development of low-cost, practical methods of mass-producing agents can help alleviate this restriction on biocontrol implementation.

The feasibility of managed insect mass-production in weed biocontrol programs will be illustrated with a recent example involving the root weevil, *Mogulones cruciger* Herbst, introduced from Europe to Canada for control of the invasive rangeland weed, *Cynoglossum officinale* (L.) (houndstongue). The weevil has successfully established in British Columbia (BC) and Alberta (AB), is predictably reducing *C. officinale* populations, and quickly dispersing to new patches of the weed. However, because *M. cruciger*

is difficult to collect en masse from field sites, and expensive to rear in the laboratory, requests for it quickly outstripped supply. A research project was initiated to develop a cost-effective method of mass-producing the weevil to help meet the demand. The method involved growing *C. officinale* as a crop, seeding *M. cruciger* into the crop for propagation, and after an appropriate time, harvesting the weevils for distribution and use. The project objectives were to: 1) develop best management practices for growing *C. officinale* as a crop for optimal *M. cruciger* propagation; 2) develop a method to harvest the weevils; 3) determine the cost of weevil production using the best management method; and 4) determine if there are benefits to positioning weevil production sites in the midst of *C. officinale* infested territory.

Experiments to investigate the effects of various agronomic practices on *C. officinale* growth were conducted on cultivated land, replicated in time (2002-03 and 2003-04) and place (Lethbridge, AB and Creston, BC), and included the treatments of tillage method/ground cover, fertilization, herbicide application, and seeding rate, time, depth and method. Weevil population responses to these treatments were assessed as part of the experimental design (i.e., the number of larvae produced per plant per treatment), and in some instances, explored further in laboratory experiments. A suitable method of weevil harvest was developed, and an economic analysis was conducted to determine the cost of weevil production. After the last weevil harvest, the degree and distance of dispersal of *M. cruciger* to *C. officinale* patches that naturally occurred within 7 km around the production plots was determined by collecting *C. officinale* plants and dissecting them for larvae in 2006 and 2007. The data were mapped using Global Positioning System equipment and software.

Any agronomic practice that increased *C. officinale* root size increased weevil production because the weevil prefers large plants for feeding and egg-laying. In particular, the addition of nitrogen fertilizer increased both root size and larval numbers per root, and can increase the egg production of female weevils by 25%. The best management method for growing *C. officinale* as a crop for biocontrol agent propagation involved sowing the weed in October at a row spacing of 67 cm (i.e., 13 seeds m⁻²); applying fertilizer in the following spring at a rate recommended for cereal; applying glyphosate at 1.25 l ha⁻¹ in late fall or early spring before *C. officinale* seedlings emerge to control winter annual weeds; applying either imazamox + imazethapyr or nicosulfuron and using inter-row cultivation to control later emerging annual weeds. Wet-dry vacuum cleaners were used to harvest the weevils from *C. officinale* trap plants that were pre-planted separate from but near the crop, and cardboard box separators were used to sort the weevils from vacuumed debris. Considering all fixed and variable costs, the total cost of production was \$0.10-0.12 CAD per weevil, which

is considerably lower than that estimated for other weed biocontrol insects reared in a managed outdoor setting.

Approximately 85,000 *M. cruciger* were harvested from the production plots and distributed for release on *C. officinale* infestations throughout southern BC. Although the project was considered a success, only 10-12% of the weevils produced were actually harvested. It is suspected that many of the uncollected weevils dispersed to surrounding patches of *C. officinale*, which was confirmed by our dispersal study. The control of *C. officinale* infestations surrounding the study sites was a project bonus. Future research should improve the efficiency of weevil capture during harvest to increase the numbers for distribution, and to lower production costs.

588. Application of Biological Control to Vegetation Management in Forest Ecosystems. Simon Shamoun¹; ¹Canadian Forest Service, Pacific Forestry Centre, Victoria, BC, Canada

The growing demand for forest production and sustainability has increased the intensity of forest management practices. This requires good control of the vegetation competing with commercially planted conifer species. Mechanical, manual or chemical herbicides can control such forest weeds, but are expensive and have non-target effects that are of environmental concern. One viable option is the utilization of naturally occurring plant pathogenic fungi as an inundative biological control approach or mycoherbicides (i.e., the use of formulated products of indigenous fungal plant pathogens that are applied directly onto native target forest weeds in a similar fashion as chemical herbicides). The discovery and development of potential biocontrol agents to suppress forest weeds is receiving increased attention in the management of conifer plantations. The largest groups of forest weeds in Canadian conifer plantations are vigorous perennials that colonize rapidly after disturbance such as harvesting practices and fire. Among these forest weeds targeted are weedy hardwood species such as big leaf maple (*Acer macrophyllum*), red alder (*Alnus rubra*), and trembling aspen (*Populus tremuloides*). Other herbaceous species are bramble (*Rubus* spp.) and salal (*Gaultheria shallon*). Fungal plant pathogens from these weeds have been isolated, identified, tested by following Kochs postulates and evaluated under greenhouse conditions for their potential use as biocontrol agents. Thus far, application of formulated product of *Chondrostereum purpureum* onto cut stumps of weedy hardwood species prevents sprouting. A field trial experiment was conducted to test the efficacy of *C. purpureum* to inhibit the stump sprouting in red alder compared to manual brushing and chemical herbicide treatments. Field examination made one year post-treatments showed near complete mortality of stumps treated with *C. purpureum* (92%) or chemical herbicide (Vision) (97%). By the second year after trial

establishment, the *C. purpureum* treated red alder stumps had no resprouts, which was equivalent to those treated with chemical herbicide and was significantly less resprouting than on untreated formulation and manual controls. The Canadian Forest Service- Pacific Forestry Centre and commercial partner MycoLogic Inc. of the University of Victoria have collaborated since 1994 in order to generate data (scientific knowledge) relevant to the registration requirements by the Health Canada- Pest Management Regulatory Agency (PMRA) and the US Environmental Protection Agency (EPA). On September 23, 2004, EPA issued registration of the product Chontrol Paste (EPA Registration Number 74200). On November 22, 2004, the PMRA also granted registration for the Cp-PFC2139 product Chontrol Paste (i.e., PMRA Registration Numbers 27822). Development and registration of the *C. purpureum* as the first commercial biocontrol agent for management of weedy hardwood species in North American forests represents a major breakthrough in forest vegetation management practices and an additional valuable tool to our forest vegetation management tools box. Ongoing research and development activities are focused on other biocontrol agents for management of salmonberry (*Rubus spectabilis*) and salal (*Gaultheria shallon*). To date, the use of the newly discovered (*Phoma argillacea*) has been evaluated and showing promise as a potential biocontrol agent for *R. spectabilis*. Either mycelia or conidia were applied to foliage of salmonberry which were incubated for 48 hours at 100% R.H. under greenhouse conditions. Extensive necrosis of leaves and stems developed within 14 days. A minimum of 18 hours of continuous leaf wetness was required for infection to occur. To bypass the dew period and enhance the efficacy of *P. argillacea*, a new corn-oil based formulation was developed which completely control the salmonberry. In addition, the use of another newly discovered (*Phoma exigua*) has been assessed and showing good potential as a biocontrol for salal. A formulated product of *P. exigua* containing 20% mycelia, in 0.5% Potato Dextrose Broth (PDB) plus 0.5% gelatin could kill 3-month-old salal seedlings within 14 days. However, in the same study, the 3-year-old salal plants treated with the same formulated inoculum, resulted in an average of 77%. A 77% leaf infection caused by *P. exigua* is still acceptable compared to most of the registered chemical herbicides used to control of salal which causes less than 60% damage in Canada. Furthermore, another foliar pathogen of salal is *Valdensinia heterodoxa* is showing promise. The micro-environmental conditions in these sites are highly conducive for the establishment of the infection and the enhancement of the efficacy of a solid-based formulated product (i.e., *V. heterodoxa* colonized salal leaf pieces or wheat-salal-potato dextrose broth) of *V. heterodoxa* for management of salal. In spite of the potential results presented, there are still several constraints in the development of commercial biocontrol agents need to be overcome. These constraints are biological, environmental,

technological and commercial limitations. In conclusions, the exploitation of plurivorous, wood rotting fungi has shown promise while using other foliar fungal pathogens have exhibited potential as biocontrol agents for management of forest weeds in conifer regenerating sites.

589. Efficacy of Granular Formulations Containing *Phoma macrostoma* for Control of *Taraxacum officinale* in Turf.

Karen Bailey¹, Jo-Anne Derby¹, Russell Hynes¹, Stuart Falk²; ¹Agriculture & Agri-Food Canada, Saskatoon, Saskatchewan, Canada; ²The Scotts Company, Marysville, Ohio, United States of America

The fungus *Phoma macrostoma* is being developed as a bioherbicide for control of broadleaf weeds in turf. When applied to turf, the fungus causes emerging plants of *Taraxacum officinale* to turn white and die, but causes no symptoms on any grass species. Granular formulations were developed to test the efficacy of *P. macrostoma* under field conditions in Saskatoon in 2006 and 2007. The technical grade active ingredient (TGAI) was produced by growing *P. macrostoma* in solid state culture and then grinding the biomass into a powder. The TGAI was used to create 2 proprietary granular formulations (F2006 had a single large particle size whereas F2007 was made into large and small particle size granules). The formulations were compared to either the TGAI or herbicide standard (containing 2, 4-D, MCPP-p and dicamba), and an untreated control on a lawn that was naturally infested with *T. officinale*. The TGAI and 2X and 1X rates of F2006 provided control equivalent to the herbicide standard which was greater than 85%. Less weed control was obtained at 1/3 X and 1/2 X rates of F2006 (78% and 50%, respectively). The small particle granules of F2007 at a 1X rate provided equivalent weed control to the herbicide standard (58% and 62%, respectively). The small particle size applied at 1/2 X rate and the large particle size at 1X rate gave lower weed control (23% and 31%, respectively). The large particle size at 1/2 X rate provided no control. In conclusion, a bioherbicide containing *P. macrostoma* can provide control of *T. officinale* in turf equal to that of the herbicide standard. However, at lower rates of application the formulations are not as effective as the TGAI. Studies are being conducted to determine the binding and dispersion properties of the formulated granules.

590. Possibilities of Activity Enhancement of *Zygogramma bicolorata*, a Biocontrol Agent of *Parthenium hysterophorus*, by Temperature Regulated Diapause Aversion. Puja Ray¹, Sushil Kumar¹; ¹National Research Centre for Weed Science, Jabalpur, Madhya Pradesh, India

Parthenium hysterophorus L. is an annual herbaceous weed of neotropical origin. Due to its extremely wide

adaptability, high seed bank and low requirements, parthenium has spread in all parts of India, displacing native vegetation and causing health hazards in both human and live stock giving it a status of one of the seven worst weeds of the world. *Zygogramma bicolorata* Pallister. (Mexican beetle) is an effective biocontrol agent of parthenium. The beetle was introduced in India, Australia and several other parthenium infested regions of the world and has shown substantial effect in keeping the weed population down. Although *Z. bicolorata* is a good biocontrol agent of parthenium yet it has certain drawbacks, which hamper its biocontrol efficacy, for instance low to nil population of the beetle in the field when parthenium is at its early growth stage. As a result when population of the beetle rises the host weed has already reached its flowering stage to produce large number of seeds other than causing its usual menace. If *Z. bicolorata* remains active throughout the year, it can be more useful in parthenium suppression. The main cause of its inactivity is diapause.

Diapause in insects is a genetically determined, developmental process in response to environmental stimuli and thus the expression of diapause is subject to both environmental and genetic factors. It enables insects to synchronize life cycle with favourable conditions and to avoid or survive unfavourable periods. Diapause in temperate regions is fairly understandable as temperate regions are characterized by substantial, rather clearly defined and relatively predictable seasons. Diapause in tropical insects is more difficult to study than diapause in temperate zone as in *Z. bicolorata* which undergoes diapause even when the climate is most congenial for insects to breed with lot of naturally growing parthenium in the field conditions yet the beetle is seen to enter diapause increasingly from August to the end of winter in February. Therefore, a study was conducted to understand the diapause behaviour of *Z. bicolorata* and explore possibilities of its aversion by temperature regulation.

In a population of 0-day beetles kept at room temperature (26±10°C), 62% beetles entered diapause in 75 days. In other experiments, diapause ranged from 0 to 2.3% in 0-day beetles kept at 35°C while in the population of older beetles, only 7% beetles entered diapause in first 10 days of being kept at 35°C, after which no diapause took place even at room temperature. It proves that initial heat treatment can reduce diapause per cent in *Z. bicolorata*. Such diapause averted beetles can be especially useful for augmentative release of the beetles for management of parthenium. Further in 0-day beetles kept at 10°C, less mortality (3.6%) occurred and about 10% beetles entered diapause while rest of the beetles showed reduced activity and appeared to be in quiescence stage and few hours of room temperature (26±10°C) brought the beetles into normal activity.

Thus with further studies diapause averted beetles can be stored at low temperature for long time with less loss

due to mortality and can be augmented as and when required.

591. Are there any General Patterns of Plant Invasions?. Marcel Rejmanek¹; ¹University of California, Davis, Davis, California, United States of America

Plant Invasions, Causes, Consequences, Impact

Historically, there have always been spreading and migrating plant taxa. Colonization of deglaciated areas has been very well illustrated by many examples and we know that floras of many islands would not be here without occasional long-distance dispersal events. Now, however, the rate of human-assisted migrations (invasions) of plants is several orders of magnitude higher. Biological invasions are a widespread and significant component of human-caused global environmental change. There are three reoccurring major questions of invasion biology: (1) Are there any inherent differences in invasiveness among plant taxa? (2) Are some ecosystems more or less resistant to plant invasions? (3) What are consequences of plant invasions? An emerging theory of plant invasiveness based on biological characters has resulted in several rather robust predictions, namely for woody seed plants. However, in spite of the exponentially growing number of publications, there are still serious gaps in our understanding of invasive plants. Operational criteria for impact assessment of alien plants are one of them. Invasive species are often blamed for extinction of rare species. Invasive predators, pathogens, and herbivores provide several conclusive examples. As for plants, however, we still have to reach a more balanced view of what is really going on. Plant invasions are very often just symptoms of human-created changes in our environment rather than causes of those changes.

592. Understanding Patterns and Impacts of Invasive Species: Lessons from Two Fabaceae Species in Chile. Anibal Pauchard¹; ¹Universidad de Concepcion, Concepcion, Chile

Invasive trees and shrubs can greatly modify ecosystem properties, altering ecosystem structure and function, with potentially devastating impacts on native biota. However, few studies have been able to integrate patterns of distribution and ecosystem impacts. Environmental conditions in south-central Chile are especially suitable for tree and shrubs invasions because heavy anthropogenic use has decimated native forest cover. Two invasive species of the Fabaceae family are highly abundant in this area: *Acacia dealbata* (Silver Wattle) and *Teline monspessulana* (French Broom). *Acacia dealbata* Link is a tree native to Australia, which was introduced to Chile for erosion control and now occupies up to 15% of the landscape, usually forming monotypic stands. *Teline monspessulana*

(L.) K.Koch (syn. *Cytisus monspessulanus* L., *Teline monspessulana* (L.) L.A.S. Johnson) is an introduced shrub from Europe that forms monotypic stands or is present as an understory species in native forests as well as in forestry plantations. We assessed patterns of spread, effects on fire regime and impacts on biodiversity of the introduced species *Acacia dealbata* and *Teline monspessulana* in south-central Chile, using a multiscale approach. Both species appear to be displacing native vegetation, or at least limiting the recolonization of disturbed areas by natives. Furthermore, these species increase fuel load and flammability, thus altering fire disturbance regimes. At the landscape scale, we have established the magnitude of these invasions using remote sensing techniques and field sampling. We have found that both species are abundant in area heavily affected by human disturbance, but are rare in more natural environments. *Acacia dealbata* is easy to detect using aerial photos because its bright winter bloom, which has allowed us to understand spatial patterns and spread in the last five years. *Acacia dealbata* forms dense, aggregated, monotypic stands which are self-replacing after fire or logging. *Teline monspessulana* develops a seedbank that allows for a fast regeneration after fire. Our results suggest that fire promotes *Teline monspessulana* germination, generating a dense stand which increases fine fuels. This positive feedback perpetuates both intense fires and monotypic stands of the species, with ecological, economic and social consequences. Our study highlights that in order to understand the impacts of invasive species on ecosystem function, we should consider the magnitude of the invasion, but also which are the key ecosystem processes affected by the invader. This study was funded by grants Fondecyt 1070488 and ICM P05-002.

593. Spread of an Invasive Macrophyte in Northern Queensland, Australia: Understanding Associated Factors and Areas at Risk. Lynise Wearne¹, Peta Wright¹, Anthony Grice¹; ¹CSIRO, Townsville, Queensland, Australia

Understanding the factors that influence distribution patterns of invasive species is critical for predicting spread into new areas. Although it has long been recognised that species distributions are controlled by ecological patterns and processes at various spatial scales, few studies have investigated the distribution of invasive alien plants at different scales and the associated factors determining these patterns. In tropical northern Australia, grasses introduced as pasture species from Africa and South America are transforming wetlands and riparian systems. *Hymenachne amplexicaulis* (Olive hymenachne) is an example of a recently introduced exotic pasture species which has spread rapidly into wetlands and waterways. Prior to this study, our understanding of the rate of *H. amplexicaulis* invasion and the factors which influence spread has been limited. The current study reports on *H. amplexicaulis* invasion in the lower Herbert River

catchment in north-east Queensland, Australia. Specifically we address: (1) the rate of spread of *H.amplexicaulis*, (2) the current distribution and the factors influencing that distribution and (3) areas that are potentially susceptible to *H.amplexicaulis* invasion

We used GIS and field surveys to assess spatial and temporal changes in *H.amplexicaulis* distribution and associated landscape variables at the catchment (10,000km²), property (1700 km²) and local (1 hectare) scale. The catchment scale model showed distribution of *H.amplexicaulis* associated with soil, vegetation and flood level variables. At both the property and local scale, distribution and spread of *H.amplexicaulis* was associated with flood levels, vegetation and topography. The rapid rate of increase of *H.amplexicaulis*, and associated loss of waterways since the introduction of this species in the 1980s, suggests that management must intervene quickly in new areas of invasion. The information derived from the current study can be used to identify areas of risk within areas of new *H.amplexicaulis* infestations. Predictive methods which identify high and low risk areas of weed invasions are essential tools for managers to target and prevent the spread and establishment of new weed infestations.

594. Characterizing Pathways of Invasive Plant Spread to Alaska: Propagules from Container-Grown Ornamentals. Jeffery Conn¹; ¹USDA-ARS, Fairbanks, Alaska, United States of America

Invasive plants are brought to Alaska by numerous pathways. Characterization of invasion pathways can aid efficiency of prevention by targeting the largest pathways first. This research reports on the pathway resulting from importation of soil with container-grown ornamentals containing weed seed. Surveys of greenhouses, nurseries and stores were made in Alaska to identify the types of container-grown ornamentals sold and to determine pot sizes and origin of the containers. Imported ornamentals were found to be shipped bare root, in plugs, in pots, or balled and burlapped. From the store surveys we determined that container-grown plants fit into 5 categories: 1) vegetable starts/herbs, 2) herbaceous perennials, 3) small woody plants (pots 3.8 -11.4 L), 4) large woody plants (>18.9 L), and 5) balled and burlapped trees or shrubs. We purchased or sampled plants from each of the major growers in the following categories: 10 vegetable starts, 5 herbaceous perennials, 5 small woody, 3 large woody, and 3 balled and burlapped. Not all categories could be filled for each supplier because either the grower didn't produce each category of plants or the vendor didn't carry them. Soil cores (three, 2.5 cm diameter) were obtained from costly plants that were not purchased. We also purchased plants from four Alaska nurseries that make their own soil mixtures. We purchased or took soil samples from a total of 330 containers or root balls. Soil

from container-grown ornamentals was incubated in the greenhouse. Emerging seedlings were identified and counted. Fifty four plant species were identified growing in containers or germinating from the soil, and included Canada thistle, a prohibited weed in Alaska, and nine other species listed as invasive in Alaska: perennial sowthistle (*Sonchus arvensis* L.), common tansy (*Tanacetum vulgare* L.), creeping bellflower (*Campanula rapunculoides* L.), narrowleaf hawkbeard, St. Johnswort (*Hypericum perforatum* L.), common tansy (*Tanacetum vulgare* L.), common dandelion, Western salsify (*Tragopogon dubius* Scop.) and common mullen (*Verbascum thapsus* L.). The number of species and estimated seedbank were very low from vegetables/herbs and herbaceous bedding plants (< 2 seedlings/L soil) but was greater for soil from containers containing woody plants, and especially balled and burlapped ornamentals (20 seedlings/L soil). Potting soil held very few weed seeds while mineral soil contained an average of 20 seeds/L. Suppliers of ornamentals and vendors also influenced the size of the container seedbank suggesting that weed management practiced during production and at the point of sale can greatly influence seedbanks of ornamental containers. This pathway for alien plant introduction could be reduced through consistent use of sterilized soil and good weed management. The pathway could be eliminated by prohibiting importation of soil to Alaska. Ornamentals could be shipped bare root and planted into clean soil after arrival.

595. Evaluating the Role of Vehicles in the Transportation and Spread of Plant Propagules. Lisa Rew¹, Hal Balbach; ¹Montana State University, Bozeman, MT, United States of America

Plant species are introduced to areas where they are not native by a variety of natural and anthropogenic means, and the number of anthropogenic introductions has increased in recent decades. Roads are regarded as dispersal vectors for plant species due to transport and spread by vehicles, and thereafter, by natural population expansion in the more-disturbed environments along the right of way. Plant propagules (seeds and other reproductive parts) have been observed on vehicles, but the number of studies is limited. More propagules are likely to be collected by vehicles driven off-road than on gravel roads, and by tracked or all-terrain vehicles than civilian pattern vehicles, but there are no quantitative data to support this hypothesis. Our study aims to quantify the number of propagules carried by different types of vehicle on different surfaces (gravel roads and off-road) and in different ecosystems. During the summer of 2007, light 4-wheel drive and heavier all wheel drive vehicles were driven along gravel roads for known distances and the soil and other waste removed with a commercial weed wash unit, and the waste contained. Effectiveness of the vehicle wash unit had

been evaluated previously. The waste samples were placed in the greenhouse, and germination and establishment of all individuals is being recorded over a 12 month period. Currently, after six months, we have observed over thirty species, and the total number of individual plants observed to date represents between 1 and 10 seeds per vehicle and kilometer driven. When this experiment is complete we will be able to evaluate for differences in propagule pressure between vehicle types. The study will be repeated in future years with the same vehicle types but for more surfaces and ecosystems, to provide an improved understanding and quantification of the potential of plant propagules to be spread by vehicles. These data can be used with data of non-native species frequency with distance from road to improve predictive models of rate of spread along and adjacent to roadways.

596. The Development of Cellulosic Biofuels. Chris Somerville¹; ¹University of California, Berkeley, CA, United States of America

The earth receives approximately 4000 times as much energy from the sun each year as the total projected human uses in 2050. Thus, because plants can be deployed on a large scale to capture and store solar energy, one way of moving toward the development of carbon neutral energy sources is to use plant biomass for production of fuels. In considering this possibility, the Secretary of Energy of the US has called for the replacement of 30% of the liquid fuels used in the US with biofuels by 2030.

Because of the large volume of fuel used by developed countries, the development of a large-scale biofuels industry in the developed world will require an enormous capital investment. A large-scale biofuels industry will also create competition with the use of arable land for food production. Thus, even though it is currently feasible to convert biomass to fuels by a variety of methods, there are many inefficiencies in the overall process that must be eliminated in order to make the most efficient use of land and capital. Many of these issues have been described in a workshop that was sponsored by the US Department of Energy to evaluate the scientific and technical issues associated with biofuel production in the US. The proceedings of that workshop are available online at <http://www.doegenomestolife.org/biofuels/>

In brief, the efficient production of biofuels by routes other than gasification will require innovation in three main areas: production of feedstocks, conversion of feedstocks to sugars, and conversion of sugars to fuels. At present, the main feedstocks being used for fuel production are corn starch and sugar from sugarcane. However, the demand for fuel vastly exceeds the amount that can be produced from these feedstocks so it is expected that gasoline and diesel replacements will ultimately be derived from cellulosic biomass. In this respect there is renewed interest in identifying plants that

have optimal biomass accumulation and understanding the production issues associated with large-scale cultivation and sustainable harvesting of such species. There has not been a major effort to improve herbaceous plants for enhanced biomass production and there are many outstanding questions. Additionally, the importance of enhancing soil carbon and nutrient retention while minimizing inputs will require an integrated approach to the development of cellulosic energy crops. Parallel technical developments on the biomass-to-fuels processing side also have important implications for how the industry is likely to develop. Thus, for instance, enzyme-based conversion technologies for biomass hydrolysis may be more sensitive to overall biomass composition than thermal decomposition methods.

597. Glyphosate-Resistant Wheat and Canola Systems: Volunteer Crop Persistence. Robert Blackshaw¹, Ken Harker¹, George Clayton¹, John O'Donovan¹, Eric Johnson¹, Yantai Gan¹, Rick Holm², Ken Sapsford², Bryon Irvine¹, Rene Van Acker³; ¹Agriculture and Agri-Food Canada, Lethbridge, Alberta, Canada; ²University of Saskatchewan, Saskatoon, Saskatchewan, Canada; ³University of Guelph, Guelph, Ontario, Canada

Roundup Ready (RR) canola is grown annually on three million ha in Canada and RR wheat was being considered for commercialization in past years. Concerns exist about the management of volunteer RR crops in subsequent years. Field studies were conducted over four years at eight locations in western Canada to determine the effect of various crop rotation and tillage systems on the emergence and seed bank persistence of RR canola and RR wheat. Rotations consisted of continuous cropping versus alternating crop and fallow years. Tillage consisted of conventional and zero tillage. A known amount of RR canola or RR wheat seed was broadcast on the soil surface in the fall of 2000 and volunteer populations were monitored in three subsequent years. When sufficient rainfall occurred after harvest, numerous RR volunteer plants emerged in September and October and were subsequently killed by freezing temperatures over winter. Tillage compared with zero tillage often encouraged earlier and greater emergence of volunteer RR canola and wheat plants the following spring. However, persistence over time increased slightly with tillage and may be related to induction of secondary dormancy, especially in canola. In cool, dry springs and at early seed dates, very few RR volunteers were present at seeding and control measures were not warranted. However, volunteer RR canola and wheat were nearly always present at the time of applying in-crop herbicides, thus emphasis needs to be placed on in-crop control. Inclusion of fallow in the rotation did not decrease persistence compared with continuous cropping. The majority of volunteer RR canola and RR wheat emerged in the first year after production, with only small

populations present in subsequent years. In the third year after production, RR wheat densities were less than 1 plant m² and no RR canola plants were detected. Soil seedbank data at the conclusion of the study indicated that virtually no viable RR canola or RR wheat seed was present three years after the crop production year. Results indicate that RR canola and RR wheat persistence is of relatively short duration and should pose no major agronomic problems.

598. Glyphosate-Resistant Wheat and Canola Systems: Weed Communities. Kenneth Harker¹, George Clayton¹, Robert Blackshaw¹, John O'Donovan¹, Newton Lupwayi¹, Eric Johnson¹, Yantai Gan¹, Robert Zentner¹, Guy Lafond¹, Byron Irvine¹; ¹Agriculture & Agri-Food Canada, Lacombe, Alberta, Canada

Glyphosate-resistant (GR) canola is common on the western Canadian prairies. GR wheat was considered for introduction in western Canada, but was voluntarily withdrawn by Monsanto Inc. A study was conducted at six western Canada research sites to determine GR wheat and GR canola rotation frequency effects on weed populations in GR spring wheat and canola cropping systems from 2000 to 2003. Four-year wheat?canola?-wheat?pea rotations were devised with varying levels of GR crops in the rotation in different tillage systems and seeding dates. Weed populations were determined at pre and post in-crop herbicide application intervals in 2000 and 2003. Early seeding led to higher and more variable in-crop wild oat and wild buckwheat populations. High frequencies of GR crops in the rotation usually improved weed management and reduced weed density and variability. Canonical discriminant analysis (CDA) across all locations revealed that by 2003, green foxtail, redroot pigweed, sowthistle spp., wild buckwheat, and wild oat, all associated with the rotation lacking in-crop glyphosate. Similar CDA analyses for individual locations indicated specific weeds were associated with 3 yr of in-crop glyphosate (Canada thistle at Brandon, henbit at Lacombe, and volunteer wheat, volunteer canola, and round-leaved mallow at Lethbridge). However, only henbit at Lacombe and volunteer wheat at Lethbridge occurred at significant densities. Overall, rotations including GR spring wheat and canola did not significantly increase short term weed management risks in conventional tillage or low soil-disturbance direct seeding systems. Although excellent weed control was attained in rotations containing a high frequency of GR crops, the merits of more integrated approaches to weed management and crop production should also be considered.

599. Assessing Long-Term Viability of Roundup Ready Technology as a Foundation for Cropping Systems. David Shaw¹, Robert Wilson², William Johnson³, Stephen Well-er³, Micheal Owen⁴, Bryan Young⁵, David Jordan⁶;

¹Mississippi State University, Mississippi State, MS, United States of America; ²University of Nebraska, Scotts Bluff, NE, United States of America; ³Purdue University, West Lafayette, IN, United States of America; ⁴Iowa State University, Ames, IA, United States of America; ⁵Southern Illinois University, Carbondale, IL, United States of America; ⁶North Carolina State University, Raleigh, NC, United States of America

Weed scientists from six U.S. states, Mississippi, North Carolina, Nebraska, Indiana, Illinois, and Iowa, are conducting similar studies over a four-year period at on-farm sites to determine the viability of various cropping management strategies for the preservation of Roundup Ready programs as an effective tool for weed control. This research initially employed a grower survey to determine trends, and based on the survey results a subset of the farmers surveyed were contacted to establish alternative management strategies on their farms over the next four years. Shifts in weed populations, changes in weed species present, and levels of weed control are being monitored over this period with various combinations of cropping, tillage, and herbicide rotation systems. Survey results indicated that corn, cotton, and soybean growers have noted fairly dramatic changes in their weed pressure after adoption of Roundup Ready technology. Prior to Roundup Ready usage, 18 to 25% of growers reported only light infestations of weeds in their fields, whereas after Roundup Ready adoption 66 to 79% reported only light weed infestations. Of particular note were corn growers; 35% reported very heavy weed pressure before Roundup Ready, but after Roundup Ready adoption only 8% reported continuing heavy weed pressure. A number of weed species were no longer considered to be challenging to manage after Roundup Ready adoption. However, a few had emerged as continuing or even greater problems, including morningglory species, pigweed species, and annual grasses. From the survey data collected, long-term field studies have been initiated that develop paired comparisons between grower practices versus academic recommendations for effective resistance management. The academic recommendations focus on following herbicide resistance management practices, primarily the inclusion of herbicides with other sites-of-action, particularly residual herbicides at planting. Based on producer responses, three groupings of cropping systems were

developed for the long-term field studies that were initiated 1) a continuous GR crop, 2) a GR crop rotated with another GR crop, and 3) a GR crop rotated with a non-GR crop. Weed population and economic data are being collected over the four-year period of the study.

600. Long-Term Effects of Herbicide-Tolerant Corn in the Philippines. Aurora Baltazar¹, Wilma Cuaterno², Santiago Palisada², Paulino Matamis², Roynic Aquino², Abraham Fajardo², Virginia Rendon², Eduardo Lit², Pepito Leya²,

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Next to rice, corn is the second most important cereal grown in the Philippines. Corn growers spend up to 20% or more of production costs to prevent yield losses, which can go up to more than 30%. Weed management inputs in the course of a cropping season include preemergent application of pendimethalin or atrazine, followed at early to mid-season by two to three handweeding and interrow cultivation. The introduction of glyphosate-tolerant corn expanded postplant weed control options from tedious and labor-intensive mechanical control to more cost-effective chemical control. The variation in susceptibilities to glyphosate among weed species continued use of glyphosate may result in shifts towards more difficult to control species if glyphosate is intensively used. This study was conducted to investigate possible changes in weed species associated with the adoption of weed management systems in glyphosate-tolerant corn.

Weed surveys were conducted from 2005 to 2007 in eight farmers' fields, four in Luzon (northern Philippines) and four in Mindanao (southern Philippines). In each field, the sampling sites were two adjacent 0.5 ha plots. In one plot a glyphosate-tolerant corn management system was used and the other, a control plot, was treated according to local practice. In the glyphosate-tolerant corn, 0.7-0.14 kg ae/ha glyphosate was applied twice, the first application at 15 days after planting (DAP) to weeds up to 5 cm tall and the second application at 40 to 45 DAP to weeds up to 10 cm tall. The control plot treatments included two to three handweeding and inter-row cultivation with a disc harrow at 15 to 21 DAP followed by hilling-up with a moldboard plow at 20 to 30 DAP. Weeds were collected from five 1 m² quadrats in each 0.5 ha area, then counted by species. Sampling was done twice, the first at 45 DAP (vegetative stage) and the second at 75 DAP (postflowering).

After four cropping seasons using these practices on the Mindanao farms, the dominant weeds, consisting of 30 to 80% of the total weed population, varied among the four farms. At Misamis Oriental and Bukidnon, the dominant weeds in the glyphosate-tolerant plots, *Synedrella nodiflora* and *Cleome rutidosperma*, were unchanged over the four seasons. At Tampakan, South Cotabato, *Euphorbia heterophylla*, was the dominant weed in the first season, was replaced by *Echinochloa colona* and *Eleusine indica* in the second and third seasons but returned as most dominant in the fourth season. The farm at Koronadal, South Cotabato had four different weeds dominating each season, *Ageratum conyzoides* in the first season, *Rottboellia cochinchinensis* in the second, *Cleome rutidosperma* in the third, and *Portulaca oleracea* in the fourth season.

The study was in its second season on three farms in Luzon and in the third season at Nueva Ecija. At Nueva Ecija, *Cyperus rotundus* dominated (80% of the popula-

tion) the first season in the glyphosate-tolerant plots. However, this was reduced to 38% of the weed population in the second season while *Echinochloa colona*, which was only 6% of the population in the first season had increased to 45% and became the dominant weed by the second season. In the control plots at this site, *C. rotundus* was the dominant weed followed by *E. colona*.

After four cropping seasons in glyphosate-tolerant corn weed management systems, no clear patterns in weed species shifts are noticeable in both glyphosate-tolerant and control plots in all the farms. Generally, the dominant weed did not change with weed management. However, some minor species, such as *Borreria laevis*, *Euphorbia heterophylla*, and *Boerhavia erecta* increased in populations with continuous corn production. This trend occurred in both glyphosate-tolerant corn and control plots and can not be attributed solely to the continued use of glyphosate. Continued observations into the fifth and future seasons will focus on species considered difficult to control with glyphosate, including *Commelina benghalensis*, *Commelina diffusa*, *Cyperus rotundus*, *Borreria laevis*, and *Synedrella nodiflora*.

601. Weed Infestation in Multi-Year Cultivation of Glyphosate-Resistant Maize. Arnd Verschwele¹, Norbert Müller²; ¹Julius-Kühn-Institute, Braunschweig, Niedersachsen, Germany; ²Monsanto International SARL, Morges, Switzerland

The cultivation of transgenic glyphosate-resistant crop varieties can simplify weed control in crops such as *Zea mays* (maize) and others. On the other hand, the repeated use of broadly effective herbicides, especially in the same crop, can have a negative effect on biodiversity. It was the aim of a 4-years field study to investigate weed effects of use of glyphosate in a continuous transgenic herbicide-resistant maize rotation. The studies at 3 representative sites in Germany began in 2003 and will extend over a total period of 6 years. The focus of the studies was the comparison between representative local and standard treatments in the glyphosate-resistant maize with the split application of 2 x 3 L/ha Roundup Ready (360 g/L glyphosate).

In each of these treatment plots, 4 square sub-plots in a fixed position with an area of 9 m² were installed. Within these sub-plots, a visual assessment of the percentage of weed coverage was made at a maximum of 6 times a year. To determine the number of weed seeds per species in the seed bank, soil samples were taken from the sides of the same sub-plots shortly after the maize was planted. Weeds were identified by subsequent germination tests. To include as many viable seeds as possible the soil samples were mixed and spread out multiple times, cooled and dried in between germination timings.

During the entire test period, 38 weed species were counted in the field surveys, which was far fewer than in

the soil seed bank, in which 68 species occurred. Of those, 33 species occurred with a frequency of less than 25%, and 18 of those were found only on one site in 1-2 years. Alternatively, 14 weed species were found in at least 75% of the surveys. The number of weed species in the soil seed bank tended to increase from 2003 to 2006 although there was no significant treatment effect in any of the 3 sites. This trend was not identified in the field surveys, however. The spectrum of weed species and number of weed seeds in the soil were highly location-dependent, although there was no significant effect of herbicide treatments. Above all *Amaranthus retroflexus*, *Solanum nigrum*, *Veronica persica* and *Chenopodium album* had high seed production, which results in an increase of the weed seed bank in almost all treatment variants. Only the Roundup Ready treatment showed a slight decrease by 10% in comparison from the first year to the third year. The composition and relative frequency of weeds, however, did not differ from the local standard treatment.

In addition to the total number of species, a potential influence of the herbicide treatments on the composition of the weed species was investigated. Averaged over the sites and treatments, the relative frequency of the following weeds increased: *Amaranthus retroflexus*, *Solanum nigrum* and *Chenopodium album*. In some years the soil seed bank increased by a factor of up to 5. There was a significant decrease in the seed number of *Capsella bursa-pastoris*, *Juncus bufonius* and *Solanum nigrum*, although here, too, there was no identifiable effect of the Roundup Ready treatment. Only the seed bank of *Poa annua* was significantly reduced by the high Roundup Ready dose (decrease by 41%). Other weeds such as *Echinochloa crus-galli*, *Gnaphalium uliginosum* and *Galinsoga ciliata* reacted weakly and indifferently overall. Significant effects by the Roundup Ready treatment in comparison to the standard treatment on the composition of weed species has therefore not been identified at this time. A differentiated analysis for each of the 3 sites produced the same result. Finally, the field surveys also confirmed these results of seed bank dynamics. On account of the high spatial and temporal variation, however, changes should continue to be observed, especially with the less frequent weed species.

The results so far do not indicate any significant changes in weed infestation as a result of repeated glyphosate applications in comparison to standard treatments. Certain weed species did not increase extra-proportionally, nor were others eliminated from the site after 4 years. According to the most current information from the ongoing tests, neither the weed flora nor the seed bank in the soil was influenced by the repeated Roundup Ready treatment.

602. A Long-Term Study of Weed Flora Shifts in Arable Crops in Argentina. Eduardo Puricelli¹, Daniel Tuesca¹;

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In Argentina, soybean is the main arable crop and its planted area has been increasing since 1976. Other important crops are corn and wheat. By the time of soybean introduction, conventional tillage -based on moldboard plough- was used, but due to soil conservation concerns, minimum and non-tillage practices are now widely adopted. At present, glyphosate-resistant soybean represents 99% of the area planted to this crop, and glyphosate-resistant corn area is increasing. This study analyses the long-term effect of tillage, use of glyphosate alone and with residual herbicides on weed species density, richness and diversity in three crop sequences in the central soybean region of Argentina. Studies were conducted at the Experimental Farm of the University of Rosario at Zavalla (Lat. 33°01 S, Long 60°53 W), Argentina from 1992 to 2007.

Experiments were laid out in separate crop sequences. Plots were 15 x 20 m. Three periods were considered: 1992-1997. The crop sequences were: a) wheat/soybean (WS) (double cropping of wheat and soybean grown in the same year) and corn-soybean (CS) (soybean or corn grown as a single summer crop per year with a winter fallow) and tillage systems were conventional tillage (CT) vs. non-tillage (NT). In each sequence, experiments were laid out in a complete randomized block design of two tillage systems with four replications. In NT, glyphosate was applied before planting and in CT, cultivation in summer crops was done. Herbicides applied in WS sequence were metsulfuron-methyl and dicamba in wheat and haloxyfop-methyl and imazethapyr in soybean. In SC sequence, in soybean, bentazon, haloxyfop-methyl, and imazethapyr; and in corn, dicamba, nicosulfuron, and 2,4-D. 1998-2001

A third sequence was added consisting of a soybean monoculture (SS) (soybean as a single summer crop per year) in CT and NT with the same experimental design of the other sequences. Weed control was based on glyphosate applied once before planting soybean and corn and in fallow in NT, and once at 40 days after planting in both tillage systems.

2002-2007. In each sequence, experiments were laid out in a complete randomized split-plot design of two tillage systems and two herbicide treatments with four replications. The plots consisted of two tillage systems (NT and MT). MT plots were disked-harrowed and laid out on the CT plots of the previous periods). Plots were divided in two sub-plots corresponding to herbicide treatments - application of glyphosate alone (NR) and glyphosate with residual herbicides (R)-. The residual herbicides used for soybean were metsulfuron-methyl in fallow and imazethapyr at soybean planting, and for corn, atrazine in fallow and at corn planting. All herbicides were used at the recommended dose and glyphosate dose was always 900 g ae/ha. Weed counts were taken at different intervals in fifteen randomly selected 0.35 m² quadrats per plot. Weed

density, richness, and diversity were analyzed and regressions were fitted to determine changes with time. 1992-1997. In summer crops, early-emergence annual broad-leaved species such as *Portulaca oleracea*, *Datura ferox*, and *Chenopodium album* were higher under CT than NT. With time, in NT, grassy annual populations, particularly *Digitaria sanguinalis* increased in the SC sequence, and wind-dispersed weed populations increased in the WS rotation. In all sequences and tillage systems late-emergence annual broad-leaved species e.g. *Bowlesia incana*, *Lamium amplexicaule* and *Stellaria media* were present at summer crop harvest, fallows, and in wheat. 1998-2001. Exclusive glyphosate application, reduced density of early-emergence annual broad-leaved species and grassy annuals, regardless of crop sequence and tillage system. Some new late-emerging annual broad-leaved species increased their density, particularly in NT. Among them, *Parietaria debilis* a glyphosate-tolerant species showed the highest increase in density. With time, in both tillage systems, richness of early-emergence annual broad-leaved species decreased in both, SC and SS sequences, while late-emergence annual broad-leaved species richness increased for all sequences. 2002-2007. For all sequences, density of early-emergence annual broad-leaved species was higher with tillage in NR but not in R. Grassy annuals, particularly *Eleusine indica*, were more abundant in NT in the SC sequence. In NT NR, density of late-emergence annual broad-leaved species -particularly *P. debilis*- was the highest. Richness in NT increased with time due to the appearance of species tolerant to glyphosate (*Oenothera indecora*, *Viola arvensis* and *Commelina erecta*). In this study, no species resistant to glyphosate were recorded. Diversity was similar between treatments and showed an erratic response with time. The adoption of non-tillage practices determined a steady shift in weed species density. Continuous use of glyphosate alone reduced richness and density of summer annual weeds and increased density of tolerant species. Glyphosate with residual herbicides reduced richness and density of most species minimizing selection pressure for weeds tolerant or resistant to glyphosate.

603. Impacts of Long-Term Glyphosate-Resistant Cropping Systems on Weed Communities in Ontario. Peter Sikkema¹, Robert Gulden¹, Allan Hamill², Francois Tardif¹, Clarence Swanton¹; ¹University of Guelph, Ridgetown, Ontario, Canada; ²Agriculture & Agri-Food Canada, Ridgetown, Ontario, Canada

Glyphosate-resistant (GR) cropping systems are popular and used extensively by producers. However, the long-term impacts of heavy reliance of this technology on weed community assembly are not known. Five fully-phased field experiments (2 No-tillage and 3 conventional tillage) were established at four locations in southwestern Ontario where the effects of herbicide system in maize and soybean

(glyphosate or conventional) and crop rotation (maize-soybean or maize-soybean-winter wheat) on mid-season weed community assembly were examined over a period of 6 years. Multivariate analysis on data averaged over the last 3 years of the experiment showed that weed community assembly was distinctly different among the treatments within each experiment. Mid-season weed community assembly was more similar in maize and soybean treated with glyphosate compared to the same crops treated with conventional herbicides reflecting the continuous application of the same selection pressure. Weed communities in winter wheat were distinctly different from those in maize or soybean treated with either herbicide system and showed few residual effects of herbicide system used in the previous crops. Among the five experiments, the number of weed species that were associated with herbicide system in maize and soybean contrasted between the tillage systems. With few exceptions, response of individual weed species tended to be inconsistent among experiments and the most abundant weed species also varied among experiments and treatments. Volunteer maize did not pose a serious problem using either herbicide system. The dramatically different mid-season weed community assembly in winter wheat indicates mitigation of the consistent selection pressure exerted on the weed community under high use intensities of GR technology and therefore inclusion of this crop in rotation is recommended.

604. Sustainability of Glyphosate-Resistant Cropping Systems - Results from 10 Years of Research in the U.S. High Plains. Robert Wilson¹, Stephen Miller², Andrew Kniss², Philip Westra³, Phillip Stahlman⁴, Robert Klein¹; ¹University of Nebraska - Lincoln, Scottsbluff, Nebraska, United States of America; ²University of Wyoming, Laramie, Wyoming, United States of America; ³Colorado State University, Ft. Collins, Colorado, United States of America; ⁴Kansas State University, Hays, Kansas, United States of America

Experiments were conducted at five locations: Scottsbluff and North Platte, NE; Fort Collins, CO; Torrington, WY; and Colby, KS from 1998 through 2007 to determine if glyphosate use patterns in glyphosate-resistant cropping systems influenced weed control by placing selection pressure on weed species, altered weed population dynamics, or lead to the development of glyphosate-resistant weeds. Three of the sites - Fort Collins, Scottsbluff, and Torrington - were irrigated to supplement natural rainfall, and two of the sites, Colby and North Platte, utilized only natural precipitation for crop growth. Experiments were initially designed as a two factorial split-plot set in a randomized complete block design but in 2004 were modified to further divide the subplot to include a third factor in the experiment. The two main plots were continuous glyphosate-resistant corn or a crop rotation of

glyphosate-resistant crops. At the irrigated sites the crop rotation included corn, sugarbeet, spring wheat, and soybean while at the rain-fed sites the crop rotation consisted of corn, soybean, and winter wheat. There were four sub-plots that consisted of glyphosate at 0.4 kg ae/ha applied in-crop twice each growing season (low-rate glyphosate), glyphosate at 0.8 kg/ha applied twice (standard-rate glyphosate), a non-glyphosate treatment designed to control a minimum of 95% of the weed population (non-glyphosate), or an alternating treatment of glyphosate at 0.8 kg/ha applied twice followed the next year by a non-glyphosate treatment (alternating). In 2004 each of the sub-plots were randomly divided so that half the plot received an additional non-glyphosate herbicide treatment at planting or postemergence. The seed bank was examined each year before crop planting. Weed density was measured before herbicide treatment, 2 wk after the last postemergence glyphosate treatment, and at crop harvest when crop yields were also determined. After 3 yr of using the low-rate glyphosate treatment at Scottsbluff, *Chenopodium album* density increased compared to that in the standard-rate glyphosate or alternating treatments. By the sixth year, the density of *Chenopodium album* in the low-rate glyphosate treatment had increased to the extent that corn grain yield was reduced 43% compared to the standard-rate glyphosate treatment. During the same time interval at Fort Collins *Polygonum convolvulus* increased and at Torrington *Polygonum convolvulus* and *Chenopodium album* increased in the low-rate glyphosate treatment compared to the standard-rate glyphosate treatment.

605. **Technology for Site-Specific Weed Control.** Markus Sökefeld¹; ¹University of Hohenheim, Stuttgart, Germany

In order to meet the heterogeneous distribution of weeds and weed species within agricultural fields with a feasible selective application of herbicides three basic requirements must be given:

1 Knowledge about the small-scale distribution and species composition of weeds within agricultural fields

2 A decision algorithm derived from the knowledge from 1, in order to separate sub areas for site-specific herbicide application with respect to economic weed thresholds and varying yield potential within the field

3 Application systems with the opportunity of high resolution and fast variation of herbicide, herbicide combination and the dose rate of the active ingredients for the adaptation of the decisions from 2.

1 Weed detection and classification

For a map based application of herbicides as well as for an online application detailed information about weed species composition and distribution is needed. Simple and quick methods for the reflection measurement of plant and soil make it possible to determine the coverage of green plants. A save discrimination between weeds and crops or

even between weed species is yet not possible. Thus the application of selective herbicides based on this technique is not feasible.

Camera based weed detection techniques in combination with digital image analysis have the power to distinguish between crops and weeds and the discrimination of weed species or groups of weed species like broad leaved weeds or grass weeds. A vehicle equipped with a special camera technique for taking images in combination with a GPS receiver provides high quality images free of disturbing effects by stones, soil and mulch with their associated geo-data. Knowledge based image analysis systems are used for the weed discrimination by means of characteristic contour and shape parameters. A table containing the number, coverage and type of weed in every classified image together with GPS co-ordinates is the result of the operation. This can be used for the calculation of weed distribution maps or even for online spray control.

The results of the image analysis show high identification rates between 75% and 98% depending on factors like type of crop, growth stage of weed and crop, selected parameters and classifier for identification.

2 Decision making

Methods and models for the estimation of economic weed thresholds with consideration of weed coverage, weed density, weed species, predicted yield loss and costs of herbicide application are known for more than 20 years. The idea of these models is to calculate economic weed threshold for an entire field. Local conditions which influence the weed distribution, weed species composition and growth stages and the variation of yield are not taken into account. This approach is leading to wrong decisions in many parts of the field. Only in a few cases the herbicide application is adapted to the actual weed infestation. In the majority of cases the weed infestation is over- or underestimated.

In consideration of competitiveness of weed species, weed density and yield variability within a field predicted by yield maps over several years new models are able to identify weed management zones for site-specific herbicide application.

Phytotoxic effects of the herbicides leading to a depression of yield should be taken into account for the estimation of site-specific economic weed thresholds.

3 Application systems

In order to use the full advantages of site-specific weed control herbicide application based on information about the distribution of weed species it is necessary to use an application technology, which is able to change the application rate and type of herbicide rapidly.

One possible technology are multiple sprayers with separated hydraulic systems (tank, pump lines, nozzles ,etc.) mounted on one chassis. The sprayers work independently from each other. Problems like remaining herbicide mixture after spraying and a small range of herbicide quantity regulation have not been solved.

Another approach is to employ sprayers with an integrated direct injection system. In injection sprayers herbicides and carrier (water) are kept separate. According to the indications of the weed detection, the herbicides are metered into the carrier and mixed immediately before entering the nozzles.

In current direct injection systems there are two crucial factors, which influence the accuracy of real-time patch application. The first one is lag time, i.e., the time it takes for the mixed solution to flow from the injection point to the nozzles. Commercial direct injection sprayers are working with one central injection point close to the main pump, thus lag times up to 40 s were measured. The second factor is the occurrence of non-uniform mixtures caused by inadequate mixing of herbicides and carrier due to varying physical properties of different herbicides like formulation, viscosity or solubility.

Experimental direct injection system with one injection point for each boom section (3m each) obtained a lag time between 4 s and 7 s.

Even a shorter lag time between 1.4 s and 0.8 s can be achieved by the injection of the herbicide at each nozzle.

The improvement and the combination of the three described process steps will result in a fast and precise online system for site-specific herbicide application.

606. Progress in Site Specific Weed Control/Herbicide Use in The Netherlands. Corné Kempenaar¹, Vincent Achten¹, Frits van Evert¹, Bert Lotz¹, Rommie van der Weide¹, Jan van de Zande¹; ¹Wageningen University & Research Centre, Wageningen, Gelderland, Netherlands

In order to meet quality targets for drinking water, a major reduction in herbicide use is needed (mid term evaluation of the Dutch Covenant on Sustainable Crop Protection in 2005). Herbicide use may be reduced through the application of site specific weed control. Additional benefits of site specific weed control are an increase in crop yields and an increase in farmers net return. Several projects at Wageningen University & Research Centre focus on the elements of site specific weed control, namely sensing, decision rules and actuation. Specific projects focus on (1) sensor technology for detection of weeds in crop rows, (2) decision support rules (DSR) for site specific dosing of herbicides (www.mlhd.nl), (3) actuators for mechanical and thermal control of weeds in crop rows, and (4) precision spray technology. In addition, we have projects on integration of these elements into working prototypes.

The objectives of the work presented here were (1) to develop site specific haulm killing of potato, and (2) develop a robot for control of *Rumex obtusifolius* in grassland.

The new system for site specific dosing of potato haulm killing herbicides shows how chemical weed control may look like in the near future. The system uses crop reflection

sensors to determine site specific variation in the crop. DSR have been developed to relate reflection data to minimum effective herbicide doses. Special spray technology is developed to allow a wide range of doses (0.5 - 3 l/ha). The systems run on conventional and injection sprayers. On farm tests in 2006 and 2007 show that a reduction in herbicides use of 40 % is possible with the new technology compared to standard practice while efficacy remains good.

Rumex obtusifolius is a bothersome weed in grasslands world-wide. Organic dairy farmers in The Netherlands have requested help in combating the weed. We have developed an image-processing algorithm to detect *Rumex* plants. This algorithm is at the basis of a farm-scale prototype robot (www.ruud.wur.nl). Once a plant is detected, its tap root is destroyed by a cutting blade that rotates in the horizontal plane and is pushed into the soil. Navigation of the robot is based on experience gained with a small, experimental robot.

More progress is needed to get site specific weed control to a level that it will significantly contribute to reduction in herbicide use. Technological developments during the past years have gone that fast the limitations for introduction of site specific weed control at the level of sections of spray booms (10 m²) are now more with the costs of the technologies and validated soil data and DSR, then with the technologies themselves. Improvement of weed detection sensors is also a prerequisite for introduction of site specific weed control at the level of dm².

607. Automated Detection and Spraying of Volunteer Potato Plants in Sugar Beet Fields. Ard Nieuwenhuizen¹, Jan Willem Hofstee¹, Eldert van Henten¹, Sebastiaan van der Steen¹, Jan van de Zande²; ¹Wageningen University, Wageningen, Gld, Netherlands; ²Plant Research International WUR, Wageningen, Gld, Netherlands

Volunteer potatoes (*Solanum tuberosum* L.) are a problem in the crop rotation in Dutch arable farming. Weed potatoes growing in crops like sugar beet (*Beta vulgaris*) are a problem because they maintain the sources or spread diseases like *Phytophthora infestans* and nematodes. Until present, manual removal of plants is required because plant specific application of glyphosate is needed to kill shoots and tubers of the plants. Increased costs of labour and an increase in farm acreage urged for an automated method for volunteer potato removal. Therefore, a vision based detection system has been developed and was tested under field conditions. The vision system has controlled lighting and has real-time performance; the images are processed driving up to 1.5 m/s, working over three sugar beet rows having a width of 1.5 m. The results of a test in 2007 in a sugar beet field covering approximately 50m² showed that 97% of 254 sugar beet plants and 91% of 34 volunteer potato plants were classified correctly. In addition, a micro spray system to

plant-specifically target volunteer plants with glyphosate was designed and constructed. The spray system sprays variable rate and spray patterns per individual plant. Furthermore, to find the required application rate of glyphosate to kill volunteer potato plants, dose-effect experiments were performed in the year 2006 and 2007. First, conventional nozzles were used to validate current full field control practices, spraying glyphosate with 300l/ha and concentrations of up to 5%. Second, dose effect experiments were done with the newly developed micro spray unit. Recent experiments showed that plant specific targeted droplets can kill the volunteer potato plants successfully. Now, the next stage in this research is to combine the detection and control system into a fully operational functional model of an automated volunteer potato control device and to test its performance in a proof of principle experiment. This research is supported by the Dutch Technology Foundation STW, applied science division of NWO and the Technology Program of the Ministry of Economic Affairs. In addition, the Dutch Ministry of Agriculture, Nature and Food Quality supported with programme LNV-427: 'Reduction disease pressure *Phytophthora infestans*'.

608. Identifying Weed Distribution Using Soil Properties. Hamid Salehian¹, Saeid Soltani¹; ¹Ghaemshahr Islamic Azad University, Sari, Mazandaran, Iran

Site properties and weed species abundance are known to vary spatially across fields. The extent to which they covary is not well understood. The objective of this research was to assess how canonical correlation analysis could be used to identify associations among site properties and weed species abundance within an agricultural field. For this reason one hundred eighty pieces of lands from a soybean farm were chosen (hundred square meters each) at the research station of Baycola in Neka on eastern part of Sari for sampling purposes in 2007. Eight site properties were considered in relation to six weed species that were identified and counted after all weed control operations were completed. Calculation of canonical correlation for each pair of canonical variables that the first and second pairs of canonical variables explained the majority of variation in the data and were used to identify associations among site properties and weed species abundance. The study of the first pair of canonical variable indicate that plots with extra organic carbon include a lot of abusive weed such as *Amaranthus bulbosa* and *Abutilon theophrasti*. The study of second pair of canonical variable is shown that *Cucumis melo* and *Chrozophora tinctoria* most likely were in a places where there was a very high percentage of silt and phosphorus. These results show that canonical correlation analysis is one of the best methods for determination of relationship between environmental specialties and weed species abundance.

609. Is Patch Spraying a Viable Option for UK Farmers in 2008? Jonathan Storkey¹, Paul Miller²; ¹Rothamsted Research, Harpenden, Herts, United Kingdom; ²The Arable Group, Silsoe, Beds, United Kingdom

Research conducted in the 1990's and early 2000's in the UK demonstrated the technical feasibility of targeting herbicide applications to detected weeds, many of which occurred in patches. However, commercial acceptance and uptake of such approaches has been, and still is, very limited. This paper reviews advances that have occurred in the last five years to our knowledge of weed patch behaviour and to pesticide application equipment and seeks to identify the factors that have influenced the development and commercial adoption of patch spraying. There is continuing evidence that weeds are spatially aggregated in fields. Recent developments in sprayer control systems (e.g. computer-based boom section control) and the increasing availability and reliability of in-field navigation systems have made patch spraying a much more practical technology. Although much research has been done on automated weed detection systems, the availability of practical tools for use in arable crops is still very limited. Human observation is therefore the only current option for creating a weed patch map and deciding where to treat. This is a deterrent to farmers as they (or their technical advisors) do not want to spend time mapping weeds and it is costly to employ someone to create maps. A further constraint to adoption relates to the cost/benefit balance. Our analyses have compared the potential financial benefits from the reduction in herbicide use with the costs of adoption. Clearly these calculations depend on the cost of weed control and the patchiness of the weeds, but using UK examples we concluded that the benefits were often small. Adoption may well be more encouraged by legislative requirements to reduce the environmental impact of herbicides. It is our view that future adoption would increase with the development of practical automated detection systems and the availability of better dose response curves for herbicides, so that dose could be linked to the intensity of the weed infestation.

610. An Innovative Approach for Weed Detection using Laser Scanning Technology. Hanan Eizenberg¹, Sagi Filin²; ¹ARO, Ramat Yishay, Israel; ²Technion – Israel Institute of Technology, Haifa, Israel

Precision farming or site-specific weed management has been defined as a knowledge-based technical management system that can optimize farm profits and minimize agriculture's impact on the environment. In this regard, weed detection is a key stage in developing decision support systems for site-specific weed management. The current study introduces for the first time the use of laser scanning technology for inter- and intra- row weed detection in cotton fields. Based on travel time measure-

ment and knowledge of the laser beam direction laser scanning technology allows direct measurement of the 3D coordinates of the objects in space. By scanning panoramically and in different inclination angles, a complete dense and three-dimensional depiction of the surveyed scene can be achieved.

Contrasting optical sensing driven methods that rely heavily on intensity content to distinguish weeds and crop from the ground, the analysis here is based on measurements the object geometry via height and shape. While image-driven analysis is sensitive to illumination condition and shading, and is not carry real world coordinates, laser scanning technology provides directly the 3D geometry of the terrain, weeds and crop and does not rely on external illumination sources. It can therefore operate night and day and following the analysis can derive directly operation maps. Additionally, laser-scanning technology can increase the detection abilities in several key aspects like taking into consideration the homogeneity of the crop as related to the variation of weeds. As a result, this innovative approach addresses several difficulties that arise when optical sensing means were used for separating weeds from crop.

In a field study that was conducted in Israel the weeds purple nutsedge (*Cyperus rotundus*) and *Amaranthus* spp. were successfully detected using the laser scan. The presentation demonstrates the application of the technology and its potential as a means for providing direct 3D information for precision agriculture. Additionally, the coupling with optical (and other) sensors in order to increase even further the precision of weed detection will be demonstrated.

611. Exploratory Spatial Analysis of Noxious *Orobanche* Species Data in Greece. Dionyssia Lyra¹, Dionysios Kalivas¹, Garifalia Economou¹, Kostas Zahokostas¹, Georgios Kaltsoudas¹, Vasilios Mavrozidis¹, Panagiotis Dermatas¹, Georgios Doris¹, Giannis Papaiordanidis¹, Giannis Garilas¹, Kostas Ganasoulis¹, Vasileios Bournakas¹; ¹Agricultural University of Athens, Athens, Greece

Orobanche species such as *O. ramosa*, *O. aegyptiaca*, *O. crenata*, *O. cumana* constitute major inflictions for various crops (tobacco, tomato, sunflower, faba bean, rapeseed, legumes, etc.) throughout the Mediterranean basin. Losses, due to broomrape infestations, were documented in the past especially for tobacco and processed tomato crops in Greece. The need for a broomrape site specific study has seemed to be more urgent under the implementation of agricultural restructuring that takes place in our country the recent years, as potential hosts of broomrape are thought to be expanding like forage legumes, sunflower, etc. Intensive surveys were conducted all over Greece during 2002-2007 in order to obtain quantitative information on a local, regional and supra-regional level with the aid of global positioning system (GPS) and

geographic information system (GIS) technologies. The objectives of our research were to: a) map the dispersal of the most noxious *Orobanche* species throughout Greece, the crops that were infested, the observed infestation level according to a rating scale at the field basis, b) correlate climatic parameters (degree-days, humidity indices, etc.), soil properties (soil type, pH, total N, organic material, etc.), management practises (irrigation system, fertilization, etc.) with the infestation magnitude, c) study inter-specific and intra-specific variability taking into account morphological, physiological and molecular markers and d) examine the spatial heterogeneity of abiotic and biotic parameters, in conjunction with holoparasite occurrence and severity within and between regions. According to the conducted topographic surveys, we located 48 'broomrape spots', where *Orobanche* species infested cultivations of vital economic importance. In particular, *O. ramosa* / *O. aegyptiaca* parasitized processing tomato and tobacco in Northern, Central and Southern Greece but with a variation in the infestation intensity. *O. crenata* was basically traced in Southern Greece inoculating faba bean, carrot and peas with intermediate losses in the production. In addition, *O. cumana* parasitized sunflower in Evros prefecture with a variable scale of infestation magnitude. All the data were integrated into the same GIS system. Over 20 data layers were obtained demonstrating the spatial distribution of *Orobanche* species. Statistical significant correlations among biotic and abiotic parameters with the infestation level emerged.

612. Strategic use of Diversification, Soil-Improving Practices, and Knowledge of Seedbank Ecology Contributes to Progress in Organic Weed Management. Eric Gallandt¹; ¹University of Maine, Orono, ME, United States of America

The disintegration of crop and livestock production both characterizes the modern farming system, and limits the potential internal biological controls likely essential to the development of whole-farm, systemic resistance to weeds. Animals per se are probably not requisite, the manure, compost and crop diversification - sod crops, winter and spring cereals, and legumes - may be the elements required to satisfactorily manage weeds on organic farms. Crop rotation and cover cropping are top-ranked weed management practices noted by organic farmers, practices offering such diversification. However, these practices often do not contribute to weed management goals, and may actually hinder long-term progress in reducing the weed seedbank if they permit abundant weed seed rain. Similarly, cover crops are frequently noted as 'competitive' and 'weed-suppressive', but they may offer few benefits if associated disturbance events don't prevent weed seed inputs. The importance of germination as a mechanism to deplete the seedbank has contributed to refinements in the deployment of fallow periods, some-

times varying between early- and late-season over time to avoid proliferation of particular species. Perennial cover crops, on the other hand, may actually enhance the persistence of seeds in the seedbank. The past decade has seen considerable interest in manipulating seedbanks, with considerable interest in predation, and advances related to the importance seeds availability and predator demand.

Lastly, as evidence that progress is possible, there are the few known examples of organic farmers who have seemingly 'solved' their weed problems. They share a focus on preventing seed production, reflecting the wisdom of the age-old adage ('a years seeding...'), and the more recently proposed 'No Seed Threshold' (Norris, 1999). They have experienced progress in their weed management efforts, as their seedbanks decline over time. At first consideration, their tactics - intensive use of organic mulches and summer fallowing - may seem extreme, beyond practical. They argue, however, that practices which simultaneously control weeds, improve soil quality, and permit available labor to manage other aspects of the farm are critical to sustaining their enterprises. These farmers exemplify the goal stated in the 2007 National Organic Research Agenda, published by the U.S.-based Organic Farming Research Foundation: 'to understand and develop management systems that shift the focus of pest management from use of external inputs to internal biological controls arising from the system itself, leading to whole farm systemic resistance to weeds...'

613. New Technologies Call for New Research Priorities in Physical Weed Control with Low Selectivity. Jesper Rasmussen¹, Michael Nørremark², Bo Martin Bibby²; ¹The University of Copenhagen, Taastrup, Denmark; ²The University of Aarhus, Horsens, Denmark

A web-based digital image analysis tool (IMAGING Crop Response Analyser) has been developed, tested and made public (www.imaging-crops.dk). This new technology makes possible objective estimations of crop-soil cover (i.e. how much crop is buried with soil) associated with post-emergence weed control with spring tine harrows, rotary hoes and other weeders. Objective estimation of crop-soil cover offers new possibilities to improve decision support of physical weed control practises with low selectivity because trade-offs between weed control and resulting injury to the associated crop now may be quantified, communicated and incorporated into models. The objective of this presentation is to suggest key parameters and research priorities for future research and to suggest standards for estimation and statistical test of the analytical parameters. The overall aim is to help researchers deliver reliable parameter estimates that may help to predict the optimal intensity and timing of physical weed control with low selectivity and, thereby, contribute to the theoretical and methodological framework of physical weed control. Selectivity and crop recovery are

suggested as key parameters because they are crucial in predictive models and are less influenced by site-specific soil conditions and implement settings than other parameters. Selectivity is defined as the ratio between weed control and crop-soil cover and crop recovery is defined as the ability of the crop to recover from soil coverage. Both parameters depend on the intensity of tillage. To facilitate comparisons between different studies, it is suggested that the crop soil cover associated with 80% weed control and the relative crop yield loss associated with 25% crop-soil cover are calculated with 95%-confidence intervals. Experimental protocols needed to make such calculations are outlined and factors that influence - or may influence - selectivity and recovery are listed and research priorities are given. Crop tolerance has previously been used to express the susceptibility of the crop to physical weed control, but crop recovery is shown to be more useful in decision support models than crop tolerance. Recent studies using the new digital image analysis tool and the above suggested parameter estimation procedure show that timing of weed harrowing is of lesser importance if the intensity of tillage is correctly adjusted to the growth stage compared with prediction of the optimal intensity in site-specific conditions. This latter issue remains the major challenge for future development

614. Effects of Sowing Measures on Weeds and Yield of Organically Grown Wheat. Arnd Verschwele¹; ¹Julius Kühn Institute, Braunschweig, Niedersachsen, Germany

Weed control by harrowing is an essential measure in organically grown cereals, but it is also known to be less effective against perennial weeds. Such problems might be solved by using a more effective hoeing which needs wider row spaces. On the other hand, there is a risk of low competitiveness in wide crop stands, particularly if mechanical control effects are unsatisfying.

Therefore, a new approach has been investigated by using a crop design with alternating crop bands and crop-free bands. Using hoes in the crop-free band as well as a higher crop competitiveness within the crop band are two possible effects in order to make weed control more effective.

Three winter wheat experiments were conducted in 2005, 2006 and 2007 (year of harvest) at the organic farming research area. The trials were performed in a block design with 4 replications and a plot size of 120 m² including the following row spacings:

- (a) narrow spacing: row distance of 100 mm,
- (b) band spacing: bands of 4 rows (400 mm width) alternate with crop-free bands (300 mm width),
- (c) wide spacing: row distance of 400 mm.

As a second factor we tested two winter wheat cultivars with different crop competitiveness (1. Ludwig, 2. Pegasus). Pegasus is known as a cultivar fairly adapted to the conditions of organic farming. It is characterised by

prostrated and large leaves whereas Ludwig can be described by a more upright growth and consequently a low weed suppressing ability.

Because of a very high initial weed infestation it was not possible to keep plots weed free. Depending on the weed density all plots have been harrowed 2-3 times, additionally the plots with the crop bands and wide rows (variant b and c) have been hoed two times. Among others, the following parameters have been assessed: weed coverage, weed biomass, weed number, crop yield and crop quality. Data were analysed by a multifactor analysis process using Statgraphics Plus, version 5.1. Based on all data, mean values and confidence levels were calculated by considering the 3 tested factors row spacing, cultivar and year.

The initial weed density varied from 225 to 451 weeds m². The most frequent weed species were *Lamium* spp., *Veronica* spp., *Stellaria media* and *Urtica urens*. The weed density assessed before mechanical control measures was not effected by row spacing (P=0,737) and year (P=0,069) but by cultivar (P=0,006). There were no significant interactions between these factors. However, compared to the number of weeds there were stronger effects on the weed biomass. Row distance and year did effect the weed dry matter assessed at growth stage BBCH 61-65 significantly (P=0,016 and 0,000). The following weed biomass was estimated at the 3 row spacings: (a) 21.9, (b) 2.61, (c) 45.9 g/m². Differences between (a) and (b) were not significant, but the wide spacing (c) resulted in significant higher weed infestation. In 2005 and 2006 there was also a cultivar effect on weed infestation: Corresponding to a higher crop cover, Pegasso showed a stronger weed suppression rather than Ludwig, especially in the wide spaced crop stand. No differences between both cultivars have been observed in 2007 and at the band spacing.

All factors (row spacing, cultivar, year) had a significant effect on the grain yield of winter wheat (P<0.001). The highest grain yield averaged over the 3 years (6.24 t/ha) was measured at band spacing (b) compared 5.85 t/ha at narrow spacing (a) and 5.28 t/ha at wide spacing (c). This indicates the high compensating ability of the both wheat cultivars. The results show that, at least under favourable soil and weather conditions, good weed control efficacy can be combined with high grain yield by using a band sown crop stand.

615. Organic Vegetable Cropping Systems for Purple Nutsedge Management. Carlene Chase¹, Rosalie Koenig¹, Jeffery Pack²; ¹University of Florida, Gainesville, Florida, United States of America; ²Escuela Agrícola Panamericana, Tegucigalpa, Honduras

Infestations of perennial weeds are significant obstacles to organic production and can result in growers removing infested acreage from production. Uncontrolled populations of purple nutsedge (*Cyperus rotundus*) can cause

complete crop failure. An on-farm evaluation of serial integrated crop management systems was conducted to manage purple nutsedge in organic vegetables in north-central Florida. A multi-pronged approach that involves yearlong management during fallow and cropping periods was employed. Summer fallow techniques included sunn hemp (*Crotalaria juncea*) as a cover crop, soil solarization, clean fallow with weekly tillage, clean fallow with flaming, and were compared with a weedy fallow. Two sunn hemp treatments were used so that after 12 weeks of growth stems were cut just above the soil surface and either incorporated prior to transplanting the fall crops or retained on the soil surface as mulch. The persistence of purple nutsedge suppression was evaluated in two subsequent fall cash crops (lettuce, *Lactuca sativa* and broccoli, *Brassica oleracea*) and spring cash crops (zucchini squash, *Cucurbita pepo* and bell pepper, *Capsicum annuum*) with differing canopy sizes and rates of growth and development. The additional benefit that could be obtained from a weed-suppressive infrared-transmitting (IRT) mulch was also assessed. All summer fallow treatments effectively suppressed purple nutsedge and the suppression persisted within subsequent fall and spring vegetable crops. Highest lettuce yields occurred with incorporated sunn hemp, solarization and tillage; and broccoli yields were best with flaming, solarization, and tillage. Pepper yields were higher with tillage than with all other fallow treatments. Squash was very competitive with purple nutsedge so that yields with the weedy fallow on bare ground did not differ from those of most of the other fallow treatments. The use of IRT film further reduced purple nutsedge infestation and increased squash and pepper yields. The most consistent and effective combination of treatments appears to be weekly tillage in summer followed by IRT film in spring.

616. Pre-Plant Composting of Organic Matter Helps Weed Control in Organically Grown Vegetables. Barakat Abu Irmaileh¹, Azmi Abu Rayyan¹; ¹Faculty of Agriculture-University of Jordan, Amman, Jordan

Weed management in vegetables is a must; otherwise severe yield reductions are anticipated. Several methods are normally applied for weed control including herbicides. However, chemical weed control is not a choice in organically grown vegetables. Several experiments were carried out to investigate the efficiency of pre-plant composting of several organic matters in reducing weed populations under natural weed infestations in various vegetables. Composting was carried out by incorporating organic matter in 0.4m-band in the soil of the planting rows. After incorporation, the rows were immediately covered by black polyethylene (BPE) sheets then drip-irrigated twice during a period of six weeks before planting. In a split-plot experiment, the tested organic matters were wheat hay, manures of cow, poultry or sheep,

at 10 kg per 3m X 0.4 m planting row. The check treatment included the incorporation of crop and weed residues in the planting rows. Prior to planting, the PBE sheets were removed in a set of treatments; and in another set, the PBE sheets were kept in place for the rest of the growing season as mulch which was perforated at the proper planting distances in order to plant the vegetable seedlings.

The results of the uncovered treatments indicated that composting organic matters reduced weed infestation by 15-40 % as compared with the check. Sheep manure treatment was the least effective in controlling weeds as compared to either cow manure or hay. Weeds were perfectly controlled by all treatments in the mulched treatments. Lettuce yield was the lowest in the uncovered wheat hay plots, and highest in poultry.

Other experiments included pre-plant composting of only cow manure in either PBE-covered or uncovered plots as compared to untreated checks. Weed control was complete under mulch, but ranged from 45% in beans and 73% in lettuce. Vegetable yields were significantly increased in either winter- or summer-grown vegetables, especially under BPE mulch.

617. System-Level Comparisons of Weed Control Strategies in Spring-Sown Barley. Lauren Kolb¹, Eric Gallandt¹, Tom Molloy¹; ¹University of Maine, Orono, ME, United States of America

Organic dairy farmers in New England are forced to rely on imported grains of variable cost, quality, and availability, from Canada or the Midwestern U.S.A. As fuel costs and demand for organic grains continue to rise, these farmers are realizing the necessity of becoming self-sufficient through reliable production of high quality organic grains on-farm. Weeds are one of the foremost production problems for these organic growers, as they can decrease both crop yield and quality. A field experiment was established in 2007 to identify cereal production practices that result in improved weed management. Specifically, alternative production systems that relied on either enhanced physical weed control or crop competition were established to compare weed control efficacy and crop yield in spring barley (*Hordeum vulgare* cv. 'Lucky'). Barley was sown at 163 kg ha⁻¹ at conventional-row (15 cm), narrow-row (12 cm), and wide-row (25 cm) spacing. These plots received two spring-tine harrow treatments; the wide row sowing was also subject to an inter-row hoeing. An additional treatment aimed to enhance the efficacy of crop-weed interference by sowing in a more uniform spatial distribution, accomplished by a two-pass sowing at acute angles, each at 81.5 kg ha⁻¹. A final treatment assessed the effect of a high density sowing (12 cm row spacing, 325 kg hectare⁻¹) on weeds and grain yield. Yellow mustard (*Brassica hirta*) was sown at three densities (0.0, 0.9, and 3.6 kg ha⁻¹) as a functional substitute for wild mustard

(*Sinapsis arvensis*), a common weed in spring-planted cereals. The high density and wide-row sowing resulted in the lowest weed biomass at the time of harvest. This decreased weed level did not result in significant differences in barley yield, but there are implications for decreased weed seed production. Absence of physical weed control in the control and the two-pass sowing highlighted the necessity of physical weed control and its importance in both reducing weed density and biomass and increasing yield at elevated weed densities. Simulation modeling of weed populations using published values to determine weed thresholds and predictive rankings for each system at each weed level promotes the hypothesis that weed pressure within a particular field dictates what type of cereal production system should be implemented.

618. Changes in Weed Communities During the Transition to Organic Production. John Masiunas¹, Isabel Rosa¹; ¹University of Illinois, Urbana, IL, United States of America

Our objective was to determine how transition approaches affected emerged and seed bank weed populations. We evaluated three management intensity systems combined with three soil improvement treatments as transition strategies. The high management system had a vegetable crop rotation (tomatoes, cabbage and broccoli, and winter squash). This represented a situation where the farmer had limited land and required a large income during transition. The medium management intensity system had an agronomic rotation (soybeans, wheat, and corn). This management system was a common system used by midwestern farmers transitioning to organic production. In the low intensity system we established a perennial ley (clovers, timothy, orchard grass, vetch) and manage it similar to CRP land. In the fourth year all management intensities were planted to tomatoes and peppers. The goal of the soil improvement strategies was to improve the soil characteristics, add organic matter, and supply nitrogen needed for crop growth. The soil improvement treatments were cover crops alone, cover crops and compost, and cover crops and manure. In 2003, the dominant weed species were grasses in the ley system; common lambsquarters and velvetleaf in the agronomic system; and lambsquarters, grasses, and foxtails in the vegetable system. In 2003, the ley system had the most weeds in subsequent years it had fewer weeds than other management intensities. The low weed populations were due to establishment of a vigorous mixture of perennial plants and lack of disturbance in the ley system. In the vegetable system, during the first year we used plastic mulch and straw to control weeds. The straw had seed, so volunteer wheat was a problem. In 2004 and 2005, the grain system had more weeds than the vegetable system. The higher returns for vegetable production allowed hand-weeding which likely reduced weed populations compared

to the agronomic system. The effect of soil amendment varied depending on year. In 2004, there were more weeds in the manure amendment and in 2005 there were more weeds in the cover crop only amendment. Weed species composition changed depending on management intensity and year. Species composition of the seed bank was similar to the composition of the emerged weed community with the exception that seed from *Amaranthus* species were the most common. A managed ley system may be a method for land-rich farmers to transition to organic production without increases in weed populations.

619. Changes of Weed Seedbank Characterization under Rice-Duck Farming System. Wei Shouhui¹, Zhang Chaoxian¹, Qiang Sheng²; ¹Chinese Academy of Agricultural Sciences, Haidian, Beijing, China (Peoples Republic of); ²Nanjing Agricultural University, Nanjing, Jiangsu Province, China (Peoples Republic of)

Weed seedbank is the primary source of future weed infestations and management of soil seedbank can be integrated into a strategy for controlling aboveground weed communities. Rice-duck farming, which integrated ducks with rice cultivation, can result in weed control, germination enhancement, soil disturbance and will help to reduce the size of weed seedbank. Field studies were conducted to evaluate the effects of four-year rice-duck farming on the dynamics of soil weed seedbank. The results showed that the seed proportion of 0-5 cm and 5-10 cm soil layer were reduced significantly by rice-duck farming, and weed seeds tend to distribute more evenly among soil layers. Along with the implementation of rice-duck farming, species richness and species diversity of weed seedbank decreased annually, species dominance increased steadily, but evenness of the seedbank showed no significant change. The size of weed seedbank declined annually under rice-duck farming system, the cumulative reduction was 47.70% and with an annual decreasing rate of 15%. Influence of rice-duck farming on seeds of paddy weeds was higher than wheat weeds, the density of major weed species in paddy fields, *Echinochloa crusgalli*, *Monochoria vaginalis*, *Lindernia procumbens* reduced rapidly. Under continuous rice-duck farming, dominant species of weed seedbank changed from *Lindernia procumbens*, *Mazus japonicus*, *Cardamine hirsute* to *Mazus japonicus*, *Alopecurus aequalis*, *Lindernia procumbens*, *Beckmannia syzigachne*. Similarities of weed seedbank between rice-duck farming and pre rice-duck farming declined annually, which indicated that rice-duck farming could change the species composition of weed seedbank and cause the potential weed community to shift.

620. Optimizing the Role of Cover Crop Residue Material for Weed Suppression. Marjolein Kruidhof¹, Lammert

Bastiaans¹; ¹Wageningen University, Wageningen, Netherlands

In organic farming systems, weed control is recognized as one of the main production-related bottlenecks. System-oriented approaches for ecological weed management are needed and cover crops might form an important component of such an approach. So far, cover crops have played a modest role in Dutch agriculture. Grown in autumn and winter, in between two main crops, the crops are primarily used as green manure or fodder crop. More recently they are also used as catch crop, meant to avoid leaching of nutrients in winter. In the current research the potential role of cover crops for weed management was investigated. Main focus was put on the weed suppressive effect of cover crop residue material in spring and particularly on identifying management options to maximize this effect. To better appreciate the potential of cover crop residue material the investigations were focused on three aspects, namely allelochemicals in the cover crop, the residence time of the residue mediated inhibitory potential in the soil and the variability in inhibitory effects on receptor plants. As different plant families are known to produce different allelochemicals the study was conducted with representatives of three plant families: *Secale cereale* (winter rye), *Brassica napus* (winter oilseed rape) and *Medicago sativa* (alfalfa). A first screening of extracts in Petri dish bioassays showed significant allelopathic effects for each cover crop species. Mechanical injuring of field grown cover crops enhanced the allelopathic activity per unit biomass. However, this increase was often just sufficient to compensate for loss of plant material resulting from damaging, implying the limited practical significance of damaging. Release, persistence and distribution of allelochemicals in the soil are other important determinants of efficacy and can be influenced by cover crop residue management. Different options for pre-treatment and incorporation were compared. Ground winter oilseed rape material was most effective in inhibiting emergence of fast-germinating species. Furthermore, inhibition of emergence from winter rye residues left on the soil lasted longer than inhibition of emergence from residues mixed through the upper layer of the soil. With regard to species sensitivity our results suggest that for inhibition of a receptor plant an overlap of the time course of sensitivity of the receptor plant with the time course of residue-mediated inhibitory potential is of primary importance. Variation in synchronicity of receptor species sensitivity and potential residue effects might well explain the large degree of variation often noted in field studies of allelopathy.

621. *Hydrilla verticillata* – A World-Wide Problem. Michael Grodowitz¹, Michael Smart¹; ¹U.S. Army Engineers Research and Development Center, Vicksburg, MS, United States of America

Hydrilla verticillata (hydrilla) is a rooted, submersed macrophyte with origins in Asia (and possibly Australia or Africa). Two biotypes have been identified including a monoecious and dioecious strain. It has been widely disseminated by humans initially through the aquarium trade and then from water body to water body by boats and boat trailers. It is considered one of the worlds most problematic submersed aquatic weeds. Economically important infestations now occur throughout the U.S. with growing problems being faced in South Africa, New Zealand, Sri Lanka, India, Central America, and other countries in Africa. It is also known to cause problems in its native range including Southeast Asia and portions of China, especially in rice fields and in areas subject to high nutrient loading.

Large infestations of hydrilla hinder navigation, exacerbate flooding and flood damage, interfere with hydro-power production and irrigation/potable water delivery, and severe infestations can threaten human health due to the formation of increased mosquito breeding habitat. Large hydrilla infestations also impact water quality and aquatic habitat and typically exhibit limited biodiversity. Hydrilla is a well-adapted disturbance strategist exhibiting rapid growth rates, broad environmental tolerance ranges, and early maturation giving rise to rapid reproduction through fragmentation as well as the production of long-term survival structures such as tubers and turions. Two main factors contribute to widespread formation of damaging infestations. These include a lack of diverse native aquatic plant communities either by natural or man-made reasons; i.e., empty spaces invite colonization, and a lack of host-specific plant herbivores allowing the plant to grow virtually unchecked.

Methods of control include chemical, mechanical, and biological. While chemical control has proven to be highly successful it is, in many cases, prohibitively expensive and results in only short-term control typically for only one or two growing seasons. In addition, resistance to fluridone, a commonly used chemical in the U.S., has occurred in several Florida populations. Mechanical control has often been employed using large machinery to cut or chop the plant material with harvesting for subsequent removal. Unfortunately, this method is also highly expensive, requires specific training, and results in only short-term, localized control usually for only a single growing season. Biological control methods have been employed and include the use of host-specific insect agents and the use of sterile grass carp (*Ctenopharyngodon idella*). Two leaf-mining flies in the genus *Hydrellia* have been released in the U.S. and have provided some success in slowing hydrilla growth and the production of persistent survival structures over the long-term. However, results have been inconsistent and control takes from three to five years to occur. The use of triploid grass carp is a highly effective strategy. However, grass carp do not only consume hydrilla but many other species of submersed aquatic vegetation thereby denuding systems of important plant

assemblages leading to increased nutrient release and algal production. A new control strategy being employed considers the use of an ecological approach to hydrilla management where underlying reasons for the formation of large and damaging infestations are addressed. The approach includes the use of revegetating areas devoid of aquatic vegetation to limit re-invasion and slow subsequent dispersal, and the release of host-specific insect biocontrol agents to reduce hydrillas growth and reproduction. These methods are coupled with prudent use of chemicals and/or grass carp to rapidly reduce large amounts of biomass. Since underlying reasons for the formation of the infestations are addressed such an approach leads to more sustainable and long-term control.

622. Water Hyacinth is Dispersing to other Non-Tropical Areas. Ricardo Labrada¹; ¹FAO, Rome, Italy

Water Hyacinth (WH) (*Eichhornia crassipes* (Martius) Solms-Laubach) is an aquatic floating macrophyte native to the Amazon basin, Brazil, which has spread largely throughout the world. WH is considered the worst aquatic weed in the world. Its rapid increase and spread of the plant into new areas are due particularly to its vegetative reproduction, a single shoot being able to develop very rapidly a significant infestation and moving easily with water currents, winds or by other accidental means. WH causes enormous evapotranspiration, impedes normal water flow, blocks irrigation canals and drainage systems, increases sedimentation, and seriously hampers fishing and dramatically reduces the catch and the source of food and income for local populations. It also reduces the activity of electrical power stations, and its dense stand is a habitat favourable to human disease vectors. Vegetative propagation is the most important way. However, in cool climate countries long-lived seeds of the plant are the main source of reproduction. The causes of WH dissemination have been discussed previously by several authors. Its attractive appearance seems to be the main reason for its deliberate introduction into various countries, firstly in North and Central America and the Caribbean followed by further introductions into Africa, Asia and the Pacific at the end of the XIX and beginning-middle of the XX centuries. WH is now present in more than 60 countries. It has always been considered a plant of tropics and subtropics. However, there is new evidence that WH seeds are able to survive cold weather and sometimes below zero temperatures. The FAO project on WH management and utilization carried out in Zhejiang province, China, clearly reveals that infestation in those areas was developed from seeds of the plants surviving temperatures as low as 2-40° during 10 nights of December-January. The main growth of WH plants starts there during February-March. Large infestations of WH in China are localized in water bodies of the Yangtze River basin, while in the Huangpu River in Shanghai it produces a mass of about 1

840 000 tonnes from April to October. WH is already present in areas of Spain and Portugal bathed by the rivers Tajo, Guadiana and Ruedas, where the coldest temperatures in winter time are around 6-7.50. This dissemination to soft and cool climate conditions suggests the ability of the plant to spread further and adapt to non-tropical areas. Strategies for control remain the same as in the past, i.e. short-term control methods such as physical removal (mechanical or manual) and/or chemical control to remove large infestations, while biological control releasing *Neochetina* weevils should be used for maintenance. In several countries, the technicians dealing with this control issue do not realize that the integrated approach is the only effective method to reduce heavy weed infestation. Some argue that biocontrol is not effective when large weed populations prevail, while others want to implement a control measure with an immediate effect on the weed. Unfortunately, there is no single effective tool to control high density infestations of WH, and removal combined with biological control appears to be the most suitable approach in the medium and long term. Experience in China shows that mechanical removal, if the machinery used is not very powerful, should be implemented when the infestation starts to increase rather than when it is already established. The machines will be more effective and removal will be assured. Probably removal should be implemented two or three times if biological control is not used. The presence of heavy stand of WH in certain areas may also favour the establishment of other weeds, such as alligator weed (*Alternanthera phytolaxoides*). In power station sites, WH presence is undesirable, and the only option is to apply short-term control methods repeatedly to keep the plant away from the station. Some barriers consisting of strong metal chains should be put at a certain distance from the station to avoid the movement of WH plants. Biological control should be the main control option in any integrated approach. This method has proved effective in several hot climate countries, such as Uganda, Sudan, Benin and others, but in countries with a cool climate *Neochetina* weevils are unable to survive the low temperatures, and other agents should be identified locally if available. At this point it is clear that a control approach should be developed locally according to the prevailing climatic conditions, economy and resources available. Water hyacinth is still a serious problem in several developing countries and there is a need to prioritize this problem nationally, define a clear policy for its control, and specify the role of various government and research institutions on this matter. Monitoring is an essential part of integrated WH management, and to this end enough financial and human resources should be allocated. Community participation is another condition for establishing a sound management programme.

623. *Solanum elaeagnifolium* Cav.: **Importance, Distribution and Control Methods.** Mohamed Bouhache¹; ¹Institut Agronomique et Vétérinaire Hassan II, Rabat, Morocco

Native to tropical America (Argentina, north - east Mexico and south-west USA), *Solanum elaeagnifolium* Cavanilles (Silverleaf nightshade) is a deep rooted perennial broadleaved trans continents weed. It is propagated by seed and/or vegetative fragments of all plant organs and forms large clonal infestations of many stems linked by the underground root system. It was reported as a weed or / and a colonizing invader species in Algeria, Egypt, Lesotho, Morocco, south Africa, Tunisia and Zimbabwe in Africa; in Croatia, Cyprus, France, Greece, Italy, Macedonia, Serbia and Spain in Europe; Argentina, Chile, Guatemala, Honduras, Mexico, Puerto Rico and USA in Americas; in India, Palestine, Syria and Taiwan in Asia and in Australia in Oceania. *S. elaeagnifolium* was introduced to these countries as seeds or vegetative fragments by contaminated seeds, fodder, ballast and bedding used in animal transport. However, livestock and manure, irrigation water, agricultural machinery, nursery plants and contaminated straw or seeds are considered to be the main agricultural practices spreading the weed inside of a country or a region. The rapid dissemination of this species may be explained by its high vegetative regeneration capacity, high seed production per plant and diversification and efficacy of spreading means and ways. Since the weed is adapted to a wide range of habitats and soil conditions, it infests cultivated lands, orchards, managed and natural grasslands, sides of roads; railways; canals and rivers and wastelands. *S. elaeagnifolium* competes with crops and valuable pasture species (losses of up to 64, 12 to 50, 5 to 75, and 4 to 10% were reported in maize in Morocco, wheat in Australia, cotton in USA, and sorghum in USA, respectively), exudes allelopathic compounds, interferes with animal husbandry and harvesting practices and harbours insects and diseases pests. In addition, infested lands lose considerable rental and resale values (In Morocco, the value of infested lands decreased by 25%). However, little information is available on its environmental impact. Since *S. elaeagnifolium* is officially declared as a noxious weed, a control strategy programme should be established on the basis of prevention and control. The prevention includes legislation or regulatory aspects, avoidance of spread means and extermination of isolated plants and small patches as they appear. Cultural, mechanical, chemical and biological methods may be used separately or combined in an integrated way to keep this weed under control. Deep ploughing during summer, frequent clipping at flower initiation stage, dense pasture and lucerne are implemented to reduce the weed infestation. In laboratory conditions, aqueous extracts from shoot and root of alfalfa showed a potential allelopathic effect on seeds germination and growth of *S. elaeagnifolium*. Systemic herbicides such as trifluralin, pendimethalin, 2,4D, clopyralid and broma-

cil gave a good control in cropped lands. In non cropped lands, imazapyr, picloram, 2,4D, glyphosate, sulfosate and bromacil may be successfully used. In addition, an intercropping season strategy by using glyphosate (2150 g /ha) added to ammonium sulphate (5%) at green berry stage of the *S. elaeagnifolium*, and soft water as herbicide carrier gave a successful and long term control (>90%) during the following season. Total non-structural carbohydrates (TNC) levels are a good indicator for the period of spraying either systemic or contact herbicides. The TNC were lowest at flower initiation stage and they built up between flowering and fruit maturation, and appeared to be influenced by phenological stage of the weed. In Morocco, the combination of chemical (mainly glyphosate) and mechanical (summer ploughing) control reduced density, biomass and fruit production of *S. elaeagnifolium* by >92, >94 and 100%, respectively. Several biocontrol agents have been investigated and only three candidates showed host specificity and promising use: a leaf nematode (*Orrina phyllobia* = *Nothanguina phyllobia*) which causes leaf and stem galling in USA and two leaf-feeding beetles (*Leptinotarsa taxana* and *L. defecta*) which are already released with a certain success in South Africa.

624. Current Status of Distribution and Management of Parthenium at a Global Level. Jay Varshney¹, Sushil Kumar¹; ¹National Research Centre for Weed Science, Jabalpur, Madhya Pradesh, India

Parthenium hysterophorus L. of family Asteraceae commonly known as Carrot grass, Congress grass or white top or as bitter weed or bitter broom is being rated as one of the seven worst weeds of the world. It has now spread from its native regions of south and central America to almost all the continents except Europe. During last five decades, it has spread to many of the tropical and sub-tropical regions of the world. At present it has become an invasive weed of major importance in several exotic countries and even in its native range. Parthenium has been reported in varied status of infestation in different countries, very severe in India and Australia and mild to severe in some other countries of Africa and south America.

Parthenium has been reported in the countries like Puerto Rico, United States of America (USA), Mexico, Bahamas, Bermuda, Cuba, Haiti, Jamaica, Belize, Dominica, Guatemala, Honduras, Trinidad & Tobago etc in north America. But in USA, parthenium has not achieved the status of major weed in most of the areas because of climatic conditions and dominance of many other native weeds. In South America there are reports of its presence in areas extending up to Uruguay. Southern Brazil, Argentina, Bolivia, Guyana, Paraguay, Venezuela, etc. In Australia it was first reported in 1955 and has spread from central Queensland to northern New South Wales, infesting about 170,000 km². The weed infestation caused

direct losses to the grazing industry of about \$A 14-18 million per annum while losses to the cattle industry due to parthenium have been estimated to be \$A 16 million per year in terms of control costs and loss of pasture. In Australia, it has been declared a national weed. In Africa, parthenium has been reported to affect biodiversity and agriculture in Madagascar, Mozambique, South Africa, Mauritius, the Seychelles, Kenya, Ethiopia, and Somalia etc. The weed has also been observed in world-famous Kruger National Park, to the savanna biome of South Africa. Its infestation extends from the eastern subtropical region of KwaZulu-Natal Province, from around Durban, northwards to Mpumalanga province. It has also been reported to be present from northwest and north of Pretoria upto Zimbabwe. Parthenium got entry in Ethiopia in about 1977 but now currently infested in about 120,000 hectares of land of which the share of grazing, crop and other lands is 40%, 32% and 28% respectively.

In Asia, it has been reported from Bangladesh, China, India, Mauritius, Nepal, Pakistan, Taiwan, Vietnam, etc. In India, it was first observed in Poona in 1955 as a waste land weed but now it has invaded all types of wasteland, community land and agricultural lands in almost all the states of India. Current survey revealed that about 35 million ha of land have been invaded by parthenium in India. It was estimated that Rs 168000 million is required annually to mitigate the problem manually and Rs 119000 million by chemical method besides Rs 8800 million for treatment of health hazards and about 1000 million on researchable issues including people awareness programmes. In Sri Lanka, parthenium was observed for the first time as well established weed in 1999, it is supposed that it entered in the country in 1980 along with Indian army deputed as a Peace Keeping Force. Its occurrence is reported in the neighboring country of Bangladesh and Pakistan though not in an alarming proportion. The weed has not been reported in Malaysia, Singapore and Indonesia.

Its colonization and dominance in many millions of hectares of land has resulted health related issues in man and animals, reduction in crop productivity besides disastrous effects on bio-diversity. Management strategies to reduce the infestation and spread of the weed have become prime concern in the infested areas all over the world. Manual and mechanical control including uprooting, ploughing, slashing, etc, are of little help but the same may be made effective by community efforts. Appreciable efforts have been made in Australia and India to make people aware about the parthenium and to involve people for parthenium management by various methods. Many herbicides namely atrazine, 2, 4-D, metsulphuron methyl, dicamba, glyphosate and metribuzin have been found effective against parthenium and are being in practice in the countries affected by this weed. Biological control has been considered only cost-effective, environmentally safe and ecologically viable method. Several biocontrol agents

(insects and pathogens) have been released from time to time to manage the weed in the countries infested with parthenium but serious efforts have been made in Australia only. In Australia, biological control programme was started in 1975 and is still in progress. So far, in Australia nine species of exotic insects namely leaf feeding beetle, *Zygogramma bicolorata*, stem galling moth, *Epiblema strenuana*, *Listronotus setosipennis*, *Semicronyx lutulentus* (seed feeding weevil), *Bucculatrix parthenica* (leaf mining moth), *Platphalonidia mystica* (stem boring moth), *Conotrachelus albocinereus* (stem galling weevil) and *Carmentis*.

625. Parthenium Weed Research Aids Management of this Weed in the Agroecosystems of Ethiopia and Pakistan. Stephen Adkins¹; ¹University of Queensland, Brisbane, Queensland, Australia

Parthenium weed (*Parthenium hysterophorus* L.) has been present in Australia for about 50 years, in which time it has spread from isolated infestations to establish core populations in central Queensland with scattered and isolated plants occurring south into New South Wales and north-west into the Northern Territory. Its main effect is upon livestock production, but it is also causing health concerns in regional communities. It is one of 20 weeds of national significance. To help coordinate actions on its management, a National Weeds Program has created a Parthenium Weed Management Group (PWMG) and under this group has formed a Parthenium Weed Research Group (PWRG). Funding coming from this National Program and other sources has supported the PWRG group to undertake a collaborative and technology exchange research program in the areas of biology, ecology and management, while the PWMG has focused on community awareness and the production of various extension and management packages. PWMG studies have been undertaken in two main areas: 1) biology and ecology and 2) management. Research in the area of biology and ecology has included studies on the evaluation of competitive plants to displace parthenium weed, the use of process-based simulation models to monitor and predict future spread and abundance under present and future climate conditions, the effect of the weed on human health and the ecology of its seed-bank. Management research has centred on the development of biological control approaches using plant-feeding insects and pathogens. The effectiveness of biological control is also being monitored through long term studies on seed bank size and dynamics, and fire as another potential management tool, is being evaluated. In addition to this important research, an effort has also been made to spread the most important findings and management outcomes to the wider community through an extension and education program driven by PWMG. These developments within Australia in parthenium weed management are now being applied to

countries such as Ethiopia and Pakistan where their weed managers are preparing for the rapid spread of this weed from already established widely dispersed populations. International linkage projects in both Ethiopia and Eastern Africa, and Pakistan are working towards global management solutions for this most serious invasive species built around biological control and environmental management.

626. *Ambrosia artemisiifolia* - Motivation for a European-Wide Activity. Christian Bohren¹, Georges Mermillod¹, Nicolas Delabays¹; ¹Agroscope ACW, Nyon, VD, Switzerland

Pollen of *A. artemisiifolia* is an abundant seasonal aeroallergen in late-summer to early fall resulting in millions of dollars annually in health care costs and lost labour hours. In studies performed in Europe and North America, 10-15% of the population is sensitive to this pollen causing rhinitis, oculorhinitis, asthma, and dermatitis. *A. artemisiifolia* is also a weed pest in agricultural crops. It also displaces native vegetation in its introduced range especially after a disturbance, such as overgrazing or construction which put competitive pressures on the native flora. Occurs in agricultural areas, ruderal/disturbed, urban areas, along rivers and lake sides.

A. artemisiifolia is a monoecious plant. The mechanism for pollination is through the wind, since the flowers are not attractive to insects. The fruit is a woody achene, 3-4 mm long and 1-2 mm wide, resembling a crown. Seeds are shed directly from the parent plant and most seeds land with proximity to the parent plant with a seed rain of 500-7300 seeds/square meter. Seeds enter a dormancy period. Germination occurs in the spring. Seeds are the only means for reproduction of this summer annual plant.

A. artemisiifolia is commonly found in ruderal or waste sites associated with frequent and extensive disturbance regimes resulting from human activities. Roadsides, railways, gravel pits, construction sites, agricultural fields, waterways, urban areas, and private gardens are all sites that this species establishes easily. Common ragweed is a pioneer species establishing after disturbance in early succession plant communities. It can tolerate dry soil conditions.

The seed is often found in commercial bird mixes and is considered one of the main ways the species was introduced into several European countries. The species was found in contaminated cereal seed, like sunflower and sorghum and introduced by those means as well. War has been cited as a mechanism of dispersal for this species. Horse-fodder for cavalry is considered a contaminant source along with depots for stationing troops. In Yugoslavia, war was responsible for the spread of *A. artemisiifolia* into fallow lands.

Excavation materials for construction and other substrates are exchanged almost everywhere leading to

contamination and facilitation by disturbance. The seed of common ragweed can also spread via water currents along riparian corridors.

A. artemisiifolia impact on human health, its menace of biodiversity, its pioneer character, its capacity for reproduction, its invasion pathways fully dependent on human activities lead to the conclusion, that only an international and interdisciplinary collaboration can provide sufficient control this noxious weed.

Main option of control is to prevent the ripening of seeds.

Physical: Mowing, hand-pulling, tilling and burning are all physical options that can be employed to reduce the population. Deep mowing when the plant is in flower or in seed set can reduce the pollen count or seed bank. The side-sprouts which are developed after mowing can be treated with a herbicide to kill the plant. Mechanical methods work best in areas with scattered patches.

Chemical: *A. artemisiifolia* is closely related to the sunflower and other members of the Compositae family. In a crop rotation an adapted chemical application should be considered until ragweed is under control. Dicamba, clopyralid and triazines are some substances for good control. Sulfonylureas - a family of herbicides used in almost all types of crops - are not sufficiently effective. Careful reading of the labels for application rates and local, state, and federal laws apply when using any chemical. If perennial grasses are present it is best to spot spray a selective chemical application in order to retain the vegetative cover.

Cultural: Re-vegetation of native perennials and winter annuals can out-compete and suppress annual ragweed growth. Re-vegetation after disturbance can reduce competitive advantage of ragweed for resources.

Integrated management: Because of the ability of *A. artemisiifolia* to develop side sprouts after mowing or incomplete hand pulling or less effective herbicide treatment, it is recommended to combine management techniques.

Biological: Chrysomelid beetles, as *Ophraella communa* and *Zygogramma suturalis* have a high feed potential and high reproductive potential. Some noctuid moths, as *Tarachidia candefacta* and *Epiblema strenuana*, have both been released as bio-control agents in Russia and China.

Conclusion: Its the pollen that menaces human health, but main option of control is to prevent the ripening of seeds. Pollen amount will decline, as the number of flowering plants can be reduced. Methods and costs of control measures depend on the abundance of the weed. Early detection and elimination of micro populations in areas with beginning of invasion may effectively slow down its distribution rate. Surface control with mechanical, chemical or combined methods in highly infested regions may be costly but reduce in a long term the soil seed bank. In all cases a European wide and interdisciplinary concerted action is desirable for an effective control of *A. artemisiifolia*.

627. Honeysuckle Mesquite, *Prosopis juliflora* (Swartz) DC, A Major Invasive Plant in Various Regions of the World. Ramanathan Kathiresan¹; ¹Annamalai University, Annamalai Nagar, Tamilnadu, India

Honeysuckle mesquite *Prosopis juliflora* (Swartz) DC, is an evergreen leguminous tree/shrub native to South and Central America. The weed has been introduced into several countries of Africa, Asia and Australia during the last century, considering its usefulness for growing in dry areas. If grown and used properly, the wood is an important source of domestic fuel for the majority of rural households. The fuel wood availability ranges from 40 kg/tree to 139 kg/tree. The pods are generally consumed raw by animals. Average annual pod production *P. juliflora* in India was assessed to be 20 kg/tree. The pods serve as a nutritive source of animal feed with 10% protein, 14% fibre, 55% soluble carbohydrates, 0.20% calcium and 0.15% phosphorus. Despite their use as fuel wood, animal feed and timber, the weed is also highly invasive and has a wide ecological amplitude. The distribution range of this invasive weed includes Central American Lowlands, Caribbean, South American Lowlands (Venezuela, North East Brazil, Pacific Shores) Pakistan, India, North Australia, East Africa, South Africa, The Sahel, Cape Verde Islands, Arabian-Persian Gulf and Southern Arabian Peninsula. It is reported that the infestation of this weed has reduced the carrying capacity of pastures by 75% over a 35 year period in New Mexico, reduced grass production in arid regions of United States by 50-90%, caused loss of direct costs of US \$200-500 million annually, and reduced in the mean annual run off in South Africa by 481 million m³.

Aggressive invasion of *P. juliflora* results in suppression of native bio-diversity and species richness of habitats such as pastures, woodlands and arable fields and render these sites unfit for use by forming impenetrable thickets. Adaptive eco-traits of the weed include seed dormancy, animal aided seed dispersal, tolerance to a wide range of climatic and edaphic conditions, higher root biomass and rejuvenability on lopping. Higher sugar content of the pods causing teeth decay in animals, potential allergens identified from pollen and thorns frequently distributed over the stem, make the weed environmentally malicious. Presence of *P. juliflora* along the coast and amidst mangrove vegetation in sea back waters were reported to have increased the death toll during tsunami that struck India (especially the south eastern coast) during 2005 as the hair and saree of fisher women who were floating or swimming out of tidal waves were trapped between the thorny bushes. Spread of the species is mainly through the animal aided seed dispersal by virtue of the process of endozoochory as the pods are succulent and are a preferred choice of food for animals. Further, use of stem as fuel wood by rural folk involves frequent lopping, upon which the root mass enlarges with rich food reserves, aiding rapid and robust regeneration.

At this juncture, a programme is necessary in which various control strategies should be combined with the utilization of the plant. A short term study at the Department of Agronomy, Annamalai University, India compared the efficiency of different control options including slashing close to the ground, slashing followed by digging out the root mass, slashing followed by burning the residual stumps using kerosene, and slashing followed by treating the left over stumps with a herbicide paste of 2,4-D (60 g a.i. per plant). Naturally regenerated stands of the weed are better managed by slashing and digging out the roots followed by measures of rehabilitating the land such as cropping with fodder grasses, planting smother crops or using self sown live mulches. Another study by the same Department compared the efficiency of different crops/plants for preventing regeneration of *P. juliflora* after slashing and digging out roots. Among a number of different rehabilitative cropping patterns comprising fodder grasses, prostrate legumes and self sown live mulches, prostrate legumes intercropped with sunflower performed better in restoring land and returning it to use. In woodlands with well established tree forms of the weed, a better strategy would be to thin the number of weed trees to 100/ha in a phased manner over a period of three to four years. Yearly pruning of side branches in each of such left over trees up to seven years is also needed to induce the trees to take desired crown shape and structure. The field in between the trees needs intermittent ploughing or disking to encourage suitable silvi-pastoral systems. However, managing *Prosopis* need community participation. In Sudan, herbicides triclopyr and clopyralid sprayed over foliage is reported to be effective. Regarding bio-control, the seed feeding bruchid *Algarobius prosopis* and *A. bottimeri* were shown to contain the spread of the weed in South Africa through a bio-control programme initiated in 1985 and these insects were also released in Sudan later. A bio-control program was initiated by CSIRO in Australia in 1994 and only two out of four agents tested viz. a sap-sucking psyllid *Prospidopsylla flava* causing dieback and leaf-tying gelechid (*Evippe* sp) which is a defoliator from Argentina showed host specificity. They were released throughout Australia since 1998.

628. **The Invasiveness of the African Tulip Tree (*Spathodea campanulata* Beauv.).** Ricardo Labrada¹; ¹FAO, Rome, Italy

The African Tulip tree (*Spathodea campanulata* Beauv.), originally from East and Southern Africa, is a large upright tree with green pinnately compound leaves and velvety-brown claw-like buds from which emerge 7cm wide by 10cm long bell-shaped, bright-orange coloured flowers. Some varieties of the plant bear yellow and crimson coloured flowers. The tree can grow to more than 20m in height and reproduces by seeds and runners. In Fiji the plant flowers from June to October, and seeding between

January and March. Seed production is prolific and may be long-lasting. Seeds may be dispersed by wind and/or by birds and insects. The trees may grow about one metre every month. *S. campanulata* was introduced during the 1930s as an ornamental into some islands of the Pacific, where it developed into a serious weed problem invading agricultural and forest areas. The tree was also introduced for ornamental purposes into several countries of South and South East Asia, and into various Central American and Caribbean countries in the late 1930s and during the 1940-50s. The plants uses are very limited; it serves for shade or for making fence posts. When growing without the presence of any biological regulatory agent it spreads fast. Once established at a site, the process of removing the tree becomes cumbersome and expensive. Trees when tall are difficult to remove; pruning is to be avoided since it promotes rapid regrowth. Mechanical removal is a possibility, but stems, branches and roots should be taken away from the field to avoid their regeneration. For a farmer practising shifting cultivation it is much easier to clear land with native forest than land infested with the African Tulip because native forest normally does not regrow from remaining stumps. The use of chemical herbicides, e.g. picloram, glyphosate or any other, is costly and feasible only where the infestation consists of young plants and is sparse. In Fiji by 2000 cutting seedlings cost farmers about \$48 per hectare, while the application of picloram applied to ring barking, painting trees or spraying seedlings could cost \$240. Good control is only achieved with three applications year. Plants associated with *S. campanulata* are *Serianthes melanesica*, *Psidium guajava*, *Mikania micrantha*, *Lantana camara*, *Cyathea microlepidota*, *Cassia tora*, *Leucaena leucocephala* and others. However, it is considered a threat to the floral biodiversity in Fiji due to its competition with native and endemic flora. The plant is normally not found in *Pinus* plantations, and its seeds will readily germinate in water. Its presence is not abundant in irrigated rice-fields. Taking into account that controlling the weed requires high labour inputs, preventive control measures should be applied, consisting of prohibition of plant reproduction in nurseries, limiting its planting, and raising awareness among farmers of the risks of planting *S. campanulata* in their areas. Such action will be cost-effective and may prevent spread of the plant and problems to the agro-ecosystems of these countries. It is also important to conduct research to identify the natural regulators of *S. campanulata* existing in East and Southern Africa for developing biological control of the tree, which might be a cost-effective strategy for its control and to prevent spread.

629. ***Ulex Europaeus* - A Global Weed.** Hernan Norambuena¹; ¹Instituto de Investigaciones Agropecuarias (INIA), Temuco, Region de la Aarauca, Chile

Ulex europaeus L. (gorse) is a member of the Fabaceae, native to central and western Europe, that has become one of the world's most damaging weeds. It now has established in at least 30 countries and islands but has become a serious threat in Australia, Chile, New Zealand, in western North America, including British Columbia, Washington, Oregon, northern California, and Hawaii. European colonists introduced gorse into these countries during the 1800s primarily as a hedge plant to contain livestock or ornamental, but there was also interest in its potential use as a fodder source. Since its introduction gorse has escaped cultivation and aggressively invaded natural and disturbed habitats. Gorse is common of a wide range of conditions but in temperate latitudes it is limited altitudinally by cold temperatures. This has not impeded it becoming established in montane regions where maritime influences moderate the climate. Gorse is a major pasture, forest and environmental weed. It occurs along roadsides and on disturbed land where it forms dense impenetrable stands that gradually invade open ranges and competes with grass and forb species, thus severely reducing forage quality and quantity. The plant is a significant problem in forest plantations because it hinders the establishment and efficient management of exotic forest trees, and constitutes a serious fire risk. The weed also invades native bushland thereby reducing access and conservation values, increasing fire hazards and threatening the survival of plants and animals. *U. europaeus* is a perennial spiny woody shrub that in its exotic range can live up to 30 years of age and grow to more than 3m in height. It has a large root system containing nitrogen-fixing root nodules. Flowers are bright yellow, ca 20 mm long and borne all over the plant. Flowering occurs mainly in spring, with a minor secondary bloom in late autumn and early winter. Seeds are produced twice a year in small hairy pods that are 15 to 18 mm long. The heaviest crop is produced primarily during late spring and summer. Gorse produces vast quantities of seeds that can remain viable in soil in excess of 25 years. Seed dispersal occurs mainly via the explosive dehiscence of gorse pods. Although seeds may be ejected several meters away most seeds are dispersed near the parent plant. Seeds are also dispersed by animals, wind, water and human activities such as the use of seed-infested gravel. The progressive spread and competitiveness of gorse is due to its long vegetative period, extremely rapid growth in many soil types, high seed production, climatic adaptability, and by the absence of effective natural enemies. Annually, gorse can grow 0.5-1m and produce approximately 10,000 seeds per square meter. The ability of gorse to regenerate from stumps and a long-lived seed bank make gorse an invasive pioneer species that readily invades disturbed ground and dominates early on in the plant community succession process. Following fire or mechanical clearing, gorse rapidly forms dense impenetrable thickets as a result of increased germinability of seeds on the top layer of the seed bank and/or by sprouting from living stumps. Gorse can be controlled on intensively

managed land, but, herbicides, burning or mechanical clearance have proved to be expensive or impractical on land that provides low economic returns, rugged terrain, or in sensitive habitats. In many cases, control attempts at a national level, which have included subsidies to growers and legal restrictions, have been ineffective in stopping gorse spread and impacts. Gorse now occurs on at least 3.5% of New Zealand's land area. In Australia, gorse is scattered over about 1 million ha in Victoria and occurs on rural land in all parts of Tasmania. Gorse is also spreading in New South Wales, South Australia and Western Australia and is a declared Weed of National Significance. In Chile, gorse is infesting about 100,000 ha of plantations with exotic timber species, and the weed is also spreading on rural land between the 37° and 44° S infesting pasture land and native forest. In the United States, including two Hawaiian islands, at least 30,000 ha are under increasing infestations. Given the noxious nature of gorse at a global level, infested countries should maintain programs of detection, management and monitoring to insure that the weed is kept from realizing its biological potential.

630. A Weed Traits Database for Predicting the Response of Weed Communities to Management. Jonathan Storkey¹, Niels Holst²; ¹Rothamsted Research, Harpenden, Hertfordshire, United Kingdom; ²Danish Institute of Agricultural Sciences, Flakkebjerg, Slagelse, Denmark

As part of the European Union project, Endure, an online database of the functional traits of 20 European arable weed species is being built. The weeds trait database (WTDB) is being co-ordinated with a parallel activity designing a software application for integrating weed population dynamics models and contains the core set of parameters required to model weed emergence, competition and fecundity. Additional traits, such as seed size and maximum height are included that have been correlated with these plant functions in the literature. The database is being populated by weed scientists working in 11 European countries from searches of peer reviewed journals, grey literature and unpublished data. Information on the source of the data, geographical location and experimental conditions (including crop type) are included for each data entry. As well as being a source of the parameters required by weed population dynamics models, the completed database will have two further applications. Firstly, a meta-analysis will be performed on the database to explore aspects of weed functional ecology including correlations between traits, the existence of distinct ecological strategies or functional groups and the relative magnitude of intra and inter specific variability in trait values. Secondly, the WTDB will serve as a valuable resource for applying principles of assembly theory to weed communities. Data from the literature of the effect of different management filters, for example sowing date or cultivation, on species composition will be used to validate

the theory that the relative response of different species can be predicted from their functional traits.

631. Hormesis in Mixtures – Can it be Predicted? Regina Belz¹, Nina Cedergreen², Helle Sørensen²; ¹University of Hohenheim, Institute of Phytomedicine, Stuttgart, Baden-Württemberg, Germany; ²University of Copenhagen, Faculty of Life Science, Taastrup, Denmark

Binary mixture studies are well established for mixtures of pollutants, pesticides, or allelochemicals and sound statistical methods are available to evaluate the results in relation to reference models. The majority of mixture studies are conducted to investigate the effect of one compound on the inhibitory action of another. However, since stimulatory responses to low doses of chemicals are gaining increased attention and improved statistical models are available to describe this phenomenon of hormesis, scientists are challenged by the question of what will happen in the low dose range when all or some of the substances in a mixture induce hormesis? Can the mixture effects still be predicted and can the size and dose range of hormesis in the mixture be predicted from knowledge of the dose-response relationships of the individual compounds? And how much does it affect inhibitory dose predictions if the hormetic response is ignored? Answers to these questions are yet unsettled as respective mixture studies are missing and none of the response surface models available include biphasic dose-response curves. This study therefore focused on binary mixtures with one or both compounds inducing hormesis and evaluated data of root length of *Lactuca sativa* L. and areal growth of *Lemna minor* L., where substantial and reproducible hormetic responses to allelochemicals and herbicides have been found.

Results showed that the dose giving maximal growth stimulatory effects could be predicted by the most-used reference model of concentration addition (CA), if the growth inhibitory doses (EC₅₀) followed CA. In cases of deviations from CA at EC₅₀ the maximum concentration for hormesis and the concentration of no effect followed the same deviation pattern described by curved isobole models. Thus, low dose mixture effects as well as the dose range of hormesis can be predicted applying available statistical models if both mixture partners induce hormesis. Using monotonic dose-response models instead of biphasic dose-response models for the prediction of joint effects, thus ignoring hormesis, slightly overestimated the deviation from CA at EC₂₀ and EC₅₀, but did not alter the general conclusion of the mixture study in terms of deviation from the reference model.

Mixture effects on the maximum stimulatory response were tested against the hypothesis of a linear change with mixture ratio by constructing 95 % prediction intervals based on the single dose-response curves. Four out of the six data sets evaluated followed the model of linear

interpolation reasonably well, which suggested that the size of the hormetic growth stimulation can be roughly predicted in mixtures.

632. Individual-Based Modeling Shows that Low Herbicide Application Rates Can Lead To Faster Development of Resistance. Michael Renton¹, Art Diggle², Stephen Powles¹; ¹University of Western Australia, Perth, WA, Australia; ²Department of Agriculture and Food Western Australia, Perth, WA, Australia

An individual-based polygenic stochastic simulation model of weed population dynamics is used to investigate whether reducing in-crop herbicide application rates could increase the rate at which herbicide resistance is likely to be developed. It is assumed that reduced rates of herbicide application will only be used if they are rates that are effective in controlling weed populations in the absence of resistance. The model allows a range of hypotheses to be considered regarding the number of genes involved in resistance; the way that alleles of these genes combine to confer resistance; the initial frequency of these genes; and the way that environmental and phenotypic variability influences the effectiveness of a given dose of herbicide on a given genotype. Results indicate that in most cases where resistance depends on more than one gene, low herbicide application rates lead to increased rates of development of resistance, and that in some cases the difference is highly significant. The relationship between low herbicide application rates and faster development of resistance is shown to depend on whether 'major' genes are present in the population in addition to 'minor' genes and on the relative initial gene frequencies. These results have clear and important implications for the management of herbicide resistance in the field.

633. Stella® Modeling Encourages Systems-Thinking in an Undergraduate Weed Ecology and Management Class. Lauren Kolb¹, Nadiya Dragan¹, David Merrill¹, Kara Cox¹, Eric Gallandt¹; ¹University of Maine, Orono, ME, United States of America

Systems-thinking is a critical skill set in understanding, developing, and deploying ecologically-based weed management strategies. By studying germination, establishment, seedling mortality, competition, reproduction, and seed fate, students develop a static understanding of these processes. Students typically spend little time on quantitative relationships between states. Because they are unable to manipulate or otherwise explore how perturbation at a particular point may affect population dynamics, theories related to multiple-stress approaches to management often remain an abstraction. In the fall semester 2007, students in PSE403, a senior-level class in Weed Ecology and Management, were required to purchase a

student license for Stella®. This software permits even first-time modelers to evaluate complex system dynamics using an icon-based, drag-and-drop modeling environment. Students were introduced slowly to the software, beginning with simple quantitative relationships between the seed-bank and establishment, progressing to seedling survival and maturation, then seed rain and predation. Basic models were provided as examples. Each student had to research relevant parameters for a particular species of interest and had to justify estimated parameters when published values were unavailable. In the class of twelve, half of the students became highly engaged in the activity, routinely meeting to share breakthroughs in approach. Despite considerable frustration with the steep initial learning curve, they developed an impressive understanding of the interrelated effects of mortality at various life stages on fecundity and population dynamics. Rather than focus, for example, on impressive cultivation efficacy of, say, 80%, these students understood that this really means 20% survival, which may be entirely unacceptable, lacking appropriate stresses at other life stages. Students' comments regarding the activity reflect both the stimulation and the aggravation that this exercise provided. One student felt the model was a great help in piecing together detailed information from the literature review and aided in the comprehension of the complex workings of a weed's lifecycle. Another realized the importance of recognizing temporal and spatial variances of the parameter values, both of which will affect the ability of the model to mimic reality. All of the students agreed that the actual process of creating the model, not the finished product, provided the best opportunity to fully comprehend the principles governing weed population dynamics.

634. The Economic Impact of Biocontrol Programs. Rachel McFadyen¹; ¹CRC for Australian Weed Management, Brisbane, Queensland, Australia

Weed biocontrol programs are largely paid for by governments, who increasingly are using Risk-Benefit-Cost Assessment, based on quantitative assessments of these risks and benefits, to make policy decisions at all levels. Cost-effectiveness of a control method justifies continued investment: eg economic benefits from pre-introduction screening of plant imports is a justification for an expensive system of border controls. Risk Assessment requires quantitative assessment of probabilities, including the probability that the return from the program will exceed costs. Probabilities are calculated from historic data, and it is therefore important to include failures in any analyses for a true estimate of success rates while also including benefits from partial successes. The demonstrated cost-effectiveness can be used to prioritise biocontrol against other weed management methods. Yet few economic impact assessments of biocontrol programs have

been undertaken world-wide, and none of the whole suite of failures as well as successes.

For this reason, an economic impact assessment of all weed biocontrol programs in Australia since 1903 was undertaken by the consulting firm AEC Group Ltd and funded by the Weeds CRC. A total of 36 weed biocontrol programs have been undertaken in Australia in the 100 years to 2004, but for three of these (against crofton weed, St John's wort and docks), although largely successful, key data on costs or benefits could not be obtained. Only nine programs out of the 36 were failures, ie resulted in few or no economic benefits. Three programs where successful control of the weed was achieved (alligator weed, groundsel bush and sida) returned a benefit/cost ratio <1 because the actual economic impact of the weed was small. For seventeen programs out of the 33 assessed, economic benefits exceeded costs, and thirteen of these resulted in very large economic benefits. Two programs usually considered failures returned strongly positive benefits because small reductions in the weed problem nevertheless resulted in considerable cost savings.

Overall, the study demonstrated annual benefits of \$95.3 million from an average annual investment of \$4.3 million (Australian \$\$, 2005 values), a b/c ratio of 23:1. Even with the enormous economic impact of the prickly pear success excluded, the b/c ratio of all other programs was 12:1. Program costs varied greatly, and the cheapest successful program was against annual ragweed at a total cost of Aus\$0.6m. The most expensive was against *Mimosa pigra*, where work continued over decades with years of overseas research and employment of several scientists, for a total cost of Aus\$21.6m. Median cost for the 17 successful programs was Aus\$7m and the duration 14 to 27 years.

The study demonstrated the importance of quantifying the economic costs of the target weed at the start of control programs, so that benefits from any reduction in the weed can in turn be quantified. This is best done as a b/c study by independent economists prior to starting the program, which then becomes part of the policy decision process. Such analyses clarify where data are missing as well as identifying critical outcomes. For most weeds, even non-production impacts have an economic aspect ? if control was cheap or easy the community would not permit weeds to overrun environmental areas. Economic impact is the sum of many factors: loss of agricultural productivity; actual and potential extent of infestation; spread rate; cost of removal; and frequency of recurrence. Initial measurement of these is essential to make future assessments possible. Analyses can be repeated during programs, eg as suitable agents are found, and to clarify the spread rate of weed. Ex-ante studies, using realistic probabilities of success based on historic rates for the country and type of weed, and including the full range of potential costs and benefits, are powerful tools to convince funding agencies. Later ex-post analyses based on these data will clarify the true probabilities of success or failure and therefore return-

on-investment for weed biocontrol as well as other management approaches.

Given these very large returns, why is there not more investment by governments in biocontrol? Benefits are underestimated for many reasons: long delays from commencement to field results; difficulties in assessing impacts of biocontrol; underestimation of economic benefits from partial successes; difficulties in assigning monetary values to biodiversity and social impacts. And past successes are often forgotten: once active management is not required, people forget how costly the weed problem had been. Risks are over-estimated: failure rates are calculated for each individual agent released rather than for control programs as a whole, and risks of non-target damage to the environment are not compared with damage from alternative control methods. An excessive level of proof may be demanded: detailed scientific studies demonstrate impact in small-scale plots but not landscape-scale reduction in weed costs. Independent economic measures, eg properly-conducted end-user surveys, demonstrate cost reductions over several years, but lack proof that this is due to biocontrol. Ideally, there should be both detailed in-field evaluations and independent evidence of end-user cost savings.

635. SolviNix, A Bioherbicide for Tropical Soda Apple (*Solanum viarum*). Raghavan Charudattan¹, Ernest Hiebert², Mark Elliott¹, James DeValerio¹, Gabriella Maia¹; ¹University of Florida, Gainesville, FL, United States of America; ²BioProdex, Inc., Gainesville, FL, United States of America

Tropical soda apple (*Solanum viarum*; abbreviated: TSA), is an invasive noxious weed in Florida and several southeastern states in the USA. It is the number one exotic invasive weed species in cattle ranches throughout Florida. Currently, more than a million acres of ranch and natural lands are estimated to be infested with this troublesome weed. TSA is highly susceptible to Tobacco Mild Green Mosaic Tobamovirus (TMGMV) and is killed from a hypersensitive reaction to the virus infection. We have established that TMGMV could be used safely and effectively as a bioherbicide for TSA. TMGMV provides nearly 100% TSA control, but repeat applications may be necessary to treat plants that emerge after the initial treatment and plants that are missed in the first treatment. The University of Florida Research Foundation has patented the use of the virus as a bioherbicide and licensed BioProdex, Inc., a start-up, small-business enterprise in Gainesville, to develop and register a commercial bioherbicide product. BioProdex has developed an industrial process to mass-produce TMGMV. It has also developed two commercial formulations, SolviNix LC and SolviNix WP, and obtained an EPA Experimental Use Permit (EUP) to field-test and register one or both formulations. SolviNix should be applied as a post-emergent aqueous

spray, and applications could be made with a boom sprayer that is modified to abrade and spray simultaneously or with a high-pressure sprayer. The former is used in large open areas and the latter for spot applications. An overview of the research and development of SolviNix will be presented.

636. The Bugs that Ate Garlic Mustard: New Possibilities for Biological Control. Colin Yates¹, Stephen Murphy¹; ¹University of Waterloo, Waterloo, ON, Canada

The first evidence of herbivory on a population of *Alliaria petiolata* (M. Bieb.) Cavara & Grande (Garlic Mustard) in southwestern Ontario, Canada was observed in the summer of 2007. In recent years, evidence of herbivory on *A. petiolata* has been observed in the United States; however these observations have failed to show prolonged evidence of damage upon garlic mustard communities. *Ceutorhynchus erysimi* Fabr., *Plutella xylostella* L. (Diamondback Moth), and *Philaenus spumarius* (Meadow Spittlebug) were identified attacking, and successfully proceeding through different life cycle stages. As a result of these observations we hypothesize that the population of *A. petiolata* may be demonstrating (a) evolution of increased competitive ability (EICA) or (b) the population of herbivores present have evolved phenotypically to acknowledge *A. petiolata* as a host. There are many potential implications a result of these observations for furthering our understanding of the invasive pattern of *A. petiolata* and therefore potential biological control.

637. Atrazine and Amphibians: Lessons Learned from Risk Assessment of Reproductive Effects from Agricultural Uses. Keith Solomon¹, James Carr², Louis Du Preez³, John Giesy⁴, Ronald Kendall², Ernest Smith², Glen Van der Kraak¹; ¹University of Guelph, Guelph, ON, Canada; ²Texas Tech University, Lubbock, TX, United States of America; ³North West University, Potchefstroom, South Africa; ⁴University of Saskatchewan, Saskatoon, SK, Canada

The herbicide, atrazine is widely-used in agriculture for the production of corn and other crops. Atrazine is found in surface waters and several reports on the effects of atrazine on aquatic wildlife have been published in the literature. Several of these reports relate to endocrine and/or reproductive responses for which reliable guideline tests and a framework for regulation have not yet been developed. In the case of atrazine, there was inconsistency in the effects reported by different authors and inconsistency between studies in different laboratories. Some studies reported adverse effects on sexual development of atrazine in frogs and other amphibians. To assess whether atrazine causes adverse effects in frogs through mecha-

nisms mediated by endocrine and other pathways, several hypotheses were tested in laboratory and field studies. In some cases new test protocols were developed to characterize effects. Results of these and other tests were evaluated using guidelines for the identification of causative agents of disease and ecoepidemiology derived from Koch's postulates and the Bradford-Hill guidelines. The hypotheses were: Atrazine used in crop protection causes adverse effects in amphibians through; 1) estrogen-mediated mechanisms, 2) androgen-mediated mechanisms, 3) thyroid-mediated mechanisms, 4) adverse effects on gonadal development in amphibians, or 5) adverse effects at the population level in exposed amphibians. The biological plausibility of the proposed mechanisms of endocrine disruption was critically assessed in relation to results of controlled laboratory and microcosm studies as well as field observations. These data include DNA genotyping in relation to the haplotype-specificity of a developmental response based on the presence of testicular ovarian follicles in male frogs and the potential for transgenerational effects resulting from exposure to atrazine in frogs. Based on a weight of evidence analysis of all of the data, the central theory that environmentally relevant concentrations of atrazine affect reproduction and/or reproductive development in amphibians is not supported by the vast majority of observations. The same conclusion also holds for the supporting theories such as induction of aromatase, the enzyme which converts testosterone to estradiol. We concluded that environmentally relevant concentrations of atrazine do not affect amphibian growth, sexual development, reproduction, and survival. Assessing risks from effects on reproduction and development in amphibians and other aquatic organisms presented several challenges that provide useful lessons for addressing this issue. These lessons will be useful in developing a framework assessing environmental risks from putative endocrine and developmental disruptors.

638. Assessing the Value of Atrazine and the Value of Educating Producers About Proper Use of Atrazine in Pesticide Applicator Recertification Programs. Glenn Nice¹, Fred Whitford¹, Bill Johnson¹, Cheri Janssen¹; ¹Purdue University, West Lafayette, Indiana, United States of America

Rationale or justification for the research

Atrazine is the most widely used restricted-use herbicide on corn with 39 million pounds applied to 49% of the corn acres nationwide (USDA, 2006). However, atrazine has occasionally been found in surface water and is currently undergoing a reregistration process through the U.S. Environmental Protection Agency (EPA). As part of the reregistration process, monitoring for atrazine in surface water is done by a watershed by watershed basis. Watersheds that have atrazine or metabolites which exceed threshold values are monitored by-weekly during the peak

use season. Watersheds that have a 90-day rolling average above this limit during the sampling time have to submit a mitigation plan to the EPA. If levels are found above this limit again, the growers lose the ability to use atrazine in that watershed.

Private pesticide applicators are required to have a private pesticide applicator permit to apply atrazine to their fields. To maintain this permit applicators have to attend three two hour long continuing education programs over a five year period. These programs present an opportunity to introduce applicators to new regulatory issues and to educate applicators on the safe and effective use of pesticides. Although, large efforts are put forth on these educational programs state wide, there is a question as to how effective these programs are at increasing awareness and educating individual growers.

Objectives

To assess grower awareness of ground water contamination with atrazine, to monitor the long-term impact of the educational efforts, and to assess which tactics were being adopted to reduce off-site movement of atrazine. These surveys also evaluated the value of atrazine as perceived by the corn growers themselves and the anticipated cost of losing atrazine as a tool.

A brief description of methods used

These programs are county based and must require a regulatory topic. In 2005/2006 recertification cycle, off-site movement of atrazine into surface water was the regulatory topic. A total of 2887 participants in 69 meetings were given a survey to complete at each program throughout the state of Indiana. One year later, follow up surveys were mailed to the participants to determine if they were still using atrazine and what strategies were adopted to reduce the off-site movement of atrazine.

Results

At the onset of the program participants were asked to indicate their level of concern regarding this topic, 35% of participants indicated that they viewed atrazine ground water contamination of high concern. At the end of the program 66% indicated that it was of high concern, suggesting that the program was somewhat effective in increasing concern. When asked in the follow up survey if they were or had become more aware of the water quality issues surrounding the movement of atrazine 96% said that they were more aware. Sixty five percent of the participants had turned to the atrazine label as a source of information, while 39% had turned to the Extension publications distributed at the program, and 19% had consulted their crop advisor or Purdue Extension educator.

Growers farming more than 800 ha had a higher degree of concern than small growers regarding the loss of atrazine as a weed management tool. Eighty-nine percent of the growers thought there would be a 314 to 1255 kg/ha yield loss if atrazine was removed from the marketplace. Eighty-four percent of the growers estimated that weed control costs would increase \$15 to \$25/ha if no other

products were available to replace atrazine, which indicates that atrazine is still perceived as a valuable tool in corn production.

When surveyed on which strategies they would implement to reduce the off-site movement of atrazine; the three most commonly selected strategies to reduce atrazine movement were to pay more attention to label setback distances, establishing of grass filter strips around surface water, and reducing atrazine rates by tank mixing with other herbicides. In the follow up survey one year later, the highest percentage of responders (57%) indicated that they applied atrazine in a tank mix with other products. Many producers (39%) used herbicides-resistant varieties/hybrids which allow for the use of herbicides such as glyphosate or glufosinate as a replacement product. Others applied atrazine at lower rates (38%) and followed setback distances on the label more closely (36%).

Conclusions

The results of the survey confirm that atrazine is a valuable weed management tool to Indiana growers. The loss of atrazine as a weed management tool is perceived to have an impact on both corn yield and the economics of weed management. The participants of the survey indicated that atrazine movement into surface waters is not only the concern of environmental groups but a concern of the individuals that use atrazine. Most individuals who participated are willing to adopt strategies that would reduce the potential of surface water contamination. The use of county based programs such as the Pesticide Applicator Recertification Program is an effective tool to disseminate information and educate participants on regulator and environmental concerns.

639. Pesticide Registration and Management in China. Zhang Hongjun¹, Liu Xue¹; ¹ICAMA, Beijing, China (Peoples Republic of)

The production, application, distribution, and export of pesticides in recent years in China were briefly reviewed. The pesticide registration and management was introduced in detail in the paper, which included the basic laws for pesticide registration and management, the procedures and steps for registration, the main tasks and basic functions for ICAMA which is the important organization for pesticide registration authorized by the government, the establishment and standardization of the guidelines for the pesticide registration, the supervision for the pesticide market, and some identification and solution for pesticide illegal cases.

With much experience in this field and considering the status of China, the suggestions for innovation on pesticide registration were pointed out. The basic law for registration could not adapt the development, and should be revised. The revised new law should describe the requirements for the pesticide production, registration, export, application, supervision and so on. Some new

guidelines should be established, for example, the guideline for pesticide resistance, for environmental risk evaluation, for ecological risk evaluation, long-term persistence and damage to succeeding crops, GAP, and so on. The data for registration could be accepted by the developed countries in the future. The authorized organizations from the capital to local organizations with some different tasks for pesticide registration should be supervised and trained and the good system could be run in a good way. The high toxicological pesticides should be replaced with the good researches which should be conducted gradually. The disposals for pesticide should be callback and retreated with some allowance. The old pesticide should be reviewed and revaluated with the new developing technologies. The farmers should be trained, and the manufacturers with good records and credit standing should be praised and encouraged. The pesticide registration should be managed in scientific, determined, procedural way, and it could be good to control the pest and facilitate the sustainable development of agriculture in China.

640. The Spatial Spread of *Microstegium vimineum* (Japanese Stiltgrass), an Invasive Weed. Emily Rauschert¹, David Mortensen¹, Ottar Bjornstad¹, Andrea Nord¹, Nora Peskin²; ¹The Pennsylvania State University, University Park, PA, United States of America; ²Gobierno de la Ciudad de Buenos Aires, Buenos Aires, Argentina

Microstegium vimineum (Japanese stiltgrass) is a nonnative weed of particular concern in forests, where its rapid invasion threatens native diversity and interferes with forest regeneration. It has been reported to invade entire forests in Maryland and Pennsylvania, USA, in a time span of less than 10 years, thus it is critical to understand the invasion process of this species. The dynamics of new infestations of *Microstegium* were studied by establishing 30 patches in 2003 in different habitat types (roadside, intact forest, disturbed forest and wet meadow areas); subsequent population growth and spatial expansion were monitored until plots were terminated in 2006. We developed a spatial model of patch growth, using maximum likelihood techniques to estimate dispersal and population growth parameters. The patches expanded surprisingly slowly for a species considered to invade rapidly: the furthest distance new seedlings were found beyond the original patch area was 4 m in the four years of the experiment. At the end of the experiment, the majority of new seedlings were still within 1 m of the original patch. There was considerable variation in patch performance within a habitat; some patches did expand rapidly while others actually decreased in spatial extent. While patches created in roadside and wet meadow habitats tended to have farther dispersal and greater reproductive ratios than those in forested communities, there were often outlier patches in each environment that raised questions about the relevance of classifying habitat. The long-term

projections of the models suggest much slower spread than has typically been observed for *Microstegium*. The relatively small scale of natural dispersal suggests that human-mediated dispersal, likely influenced by forest road management, is responsible for the rapid spread of this invasive species.

641. Changes in Seed Bank Communities Associated with Plant Invasions. Margherita Gioria¹, Bruce Osborne²; ¹Arizona State University, Tempe, Arizona, United States of America; ²University College Dublin, Dublin, Ireland

Despite increasing appreciation of the ecological and evolutionary importance of soil seed banks, little information is available on the impacts of invasive species on this dynamic component of plant communities. In this study, the effects of three major invaders in Ireland (*Gunnera tinctoria*, *Fallopia japonica* and *Heracleum mantegazzianum*) on whole seed bank species assemblages were investigated using a multi-site comparative approach. The seed bank of invaded and uninvaded areas was sampled at three sites per invader, from four random plots (4 m²) and three soil depths (0-5, 5-10, 10-15 cm). Soil samples were collected in May and October, and the seedling emergence approach was used to assess the viable seed bank. Permutational multivariate analysis of variance (PERMANOVA) and analysis of dispersion (PERMDISP) were applied to the analysis of seed bank data, enabling the partitioning of variation and the use of different transformations and resemblance measures. The structure of invaded seed bank communities was significantly different from that of uninvaded ones, at each soil depth. A total 79 forbs and 14 grasses were recorded in the seed bank of uninvaded areas, compared to 62 and 9 species found in the invaded seed bank, respectively. Diversity and evenness were significantly lower in invaded seed bank communities. Species characterised by a persistent seed bank and/or by effective dispersal mechanisms were still found in the invaded seed bank. Conversely, species producing only transient seeds virtually disappeared. The seed bank of *Gunnera tinctoria* was large and persistent (60 428 ± 47 131 seedlings m², mean ± SD), whereas that of *Heracleum mantegazzianum* was transient (9,762 ± 390 seedlings m²) and only found in October, in the top soil layer. No seedlings of *Fallopia* spp. were recorded at the study sites. Comparative multivariate analyses combining data for the three invaders showed that *Fallopia japonica* had the greatest impact on seed bank communities, suggesting a higher invasive potential for this species. The results of this study have important implications for the development of management strategies. Removal of the seed bank of *G. tinctoria*, for instance, may be unrealistic because of a large number of long-lived viable seeds. Clear objectives on the composition of the vegetation after the restoration of invaded sites should also be set and should account for the composition of the seed

bank of invaded areas, since disturbance could promote the emergence of undesirable species, such as *Juncus* spp. and other agricultural weeds.

642. Establishment of a Precaution and Control Program for Invasive Alien Plants-A Case Study of Goldenrod (*Solidago canadensis*) in China. Sheng Qiang¹; ¹Nanjing Agricultural University, Nanjing, Jiangsu Province, China (Peoples Republic of)

Goldenrod (*Solidago canadensis*), native to North America, has invaded China and caused a big ecological trouble in eastern China. It has been regarded as one of main eradication targets in Plan of Action of the Eradication of IAS in China launched by the Ministry of Agriculture, China in 2003 and 2005. A quantitative survey of goldenrod was made in Jiangsu Province. Morphological characteristics and ecological distribution of 40 populations collected from eastern China were comparatively studied. The character of its reproductive biology was observed through LM and ESM. The distribution pattern of this weed was quantitatively described in this province. Through AFLP and ITS marker techniques, genetic diversity was studied and moreover a kind of cutflower ?Hungyinhua? widely grown in China was identified as *Solidago canadensis* complex. An inhibitor for flower bud differentiation was developed and applied at a large scale so that it completely halted seed set through inhibition of microspore and megaspore development. As a result, it is helpful to slow down speed of the weed spread to new areas. We screened five different combinations of herbicides such as glyphosate, 2,4-D and sulfometuron-methyl to extend to whole province, established eradication programs and trained administrators, farmers and extension agents at local plant protection units. A total of 10,000 ha areas of invaded goldenrod were eradicated, out of which the first tenth land was reclaimed. Five natural enemies, found on goldenrod, were evaluated as potential biological control agents. A technique was developed using stalk of goldenrod as media to culture more than ten kinds of edible mushrooms. The information system of invasive alien plants on web was built with the most species in China, providing information about biology, monitoring prevention of the worst invasive weeds including goldenrod (<http://weed.njau.edu.cn>). It has become a hot website that has been visited 0.75 million times since 2004. The knowledge of alien plants has been spread through the internet, TV, newspaper, broadcast and short training courses in order to enhance public awareness. In conclusion, we have established integrated management system with combination of precaution and emergent eradication including biological control for long-term management, utilization through ecological way for prevention, chemical control for rapid response, building information system and enhancement of public consciousness for prevention. The international collaborative

research project among China and North America, even including other invaded countries, needs to be initiated to study the biology, ecology and natural enemies of goldenrod.

643. Differences in Growth and Competitive Ability between Native and Introduced Populations of *Genista monspessulana* (French Broom). Richard Smith¹, Angelica Herrera², Raymond Carruthers¹; ¹USDA-ARS, Albany, California, United States of America; ²USDA-ARS, UC Berkeley, Albany, California, United States of America

Several hypotheses have been proposed to account for the success of non-indigenous plant species in their introduced range. The EICA (evolution of increased competitive ability) hypothesis proposes that the low abundance or absence of herbivores in new environments may drive selection for genotypes with increased growth and competitive ability compared to those in the native range. We tested this hypothesis using *Genista monspessulana* (French broom), a woody leguminous shrub native to Europe, which is currently spreading throughout California, USA. Seeds of *G. monspessulana* were collected from five populations in both its native (France and Spain) and introduced (California) range and were used to conduct three comparative studies. In the first study, seeds were weighed to assess variation in seed mass between native and introduced populations. In the second study, plants were grown in a common-greenhouse experiment to determine whether populations differed in growth response. In the third study, plants were grown with and without a native plant community to determine whether populations differed in their growth and competitive abilities and impacts on a native plant community. In general, our results support the prediction of the EICA hypothesis and indicate that introduced populations of *G. monspessulana* produce larger seeds and seedlings than populations from the native range. A better understanding of the factors that drive population-level variability across the native and introduced range of *G. monspessulana* may improve our ability to predict impacts associated with its spread and aid the development of more effective management strategies.

644. Modelling Weed Population Dynamics: Problems & Prospects. Robert Freckleton¹; ¹University of Sheffield, Sheffield, S Yorks, United Kingdom

The biggest challenge for quantitative weed ecologists is to produce predictions of how weed populations will respond to changes in management and the environment. Population modelling is one approach to generating predictions and is used in applications such as forecasting species' responses to management, biodiversity consequences of changing cropping practice and the invasion of

exotics. Recent reviews have highlighted that models are commonly employed by weed biologists, however have highlighted that there may be a number of limitation. In some cases the key limitation in developing models is the availability of high quality data: ideally spatially and temporally replicated population censuses should be available to parameterise and test models. There are, however some technical issues. I review some of the problems that have been encountered in developing predictive models in weed ecology. The include the problems of accounting for spatial and temporal variability, accounting for error in the data, as well as the numerical instability of models for populations that are close to an extinction boundary. I look at some of the solutions that have been suggested: in the main, dealing with such issues is difficult, at best, unless large amounts of data are available. Density-structured models have been suggested as a possible tool for dealing with some of the problems in ecological modelling: models are numerically stable, easy to parameterise and use data that are readily collected at large spatial scales. Using UK arable weeds as a case study, I discuss how this approach can be used as the basis for developing large-scale surveys and to generate models that link population dynamics to changes in the environment and management.

645. Population Regulation by Population Size: Small Populations of Weeds have Demographic and Genetic Limitations on Reproduction. Jeffrey Firestone¹, Marie Jasieniuk¹; ¹Univ. California, Davis, California, United States of America

Weeds and invasive plants are generally studied when they are plentiful and have their greatest impact. Yet, success at introduction, colonization, range expansion and control or eradication is often driven by their dynamics when in small populations. Ecologists have long known of processes such as pollen limitation and inbreeding that unduly affect small populations, but these are almost never considered in the context of weeds, known for their explosive growth rates.

To determine if the dynamics associated with small population size could depress weed seed production and fitness, 54 independent 'invasions' were created, composed of the common weed and invasive grass *Lolium multiflorum* (ryegrass). Small populations generally have both small demographic population size (e.g. pollen quantity) and small genetic population size (fewer individuals generally carry fewer alleles). The experimental design separated the effect of these two sizes by having three levels of genetic diversity (via three levels of relatedness among individuals in a plot) and independent variation in the number of plants and their growth and pollen production (achieved through cloning genotypes) for a total of 711 pollen donors. The proportion of florets maturing a seed was the primary measure.

A smaller demographic population size did predict a smaller proportion seed set across all 54 plots. Genetic diversity alone was not predictive of seedset but interacted with population size (transformed ANCOVA: Diversity effect $p=0.38$; demographic effect $p=0.0081$; interaction $p=0.0468$). The lowest diversity and intermediate diversity treatments each had reductions in proportion seed set in smaller populations, while the highest diversity treatment had no relationship ($p=0.0005, 0.0041, 0.9878$ respectively). Pollen limitation appears to reduce the quantity of seed a plant in a small population produces below what it has the resources to produce. Either this effect is created by limited genetic diversity, or the range of population sizes over which it occurs is much larger with limited diversity.

Our results suggest that, in outcrossing plants, founding population size can strongly affect the probability of success of weed invasion and the control thresholds for managing patchily distributed weeds. Because a lack of genetic diversity in *L. multiflorum* plots clearly reduced seed production, our results further suggest that continued introduction of new genetic material to a population may facilitate weed reproduction by removing a significant limit on population growth.

646. A Quantitative Analysis of Temperature-Dependent Dormancy Changes in *Polygonum aviculare* Seeds. Diego Batlla¹, Andrea Grundy², Katherine Dent², Heather Clay², William Finch-Savage²; ¹Facultad de Agronomía, Universidad de Buenos Aires, Ciudad de Buenos Aires, Buenos Aires, Argentina; ²Warwick HRI, Warwick University, Wellesbourne, Warwick, United Kingdom

Establishing quantitative relationships between environmental signals and changes in weed seed dormancy status is essential for the prediction of weed emergence. The objective of this work was to quantify the effect of temperature on *P. aviculare* seed dormancy release and induction. Seeds were stratified for different periods at 2, 6 and 10 °C and then placed to germinate at constant temperatures (6, 10, 15, 20 and 25°C). The seeds which remained un-germinated were then incubated in an alternating temperature regime (6/22 °C). Final germination percentage recorded in these experiments was simulated through an optimisation procedure based on a simple model: $G (\%) = dt * (drt - dit)$; where d is days of stratification at temperature t , and drt and dit , are the dormancy release and induction rates at temperature t , respectively. Results showed that temperature ranges that induced and released dormancy overlapped. Dormancy release rate was inversely related to temperature, and showed an exponential decrease from low temperatures to no dormancy release for seeds exposed to 20 and 25 °C. In contrast, dormancy induction rates were positively associated with temperature and showed an exponential increase with almost no dormancy induction at low temperatures and maximal induction at 25°C. Compari-

sons of dormancy release and induction rates revealed that high temperatures have a stronger effect on dormancy induction than low temperatures have on dormancy release. Estimated dormancy rates from the model were successfully used to simulate dormancy changes of *P. aviculare* seeds stored under laboratory and field conditions. These results suggest that similar simple model structures could be used not only to quantify temperature effects on seed dormancy status of other weed species, but also to predict dormancy status in relation to storage or field temperature.

647. Analysis of Early Growth of Weeds and Crops as Influenced by Temperature Regime. Ivan Sartorato¹, Guido Pignata¹, Maurizio Sattin¹; ¹National Research Council - CNR, Legnaro, Padova, Italy

In a plant community, the relative size of the plants when competition starts is considered to be a good predictor of the final outcome of competition. For any plant, the seedling stage is therefore critical in all plant communities because it heavily influences the competitive hierarchy, which in turn influences competitive relationships and weed community dynamics. Despite its paramount importance, scant information is available on weed seedling growth, especially for summer weeds growing in Mediterranean environments.

The aims of this research are: (i) to acquire precise information on the variability of relative growth rate (RGR) and its components during early growth in several weeds and crops with a very wide range of seed weights, (ii) to quantify the influence of two temperature regimes on RGR during early growth.

20 spring-summer weed species and 4 crops were grown in hydroponics in a growth chamber at two different temperature regimes (10/21 and 15/25 °C night/day, day-length 14 hours); mineral nutrition was supplied with full strength Hoagland's solution.

Dry seed weight of the considered weeds varied from 0.02 (for *Cyperus difformis* L.) to 56 mg (for *Xanthium strumarium* L.), while it varied from 5 to 159 mg for the crops.

During the first 20 to 60 days after emergence (depending on temperature regime and initial seedling size), 8 to 12 harvests were done and dry weight of roots, shoots and leaves, as well as leaf area, were measured. Three replicates of 5 to 20 plants each were collected at each harvest. The growth analysis was based on a functional approach to calculate both growth and partitioning parameters and lack of fit was tested of fitted curves.

To compare experiments from different temperature regimes, the time was expressed as temperature sum.

The experimental procedure allowed a precise estimate of growth parameters from the very early stages. All species showed 'strict' exponential growth during the

whole period considered, thus determining a constant RGR throughout, which ranged from 0.007 to 0.067 ($^{\circ}\text{d}^{-1}$). As expected, seed weight (excluding seed coats) and RGR are negatively correlated, with a closer relationship at higher temperature. However, RGR of minute seeded plants tends to deviate from the general relationship and not be as high as expected.

Analysis of RGR and its components may allow the identification of physiologically based functional groups, a useful concept for assessing weed communities and driving management approaches.

648. Evaluation of Base Temperature of Several Weed Species. Jean-Philippe Guillemain¹, Carole Reibel¹, Sylvie Granger¹; ¹Enesad - UMR BGA, Dijon, Bourgogne, France

Predicting effects of crop-weed competition are required to simulate plant growth in several situations, with or without competition. The lack of knowledge of biological parameters for weeds restrains the development of models including weeds. Temperature is one of the most important factor controlling plant growth. Consequently heat unit models are usually used to describe growth of crops. Such approach is based on the use of base temperature (lower limit when development starts) of germination. Base temperature may vary between weed species, thus we focused our work on the acquisition of this biological parameters for many weeds. This acquisition is necessary to the development of plurispecific models for crop-weeds competition.

The experiments were conducted to determine base temperature of three species: *Avena fatua* L. (often present in winter crop), *Chenopodium album* L. (present in some spring crops) and *Solanum nigrum* L. (summer weed), collected in the same geographic area (Côte d'Or, department of Eastern France).

The effect of temperature (10°C to 30°C) on germination response was tested in thermostatically controlled chamber without light. All seeds were placed in glass Petri dishes with moistened filter paper with 1% solution KNO₃. Seeds were checked for germination every day up to 28 days. The time course of germination was modelled using the logistic function and germination rate (1/day number required to reach 50% of maximum germination (1/t₅₀)) for each temperature was evaluated.

The base temperature was defined as the intercept of the linear regression between temperatures and germination rates. Non linear data from low and high extremes had to dropped to evaluated an accurate base temperature of plant. The regression equations were: $1/t_{50} = 0.0103 \times T - 0.0203$ ($r^2 = 0.93$) for *A. fatua*, $1/t_{50} = 0.0284 \times T - 0.1643$ ($r^2 = 0.98$) for *C. album* and $1/t_{50} = 0.0159 \times T - 0.1864$ ($r^2 = 0.955$) for *S. nigrum* (T for temperature). Base temperature identified for *A. fatua*, *C. album* and *S. nigrum* were 2°C, 5.8°C and 11.7°C respectively.

The values are very contrasted and that explains the presence of these weeds either in winter, spring and summer crops according to the climatic conditions favourable to their germination. These results confirm the need of knowledge of biological parameters to build and develop plurispecific models for crop-weeds competition.

649. Novel Weapons and Exotic Plant Invasions. Ragan Callaway¹; ¹The University of Montana, Missoula, MT, United States of America

Allelopathic effects have been attributed to a number of exotic invasive plants and recent research has also suggested the possibility that some invaders may possess novel chemicals that are more phytotoxic to naïve and non-adapted native plants, soil microbes, or herbivores in the invaded range than adapted species in the invaders native range. Such biogeographical differences in the effects of phytotoxic, antimicrobial, or defense biochemistry have been called the Novel Weapons Hypothesis (NWH). *Centaurea* species have been studied in the context of the NWH, and in particular *C. maculosa* for which there is evidence for root mediated allelopathy. *Centaurea* roots exude the chemical (\pm)-catechin, which has been reported as phytotoxic in vitro, in sand culture, in controlled experiments with field soils, and in the field. However, exudation rates, field soil concentrations, and toxicity at ecologically relevant concentrations remain questionable. I will discuss a suite of new results for the effects of (\pm)-catechin in soil and in the field. Biogeographic comparisons of (\pm)-catechin toxic effects and the general competitive effects of *C. maculosa* indicate that the weed has strong effects on North American species than European species. The NWH has also been explored in the context of soil microbes. *Alliaria petiolata* (garlic mustard) inhibits mycorrhizal fungal mutualists of North American native plants, and has far stronger inhibitory effects on mycorrhizas in invaded North American soils than on mycorrhizas in European soils where *A. petiolata* is native. This antifungal effect appears to be due to specific flavonoid fractions in *A. petiolata* extracts. Furthermore, suppression of North American mycorrhizal fungi by *A. petiolata* corresponds with severe inhibition of North American plant species that rely on these fungi, whereas congeneric European plants were weakly affected. These results indicate that phytochemicals, benign to resistant mycorrhizal symbionts in the home range, may be lethal to naïve native mutualists in the introduced range and indirectly suppress the plants that rely on them. Finally, ongoing comparative studies of growth rates of North American and European generalist insect herbivores indicate that North American species perform much worse on *C. maculosa* than European species. By transporting organisms far beyond their historical dispersal limitations, humans may have mixed plants, animals and microbes that

do not share common evolutionary trajectories. Evolutionary naïveté to the particular biochemistry of some exotic species may contribute to invasive success.

650. **Benzoxazinones as Natural Herbicide Models.** Francisco Macias¹, Jose Molinillo, Nuria Arroyo, Rosa Varela; ¹University of Cadiz, Puerto Real (Cadiz), Saharai Republic, Spain

DIMBOA and DIBOA have been described as important allelochemicals from Gramineae as well as Acanthaceae, Ranunculaceae and Scrophulariaceae plants. Several bioactivities have been described and evaluated for these compounds and their degradation products. These activities include fungistatic, anti-feedant and phytotoxic. In our ongoing studies about allelochemicals as alternative herbicide models, different amounts of starting allelochemicals and degradation products were needed for the preparation of suitable analytical standards and soil dynamic studies. Isolation and synthetic methodologies have been optimized for them.

2-Deoxy derivatives of benzoxazinones DIBOA and DIMBOA has been proposed as useful candidates for natural herbicides models development. In this context, a second generation of chemicals, which include structural modifications to enhanced their phytotoxicity and selectivity have been synthesized and tested on rice, the Standard Target Species (*Lepidium sativum* L., *Lycopersicon esculentum* Will., *Allium cepa* L., and *Triticum aestivum* L.), and common weeds (*Lolium rigidum*, *Avena fatua* L. and *Echinochloa crus-galli*). We have studied the structural requirements for this activity, as well as some molecular properties that can be related with the results obtained. These modifications include the introduction of side-chains of different length to regulate their lipophilicity, and the introduction of halogenated substituents that modify the electronic properties of the aromatic ring.

Those compounds that present an halogen atom at position 8 have shown high selectivities. These products showed strong inhibition effects on *Echinochloa crus-galli* at concentration lower than 1 μ M, whereas rice seeds growth with low effect at that concentration. On the other hand, those compounds which present an halogen atom at position 6 showed the lower values for IC50 on weeds whereas effects on wheat are very low.

D-DIBOA degradation experiments were performed in wheat crop soil. The results permitted to estimate its half life in this environment, being longer than the one for the natural allelochemicals DIBOA, which is too short. This could be an advantage from the point of view of the reliability of its phytotoxicity bioassays. This factor, in addition to the thermodynamic, electronic, and steric properties contributes to increase the activity of these chemical and its analogues in comparison to natural benzoxazinones.

These results allow us to propose these compounds as a potential rice and wheat protection tool against *Echinochloa crus-galli*, *Lolium* spp, and *Avena fatua*.

651. **The Function of Momilactone A and B in Rice Allelopathy.** Hisashi Kato-Noguchi¹; ¹Kagawa University, Miki, Kagawa, Japan

Momilactone B was recently isolated from rice (*Oryza sativa* L. cv. Koshihikari) root exudates as a potent rice allelochemical. Momilactone B was first isolated with momilactone A from rice husks as growth inhibitors involved in seed dormancy, and both momilactone A and B were later found in rice plants as phytoalexins. However, there is no information available if momilactone A is secreted into rice rhizosphere and involved in rice allelopathy. In this paper, release level of momilactone A and B throughout life cycle of rice plants, and growth inhibitory activities against weed species and rice itself were determined to know the functions of momilactone A and B in rice allelopathy.

Rice plants were grown hydroponically and concentrations of momilactone A and B in rice plants and in rice culture solutions were determined. Momilactone A and B were found in shoots and roots of rice plants throughout the rice life cycle. The level of momilactone A and B in the shoots and roots increased over vegetative growth stage until flowering initiation, and then decreased. However, the rice shoots and roots contained much greater momilactone A than momilactone B.

Momilactone A and B were found in all culture solutions in which rice plants were grown hydroponically. The concentrations of momilactone A and B in the culture solution increased rapidly from day 30 until day 80 when flowering started, and then decreased. The release rate of momilactone A and B, respectively, at day 80 was 1.1 and 2.3 μ g /plant/day, which was 55- and 58-fold greater than that at day 30.

In the present experiments, only rice roots were immersed in the culture solution. Thus, the rice plants probably release momilactone A and B from their roots into the solution. Although concentration of momilactone A in rice plants was much greater than that of momilactone B, release level of momilactone B was greater than that of momilactone A, which suggests that momilactone B was selectively released into the culture solutions by roots than momilactone A.

The biological activities of momilactone A and B were determined with two weed species, *Echinochloa crus-galli* and *Echinochloa colonum*. Momilactone A and B, respectively, inhibited the growth of roots and shoots of *E. crus-galli* and *E. colonum* at concentrations greater than 10 and 1 μ M. Increasing the concentrations increased the inhibition. Comparing I50 values (the concentrations required for 50 % inhibition of the growth), the inhibitory activity of momilactone B on the growth of *E. crus-galli* was 7.4-

fold greater than that of momilactone A, and the inhibitory activity of momilactone B on the growth of *E. colonum* were 19.2-fold greater than that of momilactone A. Thus, effectiveness of momilactone B on the growth inhibition is much greater than that of momilactone A.

Toxicities of momilactone A and B to rice seedlings themselves were determined. No visible damage to rice seedlings by momilactone A and B was observed except for occurrence of growth inhibition in the seedlings. Momilactone A and B, respectively, inhibited root and shoot growth of rice seedlings at concentrations greater than 100 and 300 μ M. The effectivenesses of momilactone A and B on the growth inhibition of rice seedlings were 1 % of those on the growth inhibition of *E. crus-galli* and *E. colonum*, suggesting that the toxicities of momilactone A and B to rice seedlings are probably much less than those to *E. crus-galli* and *E. colonum*.

These results suggest that rice plants may be able to inhibit the growth of their neighboring plants due to the secretion of momilactone A and B into their rhizosphere without serious toxicity of momilactone A and B to rice plants themselves. Thus, momilactone A and B may play an important role in rice defense mechanism in the rhizosphere for the competition with invading root systems of neighboring plants. However, the involvement of momilactone B for the defense mechanism is greater than momilactone A because growth inhibitory activity and release level of momilactone B were much greater than those of momilactone A.

652. Inhibition of Plant Enoyl (Acyl Carrier Protein) Reductase by the Natural Diphenyl Ether Cyperin. Franck Dayan¹, Zhiqiang Pan¹; ¹USDA-ARS NPUPU, Oxford, MS, United States of America

Cyperin is a natural phytotoxic diphenyl ether produced by several fungal plant pathogens. At high concentrations this metabolite is known to inhibit protoporphyrinogen oxidase, a key enzyme in porphyrin synthesis. However, unlike its structurally similar synthetic protoporphyrinogen oxidase-inhibiting herbicide counterparts, the mode of action of cyperin is not light-dependent, causing loss of membrane integrity in the darkness. This natural diphenyl ether inhibits *Arabidopsis thaliana* enoyl (acyl carrier protein) reductase (ENR). This enzyme is also sensitive to triclosan, a synthetic antimicrobial diphenyl ether. While cyperin was much less potent than triclosan on this target site, their ability to cause light-independent disruption of membrane integrity and inhibition of ENR are similar at their respective phytotoxic concentrations. The sequence of ENR is highly conserved within higher plants and a homology model of *A. thaliana* ENR was derived from the crystal structure of the protein from *Brassica napus*. Cyperin mimicked the binding of triclosan in the binding pocket of ENR. Both molecules were stabilized by the π - π stacking interaction between one of their phenyl rings and

the nicotinamide ring of the NAD. Furthermore, the side chain of tyrosine is involved in hydrogen bonding with a phenolic hydroxy group of cyperin. Therefore, cyperin may contribute to the virulence of the pathogens by inhibiting ENR and destabilizing the membrane integrity of the cells surrounding the point of infection.

653. Advances in Non-Chemical Weed Control in Urban Landscapes. Mario Lanthier¹; ¹CropHealth Advising & Research, Kelowna, British Columbia, Canada

In 2001, the Supreme Court of Canada recognized the authority of municipalities to enact bylaws on pesticide use, provided the aim is to protect 'the health of its inhabitants by restricting non-essential uses of pesticides'. These 'non-essential uses' include weed control in lawns, shrub beds and sidewalks, whereas 'essential' pesticide use would be rodent management in buildings and protection of food crops. The Court's decision led dozens of Canadian municipalities to enact pesticide reduction bylaws, and many school districts to voluntarily implement similar measures. The result was the removal of pesticide tools traditionally used by landscape managers in public agencies and private companies.

Pest management without pesticides is difficult for weeds. Prevention remains a cornerstone practice, such as paved mow strips under fence lines, mulches and ground covers in shrub beds, and sealing cracks in asphalt and concrete areas. Treatments based on mechanical control include hand weeding and use of mowers and string trimmers.

Newer non-chemical methods have been implemented to various degrees. The most widely adopted has been acetic acid, found in household vinegar. This 'least-toxic' product is allowed for use by organic farmers and is an 'acceptable' pesticide in most municipal pesticide bylaws. A commercial formulation is registered in Canada as a post-emergence herbicide. Weed control is rapid and excellent, especially at concentrations of 10% and 20% or with addition of 1% soap to help distribution on the target weed. However, the higher concentration can cause skin burning, the product controls only above-ground parts, and spray equipment must be thoroughly cleaned.

Another widely adopted tool is the hand-portable infrared radiation equipment equipped with a propane cylinder. The application of intense heat for a few moments results in coagulation of albumoid compounds inside plant cells, interfering with photosynthesis and leading to plant death. The time of application is short, but large weeds require a second application, weed roots are not affected, and there is no residual activity.

A product developed in Eastern Canada based on *Sclerotinia minor* was registered in 2007 as a post-emergence herbicide for dandelion in turf. The naturally-occurring fungus invades the plant and secretes oxalic acid, which destroys above-ground tissue. Studies show 60%

control when applied over growing dandelion, without impact on grasses. A commercial product is expected for 2010.

Two methods have not been widely adopted. Steam from hot water applied directly to weed foliage melts the waxy coating, resulting in loss of moisture and dehydration. The initial purchase is expensive, the equipment travels slowly, and the water reservoir requires frequent filling. Corn gluten meal is said to prevent seed germination for many weeds commonly found in turf areas. Commercial programs have not been successfully developed.

654. DuPont Aminocyclopyrachlor (Proposed Common Name) (DPX-MAT28/KJM44) Herbicide for use in Turf, IWC, Bare-ground and Brush Markets. Jon Claus¹, Ronnie Turner¹, Gregory Armel², Mark Holliday¹; ¹DuPont, Wilmington, DE, United States of America; ²University of Tennessee, Knoxville, TN, United States of America

Aminocyclopyrachlor, a new active ingredient herbicide from DuPont, is currently under development for a number of non-crop markets including turf, brush, bare-ground, and invasive weed management. Aminocyclopyrachlor is novel chemistry that will provide better efficacy and environmental safety in all non-crop markets when compared to key commercial standards. This highly potent herbicide provides broad-spectrum control of Asteraceae, Fabaceae, Chenopodiaceae, Convolvulaceae, Solanaceae and Euphorbiaceae, as well as many other broadleaf and woody weed species. Aminocyclopyrachlor also controls important ALS, PPO, triazine and glyphosate resistant weeds such as, *Amaranthus* spp., *Kochia scoparia*, *Conyza canadensis*, *Ambrosia* spp., and *Salsola iberica*. Aminocyclopyrachlor, will be the new standard for broadleaf weed control in turf, invasive weed management, bare-ground and brush. Field efficacy results and proposed directions for use will be presented.

655. Absorption and Translocation of 14C DPX-KJM44 and DPX-MAT28 in *Cirsium arvense* (Canada Thistle). Bekir Bukun¹, Scott Nissen¹, Philip Westra¹, Galen Brunk¹, Dale Shaner¹, Todd Gaines¹; ¹Colorado State University, Fort Collins, Colorado, United States of America

In field experiments, DPX KJM44 and DPX MAT28 have shown excellent activity on a broad range of broadleaf invasive weeds including *Cirsium arvense* (Canada thistle). Experiments were conducted to compare the adsorption and translocation of DPX KJM44-38 and DPX MAT28-013 (DuPont Crop Protection) in *Cirsium arvense*. Root segments were collected from a non-crop area near Fort Collins, CO and used to propagate uniform plant material. Plants were oversprayed with formulated

DPX KJM44 and DPX MAT28 plus 1% MSO at an application rate of 0.14 kg/ha when the plants were rosettes with six leaves. A single leaf was protected from the overspray with aluminum foil and treated with 0.5 µL droplets of spray solution plus radiolabeled herbicide. Plants were harvested 24, 48, 96 and 192 hours after treatment (HAT) and separated into treated leaf, shoot and root. Tissue samples were dried, oxidized and captured 14CO₂ determined by liquid scintillation spectroscopy. DPX KJM44 showed approximately 30% more uptake than DPX MAT28 with maximum absorption for both compounds occurring 48 HAT. Approximately 85% of applied DPX KJM44 was absorbed into the treated leaf compared to 60% for DPX MAT28. Translocation of both herbicides to above and below ground plant part was similar when based on the amount of herbicide absorbed. Approximately 30% of absorbed 14C labeled compound was translocated to leaves above and below the treated leaf. Approximately 10% of absorbed 14C herbicide translocated to the plant crown and root. The differences between absorption of the two herbicides most likely are related formulation differences.

656. Response *Cyperus esculentus* to Sulfosulfuron in Turfgrass. Prasanta C. Bhowmik¹, Dipayan Sarkar¹; ¹University of Massachusetts, Amherst, MA, United States of America

Cyperus esculentus (yellow nutsedge) is a common weed among other weed species in turfgrass environments. It is difficult to control this species selectively. The objective was to evaluate sulfosulfuron (Certainty), a sulfonylurea herbicide, for selective control of *Cyperus esculentus* and other broadleaf weeds. Six different experiments were conducted over the last seven years. Experimental turfgrass areas were maintained under normal management practices. All treatments were applied to 1 by 3 m plots with a CO₂-backpack sprayer at a pressure of 152 kPa in either 467 or 934 L ha⁻¹. *Cyperus esculentus* was treated with sulfosulfuron at 17.5 to 105 g ai ha⁻¹ at the 15 to 20 cm growth stages. In a broadleaf trial, POST treatments were applied on June 8 and July 20, 2005. All sulfosulfuron treatments were applied with a non-ionic surfactant, X-77 @ 0.25% (v/v). Turfgrass injury was visually estimated on a scale of 0 to 100% (0% = no injury and 100% = dead turfgrass). Weed control was visually estimated on a scale of 0 to 100% (where 0% = no weed control and 100% = complete control) 2, 4, 8 and 12 weeks after treatment (WAT). POST application of sulfosulfuron at 35 g ha⁻¹ completely controlled yellow nutsedge, irrespective of the volume of applications (467 or 934 Lha⁻¹). These treatments resulted in 50 to 85% control of *Agrostis palustris* (creeping bentgrass) and gave 20 to 70% control of *Trifolium repens* (white clover). In general, *Trifolium* recovered specially from one application of low rates (17.5 to 35 g ha⁻¹) of sulfosulfuron as compared to sequential

applications. Our results demonstrate that sulfosulfuron is effective in controlling yellow nutsedge and would provide an alternative control practice in turfgrass areas.

657. Control of *Cyperus rotundus* in Turfgrass with Four Consecutive Years of Postemergence Applications of ALS-Inhibiting Herbicides. Kai Umeda¹; ¹University of Arizona, Phoenix, Arizona, United States of America

The ALS-inhibiting herbicides, imazaquin, halosulfuron, trifloxysulfuron, sulfosulfuron, and flazasulfuron were applied multiple times during each July and August from 2004 to 2007 to observe and determine efficacy to reduce populations of *C. rotundus* in regularly maintained landscape turfgrass, *Cynodon dactylon*. The small plot experiment replicated four times in a randomized complete block design was sprayed with a backpack sprayer. In Year 1, imazaquin at 560 g a.i./ha, halosulfuron at 69 g a.i./ha, and trifloxysulfuron at 29 g a.i./ha were applied three times and sulfosulfuron at 105 g a.i./ha and flazasulfuron 53 g a.i./ha only once. Imazaquin, halosulfuron, and trifloxysulfuron were also combined with MSMA at 3.36 kg a.i./ha to compare additive or synergistic effects to enhance *C. rotundus* control. During Years 2 to 4, all herbicides were applied two times at an 8 week interval.

In September of Year 1, multiple applications of imazaquin, halosulfuron, and trifloxysulfuron or the combinations with MSMA gave acceptable control at 80% or better. Single applications of sulfosulfuron and flazasulfuron gave acceptable control for only 3 to 4 weeks. In Year 2, all treatments demonstrated effective control ranging from 86 to 97%. At the end of Year 3, *C. rotundus* control ranged from 73 to 99% where imazaquin, trifloxysulfuron, sulfosulfuron, and flazasulfuron treatments approached near complete control. At the beginning of Year 4, *C. rotundus* was slightly reduced and control was 55 to 69%. In October of Year 4, the degree of control was 78 to 96% control by the various herbicides and combinations with MSMA. *C. rotundus* control with ALS-inhibiting herbicides requires multiple applications over more than 4 years in managed turfgrass.

658. Challenges in Field Crops Production under Conservation Systems of Tropical Agriculture – an Overview of Weed Science in Brazil. Rubem Oliveira¹; ¹State University of Maringé, Maringé, Paraná, Brazil

Successful weed control is a key requirement of modern crop production systems. However, achieving good weed control continues to pose difficulties. Effective and economic weed control is usually achieved when an appropriate control method is applied to a susceptible weed at the correct growth stage. Although new trends in weed control are going towards integrated management,

most cropping systems still rely heavily on the use of herbicides. There is a growing interest and demand for agricultural products derived from organic cropping. This interest has brought to attention of both weed scientists and growers the need for the search of suitable weed control methods. From this point of view, there is a growing interest for alternative methods of weed control, including cultural methods such as maximizing crop initial growth and or minimizing/delaying weed emergence in crop cycle. The search for biological methods of weed control is so far restricted to the use of allelopathic effects of cover crops. New challenges in chemical weed control for tropical agriculture include particular issues for specific crops. As in the rest of the world, there is a concern about the severe restriction on releasing new herbicide molecules by the industry. Simultaneously, there has been a significant growth of generic formulated herbicide market. Both facts seem to be impacted by the increase of glyphosate-resistant (GR) crops area, especially soybeans and cotton. Glyphosate is by far the most important active ingredient to agriculture in Brazil, not only because of GR crops, but mainly because it is the basis for no-tillage cropping systems. Although soybeans still represents the largest herbicide market in country, cotton has resumed the expansion of cultivated area and currently faces important challenges related to weed control. There is an urgent need to provide more specific rate and herbicide recommendations, since cotton is cultivated under a great variety of soil and weather conditions. Site specific rates may contribute to reduce problems related to deficient weed control, crop injuries and carryover events observed so far. In view of two or more cropping cycles in a single year, other carryover problems have been identified in soybeans, corn, wheat and sugarcane areas. GR soybeans area is continuously increasing and the rise in glyphosate use has led to new weed problems. Species like *Conyza canadensis*, *C. bonariensis*, *Lolium multiflorum* and *Euphorbia heterophylla* have evolved resistance to glyphosate in the last 3-4 years, and other species are currently under investigation. The single use of glyphosate has also provided selection of tolerant weed flora, with increasing problems to control species like *Ipomoea grandifolia*, *Commelina benghalensis* and *Alternanthera tenella*. Much attention has been given to sequential applications and tank-mixed alternatives to provide adequate control of these species. Resistance is also an important issue in flooded rice, since herbicides are the main tool in weed control for these areas. Also, the potential of rice herbicides as environmental (soil and water) contaminants have been discussed. There is also a special interest on the rising demand and in the strong increase in sugarcane cultivated area, due to its potential as biomass for ethanol production. The search for a larger market share has increased industry efforts to offer a more suitable portfolio. In particular, the use of sugarcane harvesting without residue burning is becoming an important research demand for weed scientists. There is a continuous

search for effective herbicide treatments both for areas with significant biomass cover and for areas harvested during the dry period of the year. With increased acreage of herbicide application and use of chemical methods, much research is yet to be done to understand the effects of climate and soil on the potential of herbicides to contaminate soil and groundwater. Further research is also required in forest plantations and minor crops (such as HF). A great number of unanswered questions represent a wide variety of opportunities for field and lab research work.

659. Weed Dynamics and Grain Yield as Influenced by Tillage and Weed Control Methods in Rice-Wheat Cropping System in Chhattisgarh, India. Amrit Singh¹, Tapas Choudhary¹, S Kolhe¹, B Chandrakar¹; ¹Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Rationale:

On an average around 30% of the total expenditure of crop production is incurred on tillage operations. The primary objective of tillage is to control weeds and about 50% of energy required for tillage is spent for weed control. The significant improvement being made in the field of herbicide technology, the necessity of soil manipulation for weed control has decreased. In conventional tillage, more diverse and intense weed population often need to be managed with fewer weed control tools, therefore, keeping above in view, the current study was undertaken with the objective that:

1. To quantify the weed flora under various tillage system and subsequent crop
2. To evaluate the effect of cropping system on weed growth and grain yield of cropping system

Methodology:

A field experiment was started in wet season of 2005 with direct seeded line sown rice as first crop and wheat as subsequent crop in winter season. The soil of experimental field was inceptisol, nearly neutral in reaction with low organic carbon and available Nitrogen, medium in available Phosphorus and high in available potash. The experiment was laid out in Split Plot Design replicated thrice. Two tillage practices i.e. Zero tillage and Conventional/intensive tillage were kept as main plots and three treatments of weed control in rice namely farmers practice i.e. hand weeding twice, recommended herbicides i.e. Butachlor 1.5 kg/ha as pre-emergence followed by Phenoxaprop-P-Ethyl @ 56.25 g/ha, Ethoxysulfuron @ 15 g/ha as post-emergence and a Weedy check were kept in sub-plots. Similarly in wheat, three weed control treatments namely Farmers practice i.e. hand weeding twice, recommended herbicides i.e. application of Pendimethalin 1.0 kg/ha as pre-emergence followed by Metsulfuron 2 g/ha as post-emergence and a Weedy Check were in sub-plots. Main plots were similar to rice. Medium duration varieties of rice and wheat were under test.

Results:

Weed flora and weed population

In rice, weed flora of the experimental field in the initial two years (2005 & 2006) consisted of *Echinochloa colona*, *Ischaemum rugosum*, *Fimbristylis millacea*, *Cyperus iria*, *Alternanthera triandra*, *Cynotis axillaries* and *Croton banplandianum*, but in 2007, *Setaria glauca* emerged as new weed and *Fimbristylis millacea* disappeared.

In wheat, weed flora of the experimental field consisted of *Echinochloa colona*, *Cynodon dactylon*, *Alternanthera triandra*, *Melilotus indica*, *Chenopodium album*, *Melilotus alba*, *Anagalis arvensis*, etc. Broad leaf weeds completely dominated the flora as compared to grasses.

Yield attributes and grain yield:

In the initial two years, the grain yield of rice was not influenced significantly due to tillage methods, but during 2007, the grain yield was significantly higher under zero tillage than conventional tillage. Yield attributes like plant height and test weight did not differ significantly due to tillage but effective tillers were significantly superior under zero tillage than conventional tillage. Among the different weed control practices, farmers practice produced maximum grain yield which was significantly superior over recommended herbicide and unweeded check.

Grain yield of wheat was influenced significantly due to tillage methods. Significantly higher grain yield was recorded under conventional tillage than zero tillage. Similar trend was also noted for yield attributes except test weight. Significant variation in grain yield and yield attributes was also registered due to various weed control treatments. Grain yield of wheat was significantly higher under recommended herbicidal treatment as compared to farmers practice and weedy check.

Conclusion:

In the initial two years i.e. 2005 & 2006, the grain yield of direct seeded rice was not influenced significantly due to tillage methods and produced similar dry matter of weeds and grain yield. However, during 2007, the variation in dry matter production of weeds and grain yield was significant due to tillage methods. Grain yield obtained from zero tillage was significantly higher than conventional tillage. Among the weed control measures, farmers practice i.e. hand weeding twice performed at 20 and 40 days after sowing increased the grain yield of rice over recommended herbicide and weedy check by 48.09 and 96.64 per cent, respectively. Grain yield was significantly higher under conventional tillage than zero tillage. Grain yield of wheat was significantly higher under recommended herbicidal treatment than farmers practice and weedy check by 9.85 and 31.33 per cent, respectively.

660. Weed Survey, Weed Escapes and Crop Yield in Glyphosate-Resistant Soybean in Argentina. Julio Scursioni¹, Emilio Satorre¹; ¹Facultad de Agronomía, Buenos Aires, Argentina

Glyphosate resistant crops have been rapidly adopted by farmers of Argentina where almost the whole area is cropped with RR soybean varieties. There are different questions about the effects of this technology: (i) What is the effect in terms of weed community (weed shifts)?; (ii) Is it possible to obtain high crop yields and also less impact on weed diversity? Glyphosate controls many weeds efficiently but some of them can escape glyphosate treatments. Identifying these weeds and the processes that allow them to escape will permit to develop effective management strategies. During 2002 and 2003 weed surveys on soybean fields were carried out in the rolling pampas area in Buenos Aires, Argentina. Constancy (number of fields with presence of the weed respect to all the fields surveyed); frequency (number of samples with the species respect to the total samples within each field) and density (average number of individuals/m² for each weed species on each field) were calculated for all weeds. Number of weeds in the whole area and the average number of weeds by each field were also registered. Field experiments were also done with the aim of studying the effect of glyphosate strategies on crop yields and weed community. All were post-emergence treatments and included: (i) one pass glyphosate when weeds were 5-10 cm height; (ii) one pass glyphosate when weeds were 20 cm height; (iii) two passes glyphosate, when weeds were 5-10 cm and again at 20 cm; (iv) imazetapir plus glyphosate when weeds were 5-10 cm height and (v) the weedy check. Results from our survey compared with data from years previous to RR technology, showed that there were no significant effect of glyphosate application in terms of number of weeds. However, there were changes in weed composition. Forty and thirty-five weed species were registered at the surveyed area in 2002 and 2003, respectively. Fourteen and eleven weed species were found as average in each field. *Anoda cristata*, *Digitaria sanguinalis*, *Stellaria media*, *Chenopodium album*, *Cyperus* sp. and *Portulaca oleracea* were registered in more than 80% of the fields. Weeds that were important in previous years as *Datura ferox* and *Amarantus* sp. declined their constancy. *Sida rhombifolia* increased its presence on the fields and late emergence species as *Stellaria media* were frequent at the end of the crop cycle. Regarding field experiments, with one pass glyphosate is possible to obtain both high crop yield and less effect on weed community. However it depends on weed abundance at the early crop stage. Knowledge about weed composition and the ability to predict weed emergence are necessary to get both high production and sustainability with RR technology.

661. Effect of Soil Tillage Systems on the Control of Perennial Weeds in a Fluvisol. Rusu Teodor¹, Gus Petru¹, Bogdan Ileana¹, Moraru Paula¹, Pop Adrian¹, Oroian Ioan¹, Pacurar Ioan¹, Paulette Laura¹; ¹University of

Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, Cluj Napoca, Cluj, Romania

A research study was conducted in the pedoclimate of Cluj-Napoca, Romania, investigating the control of perennial weeds by conventional tillage and minimum tillage. The experiments took place in 2004-2007 at the University of Agricultural Sciences and Veterinary Medicine in Cluj Napoca, on a moderately fertile fluvisol. The humus content was 3.01%, pH was 7.2, and soil texture was clay (42% clay in the arable stratum). The experimental field has an annual temperature of 8.2°C and annual rainfall of 613 mm.

The experimental design was a randomized complete block design with three replications. The area of a plot was 300 m². Except for the soil tillage system, all other variables were held constant, including the herbicide used. The weeding level of the land was assessed by numerical method using a 0.25 m² framework. The reserve of seeds bank in the soil was assessed by volumetric method, respectively with cylinders of size 100 cm³ and the washing of soil samples that was made on sieves of 0.25 mm size. The results were statistically analysed by ANOVA and Duncan's test. A significance level of P 0.05 was set a priori.

Analysis of soybean, wheat and corn crop weed population depends heavily on soil tillage and *Convolvulus arvensis* percentage. This is evident by the relationship between plant development and soil tillage system. *C. arvensis* percentage in the weed community was highest in the disk + rotary harrow minimum tillage treatment, at 39.1% in soybeans, 4.2% in wheat and 24.2% in corn. Ploughing decreased *C. arvensis* percent to 19.2% in soybean, 0.9% in wheat and 3.8% in corn. Soybeans had a very low level of weeds at harvest. Of the 2.3-2.9 weeds m² present, *C. arvensis* represented only 0.3-0.6 weeds m² (10.3-39.1%). Using genetically modified, Roundup Ready soybeans, weed control was more successful. Under such conditions, differences between minimum tillage systems and conventional tillage were insignificant. In the para-plow + rotary harrow minimum tillage system, applying Roundup herbicide at 4 l/ha in two treatments (2+2) controlled almost all weed species and partially controlled *C. arvensis*, *Stachys palustris* L. and *Cirsium arvense* L.

Research of weed seeds from soil at the end of a 3 year crop rotation, show an 11% increase in total weed seeds at 0-30 cm, from 22,288 seeds m² under conventional tillage, to 24,663 seeds m² under minimum tillage. Thus, 91% of weed seeds from minimum tillage were located in the upper 10 cm, compared to 71% under conventional tillage. The number of *C. arvensis* seeds in the upper 10 cm of soil increased 169% under minimum tillage where 77% of the such seeds are present.

662. Improved Weed Management and Production Methods for Conservation Tillage Dry Bean. Robert Blackshaw¹; ¹Agriculture and Agri-Food Canada, Lethbridge, Alberta, Canada

Multi-year field studies were conducted to determine improved weed management and crop production methods for dry bean grown under conservation tillage practices. Study 1 examined zero tillage dry bean production when planted into wheat, barley, canola or flax stubble. Dry bean emergence was delayed by 3 days in one of six site-years with zero tillage compared with conventional tillage but maturity was not affected. Dry bean density was similar or higher with zero than with conventional tillage. Weed densities were slightly higher with zero tillage but were well controlled with postemergence sethoxydim and bentazon. Over all previous crop stubbles and years, dry bean yield was similar with both tillage systems. Study 2 examined the potential benefits of a cereal cover crop preceding dry bean production. Fall-seeded cover crops were often superior to spring-seeded cover crops in terms of providing sufficient ground cover to reduce soil erosion and reducing weed emergence and growth. Among the fall-seeded cover crops, winter rye provided the greatest ground cover and often caused the greatest weed suppression. Dry bean density was not affected by any of the cover crops, but fall-seeded cover crops delayed emergence by up to 5 days and delayed maturity up to 4 days. Nevertheless, cover crops increased dry bean yield by 5 to 13% when in-crop herbicides were used and by 20 to 90% in the absence of in-crop herbicides. Study 3 identified suitable herbicide programs for conservation tillage dry beans. Surface-applied granular ethalfluralin applied the previous fall followed by in-crop bentazon/imazethapyr or imazamox effectively controlled weeds and resulted in good dry bean yields. Overall results indicate that farmers should consider zero tillage dry bean production when sufficient previous crop residues exist. However, if dry bean is to be grown following low residue crops, such as potato or sugar beet, then farmers should consider including a cover crop in their cropping system. Information gained in these studies will be used to advise farmers on more sustainable dry bean production practices.

663. Development of Crop Production in China: A Case Study in Rice. Bao-Rong Lu¹, Hui Xia¹; ¹Ministry of Education Key Laboratory for Biodiversity Science and Ecological Engineering, Institute of Biodiversity Science, Fudan University, Shanghai 200433, China

Introduction. There is an old Chinese saying “food is the haven for civilian” that precisely reflects the importance of food culture and crop production in the historical development of China. As a typical agriculture-based country, China has a long record of traditional agriculture,

with the major proportion (<85%) of its population working in agriculture sector before 1980s. China holds the largest world population (1.3 billion) but has relatively small farming lands—about 122 M ha in total area (MLRC 2006). Statistical analysis demonstrated that China feeds >20% of the world population using <8% of the world arable land, indicating the severe pressure of agriculture and crop production in this country. Nevertheless, China has successfully managed to feed its population with limited farming lands. The achievement of such an agriculture model is largely owing to its unique crop production system: intensive farming with the aim of maximum output per unit area and continued improvement of the system.

The crop production system in China can be traced back from the history of traditional agriculture, which has been significantly developed with the advances of modern science and technology. The development of crop production in China has processed a transition from a low-input and low-output model to the high-input and middle- to high-output model. In the development of crop production during the past a few decades, two key factors have played an important role: effectively utilizing agro-biodiversity and applying updated agro-technology. This review will present the development of crop production in China under the influence of the above two factors, using rice as a case study because rice represents the most important crop in China. For a better understanding of the process, we shall arbitrarily divide the development of crop production in China into four major phases and discuss the unique characteristics and challenges in crop production by each phase.

Traditional model of agriculture and crop production. China has a history of traditional agricultural practices for >5000 years. The traditional agriculture and crop production in China are characterized by intensive farming on a small house-hold scale, but with low to medium production. The intensive farming practices are mainly characterized by: 1) adopting the cultivation systems of rotation, intercropping, and relaying of different crop species/varieties; 2) preventing drought in north and promoting paddy-upland crop rotation in south; and 3) intensive weed control and field management, e.g., fertilizer and irrigation (Guo *et al.* 1986). After the World War II, there was a period of speedy recovery of agriculture and crop production in China and the agricultural production system was gradually in place during that period. With the increase in population, the farming area was rapidly increased from about 124 M ha in 1949 to 141 M ha in 1950, of which about 88% of the farming area was cultivated with food crops. The farming area for crop cultivation have maintained at a similar level for the past five decades. Among the farming area, about 21% was cultivated with rice that provided 43% of the total food production in China (NBSC 2006). In the early 1960s, the Chinese Ministry of Agriculture announced a general guide for rice production: 1) shifting rice production from

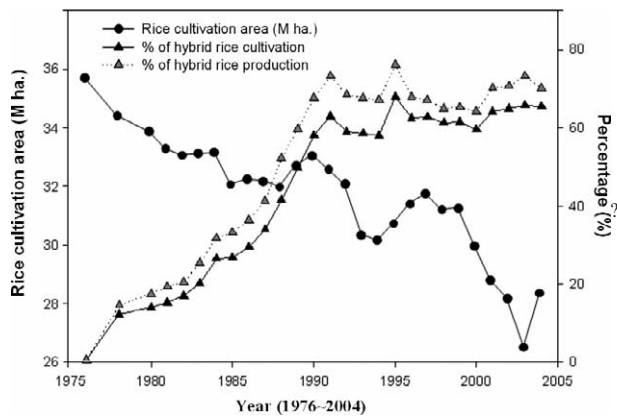


Fig. 1. The rapid increase in cultivation area for hybrid rice with the decrease in total rice cultivation area, and the increase in production by the application of hybrid rice. Data sources: CAAS & HNAAS (1991), Mao *et al.* (2006).

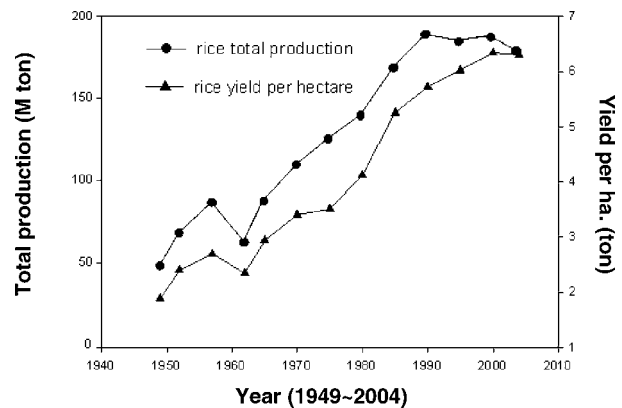


Fig. 2. Rice production from 1949–2004 as reflected by the total production and yield per ha.

single cropping to double cropping; 2) applying intercropping and relayed cultivation systems; and 3) promoting both *Indica* (hsien) and *Japonica* (keng) rice for adapting to different climate conditions. As a result, the cultivation area for rice with double cropping increased to about 13 M ha in 1976 from 4.3 M ha in 1949 (NBSC 2006). In this period (1940s~1960s), the major rice improvement effort for new varieties was to screen and select the elite rice germplasm from traditional rice varieties. With the gradual increases in applying chemical fertilizers (e.g., 78,000 ton in 1952 and 630,000 ton in 1968) (NATESC 2002) in addition to manure use, and applying pesticides, rice yield was dramatically increased from 1.89 ton per ha in 1949 to 2.69 ton per ha in 1957 (NBSC 2006). With enormous labor inputs into crop production, increases of crop cultivation area, adjustments of agriculture policies, and the utilization of crop biodiversity for variety improvement, China met the basic demands for food production in the 1950s. The intensive farming style with significant labor inputs, manual weed control, and field management was very successful in agriculture and for the development of rice production.

Dwarf germplasm and hybrid vigor: a great advancement for rice production. During the period of early 1960s to later 1970s, population in China increased to about 900 million, which exerted a severe challenge for food security and crop production. This situation required more efficient crop production by applying elite genetic resources and new technologies for a significant improvement.

The first milestone development of rice production was the promotion of dwarf rice varieties that was produced through utilization of dwarf germplasm (e.g., Dijaowujian) to hybridize with high production varieties. The combination of germplasm and genetic breeding technology resulted in a number of new rice varieties with short plants and stronger tillering ability. The high yielding dwarf rice varieties could resist lodging under heavy fertilizer application and increase the harvest index to 0.55 from 0.38 of traditional varieties (Cheng *et al.* 2007a).

A few famous dwarf rice varieties, such as Guang-chang-ai, Zheng-zhu-ai and Er-jiu-ai (where the character “ai” stands for dwarf) were developed and widely grown in China since the early 1960s. The application of this technology brought an additional yield of 0.75~1.5 ton per ha. As a result, the average rice yield exceeded 4 ton per ha by 1978 from the level (ca. 2.7 ton per ha) mentioned previously, and the total rice production increased to 136.9 Mt in 1978 from 62.9 million tons in 1962 (NBSC 2006).

The second significant development of rice production was the promotion of hybrid rice with high yielding and early-ripening characters (Cheng *et al.* 2007a) in the end of 1970’s. The three-line system of hybrid rice was developed with the introduction of a male sterile gene from wild rice (*Oryza rufipogon*). Many semi-dwarf hybrid rice varieties such as Guichao-2, Teqing-2 and Shanyou-63 with strong hybrid vigor were developed. These hybrid rice varieties brought an additional yield up to 20%, compared with the conventional rice varieties. The cultivation area for hybrid rice varieties expanded quickly from 5 M ha in 1978 to about 16 M ha in 1990, which was accounted for >60% of total rice cultivation area in China (Fig. 1) (CAAS & HNAAS 1991; Cheng *et al.* 2007a; Mao *et al.* 2006). The extensive promotion of hybrid rice had largely increased rice production per unit area, which could be reflected by the significantly enhanced rice yield to ca. 5.8 t per ha in 1997 from ca. 4 t per ha in 1978. As a result, the total rice production increased to 186.2 million tons in 1992 (Fig. 2).

The adoption of dwarf and hybrid rice varieties had resulted in the considerable change of traditional farming styles to a high-input model with increased chemical fertilizer and pesticide uses, which has led to the great increase of rice production. For example, the chemical fertilizer use increased from 3.51 million tons in 1970 to 12.96 million tons in 1980 (NATESC 2002). During this period, the intensive farming management by manpower still characterized Chinese agriculture and crop produc-

tion, with successful weed control mainly by manual weeding.

Modern agriculture: structure adjustment and reformation. The tremendous social-economic changes in China after 1978, particularly the implementation of family-contract responsibility system, opened a new dimension for agriculture development, which promoted a multi-production system in agriculture. The agriculture reformation was accelerated by the change of food consumption pattern (Table 1) (Wang & Yang 2007) and urbanization that bought more rural labor (118 million in 2004) into cities. As an example, the proportion of cultivation area for food crops reduced to 66% (101 m. ha.) from 90% (about 130 m. ha.) during the past four decades (NBSC 2006). The challenge of speedy decrease in agriculture land and growing demands of more food to support the increasing population required more efficient food crop production per unit area.

To meet such a challenge, the development of rice varieties with even higher yield combining the concept of new plant type and hybrid vigor between *Indica* and *Japonica* rice was targeted. The development strategy for the so called “super rice” resulted in a general increase in rice production (Fig. 2). The first “super rice” variety (Shengnong-265) with a yield of 10.99~11.14 t per ha was developed in 1996. Since then, other “super rice” varieties such as Shengnong-606, Liangyoupei-6 and Xieyou-9380 were developed with the yield of 11.99, 11.13, and 11.83 t per ha., respectively. To date, thirty-four “super rice” varieties have been developed and cultivated on a total area of 13.5 M ha (Cheng *et al.* 2007b). The Chinese Ministry of Agriculture intended to promote major “super rice” varieties that would cover 30% of the total rice cultivation area by 2010.

Protective farming technology was introduced to China for the purpose of labor-saving and resolving problems such as soil erosion. The protective farming technology started in mid-1990s and mainly included non-tillage, throwing seedling, and straw cover techniques for rice production. With the rapid loss of rural labor, the traditional intensive farming system began to and will certainly shift to a labor-saving farming system for rice production from transplanting to direct seeding. For example, direct seeding by a machine was applied in rice production of 4.01 M ha that accounted for 1.34% of the total rice cultivation area (Wang *et al.* 2006). Direct seeding will be a promising technique in future with the further reduction of rural labors. At the same time, the application of herbicide to control weeds in rice field became a common practice for saving labors. The application of herbicides in China has quickly increased to 72,800 ton in 2007 from the first use of herbicides (1,067 ton) in 1970. The application of chemical fertilizers was continued to increase with the adoption of high yielding varieties to 47.6 million tons in 2005 from 16.6 million tons in 1983 (NATESC 2002). The pesticide use was also increased largely from 0.76 million tons in 1990 to 1.46

Table 1. The change of food consumption and main crops cultivation (%) since early 1980s. Data Sources: Wang & Yang (2007), NBSC (2006).

	Pattern of food consumption (kg/year)			
	cereal	vegetable	edible oil	meat & egg
1985	196.2	137.8	4.9	25.8
1995	177.9	110.6	6.5	31.2
2005	142.9	110.4	7.63	43.9
	Proportion of crop cultivation (%)			
	food crop	vegetable	oil plants	others
1985	79.3	2.2	15.0	3.5
1995	65.2	11.6	14.3	8.9
2005	55.1	18.9	15.3	10.7

million tons in 2005 because of the high-input and high-output model for rice production.

The high level of chemical fertilizer, pesticide, and herbicide uses in rice production, as well as the change to a labor-saving farming style brought some ecological problems, including more frequent occurrences of weeds in rice field. This has brought severe challenges for weed control in the future.

Technology-oriented agriculture and crop production. The fast development of crop production in China has offered great opportunities for food security but also accumulated difficulties. The overuse of chemical fertilizer has degraded the structure and quality of soils, which limited the potential of further yield increase. The abuse of pesticides has caused disasters in agricultural ecosystems, which not only led to pollution in soil, water, and atmosphere but also caused pests to develop resistance. In addition, the increase of weed problems from less weed control and misuse of herbicides also caused yield losses. Therefore, developing a more efficient and environmental-friendly crop production system is urgently needed.

Biotechnology is a new technology that has a great impact on contemporary agriculture and crop production worldwide. The rapid progress of transgenic biotechnology in China has promoted the commercialization of insect-resistance transgenic (*Bt*) cotton that covered >3.5 M ha accounted for ca. 66% of total cotton plantation in 2006 (James 2006). This has brought tremendous benefits to Chinese economy, environment, and farmers' health (Pray *et al.* 2002). Transgenic rice may be the next major biotechnology crop for commercialization in China. Ca. 300 transgenic rice lines with different novel traits entered application for biosafety assessment (Table 2). Undoubtedly, the future commercialization of transgenic crops will significantly change agriculture and crop production in China. Molecular-marker assisted breeding has also provided a powerful tool for crop genetic improvement by effectively identifying the target traits. Progress has been made in identifying QTLs of important agronomic traits, such as grain yield and quality, growth and

Table 2. Transgenic rice with different traits developed in China.

Transgene	Trait	Developer	Status
<i>CpTI</i>	Insect resistance	CAS	Production testing
<i>Cry1Ab</i>	Insect resistance	Zhejiang university	Production esting
<i>Cry1Ac & CpTI</i>	Insect resistance	CAS	Production testing
<i>Cry1Ab & Cry1Ac</i>	Insect resistance	HZ University	Production testing
<i>aroA</i>	Herbicide resistance	FAAS	Environmental testing
<i>bar</i>	Herbicide resistance	CAS	Environmental testing
<i>Xa21</i>	Bacterial blight resistance	CAAS	Production testing

development, and resistance to biotic and abiotic stresses (Wang *et al.* 2006). The initiation of China Rice Functional Genomics Program for functional genomics will largely promote the development of rice production in China.

More efforts to develop an environment-friendly farming system were made in China for rice production in the biotechnology era, including the application of biological pesticides, adoption of rice-fish and rice-duck farming systems to protect the agro-ecosystem from increase in total nitrogen in soil and reduce chemical fertilizer and pesticide uses (Lu & Li 2006). Other ecological farming models developed from traditional agriculture have played an important role in rice production in less developed agricultural ecosystems. Among these are the effective uses of biodiversity to control rice diseases by mixed cultivation of modern and traditional rice varieties (Zhu *et al.* 2000), in which the disease-susceptible traditional rice varieties planted in mixtures with resistant modern varieties had a 89% greater yield and 94% less incidences of blast than when the traditional varieties were grown in monoculture. This demonstrates another crop production model to control pest and disease with less pesticide use.

The new technology-oriented rice farming system aims for a high production but with reduced chemical fertilizer and pesticide uses in the system. It emphasizes the role of new technology for higher production, but at the same time it highlights the importance of more sustainable agriculture. This attempt might bring more challenges to the weed control in future because the new production system will gradually shift to a less labor-intensive management in agriculture.

In conclusion, agro-biodiversity and science & technology are always the key factors for the improvement of crop production, which is mirrored by the major advancement of rice production in China by promoting dwarf and hybrid rice, as well as “super rice”. Statistic analysis demonstrated that the adoption of new technology has brought an accumulative increase in rice yield for about 80% from 1978–1992. The application of biotechnology may bring an even greater achievement in rice production, although its impact on weed control, farming styles, and agro-ecosystems is yet to be thoroughly assessed.

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664. **Spatial Weed Patterns and Relative Time of Emergence Profoundly Affect Weed Performance and Crop Yield.** Therese Berge¹, Are Aastveit², Haldor Fykse²; ¹Bioforsk - Norwegian Institute for Agricultural and Environmental Research, Aas, Norway; ²Norwegian University of Life Sciences, Aas, Norway

Weeds apparently occur in patches within agricultural fields, whereas several models for weed-crop competition assumes random weed distributions. A field experiment was conducted to estimate the influences of spatial pattern (patchy vs. random) of volunteer spring turnip rape (*Brassica rapa* ssp. *oleifera* (DC.) Metzger) for above-ground biomass and height of *B. rapa*, and on crop yield of spring wheat (*Triticum aestivum* L.). Spatial pattern effects were compared with effects due to relative sowing time of weed and crop. The weed was sown in a random or patchy pattern at three overall densities realistic to farming field conditions, either mixed with spring wheat sown with normal density (250 kg ha⁻¹) and row spacing (0.125 m), or in monocultures, and either sown 1-2 days or 7-8 days after the crop sowing (DACS). As expected, weeds in wheat plots sown 7-8 DACS were small compared to weeds sown 1-2 DACS, and mean (across weed patterns and densities) crop yield losses compared to weed-free yield were 17% and 26%, respectively. When weeds were sown 7-8 DACS in wheat plots, no significant pattern effect on weeds or on crop yield were detected. When weeds were sown 1-2 DACS, however, the effect of weed pattern was great and the patchy weeds were on average 47% lighter and 10 % shorter than the randomly distributed weeds, and mean crop yield losses were 16% (patchy) and 36% (random distribution). Results demonstrated that relative weed emergence time and spatial weed patterns greatly influence outcomes of intra-weed competition and weed-crop competition. Awareness of these effects is important when conducting plant experiments in general, and crop yield estimates for whole fields in particular

665. **Compositional Changes in Weed Flora as Influenced by Long-Term Saffron (*Crocus sativus*) and Black Zira (*Bunium persicum*) Intercropping.** Mohsen Mesgaran¹, Hamid Mashhadi¹, Mahmood Khosravi², Eskandar Zand³, Hassan Alizadeh¹; ¹University of Tehran, Karaj, Tehran, Iran; ²Ferdowsi University of Mashhad, Mashhad, Khorasan, Iran; ³Plant Pathology Institute of Iran, Tehran, Iran

The development of integrated weed management strategies requires knowledge of mechanisms that influence compositional changes in weed flora. A 6-years study was initiated in 1999 and the response of above ground weed flora to the intercropping of saffron (*Crocus sativus* L.) and black zira (*Bunium persicum* Boiss, *B. Fedtsch*), two perennial crops, was investigated. Mixtures consisted of 0/

100, 25/75, 50/50, 75/25 and 100/0 saffron/black zira ratios, each planted at 3 densities of 30, 50 and 70 plant m². A split plot design based on randomized complete blocks with 4 replications was used. Densities were assigned to main plots with ratios constituting subplots. Mixture ratios caused drastic species compositional changes in weed flora for which univariate and multivariate (Canonical Discriminant Analysis: CDA) explored four major associations: 1- weeds that preferred higher ratios of saffron in mixture e.g. grasses field *Convolvulus arvensis* L. (bindweed) and *Amaranthus* spp. (pigweeds); 2- weeds that preferred higher ratio of black zira in mixture e.g. Persian speedwell (*Veronica persica*), Brassicaceae complex, Polygoaceae complex and *Fumaria vaillantii* Lois. (earthsmoke); 3- weeds that were more abundant in 50/50 mixtures e.g. Caryophyllaceae complex and 4- weeds that showed no specific pattern e.g. *Chenopodium album* L. (lambsquarter). The effect of planting density on weed populations was variable, and vanished over time. These findings improve current understanding of crop-weed community structure and may help in developing weed management practices.

666. **Shifts in Weed Density over 14 Years in Nine Cropping Systems.** A Gordon Thomas¹, Julia Leeson¹; ¹Agriculture and Agri-Food Canada, Saskatoon, Saskatchewan, Canada

A long-term multidisciplinary project was established on a 16 ha site at Scott, SK to study the sustainability of nine alternative cropping systems. Scott, located near the geographic centre of the Canadian Prairies, has a semi-arid climate favouring small grain cereals, cool-season oilseeds and pulses and perennial forages. Systems were defined in terms of combinations of three input levels (high, reduced and organic) and three cropping rotations (fallow-based, annual grains and perennial-based). The high input level receives pesticides and fertilizer as required based on conventional recommendations. The objective of the reduced input level is to decrease pesticide, fertilizer and fossil fuel inputs. The organic input level conforms to industry standards. Each cropping rotation follows a six-year cycle with all phases present in each year. The fallow-based rotation is typical for the area, the annual grains rotation includes a diversity of annual crops and the perennial-based rotation includes three years of perennial forage and annual crops. Weeds were counted annually in July after the application of in-crop management practices from 1994 (site characterization year) to 2007. Multivariate analyses of the densities of the 61 most common species indicated that initial spatial distribution of the weeds, year and cropping system accounted for 47%, 30% and 23% of the explained variance in the weed community, respectively. The variance accounted for by system has steadily increased through time, while the importance of the initial spatial distribution of the weeds has declined.

The high variance still associated with the initial spatial distribution of weeds emphasized the importance of characterizing the study site before the establishment of treatments. The large yearly fluctuations in weed densities illustrated the need for regular monitoring. The variance attributable to year and initial spatial distribution was removed from the analysis to enable the interpretation of system effects. Changes in weed community composition over time attributable to cropping system were illustrated by comparing the systems to the high input, fallow-based reference system. The analysis identified problematic weed species associated with the cropping systems after fourteen years. *Setaria viridis* L., *Chenopodium album* L. (Beauv.) and *Thlaspi arvense* L. were abundant in the three organic systems. While the organic systems had the largest yearly fluctuations in the densities of these species, the densities of these species appear to have reached equilibrium after a three-year transition period in the fallow-based and annual grains rotations.

667. Occurrence of Weed Species along a Climate Gradient in Europe. Terho Hyvonen¹, Michael Glemnitz², Laszlo Radics³, Jorg Hoffmann⁴, Gyula Czimmer⁵; ¹MTT Agrifood Research Finland, Jokioinen, Jokioinen, Finland; ²Leibniz Centre for Agricultural Landscape Research, Muncheberg, Muncheberg, Germany; ³Corvinus University, Budapest, Budapest, Hungary; ⁴JKI, Federal Research Centre for Cultivated Plants, Braunschweig, Braunschweig, Germany; ⁵West-Hungarian University, Masonmagyarovar, Hungary

Climate limits the distribution of weed species at broad spatial scales. Climate change may, therefore, alter the distribution patterns of weed species. The objective of this study was to analyse comparative data sets on the occurrence of weed species along a climate gradient in Europe and to explore the role of climatic factors restricting their distribution. The study aims to detect the weed species which could potentially invade to Northern Europe as a consequence of climate change.

The weed flora data was collected through field surveys from a south-north climatic gradient going across Europe from Mediterranean to boreal climate zone. The study regions along the transect were selected according to climate change scenario from IPCC (1996) with a criterion of 1.5 °K difference in the annual average temperature between neighbouring regions. The criterion was the lower value of predictions from IPCC for the temperature increase in the next 100 years. Eight regions were included in the study (Lecce (I), Roma (I), Udine (I), Magyaróvár (H), Müncheberg (D), Osby (S), Uppsala (S) and Vaasa (FI)). In each region, three field surveys were conducted in 1999-2003. Nine fields were analysed in each region each year (the total number of fields studied was 210). Among them 3 conventionally cultivated and 3 organically cultivated cereal fields as well as 3 one-year fallows were

included in the study. In each field species inventory was conducted with assessment of abundance of each species. Descriptive data on the crop stand, soil and crop management were obtained from local farmers.

In total, 768 weed species were found in the study. The number of species decreased from south to north. Three species groups could be differentiated based on their preference for climate: the species having strong preference for climate (378 species occurring in single region), the species having moderate preference for climate (318 species occurring in 2-4 regions) and the species with no or only slight preference for climate (77 species occurring in 6-8 regions). The results show, that the increasing species richness from North to South Europe was carried by the fraction of the rare or less frequent species. Within the group of species with Mediterranean origin, we can identify already some species which showed no strong relation to the climate anymore. These species are flexible in their climate requirements and have a great potential to invade to northern as a consequence of climate change. The invasion is, however, not only dependent on the climatic factors but also other factors such as soil characteristics and cropping measures.

[Generalized Linear Models (GLM) will be applied for further analysis to explore the response of individual weed species to explanatory variables. These results will comprise the results section of the final version of the abstract.]

668. Birch Tar Oil: A Potential Herbicide from the Forests of Finland. Jukka Salonen¹, Kari Tiilikkala¹, Pentti Ruuttunen¹, Isa Lindqvist¹, Bengt Lindqvist¹; ¹MTT Agrifood Research Finland, Jokioinen, Finland

The potential for developing natural pesticides from plant chemicals has long been recognized and represents an alternative screening and discovery strategy for developing new plant protection compounds. Birch tar oil (BTO) is a distilled by-product from the patented pyrolysis process (Charcoal Finland Ltd) of producing charcoal from *Betula* species. BTO contains various types of phenols, but is a typical mixture of chemical compounds with a complex molecular structure. No comprehensive information on birch oil components following pyrolysis is available. The first successful application of BTO was as a repellent against slugs and snails. Subsequently, our screening programme with BTO in the greenhouse and field was extended to weed control and some of the initial results are available. BTO has been applied at different concentrations, spray volumes and crop growth stages. BTO has proved to be a broad-spectrum contact herbicide with a high foliar burn-down effect, both against annual and perennial broad-leaved weeds. It is mainly intended for use as a non-selective herbicide in non-crop situations and for inter-row application in row crops. However, field experiments with potato showed relatively good selectivity;

pre-emergence applications did not cause any damage. Even application at 50 % BTO on 28 cm high potato caused only some necrotic foliar spots without any reduction in tuber yield. Concentrations of 30-50% are probably sufficient for adequate weed control. At these rates, more than 80% reduction of biomass was achieved against *Matricaria matricariodes*, *Chenopodium album*, *Stellaria media*, *Lamium purpureum* and *Galium spurium* in potato and carrot fields. Comprehensive studies determining the ecotoxicological effects of BTO on non-target soil organisms indicated that direct and indirect effects of BTO on soil food-webs appear not to be significant. The majority of acute toxicity values (EC50) of the BTO were less than 100 000 µg/L, indicating BTO to be practically non-toxic for most aquatic organisms. BTO is a relatively sticky oil and new application techniques and product formulations have to be developed before introducing it into practice. Furthermore, the strict registration policy of plant protection products in the EU could limit commercialization of BTO in the member countries.

669. Characterization of Strigolactones, Plant Derived Signals for Symbiosis and Parasitism. Koichi Yoneyama¹, Xionan Xie¹, Kaori Yoneyama¹, Yasutomo Takeuchi¹; ¹Utsunomiya University, Utsunomiya, Tochigi, Japan

Both arbuscular mycorrhizal (AM) fungi and root parasitic plants *Orobanchae* and *Striga* spp. take advantage of strigolactones released from plant roots as signal molecules in the initial communication with host plants in order to commence mutualism and parasitism, respectively. Therefore, chemical structures of major strigolactones and their distribution in the plant kingdom should be determined to promote symbiosis and prevent parasitism through the manipulation of production and/or exudation of strigolactones. In this study, characterization of strigolactones in the root exudates from various plants grown hydroponically was conducted by comparing retention times of germination stimulants on reverse phase HPLC with those of synthetic or natural standards and by using LC/MS/MS. All the plants examined so far, even non-hosts of AM fungi, were found to exude mixtures of strigolactones. Among the strigolactones identified, orobanchol, orobanchyl acetate, and 5-deoxystrigol seem to be distributed widely in the plant kingdom. The amounts of total strigolactones varied greatly with plant species, growth stages, and growth conditions. In general, the production by non-hosts of AM fungi was only 1/1000-1/100 that by host plants. Structures of novel strigolactones from tobacco, sorghum, flax, cucumber, and other plant species will be presented and discussed in relation to the tentative biosynthetic pathway of strigolactones.

670. Phytotoxic Sesquiterpenes in Exudate of *Heterotheca subaxillaris* (Lam.) Britt. & Rusby. Masanori Morimoto¹; ¹Kinki University, Nara, Japan

Objective: A natural product showing phytotoxicity may be utilized directly as a natural herbicide, or can serve as a lead compound for the development of a synthetic herbicide. Phytotoxic allelochemicals are occasionally studied for the discovery of new herbicides. In a screening test of natural phytotoxins from plant, it was found that the rinsate from the aerial parts of *Heterotheca subaxillaris* had a significant plant growth inhibitory activity against *Agrostis stolonifera* and *Lactuca sativa* seedlings. *H. subaxillaris* (Asteraceae) is a common annual or biennial weed that grows in sandy field throughout U.S.A. This plant exudes a large amount of oil drops on the leaf surface and a characteristic camphor-like smell, so the common name of this species is camphorweed.

Methods: Phytotoxicity of the extract, fractions and sesquiterpenes were obtained for both *L. sativa* cv. Iceberg (lettuce) and *A. stolonifera* cv. penncross (bentgrass) using a 24-well plate bioassay. *Lemna paucicostata* (duckweed) bioassay was performed with remarkable phytotoxic sesquiterpenes. Specimens of *H. subaxillaris* were collected from sandy field and road side in Oxford, Mississippi, U.S.A. The fresh aerial parts were rinsed with dichloromethane (DCM) and the DCM solution was condensed to obtain the brown oil (yield ca. 8%) as rinsate. The oil was separated using by silica gel column chromatography with bioassay guided fractionation and purification of these active compounds were using HPLC and PTLC. These isolated compounds were analyzed and identified by their spectroscopic data. Some of them were converted to methylester using by BF₃-MeOH complex for structure activity relationship (SAR).

Results: The calamenene-type sesquiterpene carboxylic acids and respectively alcohols were obtained as phytotoxins. Other analogues were isolated and evaluation of their phytotoxic property for SAR. Esterification of calamenene carboxylic acids decreased this activity against *A. stolonifera* seedlings and were no longer active against *L. sativa*. This fact suggested that the appearance of this activity was dependent on the presence of the carboxyl group in the chemical structure. The substituent at C-7 is acceptable for carboxyl, ketone, alcohol showing plant growth inhibitory activity.

Conclusions: Phytotoxic calamenene-type sesquiterpenes were purified from the rinsate containing the oil exudate on the leaf surface of *H. subaxillaris*. 2-Methoxycalamene-14-carboxylic acid was the most potent plant growth inhibitor isolated from this extract. Though their analogue also showed phytotoxicity against *A. stolonifera* and *L. sativa* seedlings, esterification of calamenene carboxylic acids decreased this biological activity. The carboxylic acids were more active than their corresponding alcohols against *L. paucicostata*.

671. **Phytotoxic Eremophilanes from *Ligularia macrophylla*.** Stephen Duke¹, Charles Cantrell¹, Franck Dayan¹, Frank Fronczek², Leonid Mamonov³, Juriy Vassilyev³; ¹USDA, ARS, University, MS, United States of America; ²Louisiana State University, Baton Rouge, LA, United States of America; ³Instit. Plant Biology & Technology, Almaty, Kazakhstan

Extracts of *Ligularia stenocephala* are reported to have weed-killing activity. *Ligularia macrophylla* (Lab.) DC., a plant from high altitude areas of Kazakhstan, was examined for the presence of phytotoxins. Systematic bioassay-guided fractionation of the methylene chloride roots extract of *L. macrophylla* was performed to identify phytotoxic compounds. Four phytotoxic eremophilanes [furanoeremophilan-14 β ,6 α -olide, 6 β -angeloyloxy-10 β -hydroxyfuranoeremophilane, eremophil-7(11)-ene-12,8 α ;14 β ,6 α -diolide, and 3 α -angeloyloxybakkenolide A] were found. The X-ray crystal structure determination of 6 β -angeloyloxy-10 β -hydroxyfuranoeremophilane was determined. All four eremophilanes substantially inhibited growth of the monocot *Agrostis stolonifera* (bentgrass) while demonstrating little activity against the dicot *Lactuca sativa* (lettuce) at 1 mM. In a dose-response screening of all compounds for growth inhibitory activity against *Lemna paucicostata*, 6 β -angeloyloxy-10 β -hydroxyfuranoeremophilane was the most active with an I50 of 2.94 ± 0.16 mM. Few synthetic herbicides have this level of activity in this bioassay. This compound also caused the greatest reduction of photosynthetic electron flow; however, its primary mode of action remains to be determined. No significant effects were found on mitosis. The most active compound (6 β -angeloyloxy-10 β -hydroxyfuranoeremophilane) deserves further study for structure optimization and to determine its mode of action.

672. **Response of 3 Native Hawaiian Grasses to 5 Postemergence Grass Herbicides.** Joseph DeFrank¹, Orville Baldos¹; ¹University of Hawaii at Manoa, Honolulu, Hawaii, United States of America

The Hawaii Department of Transportation has provided funding to develop protocols for the establishment of native Hawaiian plants for roadside stabilization and as a mitigation measure against the spread of invasive plant species. Postemergence control of grassy weeds is required during the establishment of native grasses grown from seeds or vegetative parts. Growth of 3 native Hawaiian grasses, (*Heteropogon contortus*-HC, *Eragrostis variabilis*-EV and *Sporobolus virginicus*-SV) considered useful for roadside plantings, was determined in response to spray applications of 5 postemergence grass herbicides. The herbicides evaluated were quizalofop p-ethyl (.07 and .09 kg ai/ha), fluazifop-p-butyl (.21 and .28 kg ai/ha), sethoxydim (.38 and .52 kg ai/ha), clethodim (.20 and .28 kg ai/ha) and imazapic (.14 and .21 kg ai/ha). At 141 days

after spray application, above ground parts of 2 representative plants of each species were collected for dry weight accumulation as a growth response to spray applications. Although all herbicides were applied at a killing dose, none caused complete kill of any native species. The integration of numerical data and visual rating for vigor allowed for the ranking of herbicides from most inhibitory to least inhibitory for each grass species. With HC; sethoxydim > quizalofop p-ethyl > fluazifop-p-butyl > clethodim > imazapic. With EV; quizalofop p-ethyl > fluazifop-p-butyl > clethodim, imazapic, sethoxydim. With SP; imazapic DG > sethoxydim > fluazifop-p-butyl, clethodim > quizalofop p-ethyl. For HC, imazapic should be useful in controlling weeds actively growing when treated as well as weeds emerging from seeds. The only other herbicide that appears to be safe enough for use in HC is clethodim. Herbicides were generally more inhibitory on EV than they were on HC and SV. Only the low rate of sethoxydim, clethodim and imazapic should be used in EV and only as a spot treatment to small weed seedlings. SV was most sensitive species to imazapic and this is consistent with the product label that lists two *Sporobolus* weed species as being controlled by this chemical. Quizalofop p-ethyl and clethodim appear to be the only herbicides with potential use as spot treatment sprays to small grassy weed seedlings in SV.

673. **Chemical Control of Bermudagrass (*Cynodon dactylon* (L.) Pers) in Turf.** Vahid Zabihollahi¹, Fariba Maighany², Mohammad Ali Baghestani², Mohammad Javad Mirhadi³; ¹M.Sc. of Weed Science, Tehran, Iran; ²Iranian Crop Protection Research Institute, Tehran, Iran; ³Science and Research Campus, Islamic Azad University, Tehran, Iran

Bermudagrass (*Cynodon dactylon*) is a noxious weed in turf and landscaped. Selective control of bermudagrass in turf and landscape is very difficult. In order to evaluate chemical control of bermudagrass on turf (*Lolium perenne* 20%, *Poa pratensis*.20%, *Festuca rubra*.20% and *Festuca arundinaceae* 40%), an experiment was conducted during 2006 in IRAN, using randomized complete block design with 4 replications. Treatments were Diclofop methyl at 900 and 1080 g a.i. ha⁻¹, Fenoxaprop-p-ethyl at 60 and 75 g a.i. ha⁻¹, Clodinafop propargyl at 48 and 64 g a.i. ha⁻¹, Tralkoxydim at 250 and 30 g a.i. ha⁻¹, Sulfosulfuron at 18.9 and 24.5 g a.i. ha⁻¹ and untreated control. All treatments were repeated 4 times during the growth period of bermudagrass. The results showed that turf biomass was decreased by Diclofop methyl at 900 and 1080 g a.i. ha⁻¹ and Clodinafop propargyl at 48 and 64 g a.i. ha⁻¹, 24.24, 21.57, 26.76 and 28.29 percent, respectively. Diclofop methyl at 900 and 1080 g a.i. ha⁻¹, Fenoxaprop-p-ethyl at 60 and 75 g a.i. ha⁻¹, Tralkoxydim at 250 and 30 g a.i. ha⁻¹ and Clodinafop propargyl at 48 and 64 g a.i. ha⁻¹ decreased biomass of bermudagrass 23.82, 17.45, 27.03, 23.58, 46.82, 53.75, 40.71 and 48.33 percent,

respectively, but Sulfosulfuron (both doses) has no effect on density and biomass of mentioned weed. Overall, it could be concluded that Fenoxaprop-p-ethyl (both doses) is suitable selective herbicide for bermudagrass control on turf.

674. Weed Suppression and Drought Tolerance of Multi-species Sod for Roadside Revegetation. Jennifer Stark¹, Lisa Rew¹, Catherine Zabinski¹, Tracy Dougher¹; ¹Montana State University, Bozeman, MT, United States of America

Roadsides are typically areas of high disturbance and thus susceptible to invasion by weed species. Historically roadside revegetation has been accomplished by methods including broadcast-, drill-, and hydro-seeding techniques. While these methods have proven successful for low angle slopes, steep slopes continue to present a revegetation challenge primarily due to high soil erosion rates. Sod provides instant vegetation and a mat of established roots ready to anchor to the soil. In semi-arid regions the use of more drought tolerant and native species in sod has the potential to rapidly provide self-sustaining, low maintenance roadside plant communities. The objective of this study was to evaluate the weed suppression capabilities of multispecies sod. The multispecies sod consisted of three native grasses: *Festuca idahoensis* (Idaho fescue), *Elymus lanceolatus* (thickspike wheatgrass), *Agropyron smithii* (western wheatgrass) and one naturalized species, *Poa compressa* (Canada bluegrass). The sod was laid on bare ground using a split-plot blocked design. *Brassica napus* (canola) was sown as a surrogate weed species at six different densities below the sod to represent the weed seedbank (split-plot) and subject to five levels of watering (blocks). The high water level received a mean of 28.2 ml of water/week. The three intermediate water levels ranged from 23.7 ml to 11.6 ml of water/week. The control treatment received only natural precipitation (mean of 3 ml water/week) with no supplemental irrigation. The experiment was repeated over two years. *B. napus* suppression by the multispecies sod was evaluated by recording seedling emergence, survival and total above ground biomass for each season. In the first season (2006) weed emergence was not significantly affected by sown weed density though overall the sod suppressed 93% of the sown seeds. In the second year (2007) the percentage of weed seedlings that emerged decreased with increased sowing density ($p < 0.001$). The percentage of weeds suppressed ranged from 68% with 120 seeds/m² to 96% with 4799 seeds/m². The overall survival of the established seedlings was significantly affected by the water gradient ($p < 0.01$ in 2006, $p < 0.001$ in 2007), with decreased survival with reduced water levels. Consequently weed productivity in terms of both vegetative biomass ($p < 0.001$ in 2006, $p < 0.001$ in 2007) and seed weight ($p < 0.001$ in 2006, $p < 0.001$ in 2007) also

decreased with water level. In conclusion, multispecies sod suppressed a considerable proportion of seeds from emerging from the seedbank, and the seedlings that did establish produced less vegetative biomass and seed as the water level decreased.

675. Experimental Tests of Physical Weed Control on Urban Hard Surfaces in Central Italy. Leonardo Lulli¹, Marco Fontanelli¹, Christian Frascioni¹, Marco Ginanni¹, Michele Raffaelli¹, Daniele Antichi², Federica Bigongiali², Stefano Carlesi², Andrea Peruzzi¹; ¹University of Pisa, Pisa, Italy; ²Scuola Superiore Sant'Anna, Pisa, Italy

In Italy, weed control in urban areas is mainly performed by means of mowing, cutting and herbicide distribution. While trimmers are not effective in reducing weed density and are potentially injurious for hard surfaces and safety of citizens and operators, chemical control may induce herbicide resistance in weed biotypes and it is a likely source of environmental pollution as well as a health risk factor for humans and animals. For this reason the use of herbicides in urban areas is strictly regulated by laws. As an alternative to ordinary weed control devices, thermal equipment can be used to perform successfully weed control on hard surfaces. Moreover, flaming machines are the most efficient and suitable to carry out treatments in many urban contexts.

The aim of this study was to evaluate the effects of different management techniques on weed dynamics in two cities of Tuscany (Central Italy) and to compare the total working time and operation costs, in order to define a proper strategy for the control of weed flora growing on hard surfaces.

Research was carried out in Livorno (43°33'N 10°19'E) and Pisa (43°43'N 10°24'E) from 2006 to 2008. Flame weeding at low (6TR = 6 treatments y⁻¹) and high (12TR = 12 treatments y⁻¹) frequency was compared to chemical, glyphosate-based management (CM = 2 treatments y⁻¹), integrated management (IM = 1 herbicide + 3 flame weeding treatments y⁻¹) and mowing (MM = 4 treatments y⁻¹). Weed abundance was estimated with the Braun-Blanquet method. At the end of trials, total working time, costs of operations, manpower index (MI = total working time × average weed density) and economic index (EI = total cost × average weed density) were calculated.

Initial weed canopy cover was on average 60% of plot area. The optimal range of weed density (0-10%) during the entire experimentation period was reached only with flame weeding 12TR. Flame weeding 6TR considerably reduced the weed canopy but to a lower extent (about -38%) than flame weeding 12TR. CM was really effective but just for about 40-50 days after each treatment, then a massive weed regrowth was always observed, especially during spring and summer. IM, in contrast, allowed a higher (-40%) and more constant reduction in weed

density. MM reduced weed cover just after each intervention but determined a rapid plant regrowth so that weed density ranged between 24 and 99% during the study period.

Total costs for flaming management were slightly higher than CM and IM, but 50 to 70% lower than MM. However, the low manpower and economic indexes obtained with flame weeding suggest that this technique can be considered a valid alternative weed management strategy in Italian urban areas.

676. Impact of Tillage on *Commelina benghalensis* L. Management. Barry Brecke¹, Theodore Webster²; ¹University of Florida, Jay, Florida, United States of America; ²University of Georgia, Tifton, GA, United States of America

Commelina benghalensis L. (Benghal dayflower) is an exotic invasive weed that poses a major threat to agricultural production in the U.S.A. *C. benghalensis* is listed as a U.S.A. federal noxious weed and was identified among the worlds worst weeds, negatively affecting 25 crops in 29 countries. Studies were conducted at the University of Florida, West Florida Research and Education Center, Jay, FL, and at the University of Georgia, Tifton, GA, U.S.A. in areas naturally infested with *C. benghalensis* to determine the effect of tillage on management of *C. benghalensis*. Peanut (*Arachis hypogaea* L.) and cotton (*Gossypium hirsutum* L.) were grown under two tillage regimes: 1) conventional tillage which included use of a moldboard plow, disk and field cultivator prior to planting and 2) reduced tillage which included use of a strip-till implement fitted with an in-row subsoil shank, closing discs, and rolling baskets. The strip-tillage operation left at least 50% of the soil surface undisturbed. Cotton in the study area was treated with the herbicides pendimethalin applied preemergence followed by metolachlor plus glyphosate applied early postemergence to cotton with three to four leaves. Peanut was treated with pendimethalin preemergence followed by metolachlor plus gramoxone early postemergence. Mid-season weed counts indicated a lower *C. benghalensis* density in the conventional tillage area (3 plants m²) compared with the strip-tillage area (60 plants m²) in both cotton and peanut. In a second study, three levels of tillage prior to cotton planting were compared. In addition to conventional and strip-tillage, an intermediate level of tillage (para-tillage) was included. *C. benghalensis* density increased as level of tillage decreased (conventional tillage = 3 plants m², para-tillage = 9 plants m², strip-tillage = 17 plants m²). In a third study 100 seedlings (cotyledon to 1-leaf) were sampled in order to evaluate the emergence depth of seedlings under field conditions. Soil cores were collected and soil was rinsed from around the roots of the seedlings. The distance between the soil level and the seed coat (at the junction between root and stem differentiation) was

measured for each seedling. Average emergence depth was 2.69 cm, with a range of 0.5 to 9.0 cm. Only 4% of the emergence occurred from the 0.5 cm depth, with the majority occurring from 2 cm.

677. The Use of Glyphosate to Facilitate Field Preparation and Weed Management in Transplanted Sorghum Fields in Northern Cameroon. Bertrand Mathieu¹, Thierry Dore², Pascal Marnotte³; ¹Instituto de Agricultura Sostenible, Cordoba, Spain; ²INRA/INA-PG, Thiverval-Grignon, France; ³CIRAD-CA, Montpellier, France

In the northernmost part of Cameroon, clayey soils (vertisols) are traditionally prepared for the dry-season crop of transplanted sorghum by clearing and burning the plant cover that has grown during rainy season. In recent years, glyphosate use has increased considerably, as a means of controlling weeds and reducing preparation time. We carried out on-farm experiments to assess the effect of treatment, especially in typical vertisols with perennial weeds, with a view to optimizing herbicide use. We found that herbicide applications controlled weeds efficiently, but did not necessarily lead to an increase in yield. In some vertisols, total annual rainfall determined production, by controlling the amount of soil water available to the crop and the intensity of competition due to perennial weeds, such as *Launaea cornuta* and *Ipomoea aquatica*. Yield increases with herbicide treatment were thus obtained during particularly wet rainy seasons, such as that of 2001/2002. In flooded vertisols infested with *Oryza longistaminata*, weed competition proved to be the principal limiting factor whatever the climatic conditions. Herbicide treatment led to significant yield increases and decreased preparation time and labor requirements for weeding. These results suggest that site-specific chemical weed control should be based on climatic conditions and the weed population, to delay the development of herbicide resistance and to minimize environmental risks.

678. Desiccation Timing in the Succession Roundup Ready Soybean/Wheat in the Southern Region of Brazil. Antonio Galli¹, Antonio Ferreira-Neto¹, Pedro Christoffoleti²; ¹Monsanto, Sao Paulo, Brazil; ²University of Sao Paulo - ESALQ, Piracicaba, Sao Paulo, Brazil

The technology Roundup Ready[®] introduced for soybean weed management in Brazil represents greater agronomical practices simplicity when compared to the traditional non glyphosate resistant soybean. Furthermore the application of this technology represents greater flexibility and efficacy on the weed management Roundup Ready[®] soybean crop due to lower limitations for the herbicide functioning due to soil humidity conditions, and growth stage of the weed by the timing of the herbicide application, as opposed to conventional system by using

soybean varieties that are not resistant to glyphosate. However, in the Southern region of Brazil, due to inadequate use of the technology, by many growers, who are desiccating the vegetation wheat post-harvest, nonetheless after Roundup Ready® soybean crop seeding. Sometimes, due to constraint on the spraying operations, glyphosate has been even sprayed after soybean early emergence. That is certainly an abuse of the technology flexibility. Some of the problems that certainly are faced by these growers are losses of the soybean yield due to early weed competition of the weeds left after wheat harvest. Therefore, the objective this research was to study the weed interference when desiccated late, after Roundup Ready® soybean seeding, in the Southern region of Brazil. Six experiments were conducted in the region, using Roundup Ready® soybean, seeded right after wheat harvest. The experiments were conducted at the Monsanto Experimental Stations of Brazil, certified by CTNBio in order to develop experiments with genetically modified organisms, located in Nao Me Toque (RS), Rolandia, and Ponta Grossa (PR), during the growing season of 2001/2002 and 2004/2005. The experimental design used was randomized blocks with four replications, and the plot size was 3.5 m width by 10 m long. The treatments, representing the desiccation timing by glyphosate, in all experiments were: (i) seven days before soybean seeding (7 DBS); (ii) at the same day of soybean seeding (0 DBS); (iii) seven days after soybean seeding (7 DAS); (iv) 14 days after soybean seeding (14 DAS); (v) 21 days after soybean seeding (21 DAS). In all treatments a second application of Roundup Ready® glyphosate was done at 25 to 31 DAS as the selective treatment in the crop. Results indicated that it is fundamental that vegetation management (desiccation) present in the area wheat post harvest should be sprayed by Roundup Ready® prior to soybean seeding or during the first few days after seeding. Delay in the application of the desiccation herbicide, even tough controls very well the weeds might reduce significantly soybean yield. Desiccating soybean 21 DAS in average reduce 24% of the soybean yield compared to application at 0 DBS.

679. Effect of Tillage on Weed Seed Dispersal in Fields, in Interaction with Soil Structure and Tillage Depth. Hugues Busset¹, Jacques Caneill¹, Nathalie Colbach¹; ¹Inra, Dijon, France

Introduction. In fields, weeds occur in patches. Knowledge on patch distribution is necessary for understanding weed dynamics and yield loss, which contributes to reducing herbicide treatments in integrated crop protection. Tillage is the cultivation practice which is mainly responsible for seed dispersal in fields. Consequently, the objective of the present study was to analyse horizontal seed dispersal as a function of contrasted tillage tools, in interaction with initial seed depth, soil structure and tillage depth, which has not yet been attempted.

Material and methods. The field trial was based on three experimental factors: (a) the tillage tool, i.e. rotary harrow, disk tiller and tine cultivator; (b) tillage depth, either 5 or 10 cm, (c) soil structure, either fine earth or compacted, altogether resulting in 3 x 2 x 2 treatments which were replicated three times in a block-design. Instead of seeds, coloured plastic beads of 2-3 mm were introduced with an auger prior to tillage, changing colours every 1 cm. After tillage, the number and location of all beads on soil surface was determined relative to the initial position with a grid consisting of 10 x 10 cm² cells. These data were used to draw maps of the post-tillage bead location on soil surface.

Results. Longitudinal seed displacement was most important after rotary harrow and smallest after tine (e.g. up to 5.70 vs. 0.5 m in fine earth); it was increased in case of fine earth vs. compacted soil structure (e.g. 5.6 m vs. 2.1 for rotary harrow). Shallow tillage carried seed further than deep tillage; the differences between tillage depths were largest in compacted vs. uncompacted soil structure (e.g. an increase of up to 2.4 m vs 1.1 m for disk tiller) and for rotary tools (i.e. harrow and discs) vs. tine. Seeds that were initially located on soil surface were moved farthest while initially deep seeds were only rarely found on soil surface and usually close to their initial location. Rotary harrow was the only tool that displaced seeds backwards, up to more than 1 m.

Conclusion. The more rigid the tool (i.e. tine cultivator vs. other tools), the more compact the soil structure and the more soil the tool had to displace to reach the seeds (i.e. the deeper the seeds were located), the less the seeds were displaced. These results will now be confirmed with spatial statistics and introduced into weed dynamics models.

680. Influence of Planting Date on Weed/Crop Competition in a Temperate Climate. Mark VanGessel¹; ¹University of Delaware, Georgetown, Delaware, United States of America

Farmers have time periods that are favorable for growth of their crops and during that period, there is an optimum time for planting to maximize yield. In regions with an extended growing season, a second crop maybe planted (double-cropping) that provides the farmer an opportunity to maximize land use and generate additional income. Cropping sequences in these regions are often chosen with little consideration for weed management, even though environment has a strong influence on growth of crops and weeds, influencing the weed/crop interactions and outcomes. Limited research has examined the differences in weed ecology and weed management when crops are planted in succession, or double-cropped. In the southern half of the US, the summer growing season allows for the planting of soybeans (*Glycine max*) after harvesting winter wheat (*Triticum aestivum*) or a short-season vegetable. In Delaware, the critical period for weed management in

soybeans is more restrictive (shorter time period) when soybeans are planted early in the growing season (May) compared to soybeans planted after wheat harvest (late June to early July). Although production practices are identical, yield loss due to weeds is dramatically altered. Growth, competitiveness, and fecundity of three weed species were examined when soybean planting occurred from May to July. Two of the weed species are classified as short-day plants (*Abutilon theophrasti* and *Xanthium strumarium*) and one of the species is considered 'day length insensitive' (*Datura stramonium*). The short-day plants had the greatest reduction in biomass and seed production when soybean planting was delayed from May until June. Although soybean yields in the absence of weeds were reduced as planting dates were delayed, percent yield loss due to weed competition was highest with the earliest planting date. Weed control can be enhanced in fields that allow for flexibility in planting dates, or cropping sequence, since weed biomass production is not as dramatic and weeds are not as competitive when planting occurs later in the growing season. This can be beneficial for management of herbicide-resistant species, incorporated into non-chemical weed control programs, or incorporated into cropping sequences where herbicide options are limited.

681. Resource Exploitation and Chemical Interference between Soybean (*Glycine max* (L.) Merr.) Crop and Wormwood (*Artemisia annua* L.). Claudia Morvillo¹, Elba de la Fuente¹, Alejandra Gil¹, Alejandra Martínez-Ghersa¹; ¹Faculty of Agronomy, University of Buenos Aires, Ciudad Autónoma de Buenos Aires, Buenos Aires, Argentina

Interference among crops and weeds is mainly attributed to competition for resources. However, allelopathy is an important non-resource way of interference. Most studies on weed-crop interference through allelopathy were conducted in laboratory conditions using manipulative techniques, and few experiments, investigated the competition and allelopathy under field conditions. Annual wormwood (*Artemisia annua* L.) releases allelochemicals (e.g. artemisinin) affecting crop growth. Soybean (*Glycine max* L.) Merr.) is susceptible to allelochemicals since not only nodulation, and hence nitrogen fixation but also plant growth and yield may be affected. The objectives of our study were to separate the effect of competition and allelopathy in a crop-weed system under field conditions and to quantify their effect on soybean nodulation and yield. Field experiments were carried out in the Faculty of Agronomy, University of Buenos Aires (Argentina) in two consecutive years. A split plot experimental design with three replications was used. Weed-crop density levels (competition) were assigned to the main plots while allelopathy levels were assigned to the sub-plots. An additive model was used to study competition. Thus,

competition levels were: pure soybean (40 plants m⁻²), soybean (40 plants m⁻²) and annual wormwood (2, 4 and 8 plants m⁻²) and pure annual wormwood (8 plants m⁻²). Allelopathy levels were with and without allelopathy (with activated charcoal to adsorb the allelochemicals). Dry weight of roots and nodules and number of nodules of soybean and dry weight of stems, leaves and inflorescences of wormwood were recorded. Soybean yield decreased in response to the increase of relative biomass of wormwood in treatments where chemical interference was reduced. In treatments with allelochemicals, the yield remained stable and nodules were larger than without allelopathy. When allelopathy was reduced soybean yield was weed density dependent. However when competition and allelopathy occurred simultaneously yield was not affected by the presence of annual wormwood in the range of crop-weed densities studied.

682. Harmfulness of the most Wide Spread Species of Weeds and their Control in Maize under Condition of the Ukraine. Viktor Zadorozhnyi¹, Vasyl Petrychenko¹; ¹Feed Research Institute, Vinnitsa, Ukraine

Weed control in maize is one of the key elements in modern production system. The objective of this research was to investigate competitive relations of *Chenopodium album* and *Echinochloa crus-galli* and *Zea mays* (maize) and effectiveness of mesotrion used alone or in mixture with metolachlor, terbuthylazine or nicosulfuron in maize.

Field trials were conducted in 2006 and 2007 at the Feed Research Institute of UAAS. The soil was a grey wooded type with 2.2-2.4 % organic matter content and pH of 5.2-5.5. The trials were carried out using a plot size of 25.2 m² (4.2 x 6m) and 4 replications. The pre-emergence spraying was carried out the day after sowing. The post-emergence application took place when crop and grass weeds were at the 1-3 leaf stage and broad-leaved weeds were at the first true leaf stage. Herbicides efficacy was assessed 30 days after treatment (DAT) and at crop harvest by measuring the above-ground weed fresh weight. Maize yield data were subjected to the analysis of variance.

Significant reduction of maize yield 0.31 t ha⁻¹ was observed when the quantity of *Echinochloa crus-galli* was 10 plants m⁻². When the number of weeds in maize was 15 plants m⁻² yield losses increased up to 0.47 t ha⁻¹ or 8,3 %. When the number of *Echinochloa crus-galli* was 20-25 plants m⁻², the yield reduced by 11,7-14,2 % correspondingly, and at the plots where weed infestation was within 50 plants m⁻² - 18,2 %. In variants with *Chenopodium album* significant reduction of yield was observed when the quantity of weeds was 15 plants m⁻² - 2,5 t ha⁻¹. When the number of weeds was plants m⁻² the yield reduced by 6,3 %. Further increase of *Chenopodium album* quantity up to 25-20 plants m⁻² caused the increase of yield losses by 9,2-12,7%.

Application of tank mixtures of 120 g. a.i. ha⁻¹ mesotrion + 1200 g. a.i. ha⁻¹ metolachlor resulted in 90 % weed control. The tank mixture of mesotrion 72 g.a.i. ha⁻¹ + nicosulfuron 30 g.a.i. ha⁻¹ provided 100 % control of *Amaranthus retroflexus*, *Chenopodium album* and *Echinochloa crus-galli*.

Maize is extremely sensitive to weed competition. So weed control in maize should be carried out when the quantity of *Echinochloa crus-galli* in maize is 10 plants m⁻² or *Chenopodium album* 15 plants m⁻². The herbicides combinations nicosulfuron + mesotrion provide highly variable control of annual broad-leaved weeds and grasses in maize.

683. California Weedy (Red) Rice. Aida Ortiz¹, Albert Fischer², Chris Greer², Barbara Schaal³, James Eckert⁴, María Osuna², Emilio Laca²; ¹Universidad Central de Venezuela, Maracay, Aragua, Venezuela; ²University of California-Davis, Davis, California, United States of America; ³Washington University in St. Louis, St Louis, Missouri, United States of America; ⁴University of California, Davis, Biggs, California, United States of America

Although red rice (weedy rice) is not yet a problem in California, it has been identified in rice fields since 2003. The objectives of this research work were: 1) To use DNA markers to characterize red rice accessions collected in California and to compare them with red rice from a Southern US location; and 2) to characterize morphologically the same California red rice accessions and to compare them with California rice varieties. In total were evaluated 79 weedy rice accessions, 24 rice lines with red bran and 4 California rice varieties (M-104, M-202, M-205 and M-206). When using DNA markers the results indicate that California weedy rice is different than Southern US weedy rice. According to cluster made with genetic distance from microsatellites, California weedy rice was located between two groups out of three Southern US weedy rice groups. These results also show that the rice lines with red bran are different than California weedy rice, and that its cluster was near Southern US rice variety Cheniere. The morphological characterization pointed out that there are 13 variables that could differentiate California weedy rice from California rice varieties, and that it is possible to say that there are two types of California weedy rice: one type with intermediate awn and another with long awn, both of them taller than varieties, and also with pubescent leaves and lemma-palea; light green leaves; internodes with light color than nodes (pale gold); intermediate type panicle; straight axis panicle; pubescent axis panicle; high shattering panicle (more than 50%); and early to intermediate heading. Morphologically, the Non-Weedy red bran rice 1 group, have purple pigmentation in the leaf sheath, stigma and collar, as well

as red apiculus, which make this group different than others groups.

684. Evaluation of Multispecies Weed Competition with Wheat using Regression Equations. Shahrzad Noroozi¹, Daryush Mazaheri¹; ¹University of Tehran, Karaj, Tehran, Iran

Winter wheat (*Triticum aestivum*) is one of the most important agronomic crops in the world and Iran. Weed competition for moisture, nutrients and light, reduces wheat yield. Weed density is one of the most affecting factors on competition between weeds and wheat. According to Cousens' rectangular hyperbola equation, there is an inverse relationship between crop yield and weed densities; therefore, when weed densities increase, crop yield decreases. To determine the effect of weed densities on wheat yield, an experiment was conducted in 2002 in a wheat field in Shirvan Agriculture College. A15m x 150m part of a 28ha wheat field was selected as the experimental site. The area was managed like all other parts of the field, except this area were not treated with herbicides.

At the beginning of the shooting stage, 30 locations were sampled using a 50 cm x 50 cm quadrat. Assessments included number of wheat plants and tillers and number of weeds (each species separately), without destroying plants. At the end of growth season, all wheat plants in the quadrat were harvested and number of plants, seed weight and total biomass were measured. Regression model was used to determine the relative fractions of inter-specific competition. Weeds with significant inter-specific competition coefficient were considered as effective weeds. To determine the effect of these weeds on wheat yield and its components, extended rectangular hyperbola model was fitted to wheat seed yield and the density of effective weeds on wheat yield. Since there was more than one effective weed, total competitive load (TCL) was calculated using parameters obtained from rectangular hyperbola model. Effect of weeds on wheat yield and its components was calculated by replacing weed density by TCL in rectangular hyperbola model.

Despite of presence *Avena ludoviciana*, *Salsola kali*, *Rapistrum rugosum*, *Polygonum aviculare*, *Erysimum cheiranthoides*, *Chenopodium album* and *Sonchus oleraceus* in the field, regression model using stepwise procedure indicated that only *A. ludoviciana*, *S. kali*, and *R. rugosum* reduced wheat yield significantly. As weed density increased, wheat seed yield decreased hyperbolically. The increase in weed density reduced the number of fertile tillers and seeds per square meter. Similar results were found by Morishita et al. (1991) in the barley field, who reported that wild oat reduced barley biomass, number of tiller and fertile tiller per plant and per unit area. Furthermore, Balyan et al. (1991) showed that wild oat competition reduced number of fertile tiller in wheat. TCL had no effect on harvest index and kernel weight of wheat.

These results was in agreement with the results of the Mc Lelland (2000), who showed that wheat tillers were reduced by weeds but they had no effect on 1000-seed weight.

685. Effect of Reduced Herbicide Rates Based on Image Sampling and Weed Cover Thresholds. Marie-Josée Simard¹, Bernard Panneton¹, Louis Longchamps², Claudel Lemieux¹, Anne Légère¹, Gilles Leroux³; ¹Agriculture and Agri-Food Canada, Québec, Canada; ²Agriculture and Agri-Food Canada and Université Laval, Québec, Canada; ³Université Laval, Québec, Canada

Most pesticides (>70%) applied in Canadian field crops are herbicides. Reducing herbicide rates in these crops is one approach to significantly reduce the environmental pesticide load. Some weeds can be left in a crop without affecting crop yield and this knowledge could be used to reduce herbicide rates. The challenge with this approach is establishing the weed threshold. This threshold can be determined from an assessment of the relative crop-weed cover, using digital images, and used as a basis to reduce herbicide rates. Our goal was to evaluate the feasibility of this approach in a corn-soybean rotation at two locations (Beaumont and St-Jean-sur-Richelieu, QC, Canada). Two 1.62 ha fields subdivided in 18 plots (30 x 30 m) were grown in corn (2004, 2005, 2007) and soybean (2006). One third of the plots were sprayed with full rates (1X) of glyphosate or conventional herbicides, and the other plots received variable rates (0, 0.5 or 1X) of the same herbicides. Rates were based on the relative weed cover evaluated from six digital images taken before herbicide application. Every year, weeds were counted in six quadrats (50 x 75 cm) before and after herbicide application. Herbicide systems (conventional vs. glyphosate) generated similar crop yields and weed densities. Low relative weed cover at the beginning of the experiment (2004) allowed no herbicide application in most plots at both locations. Nineteen out of 24 plots received no herbicide in 2004. Crop yields were only slightly affected by the reduced rates (-10%). However, in the three subsequent years, pre-herbicide weed densities and relative weed cover were higher in plots that received no herbicide in 2004, compared to plots systematically treated at full dose, despite the application of a full herbicide dose in the no-herbicide plots after 2004. Subsequent weed generations, associated with residual populations from 2004, limited the possibility of using less herbicide for a period of three years, based on thresholds.

686. Cover Crops during Winter Fallow as a Weed Management Strategy in Maize Hybrid Seed Production. Juan Alonso¹, Elba de la Fuente¹, Santiago Poggio¹, Tomás Jándula¹; ¹University of Buenos Aires, Buenos Aires, Argentina

Maize hybrid seed production use high levels of inputs (irrigation, fertilisers and agrochemicals) to maximise seed yield. However, weed growth is usually greater than in grain maize crops because of both high resource availability and low crop cover, the latter due to spatial arrangement and small size of maize plants. This cropping system usually requires additional herbicide applications to control weeds. Thus, including cover crops in maize hybrid seed production may help to manage weeds in a sustainable way, through both preventing seed germination and suppressing plant growth. Our aim was to study how legume and grass cover crops affect weed communities during the fallow period and the following maize hybrid seed crop. Field experiments were carried out in two locations of the central Rolling Pampa (Argentina) in two consecutive years, during the winter fallow period between soybean and maize hybrid seed crops. First year experiments included two control treatments with and without glyphosate application, and cover crops of Italian ryegrass (*Lolium multiflorum*) and Persian clover (*Trifolium resupinatum*), whereas the second year experiments also included ryegrass-clover mixture. Floristic composition, ground-cover and biomass of weeds were evaluated. Ground-cover and biomass of ryegrass, clover and maize seed yield were measured. Ryegrass cover crop has the highest suppressive effect on weed growth due to its high biomass production. Common chickweed (*Stellaria media*) was the most frequent winter weed, being importantly suppressed by cover crops, particularly in those cover crops with high biomass of ryegrass. Maize seed yield was not affected by the previous treatments. Large crabgrass (*Digitaria sanguinalis*) and crested anoda (*Anoda cristata*) were the most frequent weeds in maize. Crested anoda was suppressed by cover crops, whereas herbicide applications during fallow appear to be more effective to reduce large crabgrass growth. Cover crops may contribute to sustainable weed management in hybrid seed production of maize, without affecting maize yield and economical results in a short term. Moreover, cover crops may help to maintain soil chemical and physical properties in a long term.

687. The Influence of Nitrogen Application on Critical Period for Weed Control in Corn (*Zea mays* L.). Reza Ghorbani¹, Seid Hussieni¹, Mohammad Rashed Mohasel¹, Mehdi Nassiri¹; ¹Ferdowsi University of Mashhad, Mashhad, Khorasan, Iran

The critical period for weed control (CPWC) is a period in the crop growth cycle during which weeds must be controlled to prevent unacceptable yield losses. A field experiment was conducted at Research Station of Ferdowsi University of Mashhad, Iran, in 2004 to evaluate the influence of nitrogen application on the CPWC in grain corn in competition with a naturally occurring weed population. Nitrogen fertilizer was applied at rates

equivalent to 184 and 368 kg N ha⁻¹. A quantitative series of treatments of both increasing duration of weed interference and length of weed-free period were included in each nitrogen level. The beginning and end of the CPWC based on 10% acceptable yield loss level were determined by fitting the Logistic and Gompertz equations to relative yield data representing increasing duration of weed interference and weed-free period, respectively. The CPWC in 184 kg N ha⁻¹ and 368 kg N ha⁻¹ was determined 17-40 (V3 to V8) and 18-32 days after emergence (V4 to V7), respectively. The addition of 368 kg N ha⁻¹ hastened the end of the CPWC when compared with 184 kg N ha⁻¹. It seems, in higher Nitrogen level, rapid canopy closure resulting from higher crop leaf area index (LAI) resulted in less weed interference and the critical weed free period was ended earlier. Although not very much, difference in the CPWC due to nitrogen application documented in this study, highlight the importance of integrating decisions regarding nitrogen management and timing of weed control.

688. Effective Weed Management through Appropriate Rice Establishment Techniques. Azmi M.¹, David D. E.²; ¹Malaysian Agricultural Research and Development Institute (MARDI), Kepala Batas, Penang, Malaysia; ²International Rice Research Institute, Los Banos, Manila, Philippines

Rice producers in Malaysia and elsewhere in Asia face major challenges to control weeds, and weedy rice in particular, in direct seeded rice, and these cause substantial yield losses despite increased production costs for weed control. Field experiments were conducted for three consecutive seasons to determine the effect of crop establishment methods viz: wet seeding (WS), dry seeding (DS), drum seeding (WDS), seedling broadcasting (BCS), water seeding (WTS) and manual transplanting (TPR) on crop and weed growth. Weed infestation comprised mainly weedy rice in the main season 2005/06 while a broad spectrum of weeds was recorded in off season 2006 and main season 2006/07. Across seasons, in the unweeded plots weeds caused 37% grain yield loss and there were no significant interactions with establishment method. In the three crops, rice yields from BCS were not different from TPR. In each season, the lowest yields were from DS. In season two, yields from WS and WTS were not different from TPR and BCS and in season three, yields from WS, WDS, WTS, TPR and BCS were similar. In the first season, weedy rice infestations were highest in the dry and wet broadcast seeded and in these treatments panicle densities of weedy rice were more than twice those in BCS and almost three times those in WTS. In the subsequent seasons weedy rice infestations were much lower. Weed dry weights were recorded in off season 2006 and main season 2006/07 in unweeded plots showed weed growth to be greatest in DS followed by WS and least in WTS.

Broadcast seeding of pregerminated seed into standing water (5-10 cm depth) during early crop establishment significantly reduced weedy rice populations and other weed growth compared to DS or WS and gave yields that were comparable to TPR in two out of three seasons. Infestations of grassy weeds (i.e. *Echinochloa crus-galli*, *Leptochloa chinensis*) and weedy rice were associated with DS, WS and WDS methods due to the absence of flooding in the early stages of crop growth. With water seeding the rice seeds sink below the flood water to the soil surface from where the coleoptiles grow to emerge from the water surface. As the field remains flooded until a few weeks before maturity many weed species, including weedy rice, are inhibited from germinating by the submersion. Where water supplies are adequate, with soils having low infiltration rates and well leveled fields WTS appears to be an effective method of crop establishment to address the problems of serious weedy rice or grassy weed infestations.

689. The Role of Weeds in Arthropod Diversity and Relationship with Landscape Simplification in the Rolling Pampa. Elba de la Fuente¹, Susana Perelman¹, Claudio Ghersa¹; ¹University of Buenos Aires, Buenos Aires, Argentina

Weeds growing in field crops and field margins are an important resource for higher trophic groups. However, in the Rolling Pampa agroecosystem cropping activities resulted in a reduction of perennial vegetation habitats, land use differentiation and, over last decade, in a decline in weed diversity. Thus, many arthropod species may suffer from a lack of nectar and pollen sources, shelter, hibernation, mating and nesting sites. The objective of this study is to find relationships between weed and arthropod diversity, and how it may be affected by land uses in the surrounding landscape. Weeds and arthropods were surveyed during three years in summer crops (soybean and maize) and its field margins in the center of the Rolling Pampa, Argentina. Weed cover-abundance was estimated and arthropods were sampled with a sweep net. The proportion of different land uses in the surrounding landscape of each surveyed field was estimated in circular areas of 1500 m radius using LANDSAT satellite images. Gamma (regional) and alpha (local) diversities were calculated and related to one another, and to the proportion of different land uses in the surrounding landscape using regression analysis. Arthropod gamma and alpha diversities were positively related with weed gamma and alpha diversities in field crops and field margins. Weeds alpha diversity in field crops and field margins decreased with the proportion of soybean in the surrounding landscape (1500m radius). Total and non herbivorous arthropods alpha diversity in field margins decreased with the proportion of soybean in the surrounding landscape, mainly in field margins connecting soybean crops. No relationship was found between arthropod alpha

diversity in crop fields and neighbor land uses, except for non herbivorous. In the Rolling Pampa agroecosystem arthropod diversity is linked to weed diversity at regional and local scale in field crops and field margins, and both diversities are affected by landscape simplification. It is important that crop managers begin to understand this linkage and how to manipulate the agroecosystem to facilitate effective pest management with less use of agrochemicals, considering that non herbivorous is the most affected group with landscape simplification.

690. Differences in the Presence of Seed Feeders Between Thistles, *Cirsium arvense* and *C. heterophyllum*. Stanislava Koprđova¹, Jiri Skuhrovec¹; ¹Crop Research Institute, Prague 6-Ruzyne, Czech Republic

Thistles (Asteraceae) are permanent or biennial (up to perennial) weeds, which are highly competitive and invasive, and well spread in the whole area of Holarctic ecozone. Despite that the thistles are relatively adequately armoured by spines, they support a rich and varied fauna of insect herbivores with their associated predators and parasitoids. Herbivores can significantly reduce reproductive potential of the host plant.

Our study has focused on the occurrence of seed-feeding insects (pre-dispersal seed predators) in flower heads of two studied thistle species (*Cirsium arvense* and *C. heterophyllum*). Despite some species spread particularly vegetatively (*C. arvense*), the role of pre-dispersal seed predators is highly important because of precluding their dispersion on other localities. 250 flower heads from 250 randomly chosen *C. heterophyllum* plants were collected. The same amount of *C. arvense* flower heads was harvested, the flower heads were collected from 50 plants (5 marginal flower heads per plant).

The presence and number of pre-dispersal seed predators were established. Importance and utilizability of each pre-dispersal predator was assessed according to the following parameters: prevalence (percentage of infested hosts in population), prevalence of attacked flower heads (ratio of prevalence of insect group to total prevalence), intensity (mean number of predators per infested host) and abundance (mean number of predators per potential host), and these data were compared with literature sources.

We determined seed-feeding species belonging to these insect families: Diptera: Tephritidae, Diptera: Cecidomyiidae, Coleoptera: Curculionidae, Lepidoptera: Tortricidae. The most effective biological control seem to be a combination of two and more bioagents which together create multiple stresses on the plant; e.g. Tephritidae Curculionidae in *C. arvense* and Tephritidae Tortricidae (sometimes Curculionidae) in *C. heterophyllum*.

Seed predation in *C. heterophyllum* was severalfold higher than in *C. arvense*, which was confirmed by all values of observed parameters. *C. arvense*, which due to its root system possesses a highly effective system for

propagation and persistence, additionally invests a remarkable part of resources into generative reproduction. Pre-dispersal predators could limit its propagation to new niches.

691. Effect of Seed Covering Tissues on Post-dispersal Seed Predation of Wild Oat, Wild Barley and Bitter Dock. Shahrzad Noroozi¹, Hamid Rahimian Mashhadi¹, Hassan Mohammad Alizadeh¹, Sara Ohadi¹; ¹University of Tehran, Karaj, Tehran, Iran

Seed is a key step in annual weeds life cycle and a storage organ for high energy compounds that provide resources for seed germination and seedling development and a good food reserve for seed eating animals. Seed predation could be considered as a biological weed control method in IWM. Several factors effect on seed predation including seed characteristics. Seed covering tissues are barriers to predators accessing the seed reserved component.

The effect of seed covering tissues on post-dispersal seed predation was investigated in barley fields. Field experiments were conducted in 2007 at 2 fields using seeds of *Avena ludoviciana*, *Hordeum spontaneum* and *Rumex obtusifolius*. Treatments (intact and naked seeds) were arranged in a randomized complete design. Each treatment was replicated four times. Seeds were placed on a layer of sieved field soil contained within 10 cm diameter polystyrene Petri dishes that had several drainage holes in the base. Petri dishes were buried, flush with the soil surface. 10 dishes of each species seeds were placed randomly in each plot and each dishes contained 50 seeds of a single species. Experiments were conducted simultaneously from Jun, 23 to August, 4 2007 using six sequential 1-week trials. At the end of each week, the dishes collected and replaced with another dishes containing 50 seeds.

Seed predation was significantly different between species and fields. Highest and lowest seed predation was related to *A. ludoviciana* and *H. spontaneum* respectively. For all three weed species, seed covering tissues affected on predation in both fields. Effects of field and week were significant too.

Totally, seed predation was higher in field 1. In both fields, for all species and two main treatments, seed predation increased during the time. The most and the least effect of seed covering tissues was on predation of *H. spontaneum* and *R. obtusifolius* seeds respectively.

In both fields, the highest and lowest predation was related to *A. ludoviciana* naked and *H. spontaneum* intact seeds respectively. Field 1 was surrounded by more stable habitats (alfalfa and fallow, unplugged fields) than field 2 (wheat and fallow, plugged fields). Since disturbance is lower in stable habitats and disturbance has negative effect on predation, it could explain why seed predation was higher in field 1. In *H. spontaneum* seeds, Lemma and palea are hidebound and barriers to predators accessing the seed reserve component.

692. **The Effect of Tillage on Seed Predation in Cereal Fields.** Bàrbara Baraibar¹, Paula Westerman¹, Jordi Recasens¹; ¹Universitat de Lleida, Lleida, Spain

Seed losses due to predation could be used as a supplementary tool for weed management, however, a better understanding is needed for optimal use. Tillage may affect the activity of granivores, in particular ants and rodents, which build their nests within the field boundaries. We hypothesized that the absence of tillage in cereals would favour predator populations and activity resulting in higher post-dispersal seed predation rates compared to conventionally managed fields. Seed predation was assessed in three no-till and three conventionally tilled commercial barley (*Hordeum vulgare*) fields. Seven sampling sessions occurred between April and October 2007. In each session, 2 g of two seed species (*Lolium multiflorum* and *Vicia villosa*) were exposed for 2 days to vertebrate and invertebrate predators. Seeds were provided in Petri dishes located on the soil surface (for invertebrates) or elevated (for vertebrates). A linear mixed regression model (binomial distribution, link-logit) was used to describe the percentage predation of seeds as a function of (1) type of management (no till, conventional), (2) type of predator (vertebrate, invertebrate), (3) weed species (*V. villosa*, *L. multiflorum*), and (4) sampling occasion (1 to 7) (procedure IRREML, Genstat 10). All main factors and almost all interactions significantly influenced seed predation. Predation in no-till fields was significantly higher in four out of the seven sampling dates compared. Predation by the granivorous ant *Messor barbarus* (73.9%) was much higher than predation by the granivorous rodent *Mus spretus* (4.6%). Predation of *L. multiflorum* (49%) was significantly higher than predation of *V. villosa* (12.5%). The results of our study revealed that postdispersal seed predation by ants was strongly reduced by tillage. Possibly, tillage damaged the nests, disturbed ant activity and decreased seed availability compared to no-till fields.

693. **Post-Dispersal Weed Seed Predation of *Amaranthus retroflexus*, *Chenopodium album* and *Echinochloa crus-galli* in Maize (*Zea mays* L.).** Federica Graziani¹, Euro Pannacci¹, Gino Covarelli¹, Francesco Tei¹; ¹University of Perugia, Perugia, Italy

Post-dispersal seed predation is increasingly viewed as an important process that could be exploited to improve agricultural weed management strategies in order to increase seed losses and reduce weed seedbank. Several researchers have investigated the effects that some factors (crop species, tillage practices, natural innate seed traits) can have on seed predators activity obtaining different results on weed seed predation rates. In this regard field experiments were carried out in 2005 and 2007 in central Italy to assess the effects of the weed density (high weed density, HWD, about 32 plants/m²; low weed density,

LWD, about 1 plant/m²) in maize on post-dispersal seed predation of *A. retroflexus*, *C. album*, and *E. crus-galli*. Vertebrate and invertebrate post-dispersal weed seed predation were estimated from mid August to late September with maize at growth stage from 73 to 93 BBCH, for a total of 5 sampling periods in accordance with the methodology developed by Westerman et al. 2003. Fifty seeds of each weed species were lightly glued to sandpaper cards (45 x 90 mm) dusted successively with a fine layer of sieved soil. 9 seed cards of each weed species per each sampling period were placed in each plot of about 75 m², in accordance with a completely randomized experimental design with 3 replicates: 4 seed-cards were placed without any cages (to estimate total seed predation = vertebrates + invertebrates), 3 seed-cards were inside a cage with aluminium net with mesh of 11 mm (cage excluding predation by vertebrates and so estimating predation by invertebrates), 2 seed-cards were inside a cage with aluminium net with mesh of 3 mm (cage excluding any predators). Predation by invertebrates was estimated as a difference between total predation minus predation by vertebrates. Results showed that the average total seed predation rate (i.e. vertebrate + invertebrate), on the 3 species, was significantly higher, in both years, in HWD than in LWD (68% vs 42%, on average in both years) but that difference was due only to the predation by vertebrates (27% in HWD vs 7% in LWD) while the predation by invertebrates (mainly *Harpalus rufipes*) showed no significant difference (41% in HWD and 35% in LWD). The highest predation rates were in early September in correspondence with high seed shed. Considering the predation rate of each weed (average values over all sampling period in 2005), vertebrates did not show preference in LWD while in HWD the results were *E. crus-galli* (39%) > *A. retroflexus* (26%) > *C. album* (12%). Invertebrates predated *C. album* (51%) > *E. crus-galli* (39%) > *A. retroflexus* (32%) in both HWD and LWD.

694. **Dispersal and Post-Dispersal Predation of Italian Ryegrass Seed in Unimproved Pasture.** Robert Williams¹, Paul Bartholomew¹; ¹USDA-ARS-GRL, Langston, OK, United States of America

Italian ryegrass (*Lolium multiflorum* L.) can be a productive and high-quality cool-season forage, but is considered a weed in some pastures. Italian ryegrass does not form a persistent seed bank and needs to produce sufficient seed annually for effective re-establishment. Here we examine two factors involved in seed bank development – seed dispersal and post-dispersal predation. For the dispersal study, seed traps (15-cm dia.) were placed at intervals of 0, 0.3, 0.6, 0.9, 1.2 and 1.8 m from the edge 1-m² uniform, grass blocks in the eight cardinal directions. Trapped seed were counted every 7 to 10 days until the ryegrass was harvested in July. Insect predation of ryegrass

seed over a 12-month period was determined from May 2006 to June 2007 with cards baited with 30 ryegrass seed. The cards were collected weekly and replaced with fresh cards. Although some seed (8%) were trapped at 1.8 m, 80% of the seed were found at 1 m or less from the edge of the plot. Mowing increased the seed deposited at the edge of the plot and further seed were deposited along the direction the forage was raked for removal. Weekly mean seed predation ranged from 6 to 86 % over the 12-month period. Mean predation was greater in the winter months (53%) than in the summer (34%) or fall (26%). Predators noticed in the field were mainly harvester ants, but crickets and other predators were observed. These studies indicate that the majority of the Italian ryegrass seed remains in the seed head. The seed that is dispersed falls within the shadow of the parent plant, most within a meter's distance and the seed predation in our system is approximately 40% over a 12-month period.

695. Weed, Carabid Beetle, Earthworm and Microbial Communities Respond to Tillage and Residual Effects of Crop Rotation. Anne Légère¹, Craig Stevenson, Anne Vanasse², Michèle Roy³, Roger Lalande¹, Danielle Prévost¹, Joann Whalen⁴; ¹AAFC, Saskatoon, Saskatchewan, Canada; ²Université Laval, Québec, Canada; ³MAPAQ, Québec, Canada; ⁴McGill University, Ste-Anne-de-Bellevue, Québec, Canada

Management practices rarely result in the total absence of weeds. Residual weeds (those that survived or avoided weed control operations) may have little effect on the crop but may have more effects on the diversity of other taxa potentially beneficial to the crop and to the agroecosystem. Yield results from a corn test crop seeded in 2006 after 18 years of treatments confirmed residual beneficial crop rotation effects. However, weeds only partly explained these yield variations. We hypothesized that effects were mediated through other taxa. Weeds, insects, earthworm and microbes were sampled at different times during the season. Effects of crop rotation (terminated in 2005 - cereal monoculture vs. cereal/forage or cereal/oilseed rotation) and tillage (ongoing in 2006 - MP: moldboard plow; CP: chisel plow; NT: no-till) on diversity and assembly were measured. A synthetic diversity index (Shannon's H') was calculated for communities of weeds, carabid beetles and earthworms. Multivariate analysis was conducted for these communities and for microbial populations. Weed communities sampled before and after herbicide application were more responsive to current crop management practices (tillage) than to residual effects of crop rotation. Weed communities segregated primarily between tilled and no-till treatments, but also according to crop rotation. Weed diversity was greater in the NT than in the CP or MP treatments. Residual crop rotation effects were observed early in the season, for all other taxa, that were either more diverse and/or strongly associated with

the rotation than the monoculture. Later in the season, these organisms (with the exception of *Bradyrhizobium japonicum*) were more diverse and abundant in NT than in CP or MP treatments, regardless of rotation. Taxa other than weeds appeared to be better indicators of the positive residual effects of crop rotation, when communities were assessed early in the season.

696. Weed Seed Predation in Spring Wheat and Adjacent Ecological Infrastructures. Daniel Daedlow¹, Baerbel Gerowitt¹, Lisa Dittmann¹; ¹University of Rostock, Rostock, Mecklenburg-Western Pomerania, Germany

Weed seed predation has a significant role in the regulation of weed population dynamics. Depending on habitat structure, birds, smaller mammals and arthropods are responsible for seed feeding. Enhancement of seed predation can offer options to reduce herbicide use. Ecological infrastructures like semi-natural biotopes, hedges, grass strips or strips with increased biodiversity are refuge territories for seed predators.

Our investigations focus the general level of seed predation, the parts caused by vertebrates and invertebrates and the influences of ecological infrastructure: flowering mixture and a woody hedge.

Enclosure experiments were conducted in June 2006 in North Eastern Germany close to the Baltic coast in a field with organic spring wheat. Two trials with seed cards (prepared with *Thlaspi arvense* L. and *Myosotis arvensis* (L.) Hill) were deployed, each with 9 transects, running from a flowering mixture, a grass-clover strip into the wheat field, respectively from a woody hedge into the wheat field. Nine replications were set up in a patch 150 m from the margin. Additionally, 9 control cards, protected against seed predators were randomly distributed.

Seeds remaining on the cards were counted every two days. Mesh wire cages with mesh size 12mm were used to distinguish between seed predation due to vertebrates and invertebrates. Spatial and temporal development was analysed.

Total rates of seed predation in the wheat were high, 40-51 % (95% confidence interval) after 4 days, respectively 89-93 % after 10 days of exposition. Preferences of foraging *T. arvense* and *M. arvensis* were not found.

Invertebrates, probably Carabidae, Coleoptera, were responsible for the major part of predation (80-88 %; 10 d), whereas vertebrates, presumably Muroidea, were responsible for the minor part of predation (3-9 %; 10d) but reached slightly higher rates in the ecological infrastructures flowering mixture and woody hedge (14-38 % respectively 6-25 %; 10 d).

Three homogeneous subgroups of seed predation levels were distinguished. These are almost identical with the habitats. In the flowering mixture 38-63 % seed predation was determined, 76-87 % in the neighbored wheat and highest rates in the grass clover mixture (91-99 %) and in

the centred patch (100 %). Thus, neither an overall gradient in all habitats nor an increasing sequence of habitats from edge to the centre was found. The offered weed seeds were probably less attractive in the flowering mixture where diverse plant material was present and various seeds were produced. If alternative food is scarce, like in the centre, the exposed seeds could have been the unique food supply.

In conclusion, the level of seed predation depends on the habitat type. The presence of ecological infrastructure in arable areas influences seed predation processes but could not be distinguished in this experiment from the effect of the scarcity of food.

697. Invertebrate Species in Organic and Conventional Wheat Fields in Central Italy. Federica Graziani¹, Euro Pannacci¹, Gino Covarelli¹, Francesco Tei¹; ¹University of Perugia, Perugia, Italy

In the farming system even if weeds can reduce the quality and quantity of crop production, they may be considered important components to increase the agroecosystem biodiversity. Research has shown that many arable weed species support a high diversity of insect species while reductions of host plants may affect associated insects based on weed and crop management. The aim of this study was to assess the presence of insects in *Triticum aestivum*, grown in two farming systems in central Italy: organic (ORG) (*S. Apollinare*, 260 m a.s.l.); conventional (CONV) (Casalina, 165 m a.s.l.). This assessment was conducted within post-dispersal weed seed predation studies carried out in 2005 and 2006 according to a randomized block design with 3 replicates and plots of 1400 m² (20 m width). Invertebrate density was assessed placing 3 traps in the centre of each plot, using plastic cups 80 mm x 105 mm, completely buried and containing ethylene glycol and water. Traps were left in the field, from mid May to early July in the crop, and on stubble from mid August to early September, for a total of 4 samplings each lasting 21 days. The vegetation composition was recorded in July and the percentage ground cover of each species was visually estimated. In ORG, weed flora in 2005, was composed of *L. multiflorum* (50% ground cover), *S. arvensis* (30%), *A. ludoviciana* (20%), *P. rhoeas* (5%), *G. aparine* (5%), *P. minor* (10%), while in 2006 the same species were present with lower ground cover values (65%). CONV was in both years characterized by a very low *L. multiflorum* ground cover (2%). The main species of insects belonging to the Coleoptera order in ORG were: *Brachinus crepitans*, *Pterosticus melas italicus*, *Scybalicus oblongiusculus*, *Ophonus ardosiacus*, *Calathus fuscipes*, *Amara aulica* and *Harpalus rufipes*, with an average number of 21±4.7 insects per trap in the crop and 11±2.5 insects per trap on stubble. A significantly lower number of Coleoptera was assessed in CONV, determined by *B. crepitans*, *P. italicus* and *A. aulica*, with an average

number of 5±0.8 insects per trap in both periods. Among the Orthoptera order present in both systems, but without significant differences, were: *Acheta domestica*, *Grillus campestris*, *Stenobothrus lineatus* and *Oedipoda germanica* with an average number of 5±1.7 insects per trap for all the sampling period. The insect biodiversity found in ORG was due not only to the presence of weed flora but rather as an indirect effect connected to the non employment of herbicides and insecticides. Moreover the different results on biodiversity did not influence the predation rate by invertebrates that was not statistically different between farming systems.

698. Compensation for Adverse Conditions on Foliar Applied Products by Means of Adjuvant and Formulation. Peter Baur¹; ¹Bayer CropScience AG, Frankfurt, Hesse, Germany

Under favourable application and environmental conditions many foliar applied crop protection agents (cpa) including herbicides work very well. However, under less favourable conditions performance can be reduced for a number of reasons such as failure of the active to reach the target organism or deactivation of the active post application. Less favourable conditions can be related to a diverse number of causes, for example, weather conditions before, during and/or after application, wrong tank mix partner, or not using recommended product rates or water volumes for a particular agronomic situation. To increase the complexity, the physicochemical properties of today's agrochemical active ingredients are becoming increasingly more challenging for efficient transfer of cpa to the site of action and this must be counterbalanced with proportionally higher intrinsic activity.

Most adverse conditions, whether climate, application or basic properties of the active ingredient can be compensated for by judicious use of adjuvant and formulation - not necessarily by one and the same 'unique' adjuvant or formulation type. Most adjuvant effects are spray concentration dependent and often an optimum level can be demonstrated. Beyond these thresholds no further benefit can be achieved with respect to product performance and indeed, higher than optimum levels can sometimes show adverse effects. This presentation gives some examples of the benefits and limitations of such adjuvant and formulation effects for cpa performance.

Current knowledge is that most adjuvants and adjuvanted formulations do not affect the activity of the product once inside the target organism in addition to the significant influence of the adjuvants on effective transfer to the target site in the most bioavailable form. In this respect, herbicide optimisation is particularly complex since, besides diverse physiological weed sensitivities, anatomical and physical surface properties of weed leaves and stems differ widely. These differences are significant for the physical interaction with spray and resultant

deposit, the impact of specific surface chemistry and, especially, the cuticular barrier properties against the penetration of actives.

Passive diffusion across the cuticle is the most specific step and particularly interesting for foliar applied herbicides which differ in their lipophilicity by far more than 6 orders of magnitude as indicated by, for example, the water solubility. Therefore, the general existence of different routes for the diffusion of hydrophilic and lipophilic compounds has been suggested since long. In the recent literature, some old and recent results on the penetration of hydrophilic compounds are interpreted in that way, i.e. by the existence of hydrophilic channels or pores. Whether such pores are a basic feature of the cuticle or rather occur only at specific sites such as the base of hairs, is discussed, as well as some of the recent findings on pores and their interpretations. A need for pores in our understanding of foliar penetration and the mode of action of adjuvants is also examined.

699. Emerging Regulatory Initiatives Affecting Formulations and Adjuvants. Bernalyn McGaughey¹; ¹Compliance Services International, Lakewood, Washington, United States of America

Multiple global regulatory initiatives are maturing which now or potentially will affect chemicals used in pesticide formulations. Additional disclosure procedures, data requirements and registration actions will be examined for initiatives such as the US Environmental Protection Agency's inert ingredient data review, chemical registration under REACH (Registration, Evaluation, Authorization and Restriction of Chemicals in The European Union) in Europe and related global developments.

In addition to review of the general developments under these programs, this presentation will include exploration of how the emerging regulations might affect the chemical industry serving the adjuvant and inert ingredient sector. For example, the data development program in the United States is likely to result in cancellations or in demands for additional data. The REACH program could have similar impact or even greater burdens.

Additionally, there are several initiatives amongst environmental groups for 'full disclosure' and threats of additional action or litigation connected to this. The influence these efforts have on chemical use and registration will also be discussed.

700. Herbicide Controlled Release Formulations based on Enhanced Solubilization in Micelles Adsorbed on Clay. Dana Ziv¹, Yael Mishael¹; ¹Faculty of Agricultural Food and Environmental Sciences, Hebrew University of Jerusalem, Israel, Rehovot, Israel

Controlled release formulations (CRFs) are developed to reduce herbicide leaching which can result in soil and water contamination. We designed new CRFs for sulfentrazone (SFZ, anionic) and metolachlor (MTC, hydrophobic) based on their solubilization in cationic micelles and adsorption of the mixed micelles on a clay-mineral. Using dialysis bags, we have shown that 70% of SFZ and 40% MTC were solubilized in micelles solution. The adsorption isotherms of SFZ and MTC were of an L and C shape, respectively, which was attributed to the herbicide charge and hydrophobicity. In both cases the herbicide loading was high and the release showed hysteresis. SFZ and MTC release from the CRFs applied on a thin layer of soil was substantially slower than their release from the commercial formulations. In a soil pot bioassay, SFZ CRFs yielded 40% growth inhibition of maize while the commercial formulation yielded only 17% inhibition. A soil column bioassay showed that applying the CRF resulted in 100% weed growth inhibition at the top of the column while columns applied with the commercial formulation only demonstrated 80% inhibition. In addition the MTC released from the CRF did not reach the bottom of the column (20 cm) in contrast to MTC applied in the commercial formulation which leached to the bottom of the column. These results indicate that applying the CRFs will decrease SFZ and MTC leaching and increase the herbicidal activity.

701. Future Trends in Glyphosate Adjuvant Formulation. Curtis Elsik¹, Howard Stridde¹, R. Scott Tann¹; ¹Huntsman Performance Products, The Woodlands, Texas, United States of America

The development of many crops with glyphosate tolerance has created a large demand for glyphosate herbicide formulations. Commercial aqueous solution glyphosate formulations usually contain a surfactant along with other formulation additives. The surfactant functions to help the spray solution wet the weed surface, and can also help potentiate the active ingredient. Other formulation ingredients include materials that function as humectant, antigelling agent and antifreeze agent. Various traditional petrochemical derivatives have been used to achieve this effect. A renewable natural material, glycerin, has also been used to provide all of the non-surfactant excipient properties. Research in new glyphosate adjuvants has focused on surfactant chemistries that provide high glyphosate bioefficacy in combination with low formulation irritancy and low ecotoxicity. Glyphosate resistant weeds have also presented a new challenge for glyphosate formulators. One response to this challenge has been to investigate package mixes of glyphosate with additional active ingredients. This paper deals with recognizing the trends being established that will influence future commercial glyphosate formulation development.

702. Adjuvants for Single Drop Application of Glyphosate. Solvejg Mathiassen¹, Per Kudsk¹, Ivar Lund¹; ¹University of Aarhus, Slagelse, Denmark

Targeting weeds by single drop application of herbicides can solve several environmental problems. The dose can be reduced significantly, soil deposition and leaching are avoided and selectivity problems are overcome. The optimum adjuvant for single drop application may however be different from the one maximizing activity using conventional application technology. The objective with the present study was to study the retention and biologic activity of single droplets of glyphosate applied alone and in mixture with different adjuvants. Droplets were produced by a Drop on Demand inkjet printer designed for printing on cardboard boxes. The printer generates a liquid jet that disintegrates into single droplets before targeting the plants. A commercial formulation of glyphosate (Roundup Bio, 360 g/L glyphosate, Monsanto Denmark) was applied alone and in mixture with 0.025% Zipper (organosilicone), 0.01% Control (polyacrylamide), 0.2%, Bermocoll E 230 FQ (low viscosity grade of ethyl hydroxyethyl cellulose), 0.2% Bermocoll E 411 FQ (medium viscosity grade of ethyl hydroxyethyl cellulose), 0.025 and 0.1% Adhere (diethylene glycol). The biologic activity was examined on pot-grown *Brassica napus* and *Solanum nigrum* plants. A fluorescence dye was added to the spray solutions and retention and drop volume were measured fluorimetrically. The biologic performances of the spray mixtures were not significantly influenced by the adjuvants. Drop volumes varied significantly with a minimum of 0.3 µl for Control and a maximum of 0.6 µl for Adhere. A higher retention was obtained on *S. nigrum* compared to *B. napus* and the retention with Control was significantly higher than with the other adjuvants.

In conclusion the retention was optimized by adjuvant selection without loss of biologic activity.

703. Beneficial Effect of Adjuvants in Improving Glyphosate Efficacy. Megh Singh¹, Shiv Sharma²; ¹University of Florida, Lake Alfred, Florida, United States of America; ²University of South Florida, Brtow, Florida, United States of America

All the weeds differ in their wax content and hence absorption of chemical is different. Addition of adjuvant may help to improve the absorption and efficacy of glyphosate. Therefore experiments were conducted to examine the benefit of adjuvant on the percent control and absorption of glyphosate in weed species differing in their wax content e.g. Spanishneedles (*Bidens bipinnata*), Florida beggarweed (*Desmodium tortuosum*), ivyleaf morningglory (*Ipomea hederacea*), and Johnsongrass (*Sorghum halepense*). The relationship with the amount of leaf wax was also determined. Glyphosate at 0.21, 0.42, 0.84, and 1.68 kg a.e. ha⁻¹ in efficacy studies and only 0.42 and 0.84

kg a.e. ha⁻¹, was applied in 14C absorption studies. Percent control achieved was 95-99% in beggarweed, 88-90% in Spanishneedles, and 75-84% in Johnsongrass with 0.21 kg glyphosate (± adjuvant), which was increased to 98-100% with 1.68 kg in all the test weeds. Percent control of ivyleaf morning glory was below acceptable level even at the highest rate of glyphosate. The data indicated that 14C glyphosate absorption and translocation was significantly increased with the incorporation of adjuvant. Glyphosate absorption and translocation in the test weeds was not correlated with the quantity of wax extracted. Ivyleaf morningglory has the least amount of wax, showed less absorption (62-79%) and significantly less translocation (15-39%) of 14C glyphosate as compared to other test plants and showed maximum tolerance to glyphosate. In beggarweed and Johnsongrass presence of wax, and absorption and translocation of 14C glyphosate was higher than ivyleaf morning glory. In Johnsongrass it may be possible because the polar portion of the total wax which absorbs water soluble chemicals is as high as 93%. In ivyleaf morning glory, the amount of waxes was less, possibly the non-polar portion of the total wax may be very high resulting less uptake and translocation. The data indicated the benefit of adding adjuvant to glyphosate solution.

704. Influence of Additives and Water Conditioner on Efficacy of Glyphosate and Two Formulations of 2,4-D. Grzegorz Skrzypczak¹, Lukasz Sobiech¹; ¹Agricultural University of Poznan, Poland, ul. Mazowiecka Poznan, Poland

Adjuvants usually have multiple functions in relation to pesticide and herbicide especially efficacy. Many types of adjuvant are being used in pesticide applications, either as formulation components or as tank mix additives.

An objective of this research was to determine the influence of different additives and water conditioners on the efficacy of two formulations of 2,4-D (amine and ester) as well as glyphosate applied with hard water (350 mg/l CaCO₃).

The greenhouse experiments were conducted using 2,4-D amine and ester formulations applied postemergence at reduced rate (50% of recommended rate) to oilseed rape as tested plants with water conditioner Niagara 0,1% v/v (phosponate + triphosphonocarboxylate) or EDTA 2% v/v (versene as ethylene diamine tetracetic disodium salt), ammonium sulphate 2% v/v and citric acids 0,13% v/v. Glyphosate (100 g/ha) was applied with above-mentioned additives using two species spring wheat and oilseed rape. Visual assessment and reduction of bioassay of tested plants was determined as herbicide efficacy.

Results indicated significant reduction of grass bioassay of species as glyphosate was applied with ammonium sulphate or citric acid. When oilseed rape was sprayed the best results obtained were ammonium sulphate was added

to glyphosate. Water conditioner was generally less effective for enhancing glyphosate efficacy with hard water source.

Experiments with amine salts of 2,4-D indicated that reduced rates of herbicide was effective in decreasing fresh mass of oilseed rape when applied with all tested additives but best results observed when citric acid was used. However as esters form of 2,4-D was sprayed only ammonium sulphate and EDTA gave small improving of herbicide efficacy.

705. The Effect of New Polish Experimental Adjuvants on Herbicide Activity. Kazimierz Adamczewski¹, Krzysztof Heller²; ¹Institute of Plant Protection, Poznan, Wladyslawa Wegorka Str., Wielkopolska, Poland; ²Institute of Natural Fibers, Poznan, Wojska Polskiego, Wielkopolska, Poland

The use of spray-tank adjuvants what improves the efficacy of foliar applied herbicides is well known and there are great numbers of adjuvants available for that purpose in the word market. However, not many adjuvants are available on the Polish market. The aim of the study was to evaluate the possibility of application of three experimental adjuvants for increasing herbicide activity. A series of field and greenhouse studies were conducted to investigate whether Lenmix 800 WC (80 % of raw linseed oil + 10 % non-ionic surfactant + 6 % cationic surfactant ? A + 4 % cationic surfactant ? B) and RA 2003 (24 % non-ionic surfactant Tergitol 15-S-9 + 20 % ammonium sulfate + 6,5 % triethylamine + 49,5 % water) and RA 2005 (90,6 % non-ionic surfactant Tergitol 15-S-12 + 2,2 % triethyloamine + 7,2 % water) adjuvants could improve efficacy of post-emergence herbicides. For fiber flax combinations of Lenmix 800 EC + chlorsulfuron (Glean) in WG formulation and Lenmix 800 EC + haloxyfop-R (Perenal) and + quizalofop-P-ethyl (Targa) in EC formulation were used. For sugar beet a combination of RA 2003 and RA 2005 + triflusaluron methyl (Safari) in WG formulation was used. For spring wheat a combination of Lenmix 800 EC and RA 2003 and RA 2005 + tifensulfuron methyl + tribenuron methyl (Harmony Extra) in WG formulation was used. For maize a combination of Lenmix 800 EC + nicosulfuron (Milagro) + sulcatrion (Mikado) in SC formulation was used. Atpolan 80 EC (parafinic oil) was used as standard for experiments. The field and greenhouse soil was loamy sand. The baseline for the study was the field trials set in a complete randomised block system with four replications. In the field the weeds were emerging naturally, in greenhouse winter rape as broad leaf weed was planted and pots were watered from below, after application of the product. The trials were evaluated as usual i.e. twice - three and five weeks after treatments.

After three years of field and greenhouse trials it can be concluded that the Lenmix 800 EC generally improved the

performance of herbicides. Chlorsulfuron applied in mixture with Lenmix 800 EC in fiber flax controlled effectively the majority of dicotyledonous weeds except *Viola arvensis* and *Lamium spp.* The graminicides quizalofop-P-ethyl and haloxyfop-R applied in mixture with Lenmix 800 EC controlled better the grass species *Elymus repens* and *Echinochloa crus-galli*. The addition of the Lenmix 800 EC allowed for reduction of herbicide doses by 20-25 % without loss of efficacy. In case of spring wheat field the predominant weed species were *Chenopodium album*, *Viola arvensis*, *Ammaranthus retroflexus*, *Cirsium arvense*, *Stellaria media* and voluntary winter rapeseed. Addition of Lenmix 800 EC and Ra 2003 and Ra 2005 to half the dose (15 g/ha) of thifensulfuron methyl + tribenuron methyl (Harmony Extra 75 WG) strongly enhanced tested herbicide. In case of sugar beet field the main problem were *Chenopodium album* and voluntary winter rapeseed. In greenhouse test and three year field trials the adjuvants RA 2003 and RA 2005 used with triflusaluron methyl (Safari) strongly increased the efficacy of this herbicide, from 45 % used alone to 98 % used with additives. Lenmix 800 EC applied with nicosulfuron (Milagro) + sulcatrion (Mikado) for maize increased efficacy better than Atpolan 80 EC (parafinic oil) to control *Chenopodium album*, *Amaranthus retroflexus*, *Galinsoga parriflora*, *Polygonum aviculare*, *Echinochloa crus-galli* and *Elymus repens*. The benefits of adjuvants with nicosulfuron herbicides were especially visible on moderately sensitive weeds species and weeds at more advanced growth stages.

706. Transgenic Female Sterility: A Strategy Proposed for Control of Intractable Weeds. Brian Rector¹; ¹USDA-ARS-EBCL, Montpellier, France

A system is proposed that seeks to control intractable, invasive weeds by the action of a female-sterility-inducing gene construct that would be transformed into the genome of a target species. The construct would spread female-sterility through a target population via pollen by way of wild-type plants that would act as the female parents. This spread would be enhanced by the use of a transformation vector incorporating an active transposable element. This presentation describes the composition of the female-sterility-inducing gene construct, the theory behind the spread of induced female sterility through the target population, risk management issues, and possible candidates for control by such a strategy.

707. The Emory Center for Parasitic Plant Research: Strategies and Innovations in the Control of *Striga asiatica*. Chad Brommer¹, Andrew Palmer¹, Yue Liu¹, David Lynn¹; ¹Emory University, Atlanta, GA, United States of America

Parasitic plants are damaging weeds in many areas around the world. In Sub-Saharan Africa, *Striga asiatica* is a major constraint of staple grain crops. Yield reductions account for over 3 Billion US dollars in yield loss and contribute to a cycle of poverty. Traditional control mechanisms and herbicides have led the way in Striga control, but current revolutions in bioinformatics and molecular biology/biochemistry have now redefined the ways agronomists might control parasitic weeds.

Striga control strategies were not necessary in North America until the 1950s when *Striga asiatica* plants were discovered in sites bordering North and South Carolina. The developed control mechanisms included cultural, mechanical, and chemical. The USDA/APHIS teams, in conjunction with the North and South Carolina scientists, initiated an eradication system using ethylene injection into soil contaminated with Striga seeds. This control mechanism used the basic science of Striga seed germination mechanisms to reduce seed stock. Herbicide resistant crop seeds are used in conjunction with herbicide and trap crops have also been used to control the spread of Striga.

Research in the area of Striga germination, haustoria development and host attachment have opened the way for biotechnology and bioinformatics to revolutionize the agronomic approaches to control parasitic plants such as *Striga asiatica*. Research is being conducted in the Emory CPPR to identify signal transduction chains between host and parasite and the basic physiological mechanisms of the parasite life cycle to identify unique site of action for parasite control. Approaches to control Striga and other parasitic weeds include the potential use of host-delivered RNAi, the possible use seed treatments to restrict Striga germination or attachment, novel allelochemical delivery to soil borne Striga seeds, and the potential for altering the host plant's chemistry to regulate the Striga life cycle.

708. Invasive Weed Management and Plantback Crop Response With The New Herbicide KJM-44. Philip Westra¹, Scott Nissen¹, Dale Shaner¹, Todd Gaines¹, Robert Wilson²; ¹Colorado State University, Fort Collins, Colorado, United States of America; ²University of Nebraska, Scottsbluff, NE, United States of America

KJM-44 is a new herbicide under development by Dupont for potential use in a variety of weed control settings. Initially the herbicide appears to have great potential for control of many perennial invasive weeds or shrubs in non-cropland settings. Field and greenhouse research shows that KJM-44 has excellent activity at relatively low application rates on Canada thistle, field bindweed, leafy spurge, Russian knapweed, Scotch thistle, Russian olive, and salt cedar. Many desirable restoration grasses show tolerance to KJM-44 which suggests this will be a good candidate for non-cropland invasive weed control where long-term restoration is desired. Studies were conducted in CO and NE in 2006-2007 to evaluate

the plantback response of several agronomic crops to KJM-44 in the soil. Several rates of KJM-44 were applied to soil in replicated plot studies in mid 2006. In the spring of 2007, crops such as spring wheat, corn, sunflowers, alfalfa, and soybeans were planted, grown to maturity, and in some cases harvested for crop yield. Grain corn and sunflowers exhibited very good to good tolerance to KJM-44. In NE, spring wheat was most sensitive followed by alfalfa, and then soybeans. Some crops exhibited high yield losses when planted into plots treated with the highest rates of the herbicide. Crop injury to follow crops sometimes became most evident when crop yields were obtained.

709. Current Trends of Biotechnology in Weed Management. Puja Ray¹, Durga Ray², Akhilesh Pandey²; ¹National Research Centre for Weed Science, Jabalpur, Madhya Pradesh, India; ²R.D. University, Jabalpur, Madhya Pradesh, India

Current application of biotechnology in agriculture have already resulted in increased yields, reduced pesticide use and saving of farmers time and money by using techniques like recombinant DNA, genetic engineering, tissue culture, clonal propagation, monoclonal and polyclonal antibodies, etc. Currently biotechnology also offers promising approaches to solve the emerging problems in weed control.

There is a great incentive to discover effective, economically feasible and environment friendly herbicides. Myco-herbicides containing plant pathogens such as rusts and fungi are like specie-specific natural herbicide by which augmentation of a disease by massive inoculation of the weed with the pathogen is done. Some of the bioherbicides commercially released include ABG5003, DeVine®, Casst, etc.

Naturally occurring phytotoxic compounds derived from plants like *Lantana camara* and *Parthenium hysterophorus* have allelopathic potential against weeds. Similarly bacterial byproducts like Bialaphos, isolated from *Streptomyces* spp and toxins of fungal origin like A-AL toxin from *Alternaria alternata*, Fumonisin from *Fusarium moniliforme*, etc, exhibit strong herbicidal activities against a wide spectrum of weeds.

Chemical substances like pheromones and kairomones are produced and released by a living organism with the effect of carrying a message to other individuals of a same and different species respectively. These can be artificially used in attracting the insect biocontrol agents to a desired location for enhanced weed control. Kairomone present in waterhyacinth is liberated by injuring the plants. Such plants attract the adult *Neochetina eichhorniae* more than the uninjured plants.

Application of tissue culture and genetic engineering into plants to make them transgenic with resistance to herbicide and weed allelopathy is again a significant

application of biotechnology in weed management. The particular advantage that genetic engineering offers is that the desired genes can be transferred without co-transfer of undesired characters and it enables transfer of genes across species barrier. Herbicides resistant crops containing transgenes that impart resistance to non-selective herbicides such as glyphosate have been of considerable benefit. These products help the farmers to eliminate use of some of the more environmentally unsafe herbicides and use fewer herbicides to manage nearly entire spectrum of weeds.

The application of biotechnology to enhance the potential of biocontrol agents will undoubtedly lead to better control options that will compete successfully with their chemical counterparts. Several bacteria, fungi, viruses and insects are being used to control different weed under various conditions. Biocontrol agents may become more effective as well as safer when rendered hyper-virulent yet non-problematic by biotechnology. Further by using fermentation technology several potential phytopathogens including bacteria and fungi are being multiplied in large quantities.

Thus application of biotechnology holds great promise in improving already existing biocontrol practices as well as adding new dimensions to the same.

710. Plant Collections – A Community Solution to Cultivated Plant Information. Tracy Mehlin¹, Boyce Tankersley², Min Henderson², Christopher Dunn³, Dan Stark⁴, Pamela Allenstein⁴, David Vieglais⁵, Greg Riccardi⁶; ¹University of Washington Botanic Garden, Seattle, WA, United States of America; ²Chicago Botanic Garden, Chicago, IL, United States of America; ³University of Hawaii Lyon Arboretum, Honolulu, HI, United States of America; ⁴American Public Gardens Association, Wilmington, DE, United States of America; ⁵University of Kansas Natural History Museum and Biodiversity Research Center, Lawrence, KS, United States of America; ⁶Florida State University School of Computational Sciences, Tallahassee, FL, United States of America

Over 2,000 botanic gardens and arboreta are thought to exist world-wide. Botanic gardens and arboreta fulfill a number of roles in society: as living museums; plant introduction facilities serving ornamental horticulture, agronomy and agriculture crops; ex situ conservation of endangered species; sources of plant and ecological information for a wide range of education levels; sources of plants/plant parts for research scientists; as places of beauty and relaxation, among others. Supporting all of these roles is the information collected and stored within their plant record databases, some of it spanning centuries of plant collecting and plant introduction efforts around the globe.

PlantCollections - A Community Solution was funded by an Institute of Museum and Library Services (IMLS) National Leadership Grant in the Building Digital

Resources division to provide access over the World-Wide-Web to these warehouses of information that previously were inaccessible. The audiences (data users) surveyed to determine information needs at the beginning of the project included weed scientists, botanic garden and arboretum curators, taxonomists, ecologists, conservationist, horticulturists, educators and gardeners.

PlantCollections is the beginning of a systematic inventory of the plants currently in cultivation in botanic gardens and arboreta that bridges technology, nationality, language and cost concerns. It is based upon a sustainable technology design that encourages expansion of the project. Among the benefits to scientists studying weedy plants are the following:

Scientists interested in the origins and relative weediness of cultivated plants have a new resource, PlantCollections, from which they can access decades of data collections made in botanic gardens and arboreta.

Plants with a weedy history are identified as 'spontaneous' or 'weedy' in the botanic garden records. This data, up to this point unpublished, provides insight into weedy tendencies (or lack thereof) of a very large number of taxa (47,000).

Environmental and biological data associated with wild plant collections is provided and can be compared/contrasted with their cultivated environmental conditions to identify plants exhibiting weedy tendencies and correlate this information with their native ranges.

Data users may search records from all institutions or identify specific institutions of interest.

PlantCollections is a new tool available to scientists in a number of plant science disciplines that permits multiple databases to be simultaneously queried and the responses collated to create reports, maps and collections of images.

711. AgroPhone[®], a Novel Diagnostic Tool Optimizing Identification and Control of Noxious Weeds. Christian Andreassen¹, Elo Larsen²; ¹University of Copenhagen, Faculty of Life Sciences, Copenhagen, Denmark; ²AgroCom, Kommunikation og Rådgivning, Stubbekøbing, Denmark

A new reference and diagnostic tool, AgroPhone[®] optimizes early identification of noxious weed and decision making regarding weed control.

The solution has been developed for modern mobile phones and consequently farmers have access to all available data when scouting his/hers fields. Therefore, the AgroPhone[®] software offers a unique tool for information transfer and virtually real time decision making in the field situation. Furthermore, it is applicable in both developed and less developed parts of the world because it is mediated by an already well dispersed technology. In accordance with this, the user friendly interface allows identification based on graphic elements, photos as well as text.

The application supports identification of weed species at the 2-4 true leaf stage. Decision making is aided by information about weed biology, occurrence, possibilities of confusion with other species, and listing of optimal control measures. Additionally a web based import of local climate data will be implemented.

Currently the application contains 45 weed species with images of their cotyledons, their juvenile stages as well as their flowering stage. The collection of weeds can however easily be extended.

The application is flexible and can be customized to regional or national weed populations. In addition, the application includes other aspects of plant protection such as identification and control of insect pests and crop diseases.

The application is available from the web site www.agrolearn.com from where it may be downloaded and installed directly on various mobile phone models.

712. The Relationship between Swainsonine and Endophyte Content in Different Plant Parts of Two Species of Locoweeds. Daniel Cook¹, Dale Gardner¹, Jim Pfister¹, Jessie Roper¹, Mike Ralphs¹, Kevin Welch¹, Ben Green¹; ¹USDA ARS Poisonous Plant Research Laboratory, Logan, Utah, United States of America

Locoweed poisoning is one of the most widespread poisonous plant problems in the western United States. Locoweeds are *Astragalus* and *Oxytropis* species that contain the toxic alkaloid swainsonine. Recently a fungal endophyte found in these plant species has been implicated in the synthesis of swainsonine. The objective of this study was to develop a quantitative PCR method to quantify the fungal endophyte in *Astragalus mollissimus* and *Oxytropis sericea*, thus enabling a better understanding of the role of the endophyte in swainsonine production and their relationship in different plant parts. We report here that swainsonine accumulates in all parts of the plant in both species with the highest concentrations found in the above ground parts of the plant. In addition, the endophyte can be found in all parts of the plant in both species; however, the concentration of the endophyte did not correlate with the corresponding levels of swainsonine in individual plant parts. Furthermore, we identified two groups of *Oxytropis sericea* plants that accumulate significantly different amounts of swainsonine in all tissues. The plants with the lowest concentration of swainsonine were found to have lower amounts of the endophyte. Finally, the results of this study suggest that the crown and root serve as a reservoir of the fungal endophyte for the following year's growth. In conclusion, this PCR-based technique may be useful in identifying and characterizing plant endophyte relationships for locoweed and should be relevant for identifying and quantifying both symbiotic and pathogenic fungi in other weed systems.

713. Genome-Wide Analysis of the Nitrogen Stress Transcriptome of Red Rice (*Oryza sativa* L.). Marites Sales¹, Nilda Burgos¹, Benildo De los Reyes², Vinod Shivrain¹, Kil Young Yun²; ¹University of Arkansas, Fayetteville, Arkansas, United States of America; ²University of Maine, Orono, Maine, United States of America

Red rice is a noxious weed that is difficult to control in rice production systems due to its genetic similarity to cultivated rice (*Oryza sativa* L.). Red rice competes with rice for nitrogen, the most growth-limiting nutrient. Red rice uptake of half the N requirement in rice reduces yields and lowers economic returns from N fertilization. We hypothesized that red rice will accumulate more N and produce higher biomass than rice because of adaptive molecular mechanisms absent from rice. This study was conducted to: 1) compare responses of red rice and 'Wells' rice to different N conditions; and 2) analyze the red rice transcriptome at different N conditions. Understanding gene responses to N stress is essential in developing high-yielding rice cultivars requiring less N input.

Greenhouse experiments were conducted in 2006 and 2007. Experimental design was a split-plot replicated four times, main plot being rice type and subplot being N treatment implemented at panicle initiation [T1 (Full N); T2 (N starvation); T3 (24-h N supplementation); and T4 (48-h N supplementation)]. Data collected were height, tiller number, biomass, root morphology, shoot concentrations of N and other essential nutrients, and soluble sugars. Data were subjected to analysis of variance and significant means separated ($\alpha=0.05$). For transcriptome analysis, three microarray experiments on two biological replicates were performed. Total RNA extracted from youngest fully expanded leaves was used to synthesize cDNA by reverse transcription. Amplified RNA (aRNA) was synthesized from cDNA by *in vitro* transcription and labeled with fluorescent dyes; Cy3-labeled aRNA from one treatment was mixed with Cy5-labeled aRNA from another treatment. The aRNA mixture was hybridized to 60-mer rice oligo arrays representing ~45K genes. Transcript regulation was expressed as the ratio of dye signal intensities between two different N conditions (T1 T2; T2 T3; T2 T4). Red rice was taller, had more tillers and root tips, finer roots, and higher N and biomass than Wells in both years. Sucrose in red rice was more responsive to N levels than in Wells. These findings suggest a differential response to N stress, which implicates sucrose as a signaling molecule. Preliminary genomic analysis of likely stress response networks revealed that genes involved in chlorophyll synthesis, sucrose/starch synthesis, ammonia assimilation, the pentose-phosphate pathway, and plant defense were differentially expressed. Functional classification of responsive genes is ongoing.

714. Effects of Competition Control and Fertilization in a *Pinus elliotii* Stand on a Deep Sand in the Coastal Plain of

Georgia, U.S.A. Ernest Dickens¹, David Moorhead¹, Mike Hayes¹, Bryan McElvany¹; ¹University of Georgia, Statesboro, Georgia, United States of America

Pinus elliotii (Engelm.) does not grow well on excessively well drained deep sands in the Coastal Plain region within its native range of the southeastern United States of America (U.S.A.). However, many acres of these droughty, infertile soils are planted in *Pinus elliotii* pine. The objective of this study was to determine if fertilization, herbicide use, or the combination would significantly improve growth and economic value of *Pinus elliotii* growing on low fertility, excessively well drained deep sands. Diameter, height, volume per tree, total volume per hectare, product class distribution, and economic value per hectare changes were quantified during a four-year study period.

The study area was planted with *Pinus elliotii* pine seedlings in 1984. The soils were delineated as predominantly Foxworth and Lakeland series (excessively well drained Typic Quartzipsamments). The most common understory and midstory hardwood competition species at time of treatments (March 2002) were *Crataegus* sp., *Quercus nigra*, *Quercus laevis*, *Diospyros virginiana*, *Quercus stellata*, *Prunus serotina*, and *Magnolia virginiana* in order of occurrence. *Vaccinium arboreum* and *Sabal palmetto* were the common shrub species present. The experimental design was randomized complete block with three replications per treatment. Treatment means were tested for significant differences using Duncan's Multiple Range Procedure at the 5% alpha level. All trees within each measurement plot were measured for diameter at 1.4 m (dbh), live crown length, and total height pre-treatment, and 2- and 4-years after treatment. Total volume per tree, total volume per hectare, product class distributions, and value per hectare were estimated. Plot treatments were: control (no treatment), NPK fertilization only, herbicide only, or the fertilization+herbicide combination. Treatments were randomly assigned to the plots. All treatments were applied on 22 March 2002. Foliar sampling and analysis taken prior to fertilization and herbicide application indicated N, P, and K concentrations at or below sufficiency. Soil available P was slightly above sufficiency prior to treatments.

Results after four years indicate the following. Woody competition control with the herbicide ranged from poor (*Sabal palmetto*) to excellent (*Quercus* species and *Crataegus* sp.). There were no significant increases in soil available P or foliar nutrient status with the NPK fertilizer, herbicide, or herbicide+fertilizer treatments. Two and four year mortality was excessive in the herbicide+fertilizer treatment (14%) compared to the other treatments (2% to 3%). Four year diameter growth was significantly greater in the fertilizer and herbicide+fertilizer treatments than in the control and herbicide treatments. There were no significant gains in height, live crown ratio, volume per tree, total volume, pulpwood, or superpulp volume per

hectare growth with the fertilizer, herbicide, or herbicide+fertilizer treatments compared to the control. Economically, wood value increases over the control ranged from \$55 to \$142 per hectare with the treatments.

715. Effects of Vegetation Management and other Forestry Operations on Carbon Sequestration by Intensively Managed Boreal Jack Pine Plantations - Ontario Long-Term Soil Productivity (LTSP) Study. Phillip Reynolds¹, Gordon Brand¹, Thomas Weldon¹, Neil Foster¹; ¹Canadian Federal Government, Sault Ste. Marie, Ontario, Canada

The Ontario Long-Term Soil Productivity (LTSP) Study was established in 1993 to examine the effects of harvesting and other site preparation techniques, inclusive of vegetation management, on long-term productivity (i.e., yield, biomass, Carbon sequestration) of either jack pine (*Pinus divaricata*) or black spruce (*Picea mariana*) plantations. This study reports on six replicated 10-year old jack pine plantations located within north-central Ontario. Original jack pine plantations were harvested [full-tree (FT) or tree-length (TL)], mechanically site prepared by various techniques [disc-trenching, blading (B) to remove topsoil (windrows), or no site preparation (SIP)], and treatment plots were then sub-divided into herbicided or non-herbicided sub-plots. Additionally, other plots were compacted (C) to simulate the effects of heavy equipment operations during harvesting or mechanical site preparation. The overall hypothesis of the LTSP study, a component of the larger North American LTSP study, being directed by the U.S. Forest Service, is that soil compaction or nutrient removals seriously impact future stand productivity, and presumably Carbon sequestration. For the present study, basic small plot treatments consisted of no SIP (controls), FT or TL harvesting with standard disc-trenching, and post-harvest planting on soil compacted plots (C) with or without blading (B). Additionally, each of the plots was divided into sub-plots either herbicide released annually to control weeds or no herbicide release. Objectives of this study were to 1) quantify jack pine gas exchange differences among treatments or sub-treatments for 10-year old plantations and 2) to ascertain if treatment differences affect Carbon sequestration on a stand or landscape scale. To assess these differences, gas exchange [stomatal conductance (Gs), transpiration (E), net assimilation (NA), and environmental parameters (temperature, humidity, CO₂ concentrations)] were measured in May and August at all six locations using a Li-Cor 6200 Photosynthesis System, along with soil moisture and plant water potential. Additionally, plot leaf areas were determined using a Li-Cor LAI-2000. Using measured gas exchange parameters, water use efficiencies were calculated as actual, AWUE = NA/E or as intrinsic, IWUE = NA/Gs. Mesophyll conductance (G_m = NA/mesophyll CO₂) was also examined. For both measurement times, consistent treat-

ment differences were observed at several locations. These consisted of the following: 1) stomatal conductance and transpiration were higher for compacted and bladed plots than for other treatments, with no SIP plots generally being intermediate, and full-tree and tree-length plots being lowest; 2) concurrently, both actual and intrinsic water use efficiencies were higher for FT and TL plots than for other treatments, with no SIP plots remaining intermediate, and C and B plots being lowest; and 3) basic rates of NA did not tend to differ among treatments. When herbicide effects were assessed, only transpiration differed significantly. Additionally, the foliage of trees in C and B plots was less vigorous (less leaf area) than those in FT or TL plots, and morphological appearance differences for trees were evident for the differing treatments. These foliage differences were paralleled by measurable differences in plot leaf areas as determined by the LAI-2000. Measured leaf area index (LAI) for the various treatments was a very good surrogate for mean needle leaf areas. These leaf area differences for differing treatments, coupled with similar NA rates for all treatments, equate to differing amounts of Carbon sequestration on a stand basis, depending upon prior operational treatments, and also translate to landscape differences in Carbon sequestration dependent upon prior harvesting or stand site preparation techniques used. We therefore predict that FT or TL harvesting, followed by disc-trench site mechanical site preparation, with avoidance of blading, and attempts to minimize soil compaction, will all lead to substantially greater Carbon sequestration by these intensively managed plantations. We also would hypothesize that higher transpiration and stomatal conductance in compacted and bladed plots, where trees have less foliage area than in FT or TL plots, is a likely plant compensation mechanism, allowing trees to have comparable Carbon fixation rates regardless of treatment. Even so, even with comparable C fixation rates, actual Carbon sequestration rates on a stand or landscape scale can still be expected to differ significantly, and do, dependent upon measured leaf areas associated with these stands.

716. Performance of *Eucalyptus dunnii* as Influenced by Vegetation Control when Felled at Nine Years, South Africa. Keith Little¹; ¹Institute for Commercial Forestry Research, Pietermaritzburg, KwaZulu-Natal, South Africa

In 1997, a trial was initiated to determine the impact of eight vegetation management treatments on the growth of *Eucalyptus dunnii* (Maiden) at a warm temperate site in the KwaZulu-Natal Midlands, South Africa. The treatments included variation in the area around the tree that was weeded, the type of vegetation controlled (selective weed control) as well as the planting of of *Ipomoea batatas* L. (sweet potato) cuttings as a cover-crop. There was a Weedy and Weed-free check, a 1.2 m and a 2 m Row weeding, a Broadleaves treatment (grasses only con-

trolled), a Grasses treatment (broadleaves only controlled), and the planting of sweet potato cuttings at 20 cm intervals, 1.5 m from the tree rows (16 667 cuttings ha⁻¹). Manual weeding was carried out to aid establishment of the sweet potato treatments, after which the vines were allowed to developed unchecked across the plot (Sweet potato), or the vines were kept 0.6 m from each tree (Sweet potato 1.2 m). The treatments, imposed from the time of planting, were maintained until canopy closure (14.5 months). Tree growth was monitored throughout the rotation and this together with the cost of the various weeding operations during establishment was used to make comparisons between the treatments. The dominant weed species on the site, *Acacia mearnsii* De Wild (black wattle) resulted in the early (from 88 days after planting) and sustained suppression of tree growth in those treatments where it occurred (Weedy check and Broadleaves). This resulted in a significant reduction of 54 and 41 % in merchantable volume of these treatments when compared to the Weed-free check at rotation end (9.2 years). No significant differences in tree volume were detected between the Weed-free check and the five other treatments, although there were differences associated with their weeding costs. In principle, the planting of sweet potatoes to aid as an inter- and cover- crop was successful (weed suppression, whilst not causing a reduction in tree volume), however innovative, cost-effective ways will need to be tested before they can be considered as a viable alternative to the use of herbicides. In contrast the 1.2 m and 2 m Row weeding treatments provided a cost-effective alternative to the Weed-free check, together with the added benefit of reduced herbicide use. Due to a sparse cover, the Grasses treatment did not have a negative impact on tree growth at this site. However, the abundance of grasses during re-establishment on the majority of eucalypt sites in South Africa would mean that unless past knowledge of species occurrence is known, this treatment would not be recommended.

717. Development of a Decision Support System to Optimise forest Vegetation Management Across an Environmental Gradient. Michael Watt¹, Brian Richardson¹, Wayne Schou¹, Mark Kimberley¹; ¹Scion, Christchurch, Canterbury, New Zealand

Introduction.

Development of accurate tree growth models sensitive to competition from weed species would enable plantation managers to make informed decisions regarding vegetation management. Most models developed to date have been empirical. Although these empirical models are simple to parameterise and provide reasonable estimates of growth at a regional level, the empiricism implicit within them restricts their general applicability and capacity to elucidate the mechanisms of competition influencing tree growth.

Development of more biologically realistic and generally applicable growth models requires specific knowledge of the mechanisms of interaction between trees and competitors. Research has shown that simple competition indices can be used to account for competition for light, while the effects of weed competition for water can be modelled using a simple water balance model.

The aims of this study were to (i) develop a hybrid tree growth model, incorporating these competition modifiers for light and water, which is sensitive to competition from a diverse range of weed species (ii) parameterise and validate this model using data from a nationwide series of 24 plots covering an extensive environmental gradient (iii) incorporate this model into an existing broader vegetation management (VMAN) modelling framework, which includes an integrated system of modules linked through to an economic analysis (iv) using this upgraded version of VMAN run a series of simulations which describe how the model can be used to optimise the economic efficiency of weed control on sites with varying climate.

Methods.

Overall modeling approach.

Tree diameter in plots with weeds, over the first three years following establishment, was predicted by reducing potential growth from an empirically determined optimum rate for the site (weed-free) using a competition modifier, which accounts for the degree of weed competition for both light and water availability. This was modeled using the difference form of the Weibull equation as,

$$D_t + \dot{A}t = D_t + [f(f-1(Dt) + \dot{A}t) - Dt]mC(1)$$

where D is tree diameter, t is time, mC is the product of competition modifiers for light (mL) and water (mw) and $f-1(Dt)$ is the inverse of the Weibull equation.

The competition modifier for light is best described using the following,

$$mL = 1 - (1 - e^{-z_1 cL})^{z_2(2)}$$

where z_1 and z_2 are empirically determined parameters and the competition index, cL , is the quotient of mean weed height (hw) and mean tree height, (ht).

The modifier for water, mw , was modelled by,

$$mw = 1 - (1 - e^{-z_3 \dot{e}d})^{z_4(3)}$$

where z_3 and z_4 are empirically determined parameters and $\dot{e}d$ is the treatment difference in average fractional available root-zone volumetric water content, $\dot{e}a$, between trees growing with weeds and trees of an equivalent leaf area growing without weeds.

Using the methods fully described in Watt et al., (2007) fractional available root-zone volumetric water content, $\dot{e}a$, in both treatments on day i ($= [(W_i - W_{min}) / (W_{max} - W_{min})]$) was calculated from estimates of daily, W_i , maximum, W_{max} , and minimum, W_{min} , root-zone water storage.

Daily meteorological data required for the water balance model includes total rainfall and solar radiation, minimum and mean air temperature, and average air saturation deficit. The model also requires seasonal estimates of leaf area index, maximum available soil water

storage, and five other parameters, which have been determined in a previous detailed study (see Watt et al., 2007 for details).

Equation 1 was fitted to tree diameter in plots with weeds. Using a similar methodology the equation was also used to predict tree height in plots with weeds.

Integration of the model into Vegetation manager (VMAN).

Integration of the model described above allows VMAN to be used spatially to model the effects of weed competition on tree growth at both wet and dryland sites. To incorporate the model we rescripted VMAN so that it included a water balance model. The water balance model was parameterised for the user from imported values of all requisite meteorological data, and maximum root-zone water storage.

After incorporating the model describing weed competition for water and light into VMAN we used VMAN to run a number of simulations which describe how the model can be used to optimise the economic efficiency of weed control on sites with varying climate.

Results.

Across the national plot series, Equation 1 accounted for 96% of the variance in diameter of trees growing in plots with weeds. A cross validation of this model indicated it was unbiased and relatively accurate ($R^2 = 0.92$).

Simulations from the revised version of VMAN will be presented at the conference.

Conclusions.

Equation 1 provides a sound framework for modelling the influence of a variety of weed species on young tree growth across a broad environmental gradient. The revised VMAN modeling system provides a useful means of determining the optimal treatments for maximizing returns to the grower, across a broad environmental range.

718. Ecology, Biology and Control of Some Exotic-Invasive Weeds on Federal Lands and Coastal Forests in British Columbia, Canada. Raj Prasad¹, J. Benner¹, S. Bundel¹; ¹Pacific Forestry Centre, Victoria, BC, Canada

Scotch broom (*Cytisus scoparius*), Gorse (*Ulex europaeus*), Daphne (*Daphne laureola*), and English ivy (*Hedera helix*) are four prominent, invasive plants that pose a serious threat to Garry oak and associated ecosystems on federal lands in Victoria, British Columbia. These plants colonize disturbed areas quickly, form dense monospecific stands, remain persistent for a long time and defy any easy eradication program. They suppress and inhibit the growth of native plants and ultimately arrest forest succession. Several federal departments including the Department of Environment, Department of National Defence, Department of Fisheries and Oceans, Department of Indian Affairs and Parks Canada have expressed great concerns regarding their rapid incursion, adverse

impacts and the resulting degradation of native habitats. With a grant from the Department of Environment and the Department of National Defence, we conducted research to examine the population dynamics, phenology and control methods of these invasive plants on federal lands near Victoria, B.C. Of the several methods of control tested, including manual cutting, application of a registered herbicide (Release- triclopyr), a fungal bioherbicide (*Chondrostereum purpureum*), and a commercial plastic mulch, it was found that some treatments (mulch and herbicide) provided 100% efficacy on resprouting behaviour of all four invasive species. While one bioherbicide (*Fusarium tumidum*) was very effective on Scotch broom under the greenhouse conditions, it was not applied under field conditions. The other bioherbicide (*Chondrostereum purpureum*) produced a variable response when applied under the field conditions. Manual cutting was found to be the least effective. Also a novel prospective bioagent (*Phomopsis* sp. denovo) was isolated from dying and dead samples of Daphne from the field and results from laboratory, greenhouse and field conditions suggest that it may hold great potential for control of Daphne. Continued and additional research is necessary to determine the appropriate formulations of these bioagents as well as the effectiveness of the different and integrated control treatments over a period of years. A new technology using superheated water (Aquacide) to kill vegetative shoots of gorse did not offer long term control nor was it found to be cost effective.

719. Biological Control of Competing Forest Vegetation with Sheep and Goats in British Columbia, Canada. Jacob Boateng¹; ¹BC Ministry of Forests and Range, Victoria, British Columbia, Canada

Experience in British Columbia (BC) has shown that sheep grazing method, used alone or in combination with other treatments, is an effective operational option for control of vegetation on some forest regeneration sites. This method of biological vegetation control was first used operationally on young forest plantations in BC in 1990 and continues as a program today. The sheep grazing program had its highest level of activities in 1994 with nearly 9,500 ha of young plantations brushed using 45,000 sheep. Since 2004, forest grazing with goats has also been tried operationally, and seems to hold some promise. The program has played some major role in BC where approximately, 77,500 ha of forest plantation sites had been brushed using sheep and goats between 1991 and 2006. This area represents 7.4% of the total forest vegetation management activities in BC during that period. This presentation will discuss activity trends, operational accomplishments, environmental issues and concerns relating to using domestic sheep and goats in forest settings, as well as the policies, guidelines, sheep and goat health protocols, and field monitoring criteria that

have been developed and implemented to address the issues and concerns relating to animal health, wildlife-carnivore interactions, and the environment. Our experience has demonstrated that for a successful operational grazing program of sheep or goats, there is a need for cooperation and participation of staff from various government agencies field vegetation management foresters, sheep and goats producers, grazing contractors, shepherds, veterinarians, and program monitors.

720. Empirical Characterization of Nonindigenous Species Metapopulation Dynamics In Forest Ecosystems. Bruce Maxwell¹, Jay Rotella¹, Patrick Lawrence¹, Lisa Rew¹; ¹Montana State University, Bozeman, Montana, United States of America

Estimating the invasion potential of nonindigenous species populations could be important for prioritization of management. Results from theoretical based simulation models suggested that identification of source populations and subsequent targeting those populations for management would be the most effective means of slowing an invasion. Continuous sampling along transects with a GPS through mixed forest and meadow regions was found to be the most efficient way to identify occurrence of infrequent nonindigenous herbaceous plant species. Probability of occurrence maps for each species based on many geographic variables could easily be constructed and serve as a mechanism to direct further searching for populations because only small portions of large management areas can be sampled under limited budgets. Initial transects were observed in 2001 and 2003 and observed again in 2007 to determine changes in occupation (presence/absence) of *Cirsium arvense*, *Linaria dalmatica* and *Alysum desotorum* in a 153,000 ha portion of the northern range of Yellowstone National Park, USA. The presence/absence data was analyzed using multi-state Markov models (msm package in R version 2.6.0) to estimate transition probabilities for establishment of new populations, extinction of existing populations, continued occupation of existing populations or continued non-occurrence of populations. Probability of occurrence (POO) as a measure of habitat suitability and distance from roads and trails were included as covariates of the transitions. Inclusion of POO as a covariate of the Markov transitions generally improved the models and was positively related to colonization and longevity of populations, and was negatively related to population extinctions.

721. Global Changes in Crop Production and Impact Trends on Innovation In Weed Management - An Industry View. Hermann Stuebler¹, H Kraehmer¹, M Hess¹, A Schulz¹, C Rosinger¹; ¹Bayer CropScience AG, Frankfurt, Hesse, Germany

1. Increasing demand for agricultural commodities

Media have reported extensively about acute shortages of agricultural raw materials, the growing demand for plants as a source of energy and about rising commodity prices in recent months. This is a reflection of the increased public attention on the recent drastic changes in global agriculture.

The discussion about increasing cultivation of crops for the supply of biofuels and energy is probably only one aspect and not the sole decisive factor in the overall increase in the demand for agricultural products. The increased use of bioenergy and of agricultural commodities as well as recent shortages of agricultural raw materials have led to premium prices for many agricultural products. Pricing on the international raw material markets becomes free from constraints caused by quotas, subsidies and intervention. Agricultural commodity prices are additionally heavily influenced by the increasing oil prices. This new situation offers now enormous opportunities for farmers but is also going to confront input and processing industry with major challenges. The fundamental factors driving this longer term development in agriculture are of quite diverse nature and will be discussed below.

Growing world population

Although at a somewhat slower pace, the global world population continues to grow. Current forecasts of the United Nations predict the world population to grow from ca. 6.7 billion beginning 2008 to ca. 9 billion by 2050. Between 2000 and 2030 the world urban population is expected to increase by 72%. It should be noticed that between 1950 and 1985, as the so called "green revolution" transformed agriculture around the globe, world agricultural production increased by 250%. The basis for this "green revolution" was provided by progress in science and technology and the consumption and transformation of fossil fuels. Plant breeding progress, fertilizer and chemical crop protection technologies contributed significantly to continuously improve yields. Consequently, the upcoming decades will provoke an increased challenge to agriculture and logistics.

Limited arable land

Land is a limiting resource in most countries. Only about 11% of world's land surface is used for crop production, including cultivated land under permanent crops. In Southeast Asia, East Asia and Europe, most suitable land areas are already used for agriculture and there is little scope for expansion. In developing Asia, increasing demand for a rapidly changing food basket will need to be matched by increasing yields. The availability of agricultural land per person will globally continue to decrease over the next decades. Current forecasts published by the United Nations show that the amount of agricultural land available worldwide is likely to remain stable at 1.5 billion hectares. This would mean that the available area per person would probably diminish to only about 0.16 hectare by 2050.

Growing wealth

Another important factor triggering rising demand for agricultural commodities is the increasing economic growth and prosperity, which is changing consumer habits. Per capita consumption of meat in developing countries and emerging economies is approaching the level of industrialized countries. It leads to a greater demand for animal protein. Consequently, an increasing proportion of the world's grain harvest is being used to feed animals. Global meat production is projected to more than double from 230 mio. tons in 2001 to 465 mio. tons in 2050. Global milk output is assumed to climb from 580 to 1043 million tones. Livestock currently requires 30 % of the earth entire land surface, mostly permanent pasture, but also including 33 % of the global arable land used to produce feed for livestock.

Obviously, the continuous economic growth in China and India is triggering globalization effects and the worldwide availability of technologies and know-how. It is expected that this trend will continue for the future, albeit at slightly slower growth rate.

Climate change

Climate change is one of the most critical global challenges of our time. 11 of the last 12 years rank among the warmest years with regard to global surface temperature since 1850. The rate of average warming is increasing. Studies in different parts of our world predict the increase of temperatures in today's key crop production areas will continue. This effect is accompanied by a decrease in annual rainfall. It is of special concern that erratic weather changes as e.g. short-term droughts, floodings, etc. will severely endanger stable crop production.

Fossil fuels are the single biggest source of humanity's green house gas emissions. In this respect, restoring carbon in soil offers a huge mitigation potential for agriculture. Reducing and avoiding green house gases must be an important objective for environmentally focused agricultural research.

Need for alternative energy supplies

With the increase of oil prices and the dependence of many industrialized countries on imported fuel, the interest in the use of renewable resources for fuel production has increased significantly. In order to reduce the dependence on crude oil, governments in many countries have implemented specific policies to support the exploitation of renewable energies. These policies are focusing as well on new emerging energy sources provided by agriculture. Due to rising oil prices, the use of grains and oil seeds for ethanol and bio-diesel production, respectively, has grown dramatically. For example, in 2007/08 the US is projected to use 86,4 million tons of corn for ethanol production. This is an increase of 58 % from 2006/07. The share of US corn used for ethanol production was 5 % in 1985, 15 % in 2005 and is forecasted to be at 30 % in 2010.

According to the international energy agency, 20 trillion US dollars are expected to be invested in upgrading global

energy infrastructure from now until 2030. The major reason for this is the rising energy demand, which will grow by about 60 % within this time frame. In this respect, renewable energy from agriculture will play a significant role. Increasing research efforts to improve transformation efficiency of agricultural biomass to bio-fuel is therefore justified without any doubts.

The production of bio-diesel in Argentina is assumed to rise from 26.5 million liters in 2005/06 to about 230 million liters over the next several years. In Brazil, 51 % of the sugar cane harvest has been used for ethanol production in 2006/07. For the season 2007/08, the production of the ethanol is forecasted to increase further by 15 %.

The increased consumption of agricultural commodities for food, feed and energy is currently exceeding annual production.

Global grain and seed inventories are continuing to decline significantly. At the moment, the global wheat stockpile is at a 25 years low. Cereal harvests in some countries have been lower than expected in 2007 and are further reducing the supply of wheat. Actually, counter-measures have been taken to increase cereal production in Europe and the Americas by e.g. taking set aside land back to production.

In response to recent shortages of agricultural raw materials, prices have risen sharply. Prices for corn, soy and wheat, but as well for rice and barley have increased in the meantime by 50 to more than 100 %. International research institutes are forecasting further price increases for major agricultural commodity products in the upcoming years.

2. Rising production of core crops for supply of starch, oil and protein

Although the production of total grains, oil and protein seeds increased continuously during the past 5 years, markets will remain very tight because of an even higher increase in consumption. Therefore, any reduction of global production due to weather extremes will keep commodity markets very volatile.

Starch crops

Due to the increase in demand, total grain markets are still expected to remain very tight over the next years. Despite the expected increase in global production, a world consumption higher than production in 2007/08 will leave world ending stocks down 8 % as compared to 2006/07 - the lowest level in 30 years. To counteract this effect, the northern hemisphere new season plantings of winter cereals have begun with a significant lift in seeded acreage. High prices for the upcoming harvest are expected.

Oil (and protein) crops

Global production of the seven major oil seeds (soybeans, oil-seed rape, sunflower, peanuts, cottonseeds, copra and palm kernels) has been estimated to decrease from 406 mio. tons in 2006/07 to 391 mio. tons in 2007/08. The stocks of these crops will therefore decrease. On the contrary, global vegetable oil consumption will increase reflecting higher usage by the industry. The current

phenomenal growth in EU vegetable oil consumption is playing a major role in pushing global vegetable oil prices to a very high level. The US bio-diesel market is also growing rapidly to a projected 17 % of domestic soybean oil production in 2007/08.

In recent years, world protein crop trade has been significantly influenced by China. China's soybean imports have increased by 24 million tons reflecting a sharp growth in protein meal consumption. China now accounts for almost one-half of global soybean imports.

In general, it appears that the availability of major agricultural commodities will stay under pressure over the next years to come, resulting in high competition of the available arable land for crops for feed, food or energy. Currently non cultivated and set aside areas will be put back into agricultural production.

3. Dramatic changes in agricultural production

All players in the farming and crop production industry have undergone significant restructuring and consolidation processes in the recent decades. Growers had been under economic pressure all the time. Commodity prices have been at the very low-end recently and agricultural subsidies have been under scrutiny.

Changing farm structures

Such conditions created significant structural changes within the farming sector. The trend to larger farms can be observed globally, with production of poultry, livestock, and crops all shifting to larger operations. Of course these trends vary between regions with e.g. Asia having much smaller farms than most other regions of the world. In general, large farms have lower production costs and realize higher commodity prices as well. As a consequence, their share of production is expected to increase.

In Europe, between 1975 and 1995, more than 1.5 million farms went out of business. The number of people employed in agriculture has declined continually. In Germany today, less than 2 % of the population is employed in agriculture. In the EU, 70 % of the crop production business is done with less than 700.000 farmers. Agricultural production will be shaped further by both regional and global demands. Consumers will have an increasing influence on farm production processes. Public awareness of farming is forecasted to grow. Prescribed use of farm inputs (e.g. crop varieties, fertilizers, herbicides, insecticides, fungicides) might go along with these developments. The continued improvement of tools for precision farming is expected to assist in further improvement of crop production efficiency.

Crop rotations

Global changes in agricultural production and economics have resulted in reduced crop rotations with often only 2 or 3 different crops in the rotation scheme. In Asia, rice is often grown in mono-cropping systems. Consequently, the world's big crop production belts are solely focusing on few of the seven world-core crops:

- USA: corn, soybean, cereals, cotton
- Canada: cereals, canola

- Brazil: soybeans, sugar cane, corn
- Argentina: soybeans, corn, wheat
- Europe: cereals, corn, oil-seed rape, sugar beets
- China: rice, corn, cereals, soybean, cotton
- India: cereals, corn, rice, cotton, sugar cane

The main drivers for the reduced crop rotation schemes are economic factors and policies which force farmers more and more to specialize in order to maintain profitability. Examples are the increased (and sometimes monolithic) corn production in the US due to bio-fuel initiatives by the government, increased oil seed rape production in Europe due to bio-diesel policy of the EU etc..

Conservation tillage

The adoption of conservation tillage has considerably increased in the past years. With the availability of suitable farm/ seeding machinery as well as applicable weed management systems, conservation tillage has continued to increase in different parts of the world, e.g. above 70 % in Argentinean soybean production and above 90 % in Brazilian soybean cultivation. A slow but constant increase of no-till cultivation system can be observed in the US. In high yielding crop production systems in Europe, conservation tillage is growing as well. Farmers throughout the world are recognizing benefits of this production system which helps to improve soil fertility, to sustain organic matter and to avoid soil erosion.

Furthermore, many studies have shown, that fuel consumption can be decreased by 50 to 80 % as compared to conventional tilling practices. The reduction of the number of land cultivation sequences per crop is improving the farmer's economy and additionally generates substantial environmental benefits.

Transgenic Crops

In the Americas, growers have widely adapted transgenic varieties of corn, soybean as well as cotton and canola. These varieties sometimes contain a broad range of different input and output traits, including tolerance to some herbicides. In the US and Argentina where herbicide tolerant (HT) varieties have been introduced in 1996/98, more than 90 % of the soybean areas were planted with transgenic soybean in 2006. In Brazil, the share is already at about 40 % even though the cultivation of HT soybean varieties has been legalized only in 2004. In Brazil's southern state Rio Grande do Sul, the market share of glyphosate tolerant soybeans is almost 100 %. In addition to soybeans, the adoption of herbicide tolerant multi stacked corn varieties is growing rapidly. In the Canadian canola market, three herbicide tolerance systems are dominating: RoundupReady (glyphosate), LibertyLink (glufosinate), and ClearField (imidazolinones).

4. Changes in Weed Management

Weed competition accounts for 15 to 20 % of the total pre-harvest crop losses. To protect against these losses and to preserve yield quality, an appropriate weed management system is essential. Currently around 400 different

herbicides are registered globally, but only a very small number of active ingredients dominate the market.

The leading herbicide is glyphosate, which achieved a turnover of approximately 2.5 billion Euros in the non-selective market and 1.4 billion Euro in glyphosate tolerant crops in 2006 (Bayer CropScience in-house data, 2007).

Our current herbicide portfolio has been generated during the last 50 years by a crop protection industry that has been undergoing a massive global consolidation process in the past two decades.

Starting with the invention of the first selective herbicides in the late '40s, a constant flow of innovative and ever better and broader new active ingredients provided farmers with highly effective weed control tools. These herbicides covered an increasing number of crops and offered broad application opportunities from pre to post application. The biggest single herbicide market segment is the non-selective herbicides segment which covers fruits, vines, plantations as well as non-agricultural uses.

The average approval rate for novel herbicides has been at around 10 to 12 active ingredients per year over the last 3 decades. This figure has become significantly lower in the recent years as a consequence of increased requirements for agronomic performance in crop production as well as ever increasing regulatory demand and development costs.

After decades of significant growth of the herbicide industry, the business is now growing at a much slower pace.

Historically, herbicide innovation appeared in waves. Auxins, PS-II and PS-I inhibitors dominated the '50s and '60s of the last century. They were followed by cell division inhibitors in the '60s and '70s. Numerous different Modes of Action entered the market in the '70s and '80s, e.g. glyphosate as EPSP Synthase inhibitor, PPO inhibitors, carotenoid biosynthesis inhibitors as well as phytoene desaturase inhibitors. The '80s and '90s were dominated by the introduction of a significant number of ALS inhibitors. Each inhibitor group allowed the control of a broad range of weeds partly complementing each others to nearly complete weed control spectra in crops.

Major regulatory and political factors

Regulatory requirements for the registration of new herbicidal active ingredients have been tightened continuously. On top of the agronomical applicability and improved performance, regulatory authorities require today a full investigation of environmental, ecological (fish, birds, bees etc.) and toxicological parameters. One milestone of environmental hurdles for the development of new compounds has been the introduction of the 0,1 µg/L - 1 trigger value for water contamination in Europe already in the early '90s. This value has a major impact on development chances for new compounds and provides a certain dilemma: For environmental reasons, short residual and low water solubility compounds are required, whereas herbicides with a certain soil persistence as well as

appropriate soil mobility provide better agronomic profiles for use in key crops.

In many aspects, regulatory authorities continuously tend to tighten regulatory hurdles for crop protection compounds. The recently adopted 'draft regulation for placing pesticides on the market' by the agricultural council might leave the EU farmer with only few remaining solutions for protecting the health of his important crops. The European Crop Protection Association has therefore urged the council to decide against the hazard-based criteria as proposed by the council which could lead to a loss of a huge number of our current crop protection products. Such increasing regulatory hurdles have recently led to a ban or withdrawal of several important herbicides on EU or national level e.g. atrazin, paraquat, isoproturon (UK), trifluralin, etc..

Adoption of herbicide tolerant (HT) crops

With special focus on the Americas, a range of herbicide tolerance systems has been commercialized in seven major arable crops so far. These HT systems involve either crops with a genome actively modified by gene technology like RoundupReady or LibertyLink or with naturally mutated and selected genomes e.g. from laboratory cultivated cell or tissue cultures like the Clearfield technology. Herbicide tolerant crops are today mostly multi stacked, offering besides herbicide tolerance further traits e.g. insect resistance, quality traits etc. Herbicide tolerant crops have advantages since the herbicides used in combination with the HT crop are generally non-selective herbicides which offer a very broad weed control spectrum. The use of such HT systems is of high convenience for the farmer, since he can apply the herbicide on a need basis (economic advantages) at different growth stages of the crop. So far, glyphosate tolerance has been the most successful HT technology in corn, in soybean, and in cotton. It is also introduced in canola but in this crop 'specifically in Canada, LibertyLink as well as ClearField are the dominating HT technologies. Due to the high level of adoption of herbicide tolerant crops, the diversity of herbicides, i.e. the number of different herbicides and different modes of action used in a single crop, has decreased dramatically. The success of herbicide tolerance systems in crops has altered the dynamics of weed control drastically.

Globally, RoundupReady crop varieties dominate the herbicide tolerance sector, accounting for almost 95 % of the planted HT crops. The average market share of glyphosate in the US in corn, soybean and cotton reached 70 % in 2006 and is expected to increase further. Associated with this development is an impoverishment of the herbicide landscape in these crops: In the US the number of active ingredients used for weed control in soybeans decreased from 17 a.i.s. in 1997 to 8 a.i.s. in 2006 (number of a.i.s. accounting for 90 % of the herbicide market, dominated by glyphosate). In addition to the use in crops, glyphosate is additionally used as pre-emergence herbicide, or in crop rotations as a burn down herbicide,

leading to multiple applications of the herbicide per season which generates an enormous selection pressure to the weeds on these lands.

New weed problems

In a range of states in the US, it can be observed that weed populations are reacting to the growing selection pressure more quickly than originally anticipated. Weed shifts and herbicide resistance start to develop. In the Brazilian state of Rio Grande do Sul, the same trend as in the US can be observed. As a consequence, new weed management strategies are required.

Glyphosate is an exceptionally broad spectrum, flexible to use herbicide. It solves more weed control problems than most conventional multi herbicide packages. This has made glyphosate an ideal candidate for the development of herbicide tolerance technology. >From its Mode of Action (inhibition of the enzyme EPSP Synthase), glyphosate was considered to be a low risk herbicide to select resistant weed species. Due to the success of the glyphosate HT tolerance system and due to the excellent herbicidal performance of glyphosate, this herbicide has become the only remaining tool for weed control under many cropping situations. With the additional trend towards more conservation tillage, all means to kill weeds prior to planting by mechanical measures have become of minor importance and have been replaced by the use of glyphosate. The use of glyphosate as the only means for weed control has created an extremely strong selection pressure on weed populations. Weed species which have been intrinsically less sensitive to glyphosate have been selected (weed shift) and dominate now areas with intensive glyphosate usage history. A significant number of dicot weeds have become even more pre-dominant weeds in these areas (e.g. Ipomoea, Commelina, Amaranthus, Cyperus spp etc.). However, weed shifts can as well be attributed to ecological adaptation. Several non endemic weed species from southern Europe have been penetrating into northern countries, e.g. *Ambrosia artemisiifolia* or certain *Setaria* spp. Such invasive weeds will require new weed control tools as well.

Weed resistance and weed shifts

Since the first observation of resistance to triazines in the late '60s, numerous further herbicide resistant biotypes against most of all herbicide classes have been identified worldwide in more than 154 different weed species. Herbicides do not induce resistance per se. Continuous and repeated use of herbicides with the same mode of action on the same land selects for the rare, naturally occurring, herbicide resistant mutants of the weeds and creates an evolutionary advantage for these mutants. The economic pressure on farmers has led to an ongoing reduction of herbicide diversity in the way crops are produced today. The diversity in crop rotations, cultural practices and chemical weed management strategies has been reduced over the last decade. Soil preparation by minimum tillage instead of using the plough is definitely promoting resistance build-up and population shifts.

The inclusion of ever fewer crops in the crop rotation systems of today and the trend towards minimum-tillage agriculture severely minimize the diversity of available cultural and chemical weed management options. The excessive use of one Mode of Action in the crop rotation definitely fosters shifts of weed populations and induces the selection and manifestation of herbicide resistance.

Weed Resistance in conventional crop production

In recent years, weed resistance to herbicides in conventional crop production systems has become an increasing problem in European cereal production in the UK, in Northern Germany and in other regions. In cooperation with the crop protection industry, risk mitigation strategies are currently being worked out to cope with, and to counteract these developments. Today, weed resistance diagnosis technologies are of increasing importance to monitor the resistance developments and to design integrated herbicide programs to prevent the development and the spread of resistance.

The herbicide resistance action committee (HRAC) has classified all registered herbicides according to their mode of action. In terms of relevance for herbicide resistance consideration, a one-sided reliance on this classification will often be misleading. The association with the HRAC group does not necessarily define common resistance phenomena: Some ALS inhibitors of the HRAC group B control ALS resistant weeds which are resistant to other herbicides of the same HRAC group. Some weeds are resistant against all kinds of herbicides from different HRAC groups.

HRAC makes clear statements about what the classification cannot provide: The system itself is not based on resistance risk assessments.

It is today a great challenge for the agrochemical industry to monitor herbicide resistance in order to provide proper labelling for the adequate use of the products, to propose alternative weed control strategies and to develop new molecules with innovative, resistance breaking properties. Modern molecular tools like high throughput DNA sequencing technologies and rapid metabolic profiling are therefore used to characterize weed resistance on a molecular basis and will be introduced into crop production practice.

Resistance and shifts in herbicide tolerant crops

Weed tolerance or weed resistance to glyphosate were not known for many years after introduction of the herbicide. In 1996, glyphosate resistant *Lolium rigidum* was identified in Victoria, Australia. Within the next ten years, glyphosate resistant goose grass (*Eleusine indica*), *Lolium multiflorum*, horse weed (*Conyza canadensis*), hairy fleabane (*Conyza bonariensis*), buckhorn plantain (*Plantago lanceolata*), common ragweed (*Ambrosia artemisiifolia*) and palmer amaranth (*Amaranthus palmeri*) have been identified in more than 7 different countries.

For glyphosate resistant horseweed (*Conyza canadensis*) there were numerous reported cases of weed resistance in soybean fields in the US. It appeared in 2000 in Delaware

and is spreading very rapidly across 17 states in the US. Due to the nearly exclusive use of glyphosate in the crop rotations in the Americas, weed resistance to glyphosate is developing there at a pace comparable to resistance development against herbicides with Modes of Action which were predicted to be much more vulnerable to resistance development like PSII Inhibitors, ALS Inhibitors or others. This fast development of resistance to glyphosate came rather unexpected. After only about ten years of selective use of glyphosate in soybeans, cotton, corn and canola, more than 12 biotypes of resistant weeds have been documented; this number is rising steadily. The resistance development evolved in the areas of glyphosate tolerant resistant soybean/ corn/ cotton production in the Americas with very limited crop rotation schemes. The selective use of glyphosate began in southern Brazil with illegally imported HT soybean seed from Argentina for quite some time. Intensive uses of glyphosate during the last five years in soybean monoculture in Brazil resulted in a rapid selection and manifestation of glyphosate resistant weeds as well in Brazil.

It can be expected, that glyphosate tolerance in soybeans will sooner or later dominate the Brazilian fields. The probability of development of glyphosate resistance in weeds and weed shifts is even higher under the Brazilian production system. Mechanical weed control is not an option in Brazil: highly fragile soil systems require conservation tillage to prevent soil deterioration and soil erosion.

Consequently, in Brazil every acre of soybean is treated several times with glyphosate every season: glyphosate is used pre-planting for burn-down and followed by at least 2 applications in the crop. Without a vegetation rest in winter time weeds often have several propagation circles. Resistant biotypes and weed shifts will therefore dominate weed populations at a much faster pace.

Resistance Management Strategies

The loss of diversity in weed control tools (herbicides and mechanical tools) combined with the ongoing monolithisation of the agricultural production systems will continue to drive the changes of weed populations. Tolerant and true resistant weed species become of more and more importance. Novel, invasive plants will immigrate into crop systems to occupy ecological niches which are open due to the disappearance of easy to control weeds.

The non-selective herbicide glyphosate will continue to serve as an important weed control tool in future. But for sustainable weed management, alternative modes of action are urgently required.

In the next few years, glyphosate resistance traits in crops will be more and more combined (stacked) with additional HT systems with resistance against herbicides with alternative modes of action, like Glufosinate tolerance, ALS tolerance, Dicamba tolerance and tolerance to other auxin-herbicides. Those herbicidal alternatives will assist to manage the upcoming weed resistance and weed

shifts for some time. But most of the a.m. herbicide alternatives have inherent weaknesses. Many of them come with modes of action classes which have been applied selectively in the crop production already for decades. Weed control gaps are either inherent to these herbicides or have already developed (resistance to ALS herbicides). These weed control gaps will remain and will impair the value of these systems as valid alternative resistance management tools. Indeed, weeds with multiple resistance against more than one of these herbicides have already developed (e.g. Amaranthus, Kochia etc). In order to sustain the future of weed control, herbicides with new alternative mode of action are urgently required.

Of the HT systems available today, the tolerance system towards glufosinate (LibertyLink) can be considered as the only true alternative to glyphosate. LibertyLink delivers similar benefits as the glyphosate system and it can control weeds which are resistant to major herbicide classes. LibertyLink is today one of the dominating HT systems in Canola and it will be increasingly added to the glyphosate systems in soy and in corn in future.

Looking at the agronomic profiles of the herbicides of today, HPPD inhibitor herbicides, like Mesotrione, Isoxaflutole and Tembotrione may be ? due to their corn selectivity - the only modern alternative herbicide candidates for resistance management in this crop.

Obviously, sustainable weed management requires increasing efforts to innovate the herbicide world. Only 5 years ago there was no voice of concern that weed shifts, weed resistance and loss of herbicidal diversity could ever endanger the efficiency in the world's weed control systems. This situation has changed, however, dramatically. Recent (2006) surveys of US-American farmers, which were initiated by three large agrochemical companies, resulted in an alarming picture:

40 to 50 % of farmers are greatly concerned about growing weed resistance. 10 to 20 % of farmers responded to have own weed resistance problems on their farms. Asking Australian cereal farmers for their key buying criteria in terms of herbicides, the control of resistant weeds has become one of the most important issues.

Numerous technology gaps in weed management

As mentioned before, the innovation rate of weed management tools has slowed down in recent years. One driving factor for this development is the consolidation of the agrochemical industry which has reduced the number of innovative R & D companies to only five major global players. It is forecasted that this will leave only 2 to 3 companies with sufficient resources for the discovery of new weed management solutions in future. The other companies have reduced their herbicide research efforts due to various reasons, probably due to a low success rate among other factors.

Despite this reduction in the number of companies actively searching and developing novel herbicides, there is significant room and need for innovation in the herbicide arena: numerous herbicidal technologies are urgently

required by the market, such as global broad spectrum rice herbicides for water and spray application still not available.

Since decades no significant progress has been made in the discovery of innovative and modern herbicides for various dicot crops e.g. oil seed rape, sugar beets, cotton, vegetables etc.. Herbicide tolerance was the only choice so far.

No adequate residual herbicide solutions are available as a result of the dominance of weed management in HT soybeans by glyphosate.

Herbicides with a novel mode of action have not been discovered for a long time.

New full spectrum pre and post residual herbicide solutions for corn are not available.

The demand for true one shot / one pass weed management solutions in all major crops remains high.

After paraquat, glyphosate and glufosinate, no innovative and low dose non-selective weed control tool has been discovered.

In order to satisfy those requirements in a rapidly changing agricultural environment, increased efforts for herbicide research are justified and will be rewarded by the markets.

The innovation deficit

Today herbicides with only 6 different Modes of Action occupy approximately 75 % of the total herbicide market. The vast majority of these herbicides is much older than 10 years. As discussed, the discovery rate of novel active ingredients has slowed down significantly in the past decades. The latest discovery of a novel Mode of Action of commercial relevance dates back to the early 80s. This development is accompanied by a steep decline in the number of patent applications for novel active ingredients. In 1990 more than 250 herbicide AI patent applications were filed. This number dropped to less than 60 applications published in 2006. This decrease reflects the reduction in the number of companies actively involved in herbicide discovery, but it is also a result of the ever decreasing success rate of the remaining companies. Whereas 50 years ago it was sufficient to screen 10.000 new chemistries in the greenhouses of an ag-chem company to discover one novel herbicide, this number has increased to several 100.000 compounds per year necessary to be screened in order to identify one novel herbicide.

In addition, the requirements for registration and market success of novel herbicides have increased dramatically.

Some requirements for modern herbicides:

- Broad efficacy spectrum against grass and dicot weeds
- Distinct Modes of Action for herbicide rotation
- Flexibility for pre and post emergence use
- Low application rates and high level of economic competitiveness
- Favourable environmental behaviour
- High level of consumer safety

The developments have led the remaining Agchem-industry to support and to back-up the traditional herbicide discovery process with novel technologies:

The traditionally successful modern herbicide discovery process is based on the discovery of novel herbicide candidates based on their greenhouse performance and the subsequent chemical optimization of identified candidates. In order to increase the innovation rate, herbicide companies have complemented and expanded the traditional discovery process.

With the advent of miniaturization and automation of screening technologies and chemical synthesis, new discovery platforms were established which allow today the synthesis and the screening of hundreds of novel compounds per day in automated systems. Screening starts with miniaturized model plants in microtitered plates which allow for an unprecedented throughput. Candidates identified and selected in these miniaturized automated screens enter the traditional greenhouse screening.

In addition, target based discovery technologies used in the innovative pharmaceutical industry were added to help in the design and synthesis of novel chemistries. New screening platforms build a unique herbicide discovery network consisting of ultra high throughput in vivo screening, target based ultra high throughput biochemical screening and virtual target based discovery.

It remains to be seen if and how the invention and the application of these modern research technologies will influence the discovery process.

Without question, "best in class approach" by exploiting and expanding the scope of agronomically proven Modes of Action will remain one key-driver in the discovery of superior broad-spectrum herbicides. Novel selectivity tools will allow the expansion of the application area of these herbicides.

Importance of selectivity technology

Broad spectrum herbicides tend not to be selective. Therefore different selectivity technologies such as herbicide safeners, GMO- and non GMO based crop selectivity technologies are an integral component of every successful herbicide research.

Herbicide safeners are unique compounds that induce selectively the metabolisation of herbicides in target crops without antagonizing the herbicidal efficacy in weeds. Herbicidal phytotoxicity in crops can be avoided without impacting weed control efficiency.

Safeners were instrumental in safeguarding the commercial success of several extremely potent herbicides mainly in monocot crops (cereals, corn). On the other side, herbicide tolerance technologies provided via GMO (RoundupReady, LibertyLink?) or non GMO technologies (ClearField et al.) have driven the success of non-selective herbicides like glyphosate and glufosinate. These technologies allowed the transformation of intrinsically non-selective herbicides into selective ones, thereby enormously broadening and expanding the application range of these herbicides. Herbicide selectivity technologies will

continue to gain increasing importance and will be instrumental for the success of novel ? still to be discovered - chemistries. Since these technology systems are comprised of a superior herbicide combined with a crop designed to match the performance of this herbicide, success in GMO and non-GMO herbicide selectivity technologies requires the integration of herbicide research with bioscience and seed operations.

Outlook of future dynamics in the areas of weed management

Dramatic changes in food, feed and energy demand are currently re-shaping agriculture and are creating new and increasing demands for agricultural raw materials. They force us to further simplify crop rotation, resulting in monolithic crop production systems with 1 to 3 crops in the rotation schemes only. The diversity of herbicidal solutions is continuing to diminish. Increasing weed shifts and resistance will occur. Engagement of public research for weed management appears to stay at a low level. Only 2 to 3 industrial global players obviously remain engaged in herbicide discovery. In view of global crop production and protection and in view of the requirements for sustainable weed management solutions, it is of utmost importance to strengthen and to reinforce the world herbicide research resources.

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722. Microarray Analysis of Bud Dormancy in Leafy Spurge. Dave Horvath¹, James Anderson¹, Wun Chao¹; ¹USDA-ARS, Fargo, ND, United States of America

Only recently has there been an effort to develop and use genomics based technologies to answer fundamental question in weed science. Over 55,000 leafy spurge cDNAs from a normalized whole plant library have been sequenced. These sequences have been leveraged to develop microarrays for transcriptome analysis of weedy and invasive traits. Recently, we have used the microarrays to identify genes and physiological processes that regulate bud dormancy, a key trait that makes control of this invasive weed particularly difficult. Leafy spurge crown buds were collected monthly from August through December over a five year period, and resulting material was hybridized to microarrays. Nearly 1,000 differentially expressed genes were identified. Expected patterns of gene expression were observed for numerous previously characterized genes and physiological processes such as cold hardening and cell division indicating resolution in the analysis was sufficient for identifying differentially expressed genes. Analysis of the results indicated an unexpected role of anaerobic respiration during dormancy transitions. Likewise, STRING analysis identified potential interactions among proteins involved in carbon and protein metabolism, stress responses, cell division and chromatin/membrane modification. The gene ontology of differentially-expressed genes suggests dormancy transitions require specific alterations in transport functions (including induction of a series of mitochondrial substrate carriers, and sugar transporters), ethylene, jasmonic acid, auxin, gibberellic acid, and abscisic acid responses, and responses to stress (primarily oxidative and cold/drought). Comparison to other dormancy microarray studies indicated that more than a third of the genes identified in our study were also differentially expressed in at least two other species during dormancy transitions. This comparison allowed us to identify, and hypothesize that a particular MADS-box transcription factor related to the DORMANCY ASSOCIATED MADS-Box genes from peach may play a direct role in dormancy induction and

maintenance through regulation of FLOWERING LOCUST.

723. Genetically and Morphological Differences of *Echinochloa crus-galli* (L.) P. Beauv. Collected From Different Rice Growing Areas of Turkey. Husrev Mennan¹, Emine Kaya¹; ¹Ondokuz May's University, Kurupelit, Samsun, Turkey

Echinochloa crus-galli (L.) P. Beauv (barnyard grass) is an annual weed that is native to Asia and found throughout the world. The broad ecological tolerance and competitive ability of *E. crus-galli* makes it most important weed species in rice growing areas. Genetic studies of plants are becoming increasingly common because reliable information are needed to know populations dynamics, occurrence of herbicides resistance and demographic data.

E. crus-galli from 34 different locations were compared with respect to morphological differences and genetic variation. In order to obtain morphological variation five seeds of each population were seeded to the pots and, it was placed to greenhouse in randomized block design. Morphological parameters such as germination speed (Day After Sowing), seedling growth rate, leaf area index (cm²), plant height (cm), spikelet length (cm), above-ground biomass (g), root dry weight (g) and 1,000 seed weight (g) were measured. The parameters were measured showed that there are distinct differences between populations with respect to hierarchical cluster analysis.

Genetic variation between population of *E. crus-galli* were performed using amplified polymorphic DNA (RAPD) markers. Seven RAPD primers amplified 55 bands whose molecular weight changed between 200-4000 bp. The percentage of polymorphic bands is 74.5%. The result showed that high morphological and genetically variability was found among individual *E. crus-galli* ecotypes and varied with similar geographic locations. Phenotypic and genetic variability among *E. crus-galli* ecotypes would be influenced by agricultural practices, crop characteristic, geographic location and herbicide pressure. Differences between weed populations may affect response of chemical or biological control.

724. They Stand Among Equals: Descriptive Analysis on the New Biotypes of Weedy rice (*Oryza sativa* L.) in Malaysia. Muhamad Mispan¹, Baki Bakar¹; ¹University of Malaya, Kuala Lumpur, Federal Territory, Malaysia

Weedy rice generally includes all the species of genus *Oryza* mimicking commercial rice crops. Weedy rice has the distinct grain-shattering trait with the ability to disseminate their grains before rice harvests, and their continuous infestation reduces yields and quality of rice crops. In Malaysia, weed rice accessions (*Oryza sativa*

complex) were first observed at Sekinchan, Selangor in 1987. It is one of the most serious threats to rice production in Malaysia. These weedy rice biotypes or accessions in Malaysian rice granaries usually grow distinctly taller than cultivated rice, and can be easily identified. Since the late 2005, new biotype accessions have since evolved mimicking closely in morphology such as plant height and grain colours thus 'standing as equals' with cultivated rice like MR84, MR 219, MR220 and MR235. A series of surveys was conducted in 2006-2007 in the rice granaries of Selangor North-West Project, Tanjung Karang, Selangor, Malaysia to assess the populations of these new biotypes or accessions and their spatio-temporal patterns of distribution based on selected quantitative dispersion indices, viz. importance value index, variance-to-mean ratio (Vmr), Lloyd's mean crowding index (m^*) and Lloyd's patchiness (I_p) index. Sixteen morphologically different weedy rice accessions or new biotypes of weedy rice (NBWR) were identified using keys of identification (grain shattering percentage, pericarp colour, awn existence, panicle type and seed size). These NBWRs display opened or closed panicles, >50% or <50% of grain shattering, red or white pericarp colour, awned or awnless grains, and short or long grains. The NBWR Acc. 8 was the most dominant accession compared with other NBWRs based on importance value index throughout the 2006/2007 seasons. The variance-to-mean ratio (Vmr) values showed that all NBWRs aggregated distribution pattern except for Acc 9 and Acc 11 which displayed regular distribution pattern. The values of Lloyd's patchiness (I_p) index were tested for deviation from unity. Most NBWRs showed aggregated distribution patterns based on I_p values, and Acc 9 and Acc 11 showed a regular distributions. It is believed that a close relationship between weedy rice and cultivated commercial varieties prevails, giving a strong indication that evolutionary forces are still operating in the rice ecosystems. These NBWRs are believed to have evolved from cultivated rice as parents over the years and are believed to be derived from hybridization between different cultivars, selection of weedy traits present in cultivars, relics of abandoned cultivars, or to have been brought into the growing region through contaminated seed stocks.

725. Genetic Relationship and Diversity between Weedy Rice (*Oryza sativa* L.) and Cultivated Rice Varieties in Okayama Prefecture, Japan. Jun Ushiki¹, Maiko Akasaka¹, Hiroyoshi Iwata¹; ¹National Agricultural Research Center, Tsukuba, Ibaraki, Japan

Genetic polymorphism of 27 weedy rice accessions collected from 12 districts in Okayama prefecture, Japan and 76 rice varieties including common rice varieties in Okayama were analyzed by using 15 sets of STS (Sequence Tagged Site) markers developed for identification of Japanese rice varieties. Cluster analysis was conducted

based on the genetic polymorphism of the weedy rice accessions and the rice varieties studied and the 130 Japanese rice varieties reported by Shinmura et al. (2005). As a result, the polymorphism of 13 japonica weedy rice completely corresponded with particular japonica rice variety such as Akebono, Asahi, or Omachi, and 2 japonica weedy rice corresponded with Akebono except one marker. Most of these japonica weedy rice closely resemble to the rice varieties phenotypically except shattering habit. Because of the high degree of genotype homology and phenotype resemblance between the weedy rice and the rice variety in Okayama, we concluded that the weedy rice probably originated from the rice variety which acquired strong shattering habit by genetic mutation.

726. Weedy Rice Complex in Costa Rica: Morphological and Molecular Characterization. Griselda Arrieta-Espinoza¹, Elena Sánchez-Olguín¹, Raul Trejos-Espinoza¹, Elena Tavares-Eiraldi¹, Ana M. Espinoza¹; ¹Universidad de Costa Rica, Sabanilla, San Jose, Costa Rica

The relations of weedy rice with rice cultivars, landraces and wild *Oryza* species from Costa Rica (*O. glumaepatula*, *O. latifolia* and *O. grandiglumis*); Asia (*O. rufipogon*) and Africa (*O. glaberrima*) were studied through a morphological and molecular characterization. The morphometric study compared 27 traits analyzed with a Principal Component Analysis. The molecular characterization was performed with two markers: microsatellites and rice chloroplast sequences. The genetic structure was determined with the program STRUCTURE and chloroplast data were analyzed with UPGMA method.

Twenty-one morphotypes were identified using a three-digit code based on seed characters. The PCA showed morphometric relations of weedy rice with indica rice cultivars, *O. glaberrima*/landraces and *O. rufipogon*. A group of morphotypes showed intermediate characters between *O. sativa* and *O. rufipogon*. However, none of the weedy samples clustered with the wild rice species of Costa Rica: *O. glumaepatula* (AA genome type), *O. latifolia* and *O. grandiglumis* (CCDD genome type).

The molecular analysis using SSR showed a high diversity of weedy rice that exhibited 88 different alleles out of 115. In addition, the genetic structure analysis confirmed that weedy rice samples are mostly associated with the indica and japonica rice varieties and clustered jointly in 4 different groups. Wild rice species (*O. glumaepatula*, *rufipogon* and *glaberrima*) grouped aside and had low percentage of allelic mixture with weedy rice samples. The analysis using chloroplast sequence showed that ten weedy morphotypes clustered with indica cultivars, two with japonica cultivars and five with landraces. The wild rice species *O. rufipogon* and *O. glaberrima* grouped apart but none of the weedy rice was included in any of these two groups.

The morphologic and genetic analyses (SSR and chloroplast sequence) consistently established that the weedy rice complex is mainly related to sativa species including rice cultivars and landraces. The separation of weedy rice with *O. glumaepatula* could be explained by the geographic isolation of the species, the lack of flowering overlap and reproductive barriers with *O. sativa*. In contrast to morphological results, the molecular analyses demonstrated that weedy morphotypes are not related to *O. rufipogon* and *O. glaberrima* wild species.

727. Studies on Genetic Diversity at DNA Level Among Various Biotypes of Wild Oats (*Avena* species). Zahid Hanif¹, Zahoor Ahmad Swati¹; ¹Peshawar, NWFP, Pakistan

Weeds cause considerable losses to our major crops. These cause 25-30 % losses in staple food crop of wheat. Wild oat is highly competitive grassy weed of rabi crops, especially, associated with the wheat crop and causes approximately 60 % out of total weed losses.

In the present study, genetic diversity of 10 biotypes of wild oats (*Avena* species) which differ in certain morphological and physiological characters were analyzed using 9 Randomly Amplified Polymorphic DNA (RAPD) and 2 Simple Sequence Repeat (SSR) primer sets. RAPD and SSR primers revealed different levels of genetic polymorphisms among the various biotypes. RAPD primers GL-A03, GL-A04, GL-A12, GL-B07, GL-B19, GL-C07, GL-D17, GL-D18 and GL-E05 and SSR primers dgm 86-2B and dgm 87-2D amplified 2.1, 4, 2.4, 3.8, 3.7, 4.78, 2.33, 4, 2.58, 1.2 and 3.1 loci per genotype respectively. Range of genetic distances estimated by using individual primers was 0-100 % but on an average genetic distances were in the range of 30-65% indicating that these biotypes were genetically very diverse and possess a high amount of polymorphism. PCR amplification results suggest that the two SSRs markers (dgm 86-2B and dgm 87-2D) could be used to investigate genetic diversity in wild oats successfully. Alternately, wild oats showing maximum genetic distances among the 10 biotypes used, should be used in future breeding programs for improving the genetic base of wild oat varieties, while using it as a food or feed crop.

728. Molecular and Quantitative Genetic Diversity in *Taeniatherum caput-medusae* (Poaceae): Evidence for Multiple Introductions with Local Range Expansion. Stephen Novak¹, Joseph Rausch², Rene Sforza³; ¹Boise State University, Boise, Idaho, United States of America; ²Washington State University, Pullman, Washington, United States of America; ³USDA-ARS, Montferrier-sur-Lez, Languedoc Roussillon, France

A growing body of evidence suggests that biological invasions are often associated with increased propagule

pressure (e.g., multiple introductions). Multiple introductions can contribute to invasiveness by the introduction of pre-adapted genotypes, and can also lead to increased invasiveness through post-immigration evolution. *Taeniatherum caput-medusae* (medusahead) is a primarily self-pollinating annual grass that has invaded large areas of western United States. We assessed the introduction and spread of *T. caput-medusae* in western United States using historical information and molecular and quantitative genetic data. Early introduction sites for this grass include Roseburg, OR (1884), Steptoe Butte, WA (1901), Klamathon, CA (1903), Los Gatos, CA (1908), Mountain Home, ID (1930), Payette, ID (1944), Elgin, OR (1944) and Lapwai, ID (1946). Forty-five populations from across this region were analyzed for their allozyme diversity, and the genetic variability for 12 of these populations was also assessed using random amplified polymorphic DNA (RAPD) analysis. Additionally, quantitative genetic variation of 20 life-history and morphometric traits was partitioned at various hierarchical levels among 12 introduced populations. Across all 45 populations, a total of nine multilocus genotypes were detected, with several genotypes closely associated with early collection sites. Only 17 of 45 populations (38%) analysed in this study exhibited any genetic polymorphisms, and the among-population component of total gene diversity is very high ($GST = 0.93$). Allozyme and RAPD data were in general agreement: using RAPDs, a total of 16 multilocus genotypes were observed across all 12 populations, with only four of 12 populations (33%) being polymorphic. Most of the RAPD diversity can also be attributed to differences among populations ($GST = 0.89$). Significant differences among families and among populations were observed for all quantitative traits, and significant differences among regions were observed for 12 of 20 traits. The among-population component of the quantitative trait variability ($QST = 0.80$) shows a pattern similar to that reported for allozymes and RAPDs. Comparison of QST and GST values for each trait shows varying patterns of selection on traits among introduced populations. Taken together, the level and structure of molecular and quantitative genetic diversity reported here appear to be the product of multiple introductions, subsequent intra-regional range expansion, and local adaptation of ecologically significant traits (e.g., days to flowering) after establishment.

729. Multiple Introductions and Post-Immigration Evolution in *Phyla canescens*: Phenotypic Differentiation under Divergent Selection Pressures in Invading Populations with High Genetic Diversity. Chengyuan Xu¹, Michael Julien¹, Mohammed Fatemi², Christophe Girod³, Stephen Novak⁴; ¹CSIRO Entomology, Brisbane, Queensland, Australia; ²University of New England, Armidale, NSW,

Australia; ³Brunoy, France; ⁴Boise State University, Boise, Idaho, United States of America

The evolution of increased competitive ability (EICA) hypothesis suggests that invasive plant species may undergo selection for the loss of defence, and allocation of resources to growth and/or reproduction. More vigorous or competitive populations in invaded ranges have been well-documented in common garden experiments, but due to insufficient population genetic information it is not always clear whether post-immigration evolution has occurred because of founder effects, genetic drift and/or natural selection. Thus, supporting evidence for EICA remains inconclusive. In this study, we implement a hierarchical, multi-continent analysis of the genetics of growth properties and reproductive characteristics in *Phyla canescens* by combining results from molecular markers and greenhouse common garden experiments. Populations of *P. canescens* in its invaded regions (Australia and France) have similar levels of genetic diversity as populations in its native range (Argentina). However, the genetic diversity of native populations has been reshuffled and recombined in both invaded regions. This pattern suggests multiple introductions and gene flow among populations during the invasion of *P. canescens* into both countries. Australian and French populations display phenotypic traits associated with enhanced growth or reproduction compared to Argentine populations. French populations exhibited more vigorous vegetative growth, possibly imparting greater clonal reproduction. On average, French populations possessed faster stem and root growth, and larger ramets with thicker stems and wider leaves. This vegetative growth pattern may enhance the survival and regrowth of plant fragments after disturbance (e.g., prolonged inundation, ploughing, and mowing) in the relatively intensively managed small-plot agricultural systems common in France. In contrast, Australian populations produced more inflorescences (and potentially more seeds) under greenhouse condition, and this trait may be an adaptation to the high climatic variability of Australia. High genetic diversity and variable selection have resulted in divergent patterns of post-immigration evolution that appear to have contributed to the invasion of *P. canescens* in Australia and France.

730. Analysis of Genetic Diversity among Populations of Common Reed (*Phragmites australis*) in Iran. Marjan Dianat¹, Ali-akbar Shahnejat-booshehri¹, Hassan-Mohammad Alizadeh¹, Mohammad-Reza Naghavi¹, Hamid Rahimin-Mashhadi¹; ¹Tehran University, Karaj, Tehran, Iran

The common reed (*Phragmites australis* (Cav.) Trin. ex steud.) is a perennial weed with perhaps the largest geographical distribution of any flowering plant in the

world. Published studies of population genetic variation in *P. australis* have focused on geographically localized populations in Europe and USA and there is no study in Iran. In this study, genetic diversity of 39 populations of common reed was studied using random amplified polymorphic DNA (RAPD) markers. The 16 primers used in this study, amplified 149 scorable RAPD bands among which 123 were polymorphic (82%). Genetic similarity coefficients, based on Dice similarity index, ranged from 0.44 to 0.84, with an average of 0.60. Results showed that RAPD markers are suitable for evaluation of genetic diversity of common reed. These results support the clonal nature of *P. australis* with its growth and spread primarily vegetative propagation. In conclusion, our results indicate that there is high diversity in the populations of *P. australis* in Iran. This high level of genetic diversity leads us to think how to facilitate management of genetic resources. Moreover, information concerning the geographical and taxonomic distribution of genetic variation provides guidelines for sampling strategies of populations.

731. Aquatic Macrophytes in Brazilian Reservoirs: A Synthesis with Emphasis on Long Term Trends at the Itaipu Reservoir. Sidinei Thomaz¹; ¹Maringá State University, Maringá, PR, Brazil

Brazil's electricity is largely produced by reservoirs (c. 80%) and their construction increased mainly after the 1970. Nowadays there are 665 hydroelectricity reservoirs in all basins of the country. Following the maturation of these man-made ecosystems, most are colonized by macrophytes, and some face serious problems due to excessive macrophyte growth. In addition to local problems for fisheries, navigation and leisure, there exists special concern about negative effects on energy production. The principal troublesome species are the native species *Egeria densa*, *E. najas* and *Myriophyllum aquaticum* and the worst problems are observed in the last reservoirs of cascades, where underwater light is higher. However, several other free-floating (e.g., *Eichhornia crassipes*, *Pistia stratiotes* and *Salvinia* spp) and emergent species (e.g., *Typha domingensis* and *T. angustifolia*) also develop conspicuously in more eutrophic reservoirs all over the country, contributing to affect their multiple use. Of special concern is the increase of the alien *Brachiaria subquadriflora*, a grass that affects biodiversity in freshwater ecosystems all over the world, and *Hydrilla verticillata*, recorded for the first time in 2005 in the Paraná River basin. Giving the importance of the Itaipu Reservoir for hydroelectricity (it produces c. 25% of the Brazilian energy), an intensive monitoring program has been carried for 12 years in this reservoir, and some long term trends were detected during this time. The most conspicuous changes were the gradual, but continuous substitution of *Egeria najas* by *E. densa* in the last 5 years, and a trend of increasing the maximum depth of colonization (Zmax) by

submerged plants (from c. 1 m in 2001 to 3 m in 2007), following an increase in underwater radiation. A significant relationship between Secchi disc depth and Z_{max} was found ($Z_{max} = 1.196 + 0.722 \cdot \text{Secchi}$; $R^2 = 0.522$; $p < 0.001$), and the first variable is being used to predict zones potentially colonized by submerged plants. However, macrophytes are limited by other factors in Itaipu (e.g., long fetch, low nutrient concentrations and high turbidity at the higher reaches of arms and in the less exposed bays). An unusual decrease in water level of 5 meters in 1999, made it possible to measure the response of macrophytes to drought disturbance and to assess the possibility of using water level drawdown as a potential management tool. Submerged plants recovered very slowly, taking c. 3.5 years to reach the same number of patches measured before the drought, and followed a typical metapopulation dynamic. Differently, following water level drawdown, increases in water P lead to fast growth of floating species in some arms. Despite the presence of several potential weeds in Itaipu, its energy production is not affected by macrophytes, because they colonize only arms, since the main axis is too deep and steep. However, *H. verticillata* was recorded for the first time in January 2007 in Itaipu, and its fast growth can dislodge native species. Its monitoring and management is a new challenge facing managers in Itaipu.

732. The Role of Biological Control in the Large-Scale Management of Water Hyacinth. Mic Julien¹, Ted Center², Martin Hill³, John Wilson⁴; ¹CSIRO, Clapiers, Languedoc, France; ²USDA, Fort Lauderdale, Florida, United States of America; ³Rhodes University, Grahamstown, Eastern Cape, South Africa; ⁴Stellenbosch University, Stellenbosch, Western Cape, South Africa

The large-scale management of water hyacinth worldwide was not successful until biological control was developed. Non biological methods, although available, are either not practical or are too expensive in most situations and usually provide only short-term relief by removing biomass.

Biological control cannot eradicate water hyacinth and in this respect for large scale management it is similar to other management methods. However biological control requires the continuation of the weed at low levels to support the agents that are essential to sustained management. The benefits provided by biological control are somewhat different to other methods, reflecting biotic interactions and population regulation that occurs in natural systems. The time from agent release to control is dependant on agent-weed interactions, usually determined by temperature and nutrition. This period, which varies from two to six years for water hyacinth, often limits the consideration of biological control as a management tool. Whereas, given sufficient resources, removal of biomass using herbicides or physical means, may be

achieved in weeks or months, but follow-up will be required.

Unlike other methods, biological control agents profoundly affect the life history of surviving and regrowth plants. The stress of insect agent damage diverts water hyacinth resources from sexual reproduction into vegetative growth. External feeding damage by adults (reduces photosynthetic area and damages leaf and petiole epidermal connections) and internal feeding by larvae (damages internal tissues in lower petiole and crown and opens internal tissues to the external environment) reduces rates of production and growth of leaves, rhizomes, and daughter plants.

After herbicidal or physical methods have reduced or removed biomass, water hyacinth re-invades as there is no suppression effect on remaining plants or seed banks. Initially plants may grow more vigorously due to the release from intraspecific competition for nutrients and space. Such reinvasion is inevitable and repeated action is necessary. Costs become prohibitive for large-scale management. In inaccessible areas herbicidal or physical controls cannot be applied.

Following successful biological control the remaining plants grow under herbivore pressure with reproductive and growth potentials suppressed. This suppression is dynamic. Weed levels fluctuate with changes in conditions and with changes in agent populations, and populations of the agents change with abundance of the weed. Under successful biological control weed reduction is as much as 95%.

The most important biological control agents are the two Neochetina weevils and a moth Niphograpta from South America. These agents reduced water hyacinth on the Sepik River, PNG, so that village communities could return to near normal lifestyles (Julien & Orapa 2001). Similar results occurred in Benin, West Africa (de Groot et al., 2003), Lake Kyoga, Uganda (Ogwang & Molo, 1997), Malawi (Phiri 1999), some areas of South Africa (Hill 2003) and in Lake Victoria, Africa (Ogwang & Molo 2004, Wilson et al. 2007) .

None of these successes are a result of the primary actions of the weevils alone. This rarely occurs in biological control. The action of the agents changes the relationship of the weed to its surrounds. For water hyacinth the changes that lead to control include: reduced buoyancy caused by larval damage opening the plants to water-logging; reduced growth of rhizomes that lead to disintegration of mats (smaller mats are more easily flushed or effected by the physical environment); reduced growth and reproduction caused by the rotting of internal tissues as a result of secondary fungi entering the damaged plant (rotting and sinking); desiccation and dehydration following feeding damage by adults. These changes resulted in the weed sinking or being flushed out of the Sepik River lagoons. On Lake Victoria large mats disintegrated and sank in place (Twongo pers. comm.) while mats in open water were broken up and sank as

presumably they could not survive the combination of insect damage and wave and wind action.

In both of these places water hyacinth continues to cause hardship in some areas. That, unfortunately, is to be expected. When biological control reduces huge infestations to much lower levels, significant amounts of weed remain. Five to 10% of the former infestation on Lake Victoria equates to 1,000 to 1,600 h of weed. Such amounts cause problems when congregated in small numbers of bays or along beaches. However, biological control should continue to maintain the lowered level of weed unless something disrupts that balance. Such disruption would not normally be natural but more likely imposed by man such as ill-advised use of herbicides or toxic eutrophication. That disruptive amounts of the weed remain suggests that integrated management strategies, centred on biological control, should be developed to alleviate the problem areas and this should include total catchment management. Such integrated strategies are not new and have been developed for other aquatic weed such as *Salvinia molesta* (Julien & Storrs 1996) and water hyacinth (Jones 2001).

The well used biological control agents, mentioned above, do not work in all situations and current research is seeking and testing additional agents.

733. Global Diversity of Aquatic Macrophytes in Freshwater. Patricia Chambers¹, Paresh Lacoul², Kevin Murphy³, Sidnei Thomaz⁴; ¹National Water Research Institute, Burlington, Ontario, Canada; ²Dalhousie University, Halifax, Nova Scotia, Canada; ³University of Glasgow, Glasgow, United Kingdom; ⁴Universidade Estadual de Maringá, Maringá, Ontario, Brazil

Aquatic macrophytes include macroscopic plants and bacteria of the divisions Cyanobacteria, Chlorophyta, Xanthophyta, Rhodophyta, Bryophyta, Pteridophyta and Spermatophyta, the vegetative parts of which actively grow either permanently or periodically (for at least several weeks each year) submerged below, floating on, or growing up through the water surface. As part of a global project to identify species and generic diversity of freshwater organisms, we compiled a database of plant species fitting the definition of aquatic macrophyte, and their geographic distribution, from world and regional checklists, phytogeographical studies and taxonomic reviews. Species composition and distribution of aquatic macrophytes in the more primitive divisions are less well known than for the vascular macrophytes (Pteridophyta and Spermatophyta), which are represented by 33 orders, 88 families and c. 412 genera with about 2614 species (or ~1% of the total number of vascular plants). Whilst many of these macrophyte species have broad ranges, species diversity is highest in the Neotropics, intermediate in the Oriental, Nearctic and Afrotropics, lower in the Palearctic and Australasia, lower again in the Pacific Oceanic Islands, and lowest in the Antarctic region. For all regions

(except Antarctica), two of the three most species-rich families were Cyperaceae and Poaceae. About 39% of the c. 412 genera containing aquatic vascular macrophytes are endemic to a single biogeographic region, with 61-64% of all aquatic vascular plant species found in the Afrotropics and Neotropics being endemic to those regions. Preliminary results from a more detailed analysis of aquatic macrophyte distribution in North America also suggest greater species diversity in southern latitudes, likely related to geographic extent and duration of glaciation. Development of management strategies to control invasive aquatic weed species already established or to prevent new introductions requires knowledge of the distribution, diversity and autecology of aquatic macrophytes. Many of the threats to fresh waters (e.g., climate change, eutrophication) will result in reduced macrophyte diversity and will, in turn, threaten the faunal diversity of aquatic ecosystems and favour the establishment of exotic aquatic weeds, at the expense of native species.

734. Management of the Invasive *Lagarosiphon major* (Curly Leaved Waterweed) in Lough Corrib, Ireland. Joe Caffrey¹, Silvana Acevedo¹; ¹Central Fisheries Board, Dublin, Ireland

The highly invasive, submerged aquatic plant *Lagarosiphon major* (Curly leaved waterweed), native to southern Africa, was introduced to Ireland as an oxygenating plant for use in artificial watercourses. It was first recorded in the wild, in Lough Corrib, in 2005. Lough Corrib is the second largest lake in Ireland (178 km²) and is of major conservation and salmonid angling importance. Knowledge of the invasive capacity of this weed, and the environmental and economic havoc that it has caused over a period of 40 years in New Zealand, gave rise to serious concerns for the conservation status and overall functioning of Lough Corrib. The study undertook to assess the status of *Lagarosiphon* in Lough Corrib, the impact the weed is having on native biotic communities and methods that might be used to control or eradicate the weed.

Lagarosiphon was recorded from 64 sites in 2007, compared with 24 in 2006 and 9 in 2005. In Rinerroom Bay, where the founder population was recorded, *Lagarosiphon* expanded its range by 7.4 ha and its standing crop by 1,000 tonnes in two years.

In bays where *Lagarosiphon* had not yet colonised, indigenous plant (primarily charophyte) communities occupied extensive meadows. Where the weed was well established, however, practically no native species were present beneath the vegetation canopy. Significant differences in species composition and abundance among macroinvertebrates were also recorded within stands of native and invasive species. Results from a preliminary fish stock survey were inconclusive in respect of the impact that *Lagarosiphon* might have on the trout (*Salmo trutta*) stock

status within the lake. However, it is clear that the habitat structure produced by the tall, canopy-forming vegetation will better suit cyprinid fishes, perch and pike than it will salmonid species, for which this lake is renowned. Further surveys will be conducted in 2008.

Pilot control trials on Lagarosiphon were conducted in 2007. Of the five methods tested, most success was achieved using a large V-blade trailed behind a boat. Divers estimated that 95% of the Lagarosiphon was removed from the test plot during this operation. The percentage bottom cover present some eight months after cutting was circa 8%. During further cutting trials conducted in September 2007, approximately 300 tonnes of Lagarosiphon were removed from a 4.7 ha section of bay. The efficacy of this treatment in terms of long-term weed control and the rate of recolonisation by indigenous species will be monitored in 2008.

735. Florida's Statewide Strategies for Successful Invasive Aquatic Plant Management. Jeffrey Schardt¹; ¹State of Florida, Tallahassee, Florida, United States of America

Florida's aquatic plant management program provides examples of the importance of early detection and rapid response initiatives in eradicating pioneer infestations of invasive plants, as well as environmental and economic benefits of suppressing established invasive plants at the lowest feasible levels. Florida's *Eichhornia crassipes* (water hyacinth) management program also serves as an example of the effectiveness of intergovernmental coordination and cooperation, and public-private partnerships in bringing even seemingly insurmountable invasive species problems under control.

In 2003 a national plan was developed for the US in response to Executive Order 13112 outlining nine components for successful invasive species management including: leadership and coordination, prevention, early detection and rapid response, control and management, restoration, international cooperation, research, information management, education and public awareness. Florida's invasive aquatic plant management program is nearly 110 years old incorporating each of the aforementioned elements, some for many decades. However, it was not until the responsibility of coordinating statewide aquatic plant management efforts was assigned to one lead agency by the Florida Legislature in 1971 that invasive plants like *E. crassipes* were brought under control.

The Florida Department of Environmental Protection (DEP) coordinates multijurisdictional aquatic plant management efforts through permits, contracts, and interagency agreements to supply financial, technical, and operational resources to control invasive aquatic plants. This cooperative strategy ensures consistent implementation of a statewide management plan while avoiding duplication as well as omitting necessary control. As a result, *E. crassipes* that once covered more than 50,000 ha

of the state's 514,000 ha of public waterways now infests fewer than 800 ha at any given time. Eradicating *E. crassipes* has proven elusive; however, through frequent inspections and integrating the most appropriate management techniques for the uses and conditions at each site, this once ubiquitous non-native plant has been reduced to a minor component in Florida's multiple use public waterways.

Today, possession of 27 non-native aquatic plant species is prohibited in Florida. Annual surveillance activities document invasive plants in about 95% of Florida's 455 public lakes and rivers. More than 50 federal, state, and local governments, university and other research institutions, private companies and non-government organizations actively participate in designing, implementing, and monitoring invasive aquatic plant management under the coordination of the DEP. Nearly \$30 million are allocated annually to controlling aquatic plants to preserve attributes such as flood control, navigation, recreation, potable water supply, and fish and wildlife habitat.

736. *Myriophyllum spicatum* Monitoring and Eradication Assessment in the Pend Oreille Lake and River System, Idaho. John Madsen¹, Ryan Wersal¹, Thomas Woolf²; ¹Mississippi State University, Mississippi State, MS, United States of America; ²Idaho State Department of Agriculture, Boise, ID, United States of America

The Pend Oreille Lake and River system is the largest freshwater body in the State of Idaho, encompassing 37,200 hectares. *Myriophyllum spicatum* L. (Eurasian watermilfoil) has spread throughout much of the systems littoral zone, reducing native plant growth and diversity. We surveyed the entire littoral zone of the lake and river using a point intercept survey covering 1,671 points in both June and August of 2007. These points were located in a uniform grid with points 250 m apart in waters of less than 15m deep. This survey indicated approximately 1,700 hectares of *M. spicatum* in the entire system or approximately 26% of points in the June survey and 23% in the August survey. We also surveyed almost 2,000 points in June and August/September of 2007 in locations selected for management. The three treatments assessed were herbicide treatments using either a granular formulation of fluridone (2.3 to 7.9 kg ai/ha, treated in early July) or a granular formulation of the triethylamine salt of triclopyr (25 to 43 kg ae/ha, treated in late July), and diver-operated suction dredging. *Myriophyllum spicatum* frequency before treatment with fluridone was 45% of points and 40% of points after treatment. This difference was not significantly different based on a McNemar's Test ($p = 0.35$). Fluridone efficacy may improve with additional exposure time. *Myriophyllum spicatum* frequency of occurrence before triclopyr treatment was 61%, and after treatment was 18%. *Myriophyllum spicatum* reduction was highly significant (McNemar's Test $p < 0.0001$). Triclopyr treatments

were effective overall in reducing *Myriophyllum spicatum* occurrence. *Myriophyllum spicatum* frequency of occurrence before treatments at diver dredge sites was 36% before treatment, and 46% after treatment; but the difference was not statistically significant (McNemar's test $p=0.65$). Fluridone treatments were not effective by the time of evaluation. While fluridone usually requires 60 days of exposure for maximum effectiveness, plants in most locations did not show fluridone exposure symptoms. Many fluridone treatment sites were in exposed or moving water locations, sites that would have a low probability for effective fluridone applications. Triclopyr treatments, however, were effective in reducing the occurrence of *Myriophyllum spicatum*. Diver-operated suction harvesting did not appear effective. *Myriophyllum spicatum* management in the lake averaged over \$2,500 per hectare, with only fair results. Additional herbicides, application times, and management strategies should be evaluated in the future.

737. ALS Inhibiting Herbicides for Aquatic Plant Management. Robert Richardson¹, Andrew Gardner¹, Amanda West¹, Sarah True¹, Rory Roten¹; ¹North Carolina State Univ., Raleigh, NC, United States of America

Acetolactate-synthase (ALS) inhibiting herbicides have been commonly used in field crops and other terrestrial settings since the early 1980's. However, these herbicides have only recently been developed for use in aquatic plant management. Imazapyr (imidazolinone family) received U.S. Environmental Protection Agency federal registration for aquatic uses in 2003, becoming the first ALS-inhibiting herbicide for these sites. It was followed by penoxsulam (triazolopyrimidine family) in 2007, and imazamox (imidazolinone family), bispyribac-sodium (pyrimidinylthio-benzoate family), and other ALS-inhibiting herbicides are currently under research and development for potential registration. Research has been conducted at North Carolina State University to evaluate the efficacy of imazapyr, penoxsulam, imazamox, and bispyribac on selected aquatic weed species. This research includes: 1) *Phragmites australis* (Cav.) Trin. ex Steud. [Phragmites] and *Alternanthera philoxeroides* (Martius) Grisebach [alligatorweed] response to imazapyr; 2) *A. philoxeroides*, *Eichhornia crassipes* (Mart.) Solms [water hyacinth] and *Salvinia molesta* Mitchell [giant salvinia] response to penoxsulam; 3) *A. philoxeroides*, *Ludwigia hexapetala* (Hook & Arn.) Zardini, Gu & Raven, *Myriophyllum aquaticum* (Vell.) Verdc. [parrotfeather], *M. spicatum* L. [Eurasian watermilfoil], monoecious *Hydrilla verticillata* (L.f.) Royle [Hydrilla], and *Pistia stratiotes* L. [water lettuce] response to imazamox; and other field and greenhouse trials. Weed control was evaluated on a 0 to 100% scale, with 0% equal to no control and 100% equal to complete plant death. Non-ionic surfactant at 0.5% v/v was included with foliar applications of each herbicide. In

imazapyr field trials, rates of 1.25, 2.5, and 3.75% v/v controlled *P. australis* 98 to 100% at 15 months after treatment (MAT), and 0.5% v/v imazapyr controlled *A. philoxeroides* 89% at 12 MAT. In penoxsulam greenhouse trials, *E. crassipes* and *S. molesta* were controlled at least 80% at 1 MAT with in-water application rates of 10 ppb and foliar application rates of 25 g ai/ha. Foliar penoxsulam applications at 105 g ai/ha controlled *A. philoxeroides* 97%. In imazamox greenhouse trials, in-water treatments at 100 to 200 ppb imazamox suppressed *M. spicatum* (57 to 63% control) and controlled monoecious *H. verticillata* 83 to 96% at 3 MAT. Foliar imazamox applications at 213 g ai/ha controlled *P. stratiotes* 89% and *A. philoxeroides* 96%. Control with 568 g/ha imazamox controlled *M. aquaticum* and *L. hexapetala* 70 to 80%, but *S. molesta* control was less than 55%. In conclusion, ALS inhibiting herbicides control many common and invasive aquatic plants. However, these herbicides should be judiciously incorporated in aquatic plant management programs to limit the resistance issues that have plagued this mode of action on terrestrial sites.

738. Does Eutrophication Increase Flood Risk? (Variability in Standing Crop of Aquatic Weeds in British Rivers and Associated Manning's n Values). Matthew O'Hare¹, Claire Cailles¹, Paul Henville¹, Nicola Bisset¹; ¹Centre for Ecology & Hydrology, Edinburgh, Scotland, United Kingdom

Predicting the amount of water a river can safely convey without flooding can be an uncertain business. Aquatic weeds impede water flow and impedance varies with standing crop. As this relationship remains poorly quantified, a major source of uncertainty in conveyance estimation ensues. Surprisingly, little work has been undertaken to address this issue. Here, we aim to reduce uncertainty by quantifying the relationship between spatial variation in plant growth and flow impedance.

Eutrophication and other drivers may account for artificially high densities of weed with an associated increase in flood risk. This hypothesis remains untested despite its importance for river management. We aim to identify factors controlling variability in weed growth. The output from the work will be made available as part of a new software tool, the 'Conveyance Estimation System'. - To quantitatively relate the standing weed crop to flow impedance to identify factors controlling the spatial variability in weed standing crop, including eutrophication

Sites (36) were visited from the Scottish borders in the north down to the south coast of England. They were predominately highly alkaline waters (> 2300 µequiv/l). Weeds of interest dominated the site; either *Sparganium erectum* L. (emergent branched bur-reed) or *Ranunculus pencillatus* subsp. *pseudofluitans* (Syme) S.D. Webster and *Ranunculus fluitans* Lam. (a complex of obligate aquatic water crowfoots).

At each site the following plant measures were recorded: weed cover at 3 river wide transects, biomass per unit area (5 samples) and the cross sectional area (CSA) of the channel occupied by the plants (central transect only). Discharge and water surface slope were measured. Manning's n , a measure of water impedance by substrate and weeds, was calculated for discharge and slope. Water and sediment samples were taken and analysed for phosphate and available carbon.

Flow impedance (Manning's n) increased with standing crop for all species (*Ranunculus* spp. R_{sq} adj 63.7% $p < 0.0001$, $n = 16$, *S. erectum* R_{sq} adj 19%, $p = 0.04$, $n = 17$).

Variations in weed biomass were attributable to latitude for *S. erectum* (R_{sq} adj 76.5%, $p < 0.0001$, $n = 16$) and not attributable to phosphate or carbon levels in the water. *Ranunculus* spp. biomass was independent of latitude and total soluble carbon but was positively correlated with water soluble reactive phosphate (R_{sq} adj 47.1%, $p = 0.006$, $n = 12$)

The uncertainty in predictions of water conveyance by channels can be reduced by including measures of weed standing crop. In cases where engineers are unable to visit sites, the latitude and nutrient levels of a site can be used to give an indication of the expected plant growth and associated flow impedance.

The study provides provisional evidence that eutrophication exacerbates flood risk by increasing the density of *Ranunculus* spp. but this process does not apply to the emergent weed, *S. erectum*.

739. An Ecological Approach to Aquatic Plant Management. Michael Smart¹, Michael Grodowitz¹; ¹US Army Corps of Engineers, Lewisville, TX, United States of America

Nonindigenous aquatic weeds frequently occur in large monospecific beds, particularly in man-made, water resources projects such as multipurpose reservoirs and waterways. These large infestations cause major problems for users of water resources. Traditional management approaches using herbicides, drawdown, or the stocking of herbivorous fish, can be effective, but typically provide only short-term results. In addition, these methods can be very expensive and typically leave an empty niche that can contribute to other problems such as algal blooms or is rapidly filled with either the same or another nonindigenous.

A simple, yet often used concept of integrated pest or plant management (IPM) is one where all available management options are considered as part of a toolbox or arsenal. These tools/weapons are then used singly or in combination in an effort to maximize control without impacting the use of one or more strategies. While this approach can be effective it, too, tends to provide only short-term control by neglecting the underlying reasons for

the formation of the infestations. A more prudent and ecologically compatible approach would be the use of an ecosystem-based IPM program that relies heavily on ecosystem management and restoration strategies and addresses causative factors that contribute to such formations.

A key component of an ecosystem approach to managing aquatic plants is the use of host-specific biological control agents. Most of the economically important invasive/nuisance aquatic plants are introduced species that have escaped their host-specific herbivores and pathogens. In addition to their high intrinsic rates of increase this lack of sustained feeding and resultant damage allows the formation of extensive monospecific infestations. A second key component is the establishment of a diverse community of native aquatic plants. These plants fill the empty niche and provide competitive pressure to deter, or at least delay, recovery of nonindigenous, weedy species. By introducing a complex of host-specific herbivores and pathogens and re-establishing competitive native aquatic plants as part of an ecologically based IPM program, populations of nonindigenous weedy species can be held at non-problem levels. In addition, this approach increases the environmental and ecological value of the water body while providing a sustainable solution to the problem of nonindigenous weed infestation. Several case studies using this ecological approach will be presented.

740. Integrated Weed Management Systems in Vegetables: Current Status and Perspectives. Francesco Tei¹, Euro Pannacci¹; ¹University of Perugia, Perugia, Italy

Most vegetable crops are characterised by a low plant density, a wide row distance, a slow initial growth and, as a consequence, by a poor competitive ability. Taking into consideration that most vegetables are high-income crops, the threshold weed densities are very low and the critical periods of weed competition are pretty long. Most vegetables are minor crops, thus the availability of approved herbicides for use is scarce due to the low economic interest by the chemical industries. Special projects for supporting the registration of pest control products on minor or specialty crops (e.g. the IR-4 in USA) or for coordinating scientific and regulatory decisions on pesticides were established to alleviate the problem. In EU the already difficult situation has been worsening by the application of the directive 91/414/EEC concerning the authorization, placing on the market, use and control of plant protection products in commercial form. This directive has already caused the expiration of the authorisation of several herbicides largely used in vegetables and other ones will be withdrawn within few years. Chemical weed control in vegetables shows peculiar environmental and health concerns due to the relatively short growth cycle, fresh edible parts of vegetables, and a

coarse soil texture found in the main production areas; moreover, a repeated use of herbicides with similar mode of action may lead to a strong and quick selection of weed flora. So an Integrated Weed Management System (IWMS) in vegetables, like in any other crops, should be based on: 1) weed population management strategies by sound cultural weed control methods, i.e. any aspect of crop management that favours the crop relative to the weeds, reduces the weed seed-bank, regulates weed communities and prevents the build-up of adapted species; 2) an integration of non-chemical and chemical weed control methods characterised by a low selection pressure on weed communities, an environmental sustainability and an economic feasibility.

Regarding preventive (indirect) weed control methods, it should be pointed out that: although the crop rotation was crucial for an IWM, in practice a sound crop rotation frequently is not applied due to economic and market constraints; the strategic importance of the cover crops seems low in environments characterised by limited availability of irrigation water or high water cost; intercropping, thanks to new technical solutions for mechanical harvest, is increasing in interest in organic and low input farming systems; a stale seedbed preparation is widely applied in several vegetable crops throughout the world; the breeding of competitive cultivars is not yet enough developed even if experimental results seem to be encouraging; the transplanting instead of the direct sowing is commonly applied in order to give a higher competitive ability to the crop, shorten the critical period of competition and facilitate direct weed control; the increase of crop plant density and the adoption of a narrower row distance or twin rows in order to increase the crop competitiveness offers interesting applications but in some crops the cost of transplants, the negative effects of a higher crop density on quality product and the need to have well-spaced crop rows for the application of mechanical weed control limit the use of those cultural practices; the effect of different localised fertilisation and/or irrigation methods (e.g. starter fertilisation, band fertilisation, fertigation) on crop competitive ability against weeds should be better studied.

Regarding curative (direct) weed control methods: non-degradable black PE mulches are widely used in several vegetable crops; non-degradable photo-selective coloured plastic mulches, that combine the thermal properties of transparent films with the weed control ability of black films, show a good efficacy but not always an economic feasibility; starch-based biodegradable mulches are more and more used both in conventional and organic farming systems where they show a mulching activity for 2-4 months, that is enough to cover the critical period of competition of most vegetable crops; inter-row weeds are easily removed by inter-row cultivation (i.e. hoeing, harrowing, brushing) while intra-row weeds still constitute a major challenge aimed at minimising laborious hand weeding although new implements (i.e. finger weeder,

torsion weeder, split hoe, steering hoe) show a pretty good efficacy if their application is included in a sound IWM programme; physical and mechanical weed control methods are widely used in organic farming systems and in conventional systems where the availability of approved herbicides for use is scarce; at present, biological control does not seem to be applicable on large scale and successfully in European vegetable crops systems characterised by small fields, a high number of crop species, and pluri-specific weed infestations; chemical control still is the main weed control method in conventional and low input vegetable production systems even if concerns about food safety, environmental sustainability, weed population dynamics and application cost are increasing among public opinion and technicians, particularly because the global market shows a huge variability in crop management and regulatory decisions on pesticides.

741. Autumn Vegetable Response to Residual Terbacil, Fomesafen, and Halosulfuron. Timothy Grey¹, Stanley Culpepper¹; ¹University of Georgia, Tifton, GA, United States of America

Field studies were conducted to evaluate autumn planted crop tolerance to residual herbicides applied in the previous cotton crop or vegetable crop either the previous summer to bare-soil or the previous spring to soil under low density polyethylene mulch (LDPE). Experiments conducted in 2006-2007 and 2007-2008 included summer post directed applications to bare-soil of 0.17 and 0.34 kg/ha terbacil, 0.28 and 0.56 kg/ha fomesafen, and 0.053 and 0.11 kg/ha halosulfuron in cotton during made in July of each year and included a nontreated control. After removal of a cotton crop, autumn vegetables were planted in November 2006 and October 2007 and included transplanted kale, broccoli, cabbage, and collard (all *Brassica oleracea*). No injury was observed in 2006-2007 but severe injury was noted during 2007-2008. However, in 2007-2008 at 48 days after planting and 147 days after treatment, terbacil injured kale 26 to 53%, broccoli 25 to 53%, cabbage 41 to 93%, and collard 28 to 45%. Fomesafen injured kale 55 to 75%, broccoli 43 to 73%, cabbage 70 to 90%, and collard 43 to 79%. Cabbage exhibited the greatest injury with reductions in stand from crop death from fomesafen and terbacil. Injury from halosulfuron carryover diminished over time. No injury was observed for the 2006-2007 bare-soil experiment for any crop. Rainfall was greater between application timing and vegetable planting for 2006-2007 (33.8 cm) versus 2007-2008 (21.8 cum) which could have increased dissipation and resulted in less potential for injury. For the LDPE mulch experiments, 0.28 and 0.56 kg/ha fomesafen and 0.56 kg/ha fomesafen plus 0.8 kg/ha S-metolachlor was spray applied to soil prior to covering with (LDPE) in February 2007, and included a nontreated control. After summer vegetable crop removal, August transplanting of

cabbage, broccoli, and collard and seeded collard were made. Injury to cabbage, broccoli, and transplanted and seeded collard ranged from 28 to 87% for fomesafen at 0.28 kg/ha and 48 to 96% for 0.56 kg/ha for fomesafen alone and when combined with S-metolachlor. All LDPE mulch herbicide treatments reduced growth and all crops exhibited biomass reduction for harvests relative to the nontreated control. These data indicate that fomesafen and terbacil carryover can affect autumn planted brassica crop vegetables for bare soil applications. Additionally, spring application of fomesafen to soil under LDPE mulch had prolonged residual activity which resulted in significant autumn crop injury. Growers should use caution when considering these herbicides for weed control in bare-soil and LDPE mulch crop production as autumn crop plantings could be seriously injured and yields reduced.

742. Weed Management in Seed Production of Native Forbs Used for Restoration. Jessica Wiese¹, Fabain Menalled¹, Bruce Maxwell¹, James Jacobs², Susan Winslow²; ¹Montana State University, Bozeman, MT, United States of America; ²Natural Resources Conservation Service, Bozeman, MT, United States of America

The importance of incorporating native wildflowers into seed mixtures for disturbed land revegetation projects is widely known and accepted. However, wildflower seed producers need to gain scientific, technical, and practical knowledge for the successful production of native seeds. In particular, assessing weed management approaches represents a necessary step to facilitate the successful establishment and seed production of native wildflowers. To fill this knowledge gap, we examined the impact of pre and post-emergence herbicides alone and in combination with hand weeding on 5 wildflower species [*Dalea candida* (Prairie Coneflower), *Gaillardia aristata* (Blanket flower), *Penstemon eriantherus* (Fuzzy tongue penstemon), *Phacelia hastata* (Silverleaf phacelia), and *Ratibida columnifera* (Slender white prairie clover)] under greenhouse and field conditions. Herbicides evaluated included Treflan(trifluralin) 36.4 l/ha, Lorox (linuron) 1.121 kg/ha., Permit (halsulfuron) 91 g/ha., Plateau (imazapic) 560 g/ha, Prowl (pendimethalin) 4.2 l/ha.

Wildflower injury, percentage cover, yield, and seed germinability and viability, along with weed community composition and cover were compared across treatments. Wildflower seedling injury varied by species with trifluralin causing severely reduced emergence in 3 of the 5 studied species. Imazapic showed excellent weed control, but produced high crop injury levels. Hand weeding in addition to herbicide provided higher establishment than herbicide treatment alone. These studies will provide growers and land managers information to improve their ability to commercially grow native wildflowers and clarify

the impact of weeds on the competitive ability and growth of native wildflowers.

743. Weed Control Options in *Silybum marianum* Gaertn. (Blessed Thistle). Edita Stefanic¹, Ivan Stefanic²; ¹Faculty of Agriculture Osijek, Osijek, Osijek-baranja County, Croatia; ²Technology Development Centre Osijek Ltd., Osijek, Osijek-baranja County, Croatia

Blessed thistle is an ancient medicinal plant used to purify and protect liver that has recently received an increasing interest as a crop in Europe as well as in some other parts of the world. However, a limiting factor in blessed thistle production is weed control.

Field experiments were conducted in northeastern Croatia, to examine and compare the possibilities of selected pre-emergence applied herbicides and several options of mechanical cultivation (early in the season, late in the season, and twice in the season) on weed control, crop yield and estimated economic return. The trials were arranged as a Randomized Complete Block (RCB) design, and were conducted at two sites during a 2-yr period.

A visual inspection outside of treated plots in both years and sites determined 24 different grass and broadleaf weed species coexisted with the crop. Effectiveness of pre-emergence application of metolachlor prometryne, dime-thenamid, pendimethalin and fluchloridon were sufficient for control all weeds except the *Ambrosia artemisiifolia* L. (short ragweed). Due to the interference with this noxious weed species, a crop yield was low with significantly less number of flowers per plant compared to the ones with mechanical cultivations. Application of herbicides did not provide economically acceptable levels of short ragweed control. However, short ragweed is known to recover relatively quickly from many stresses, and have a prolonged emergence, therefore only one cultivation early in the season was also unacceptable for its control. The best option was mechanical cultivation twice in the season followed by one late cultivation.

All combinations of mechanical cultivation received significantly higher seed yield and yield components in both years and sites.

744. Control of Difficult Weed for California Strawberry Production. Oleg Daugovish¹, Maren Mochizuki¹, Steve Fennimore²; ¹University of California Cooperative Extension, Ventura, California, United States of America; ²University of California, Salinas, California, United States of America

California leads the U.S. strawberry fruit production, with annual value over \$1 billion. Weeding costs range from \$750 to \$1,750/ha even after soil fumigation with methyl bromide. Alternative fumigants provide limited control of weeds with hard seed coats such as *Malva*

parviflora (little mallow) or *Melilotus officinalis* (sweetclover) and perennial weeds such as *Cyperus esculentus* (yellow nutsedge) that penetrates through black plastic mulch. Additionally, wind-dispersed seeds of *Conyza canadensis* (horseweed) and *Sonchus oleraceus* (annual sowthistle) can reinfest a fumigated field and germinate in planting holes and furrows, adding to weeding costs. Our research focused on management of these difficult weeds. In eight studies, oxyfluorfen at 0.3 kg a.i./ha provided 89-100% control of *Malva parviflora* and most other broadleaf weeds, but a rate of 0.6 kg a.i./ha was needed for 45-95% control of *Melilotus officinalis*, and oxyfluorfen did not control *Cyperus esculentus*. A layer of recycled paper and placed under black plastic completely inhibited yellow nutsedge germination in strawberry beds in fall 2006 that otherwise germinated through plastic alone at a density of 6 plants/m². The paper deteriorated and nutsedge germinated in spring, however, prompting on-going investigation of other mechanical barriers in 2007. Flumioxazin and oxyfluorfen applied 30 days pre-plant to bed tops completely inhibited germination of wind dispersed weeds and did not injure strawberry. Flumioxazin and oxyfluorfen/napropamide applied to furrows reduced densities of wind-dispersed weeds 84-95% at 4 weeks after application and 68% during the following 8 weeks, reducing weeding time by 50% or more. A simulated drift study showed severe strawberry fruit injury for 2 weeks after flumioxazin contacted fruiting plants, suggesting that seed landing on bed tops after strawberry transplanting currently cannot be chemically controlled without crop injury; these weed species growing in areas adjacent to the production field should therefore be destroyed before flowering.

These studies showed that an integrated approach utilizing chemical and mechanical methods can manage weeds that are not controlled by fumigation.

745. Weed Management Strategies to Reduce Costs and Amount of Herbicides in the Mauritian Sugar Cane Industry. Suman Seeruttun¹, Clency Barbe¹, Azaad Gaungoo¹; ¹MSIRI, Reduit, Mauritius

Since the 1970s, weed control in sugar cane in Mauritius has been achieved by two or three herbicide applications per season, often complemented by manual weeding. The costs of this practice, necessitating between 6 and 10 kg a.i./ha per year of herbicides, was estimated at US\$ 225/ha in 2004. A project initiated in 1998 to develop strategies to reduce amount of herbicides and costs of weed control was completed in 2005 and recommendations made thereafter to growers. The new strategies are based on the critical periods of weed control (CPWC); field trials revealed that the CPWC started at least six weeks after planting or harvest and ended between 14 and 20 weeks later under the worst growing conditions. The CPWC was further reduced by at least four weeks by adopting dual row spacing. The

introduction of a new cost-effective tank-mix consisting of amicarbazone and trifloxysulfuron + ametryn enabled control within the CPWC by providing a very good post-emergence control of most weeds present prior to onset of CPWC and a relatively long residual activity to reach the end of CPWC; all this resulting in the savings of at least one application per season. In plant cane, mechanical weeding has also been tested and proposed as an alternative to herbicides during the first 12-16 weeks after planting. In ratoon crops, the new strategies promote adoption of green cane trash blanketing, an effective means of controlling weeds. Growers, particularly with the implementation of the 36% reduction in price of sugar as from 2006 and the increasing costs of herbicides and labour, are rapidly opting for the new weed management strategies.

746. Phytotoxicity on Ornamental Plants Associated with Flumioxazin. Mario Lanthier¹, Sonja Peters¹; ¹CropHealth Advising & Research, Kelowna, British Columbia, Canada

Flumioxazin is a pre-emergent herbicide of broadleaf weeds. > From 2005 to 2007, fifteen trials were conducted in commercial nurseries located in three distinct growing climates to generate efficacy data for Canadian registration. Treatments were replicated and controlled for statistical analysis of data, and applied to mimic standard grower practices. Plant injury was visually assessed by rating on a 1-unit increment scale from 0 (no damage) to 10 (91 to 100% of plant leaf surface shows injury).

In nursery field production, Flumioxazin 51WDG was mixed in water and applied to the soil surface in five separate trials near four host plants (*Acer*, *Fraxinus*, *Quercus*, *Syringa*). Damage on herbicide-treated plants was never statistically higher than untreated plants for all evaluation dates. Leaf spot was the most common injury on flumioxazin-treated plants, obvious 3 to 7 days after treatment on leaves located low on the trunk and contacted by the spray application. Plants with leaf spots on low branches had no visible herbicide injury on higher parts of the canopy, including at growing tips. Nursery growers can safely use this herbicide in field production provided they make the application to the soil and avoid drift to the crop plant by using shields or applying in low wind conditions.

In nursery container production, the product Flumioxazin 51WDG was mixed in water and applied over-the-top at the bud swell stage. Phytotoxicity was noted at all rates tested and all hosts at 3 and 9 days after treatment. First unfolding leaves showed necrotic leaf spots, necrotic leaf margins, leaves brown and leaves wrinkled. No damage was noted on subsequent unfolding leaves. Use of this formulation over-the-top of plants in container production would require clear label wording to apply only on fully dormant plants.

In nursery container production, the product Broadstar 0.25G was manually applied on the soil surface during early spring, or over-the-top during summer, in nine separate trials near 18 host plants representative of nursery production. Damage on herbicide-treated plants was never statistically higher than untreated plants for all evaluation dates, with the following exceptions. *Buxus* showed leaf wrinkling shortly after application; *Hydrangea* had significant tip dieback; *Picea* showed needle chlorosis; *Rosa* showed damage from the 2X label rate; *Spiraea* had significant tip dieback and reduced top dry weight; *Viburnum* showed necrotic leaf spots following over-the-top application. Nursery growers can safely use this herbicide in container production, except not on *Hydrangea* and *Spiraea*, provided they make the application to the surface; application over-the-top of actively growing plants requires further care such as irrigation or rainfall to wash product residue from the crop foliage.

747. The Molecular Mode of Action of Picolinate Auxin Herbicides. Terence Walsh¹; ¹Dow AgroSciences, Indianapolis, IN, United States of America

Auxin herbicides control a wide variety of primarily dicotyledonous weeds by eliciting effects on plants similar to excessive treatment with the endogenous plant hormone, auxin (indole-3-acetic acid, IAA). Synthetic auxin herbicides such as 2,4-D have been used for effective post-emergent weed control for over sixty years and new herbicide introductions with the auxin mode of action continue today. However the molecular mode of action of auxins has only recently been elucidated and shown to directly involve the ubiquitin-mediated degradation of transcriptional regulators. The chemical receptors for this pathway are components of the E3 ubiquitin-ligase SCF complex that recognize and target specific protein substrates for ubiquitylation and proteosomal degradation, leading to profound changes in gene expression.

There are several structural classes of synthetic auxin herbicides that include phenoxyacetates (e.g., 2,4-D), pyridinyloxyacetates (e.g., fluroxypyr), benzoates (e.g., dicamba), picolinates (e.g., picloram) and quinolinecarboxylates (e.g., quinclorac). By exploiting the chemical diversity of synthetic auxins, a chemical genetics approach can be used in the model weed *Arabidopsis thaliana* to probe the molecular mechanisms of auxins. Using this approach, a suite of mutant lines were recovered that are selectively resistant to the picolinate class of synthetic auxins. The sites of the resistance mutations in these mutant lines have identified a novel and distinct member of the *Arabidopsis* auxin receptor gene family that is uniquely involved in picolinate auxin action. Using available genomic resources, these observations can be extended into other plant species of relevance to weed scientists. This allows the contribution of the diversity and redundancy of auxin receptors in plant species to be

assessed with respect to the performance of and field resistance to various synthetic auxin herbicides.

748. Which Herbicides Affect Chlorophyll Fluorescence? Jens Streibig¹, Kenneth Soebye¹, Peter Hvid¹, Mads Munkegaard¹; ¹University of Copenhagen, Taastrup, Denmark

When photosynthetic active plants are darkened for a short period of time and subsequently exposed to an intensive light, a small part of that light will be reemitted as fluorescence. In healthy plants it will result in a characteristic shaped fluorescence curve as a function of time, a so called Kautsky curve. The characteristic shape of the curve is used to generate various parameters, which more or less reflect the shape of the curve. In healthy plants the maximum relative fluorescence would be 0.83 after less than 0.5 second after illumination. When plants are exposed to unfavourable environments, e.g. drought, heat, cold, deficiently of nutrients and other growth limiting factors, plants usually generate Reactive Oxygen Species (ROS) that must be quenched by the plant in order for it to sustain growth. Usually, these stressors affect the shape of the Kautsky curve. The mode of action of several herbicides also generates fatal quantities of ROS, which, if not quenched, will kill the plant. The most prominent groups of herbicides belonging to the ROS generating herbicides are those inhibiting electron flows in the photosynthesis. An overdose of those herbicides would instantaneously affect the Kautsky curve long before one can see symptoms on the plant. For other groups of herbicide the same applies, but the time lag from uptake to a visible effect on the shape of the Kautsky curve lasts much longer; and for some herbicides the Kautsky curve does not appear affected even though visual symptoms are clearly obvious. The interpretation of the Kautsky curve, however, is difficult, because it reflects complex metabolic processes. It means that we cannot exactly pinpoint a specific site or mode of action of a herbicide by looking at changes in the shape of the curve. However the shortcomings of the Kautsky curve, it is a valuable tool for studying several groups of herbicides. It is a non destructible method that can be use in controlled environment and in the field. In our laboratory we have studied how numerous herbicide groups affect the Kautsky curve: photosystem I and II inhibitors, ALS and EPSPS inhibitors, lipid synthesis and carotenoid synthesis inhibitors. Most of them affect the shape of the Kautsky curve depending on the dose administered. We have not yet been able to see any effect of ALS inhibitors on the shape of the Kautsky curve at doses relevant for the selective use of those compounds in agriculture. We will present some examples of the research and discuss the usefulness of the Kautsky curve in herbicide research and development and their practical use in crops.

749. The Role of Antioxidants in the Protection of Plants Against Inhibition of Protoporphyrinogen Oxidase. Franck Dayan¹, Lauren Dayan²; ¹USDA-ARS NPUPU, Oxford, MS, United States of America; ²Oxford High School, Oxford, MS, United States of America

Protoporphyrin IX (PP) is the last porphyrin intermediate in common between heme and chlorophyll biosynthesis. The biosynthesis of this pigment is tightly regulated and, under normal conditions, only trace amounts can be detected in plant tissues. However, levels of PP increase dramatically in the presence of protoporphyrin oxidase (Protox) inhibitors (e.g., acifluorfen-methyl). In the presence of light, accumulation of this photodynamic pigment leads to the formation of highly reactive singlet oxygen responsible for loss of cellular membrane integrity and cell death. Some plants species are less susceptible than others to these herbicides. It has been suggested that plants with high antioxidant contents are less sensitive to inhibition of Protox. We show that increasing the levels of certain antioxidants does protect plants against the herbicidal effect of acifluorfen-methyl. In particular, hydrophilic antioxidants such as glutathione and ascorbic acid (5 mM) significantly reduced loss of membrane integrity caused by 50 μ M acifluorfen-methyl. The lipophilic antioxidant α -tocopherol had not detectable effect. Conversely, inhibiting de novo glutathione biosynthesis in cotyledons with 5 mM L-buthionine-sulfoximine rendered plants more sensitive to acifluorfen-methyl.

750. The Mode of Action of Napropamide in Comparison with other K3 Type Herbicides. Tim Hawkes¹, Sophie Wood¹, Richard Wood¹, Eric Clarke¹, Kate Sharples¹, Russell Viner¹, Irina Guschina², Xueying Yang², John Harwood²; ¹Syngenta, Bracknell, Berkshire, United Kingdom; ²Cardiff University, Cardiff, Wales, United Kingdom

We have investigated the mode of action of the acetamide herbicide, napropamide within the wider context of K3 (HRAC classified) herbicides. Both the acetamides, napropamide and diphenamid appeared entirely unreactive with glutathione ($k_2 < 0.0001$ M⁻¹s⁻¹). By contrast, K3 type herbicides known to inhibit the biosynthesis of very long chain fatty acids (VLCFAs) including the oxyacetamide, flufenacet and the carboxamide, cafenstrole had low reactivities ($k_2 = 0.0006$ M⁻¹s⁻¹ and 0.0018 M⁻¹s⁻¹, respectively, at pH 7), and the chloracetamides, dimethachlor and acetochlor moderate reactivities ($k_2 0.0093$ M⁻¹s⁻¹ and 0.0099 M⁻¹s⁻¹, respectively). These chemical reactivities may provide a simplified model of the reaction with an enzyme cysteine thiol that is thought to be essential for VLCFA inhibition. In agar-plate growth tests, the predominant effect of napropamide on *Poa annua* and *Echinochloa crus-galli* was on root growth. This appearance was very similar to that observed following treatment with cinmethylin, a group Z com-

pound which also does not react with thiols and which has an unknown (possibly asparagine-related) mode of action. The effects, on the other hand, of treatment with dimethachlor were quite typical of chloracetamides with marked stunting of shoots and relatively little effect on roots. Although structurally very different, napropamide appears somewhat similar to cinmethylin in terms of its 3-dimensional molecular shape and electronic properties. We are currently investigating whether, like other K3 herbicides, napropamide inhibits plant tissue incorporation of malonate into very long chain fatty acids. If, (as the lack of glutathione-reactivity may presage) it does not, then it would seem that acetamides should not be grouped with VLCFA-inhibitor K3 herbicides.

751. Ultrastructural Changes Induced in Chloroplast, Mitochondria and Nucleus in Crickweed (*Malachium aquaticum*) Leaves by Herbicide ZJ0273 and 5-Aminolevulinic Acid. Weijun Zhou¹, Wenfang Zhang¹, Qing-fu Ye¹, Fan Zhang¹, Zonglai Jin¹, M.S. Naeem¹; ¹Zhejiang University, Hangzhou, Zhejiang, China (Peoples Republic of)

Crickweed (*Malachium aquaticum* (L.) Fries) is a predominant species of dicotyledonous weed in the field of oilseed rape (*Brassica napus* L.), one of the world's major oilseed crops. Treatments of 5-aminolevulinic acid (ALA) and new post-emergence herbicide ZJ0273 (propyl 4-(2-(4,6-dimethoxypyrimidin-2-yl)oxy)benzylamino)benzoate) were used to improve weed control efficiency. *Malachium aquaticum* leaves were treated with herbicide ZJ0273 and ALA separately and in combination at the concentration of 500 mg/l for ZJ0273 and 100 mg/l for ALA for 24 hours. Seven days later, chloroplast, mitochondria and nucleus ultrastructures in leaves were examined. Electron microscopic study of plants revealed significant differences in the ultrastructure of mesophyll cell organelles. Chloroplasts of control plants exhibited normalities at the ultrastructural level; they were lens-shaped, with a typical arrangement of grana and stroma thylakoids. The chloroplasts of plants treated with ZJ0273 or ALA were lens-shaped, whilst the chloroplasts of plants treated with ALA in combination with ZJ0273 were spherical shaped. The grana number decreased, as did the number of thylakoids per grana in the ZJ0273 and ALA treated plants. Stroma and grana lamellae in the chloroplasts of ZJ0273 and ALA treated plants appeared swollen and granal stacking became less compact. It was observed that the aggregation and enlargement of plastoglobuli in the chloroplasts when plants were treated with ALA in combination with ZJ0273. Mitochondria of the control plants were normal and mitochondrial cristae were well developed. Mitochondria of the plants treated by ALA were swollen and mitochondrial cristae were poorly developed in comparison to the control plants. Vesicles could be observed in the mitochondria of plants treated by ZJ0273. Some mitochondria membranes began to degrade

in plants treated by ALA in combination of ZJ0273. The nucleus shape of the control plants was normal. While the nucleus shape of plants treated by ALA showed no significant change in comparison to the control. Irregular nucleus shape was observed in the plants treated by ZJ0273 and plants treated by ALA in combination of ZJ0273. Present findings suggest that the combined treatment of ALA and ZJ0273 synergizes the toxicity inducing drastic ultrastructural alterations which are different from its independent effects on *Malachium aquaticum* (L.) Fries and thus could improve weed control efficacy.

752. Using *Arabidopsis* to Understand How Safeners Induce the Expression of Herbicide Detoxification Systems.

Peter Goldsbrough¹, Nahla Amin el Sherif¹, Kana Takahashi², Amy Marshall-Colon¹, Anthony Qualley¹, Natalia Dudareva¹, Ben DeRidder³; ¹Purdue University, West Lafayette, Indiana, United States of America; ²Ochanomizu University, Tokyo, Japan; ³Grinnell College, Grinnell, Iowa, United States of America

Herbicide safeners are interesting chemical compounds that enhance the selectivity of herbicides in cereal crops. The most widely accepted explanation for how safeners increase herbicide tolerance is that they induce a variety of herbicide detoxification activities in the crop plant. Among the enzymes that are induced by safeners are glutathione S-transferases (GSTs), which are critical components in phase II of the detoxification system. Plant GSTs have well described roles in the metabolism of many herbicides in crops. However, individual GSTs are also expressed in response to many other cues, including other forms of biotic and abiotic stress, suggesting that GSTs also have diverse functions in normal metabolism. One question about safeners that remains unanswered is how they induce multiple components of the xenobiotic detoxification system in plants. We chose to study this problem by examining how *Arabidopsis* responds to herbicide safeners. Treatment of *Arabidopsis* with various safeners (benoxacor, fenclorim, fluxofenim) increased GST activity in seedlings. Specific GSTs induced by benoxacor were separated by 2D-PAGE and AtGSTU19 identified as a highly induced GST. RNA expression studies showed that many GST genes were induced by safeners. AtGSTU19 and AtGSTF2, genes from different classes of the GST super-family, were among the most highly induced *Arabidopsis* GST genes. Safeners also increased the concentration of GSH and the expression of genes encoding glutathione-conjugate transporters. While safeners were able to increase the activity of multiple components of the detoxification system, they were unable to protect *Arabidopsis* plants from various chloroacetamide herbicides. Experiments with transgenic plants have shown that safeners fail to protect *Arabidopsis* from herbicide injury because the GSTs induced by these compounds are inefficient at conjugating chloroacetamide

herbicides and are not expressed in the correct tissues. In spite of the fact that safeners fail to protect *Arabidopsis*, they do induce GST expression and this has allowed us to examine the mechanism by which herbicide safeners regulate the expression of AtGSTU19. Deletion analysis of the AtGSTU19 promoter showed that an as-1 element located approximately 150 bp upstream of the transcription start site is required for safener-induced expression of this gene. Specific mutations within the as-1 element also abolished the capacity of the AtGSTU19 promoter to respond to safeners. The as-1 promoter element therefore plays a critical role in AtGSTU19 expression and induction by safeners. Salicylic acid (SA) is known to regulate the expression of many genes that contain as-1 promoter elements. RNA expression of AtGSTU19 was induced by treatment of seedlings with SA, whereas benoxacor and fenclorim were unable to induce AtGSTU19 in SA-deficient NahG plants that express a bacterial SA hydroxylase gene. However, the sid2 mutant, which is unable to synthesize SA via the isochlorismate synthase pathway, showed normal induction of AtGSTU19 by benoxacor. These results support the hypothesis that safeners function through a SA signaling pathway in *Arabidopsis* independent of SID2. To confirm that SA is required for safener activity and to investigate which SA biosynthesis pathway is involved in this process, we measured SA in *Arabidopsis* plants under control conditions and after safener treatment. The safener benoxacor produced a substantial increase in SA concentration in *Arabidopsis* plants within 6 hours of treatment in both wild type and sid2 mutant plants. These results indicate the involvement of an SID2-independent SA biosynthesis pathway, from phenylalanine and benzoic acid, in activating the expression of AtGSTU19 in response to safeners. Further experiments will be required to determine if other components of the detoxification system are regulated in the same way by safeners. Although we have established that SA is critical for the regulation of one GST gene in response to safeners in *Arabidopsis*, several questions remain to be answered. For example, how do two different safeners induce the expression of different sets of GST genes in treated plants?

753. Safening Activity of Stereoisomers of Dichloromethyl-

[1,3]oxathiolane 3-oxide, a Chiral Safener. Istvan Jablonkai¹, Julia Visy¹, Tunde Matola¹, Ian Cummins², David Dixon², Robert Edwards²; ¹Institute of Biomolecular Chemistry, Hungarian Academy of Sciences, Budapest, Hungary; ²University of Durham, Durham, United Kingdom

Safeners are chemical agents that increase the tolerance of cereal plants to herbicides without affecting the weed control effectiveness. Commercially important safeners belong to chemically diverse compounds. Among these molecules only few are optically active but none of these

used in optically pure form despite evidences that different stereoisomers exhibit differential biological activity.

MG-191 (2-dichloromethyl-2-methyl-1,3-dioxolane) is a highly active safener used in safening maize against thiocarbamate and to a lesser extent chloroacetanilide herbicides. 2-Dichloromethyl-2-methyl-[1,3]oxathiolane 3-oxide, a structural analogue of the MG-191 having two chiral centers was prepared in order to test the protective effects of stereoisomers against acetochlor in maize. One diastereomeric pair of the enantiomers was as effective as MG-191 while the other exhibited only marginal protection. The diastereomers were separated by chiral HPLC isolating four enantiomers with enantiomer purity higher than 85%. Since only 1 mg of each enantiomer was generated no growth-response studies were carried out with these compounds. However, all enantiomers were tested for their ability to differentially enhance the expression of phi class (ZmGSTF1-2) and tau class (ZmGSTU1-2) GST isoforms in maize. The effect of pretreatment on the inducibility of ZmGSTF1-2 from roots was more enhanced by the stereoisomers with higher safening efficacy while only one of these enantiomers was effective in shoots. No differential enhancement in the expression of ZmGSTU1-2 was observed in roots and shoots after treatment with the enantiomers. Our results indicate the importance of the stereochemistry in the protective effectiveness however the induction of expression of various GST isoforms may not be so critical in the safener mode of action.

754. Comparative 3D Quantitative Structure-Activity Relationship Study of Acetal, Ketal and Amide Type Safeners. Istvan Jablonkai¹, Tunde Matola¹, Tamas Komives², Barna Bordas²; ¹Institute of Biomolecular Chemistry, Hungarian Academy of Sciences, Budapest, Hungary; ²Plant Protection Institute, Budapest, Hungary

Herbicide safeners alleviate toxicity of herbicides to crop plants without altering their weed control effectiveness. The exact mechanism by which safeners protect crops against herbicides has not been established. Antagonistic interactions between herbicides and safeners at common target sites may contribute to the mode of action of safeners.

Cyclic and open-chain acetals, ketals and acetamides were prepared and tested against the herbicide acetochlor in maize. Subtle changes of the chemical structure were found to greatly affect safening activity. For structure-activity relationships, a 3D-QSAR analysis with 27 compounds was performed using Comparative Molecular Field Analysis (CoMFA). CoMFA yielded two significant and predictive 3D-QSAR models ($q^2 = 0.462$ and 0.659) suggesting that in their low-energy conformations these chemicals can be described by the same pharmacophore and may interact with the same receptor site. The derived CoMFA models can be used for the prediction of safening activity of new derivatives, visual inspection of three-

dimensional ligand-receptor interactions and in silico screening of real and virtual molecule databases.

755. Tolerance of *Asphodelus tenuifolius* to Different Herbicides at Various Growth Stages. Gul Hassan¹, Muhammad Ishfaq¹; ¹NWFP Agricultural Univ, Peshawar, Pakistan

Pakistan is an agricultural country. There exists a vast agro-ecological diversity in the country. In the vast plains of Punjab and North West Frontier Province, huge belt of sandy soils exists. On these soils, chickpea is the crop of choice. Weeds predominant in the chickpea crop include wild onion (*Asphodelus tenuifolius*), *Carthamus oxyantha*, *Convolvulus arvensis* and *Lathyrus* spp. While *Asphodelus tenuifolius* is the worst weed of the winter crops including chickpea in the sandy soils of the southern districts of North western Pakistan. Herbicides are an integral part of farmers' cultural practices world-wide. But, still no effective herbicide is available for the control of wild onion. Hence, an experiment was conducted in pots at the Department of Weed Science, NWFP Agricultural University Peshawar Pakistan during 2005-06 under completely randomized design with split-split plot arrangement, to investigate the effect of different herbicides rates on wild onion at different growth stages. Two herbicides isoproturon and fenoxaprop-p-ethyl were tried each having four doses including an untreated check. The doses of fenoxaprop-p-ethyl were 0, 0.56, 0.94 and 1.30 kg a.i ha⁻¹ while the doses used for isoproturon were 0, 3.0, 4.0 and 5.0 kg a.i ha⁻¹. Each biotype of wild onion was subjected to 4 doses of each herbicide at 2 and 4 leaf and flowering initiation stage. Each treatment was replicated twice. The data were recorded on fresh and dry weight of wild onion. The interaction of herbicides x rates and biotypes x growth stages significantly affected the fresh weight, while the interactions of herbicides rates x growth stages, biotypes x growth stages, herbicides x rates, herbicides x growth stages and the interaction of biotypes x herbicides x growth stages significantly affected the dry weed biomass. Among the herbicides rates highest (4.83 g) fresh weight was recorded in untreated check while the lowest (3.66 g) was observed at high rate. Among the biotypes, the highest (2.16 g) dry weight was recorded for Mianwali biotype while the lowest (1.37 g) was recorded for Bannu biotypes. Flower initiation stage produced the highest (3.51 g) while the lowest dry weight (0.40 g) was recorded in 2 leaf stage. In the three way interaction of biotypes x herbicides x growth stages highest (4.361 g) dry weight was observed in Mianwali in both herbicides at flower initiation stage while the lowest (0.313 g) was recorded at 2 leaf stage in fenoxaprop-p-ethyl, however it was statistically similar with the various values recorded in isoproturon applied at 2 leaf growth stage. From the data it is concluded that tolerance to the tested herbicides varied in wild onion biotypes and the tolerance increased over time.