Response of Weed Communities and Corn (*Zea mays*) to Nitrogen and Herbicide Application

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ABSTRACT

An experiment was conducted on clay soil at Lods Agronomy Research Center, McGill University to study the response of weeds communities and corn plants to nitrogen and herbicide application. The experiment was arranged as split plots design with 6 replications, in which application of herbicide (at 4 levels) and nitrogen (at 3 levels) were respectively the main- and sub-treatments. The herbicide Nicosulfuron (9 g ha^{-1}) mixed with mineral oil (Agral 90, 25% v/v) was used to control grass weeds. The herbicide dicamba (590 g ha^{-1}) was used for broadleaf control. Nicosulfuron mixed with Agral at the above mentioned rates, and dicamba at 295 g ha^{-1} were used to control both grass and broadleaf weeds. Weedy check also was considered as control. Nitrogen (ammonium nitrate) at 60,120, and 250 kg ha^{-1} was applied twice; once at planting time and again 54 days after planting. The results indicated that the density of grass weeds was higher than that of broadleaf weeds. However, broadleaf weeds could grow vigorously and by the end of the season they showed strong growth in most weedy check. Nitrogen had a pronounced effect on corn growth and yield. Reducing the nitrogen supply resulted

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in pale green leaves in the corn. Increasing nitrogen application increased the corn biomass mainly during the rapid vegetative growth stage.

Key words: Corn, *Zea mays*, weeds community, nicosulfuron, dicamba, nitrogen.

چکیده

برای بررسی واکنش ذرت و جامعه علف‌های هرز به کاربرد نیتروژن و علفکش، آزمایشی در سال ۲۰۰۱ در مرکز تحقیقات علوم زراعی لادس واقع در دانشگاه مک گیل، در یک خاک رسی انجام شد. آزمایش بصورت کرت‌های خرد شده با ۶ تکرار اجرا شد که در آن علفکش (۴ سطح) و نیتروژن (۳ سطح) به ترتیب کرت‌های اصلی و فرعی بودند. نیکوسولفورون (اولتیم ، به میزان ۹ گرم در هکتار) بهمراه روغن معدنی (آگرال ۹۰ ، ۲۵ درصد) برای کنترل علف‌های هرز کشیده برگ، دیکمبا (به میزان ۵۹۰ گرم در هکتار) برای کنترل علف‌های هرز پهن برگ و مخلوط نیکوسولفورون بهمراه آگرال در مقادیر یاد شده و دیکامبا به میزان۲۹۵ گرم در هکتار برای کنترل توام علف‌های هرز کشیده برگ و پهن برگ بکار برده شدند. شاهد بدون علفکش نیز در نظر گرفته شد. نیتروژن (نیترات آمونیوم) در دو مرحله (زمان کاشت و ۵۴ روز پس از کاشت) ودر هر مرحله به میزان ۶۰، ۱۲۰ و ۲۵۰ کیلوگرم در هکتاربکار برده شد. شمارش بوته‌های علف‌های هرز و سطح پوشش علف‌هرز معیار ارزیابی تاثیر تیمارها بودند. وزن خشک علف‌های هرز نیز در هر ارزیابی ثبت شد. ارزیابی روی علف‌های هرز پیش از کاربرد علفکش، ۲ تا ۳ هفته پس از کاربرد آن و همچنین پس از مصرف کود سرک انجام شد. نتایج نشان داد که تراکم علف‌های هرزکشیده برگ بسیار بیشتر از علف‌های هرز پهن برگ بود. اما علف‌های هرز پهن برگ نیز از رشد زیادی برخوردار بوده و در انتهای فصل و درکرت‌های شاهد، پتانسیل رشدی خود را نشان دادند. نیتروژن اثر معنی داری بر رشد و عملکرد ذرت ایجاد نمود. کاهش میزان نیتروژن مصرفی منجر به ایجاد رنگ سبز کم رنگ در برگ های ذرت شد. افزایش میزان کاربرد نیتروژن بیوماس ذرت را بویژه طی دوره رشد سریع رویشی ، افزایش داد. اختلافات معنی داری در ارزیابی علفکش کنترل کنندهکشیده برگ‌ها مشاهده شد.

واژه‌های کلیدی: ذرت، جامعه علف‌های‌هرز، نیکوسولفورون.

INTRODUCTION

Designing an effective weed management program requires understanding the effects of ecological factors on weed population dynamics, which are either successions or fluctuations. Ecological factors give rise to sequential changes, while site-specific weed management results in greater fluctuations in population dynamics. (Swanton *et al.*, 1999a; Van Aker, 2000).

Weed communities are usually patchy and vary depending on the weed species present, weed density, duration of weed growth, environment, tillage, fertilization, herbicide application, location etc. (Liebhardt *et al.*, 1989; Kapusta *et al.*, 1994; Kelner *et al.*, 1996; Swanton *et al.*, 1999a). Societal concerns about environmental safety have provoked intense interest in the development of site-specific farming practices (Van Aker, 2000). Row crops such as corn require specific weed treatment in order to produce high yields (Kostandi & Soliman, 1998; Norris, 1999).

Crop yield loss is not usually a function of a single weed species; instead, several weed species makes a community which competes against the established crop in the field (Hons & Saladino, 1995; Swanton *et al.*, 1999b). This situation complicates the analysis of the effectiveness of weed control. Controls could include reducing the number of weeds or stunting their growth. It is also noteworthy that the effect of weeds on crops might be additive at low densities, but not at high density (O'Sullivan & Bouw, 1998). Van Aker (2000) reported that under high density of wild oat (*Avena fatua*) i.e. 150 plants m^{-2} wheat yield loss was significantly high. Such conditions result in higher weed seed production and unpredicted weed patch spread. It is costly for farmers and producers to control unpredicted weed patch spread, especially if these patches become herbicide resistant (Morton & Harvey, 1994b).

Nitrogen, which affects weed seed germination, weed growth and weed seed dispersal influences the composition of weed flora (Swanton *et al.*, 1999a; Tanaka & Anderson, 2001). Increasing nitrogen may cause an increase in nitrophilous weed species such as lambsquarter (*Chenopodium album* L.) in summer crops and foxtail (*Setaria* sp.) infestation in spring wheat. It also breaks seed dormancy (Van Aker, 2000, Tanaka & Anderson, 2001). Apparently, in the case of high wild oat density, nitrogen became the limiting factor and resulted in the negative response of wheat (Tanaka & Anderson, 2001). Tanaka and Anderson (2001) concluded that increasing nitrogen at high weed density improved crop yield because high rates of applied nitrogen reduced the number of weeds. They observed that nitrogen reduced weeds from 79 weeds m^{-2} at 33 kg ha^{-1} to 12 weeds m^{-2} at 100 kg ha^{-1}. Wicks *et.* al. (1999) in a study in the Great Plains of United State concluded that the application of nitrogen above the optimum rate in winter wheat may improve weed control but it will decrease crop yield.

Herbicides are still the first choice for weed control. Approximately 95% of row crop acreage is treated with herbicides (Monks *et. al*., 1996). Nicosulfuron is one of the most promising sulfonylurea herbicides recently registered for corn. It provides good-to-excellent control of several hard to control annual and perennial grasses (Rabaey & Harvey, 1997). It is effective even at rates as low as 9 g ai ha^{-1}. Its phytotoxicity, post herbicide application, can be increased by using adjuvant in the spray mixture (Kapusta *et. al*., 1994). Nicosulfuron also has the advantage of enhanced herbicide action when combined with urea and/or ammonium nitrate when used against large crabgrass (*Digitaria* sp.) and foxtail (Nalewaja *et. al*., 1998).

Crop yield loss is due to several weed species, so the analysis of yield loss due to each weed particular species is complicated. Besides, when the number of weeds is low, the effect is additive, but this is not true for higher densities (Hons & Saladino, 1995). Despite these differences it has been assumed and incorporated into yield loss models.

Other activities such as nitrogen application rates, crop rotation, high moisture and alternation of herbicides may reduce weed density and consequently increase crop yield. The objective of this research was to determine the weed community and corn response to nitrogen and herbicide application.

MATERIALS AND METHODS

Field experiments were conducted at Lods Agronomy Research Center, McGill University in Montreal, Quebec, Canada (latitude of 45° 25’ N, and longitude of 75° 56’ W), during the 2001 growing season. The soil type was Ste Rosalie clay. Organic matter varied between 4.5 and 5.7%, and soil pH varied between 6.51 and 7.08. The experiment was set out as a randomized complete block design with a split plot arrangement with 6 replications. Four levels of herbicide and 3 levels of nitrogen were applied to the main plots and sub plots, respectively. The seedbed was prepared by a fall mould board plough followed by field cultivator in the spring before corn planting. The size of each plot was 10×10 m^2. Corn seeds were planted at a depth of 4 cm on May 10, 2001. Row spacing was 75 cm and the corn population was based on 76000 plants ha^{-1}. At planting time fertilizer was broadcast at 120 kg ha^{-1} phosphorous and 50 kg ha^{-1} potash. Nitrogen was applied as side dressing at planting time at 10, 20, and 100 kg ha^{-1}, and as a top dressing on July 3, 2001 at 50,100, and 150 kg ha^{-1}, i.e. a total of 60,120, and 250 kg ha^{-1} for N_1, N_2, and N_3, respectively.

Herbicides at three levels were used for weed control and a control (W_0) was considered. Nicosulfuron (9 g a.i. ha^{-1}) mixed with mineral oil (Agral 90, 25%v/v as a surfactant) was used to control grass weeds (W_1). Dicamba (590 a.i. ha^{-1}) was used for broad leaf control (W_2). A mixture of Nicosulfuron (9 g a.i. ha^{-1}) and mineral oil (25%v/v) and dicamba (295 g a.i. ha^{-1}) was used to control both broadleaf and grass weeds (W_3). Herbicides were applied on June 8, 2001 with a CO_2-pressurised sprayer using 8004 flat fan nozzle tip at 300 kPa pressure and a spray solution of 250 L ha^{-1}.

The presence of weeds was graded based on their frequency. So, they were graded into four groups: the mostly dominant (>60% of the plots), fairly dominant

(<30% of the plots), rarely dominant (<10% of the plots), common (present in most of the plots), and rare (rarely present in some plots).

Weed evaluation was based on stand counting, visual rating and biomass of the samples. The first evaluation was performed on June 6, 2001 (2 days before herbicide application). The second evaluation was performed on June 25, 2001 (19 days after herbicide application). The third evaluation was performed on July 25; about three weeks after nitrogen top dressing. Counts were taken from a 1×1 m^2 micro plot installed in the center of each plot, within which, the number of broad leaves, grasses, and sedges were counted. For visual rating, whole plots were rated based on the percentage of weed cover (grasses, broad leaves, and sedges). For biomass calculations, up to 10 randomly selected plants (depending on their size) of each species, (including roots) within each plot were taken and the average of dry weight (after oven drying at $70^{\circ}C$ for 24 h) of each species was determined and multiplied by the number of existing plants within the quadrate in each sub-plot. By adding the value of different species within each group (broad leaves, grasses, and sedges), the dry weight of total weeds and each subgroup in each plot were determined.

Corn plant dry weight measurements were performed on June 25, 2001 (19 days after herbicide application) and also on July 25, 2001 (3 weeks after nitrogen top dressing). Corn biological yield and seed yield were determined at the end of the growth season. Data from these different parameters were collected; mean differences were determined using the Duncan New Multiple Range Test (DNMRT) (SAS, 1996). To analyze different parameters, the relative abundance values were transformed into arc sine or logit transformation. Only broadleaf and grass weeds that occurred frequently could have normal error distribution, accounted for in the analysis. In another words, due to the inconsistency of grasses and sedges, their numbers were summed and then analyzed.

ANOVA was performed on the corn yield data using the General Linear Model (GLM) procedure of SAS and means were compared using the DNMRT test (SAS, 1996).

RESULTS AND DISCUSSION

The following weeds were present in the field:

I- Mostly dominant: lambsquarters (*Chenopodium album* L.), yellow foxtail [*Setaria glauca* (L.) P. Beauv.]

II- Fairly dominant: leafyspurge (*Euphorbia helioscopa* L.), large crabgrass (*Digitaria singuinalis*), yellow nutsedge (*Cyperus esculentus* L.)

III- Rarely dominant: sowthistle (*Sonchus oleraceus* L.), quackgrass (*Elytrigia repens* (L.) P.Beauv.), wild mustard (*Brassica kaber*)

IV-Common: Canada thistle (*Cirsium arvense* L.), barnyardgrass (*Echinochloa crus –galli* (L.) Beauv.).

V- Rare: milkweed (*Asclepias syriaca* L.), velvetleaf (*Abutilon theophrasti* Medik.), horsetail (*Equisetum palustris* L.), ladysthumb (*Polygonum coccineum* Muhl. ex Willd).

Effects of nitrogen:

A) Corn

Significant differences were observed in corn dry weight (Fig. 1a) and corn yield (Fig. 1b) due to differing nitrogen rates. However, dry weight differences on July 27, 2001 were not significant. Increasing the rate of nitrogen application increased corn dry weight and corn yield (Fig. 1a, 1b). Before tasseling and during the fast vegetative growth period the corn responded positively to nitrogen application and the results were more pronounced at this stage of growth. Later on, assimilates translocated towards the corn cobs resulting in higher corn grain yield especially at higher rates of nitrogen application.

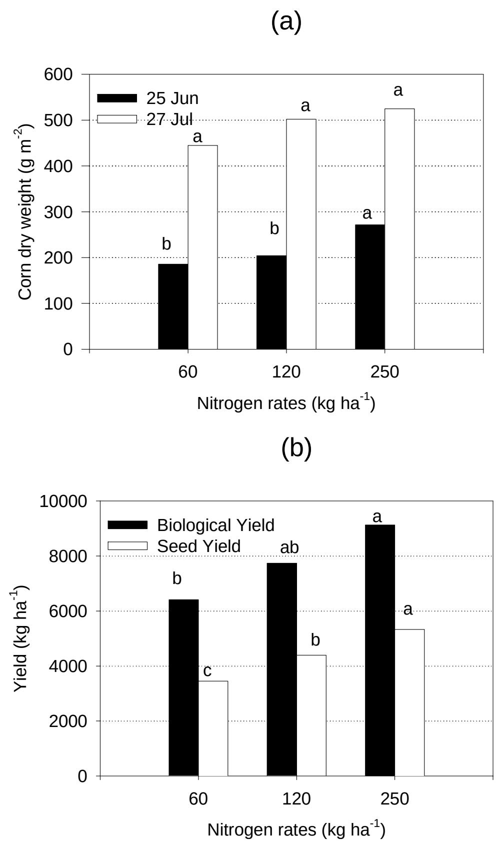

Figure 1. Effect of nitrogen application on (a) corn dry weight on June 25 and July 27, 2001 and (b) biological and seed yield of corn. Values in each series not marked with same letter are significantly different by $DNMRT_{0.05}$.

These findings are similar to those of Tanaka and Anderson (2001) at higher population density of weeds. It is possible that increasing the rate of nitrogen above the optimum level was in favor of weeds and has resulted in yield reduction, which was also observed in the Great Plains study (Wicks *et al*., 1999). However, the dry climate governing the Great Plains is not comparable to the rainy climate of Montreal (Morton & Harvey, 1994a; Rabaey & Harvey, 1997).

B) Weed community

The effects of nitrogen levels on different parameters of grassy weeds (Table1), broad leaf weeds (Table 2), and total weeds (Table 3) are shown. In all evaluations no differences were observed in the number of weeds, percent weed coverage, and weed dry weight, across the different nitrogen levels. Our results do not correspond with the findings of Tanaka & Anderson (2001) and Van Aker (2000) which indicate that the higher rate of nitrogen resulted in a reduction in weed population density. The contradictory results may be due to variation in the agro-ecological conditions where the studies were carried out.

Generally, the density of different weed species was higher in the 1st evaluation compare to 2nd and 3rd evaluations at different levels of nitrogen application. The decrease in weed number was due to self-thinning because of high competition during the early growth stages. However, the number of lambsquarter and particularly yellow foxtail increased markedly in almost all plots. This was probably due to the nitrophilous nature of lambsquarter and higher germination rate of yellow foxtail (Tanaka & Andersen, 2000).

Effects of herbicides

A) Corn dry weight and yield

Significant differences were observed among herbicide treatments on June 25 and July 27, 2001(Fig. 2a). The control and broad leaf herbicide treatments produced the minimum corn dry weight. Surprisingly, the highest corn dry weight was produced in grass herbicide treated plot during both the growing season and at harvest (Fig. 2a, 2b). Perhaps some broad leaves have a stimulatory effect on corn which resulted in higher corn dry matter production and seed yield.

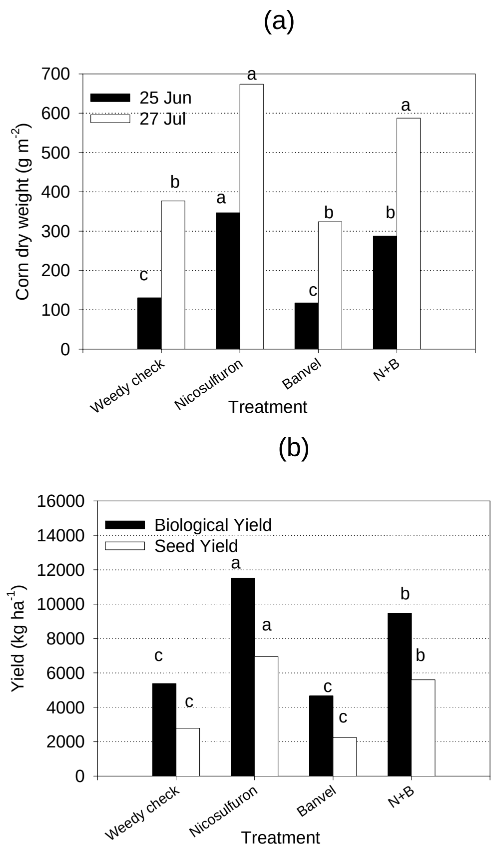

Figure 2. Effect of herbicides on (a) corn dry weight on June 25 and July 27, 2001 and (b) biological and seed yield of corn. Values in each series not marked with same letter are significantly different by $DNMRT_{0.05}$.

The same trend was observed for corn yield and higher yield observed in grassy weed control plots. Plots treated with Banvel were heavily infested by grassy weeds, and thus corn dry weight and yield was lower than in the control (Fig. 2b). Probably, the lack of competition from broad leaves resulted in high grassy weed growth and lower corn biomass.

Table 1. Effect of nitrogen rate and herbicide on grass weeds.

Treatment	**Number of weeds (Plant m^{-2})**			**Visual rate (%)**			**Weed dry weight (g)**		
Nitrogen ($kg\ ha^{-1}$)	6 Jun	25 Jun	27 Jul	6 Jun	25 Jun	27 Jul	6 Jun	25 Jun	27 Jul
60	242 a*	158 a	170 a	44 a	33 a	34 a	12.0 a	71.7 a	136.8 a
120	217 a	164 a	161 a	40 a	32 a	32ab	8.8 a	70.0 a	135.8 a
250	217 a	174 a	145 a	41 a	32 a	30 b	9.4 a	94.0 a	135.8 a
Herbicide									
Weedy check	221 ab	163 ab	171a	42 a	45 b	37 b	7.5 b	108.6 b	170.3 b
Nicosulfuron	229 ab	144 b	121 b	39 a	10 d	17 d	8.9 b	18.0 c	44.8 d
Dicamba	275 a	209 a	200 a	44 a	57 a	49 a	12.6 a	162.9 a	219.7 a
Nicosulfuron + dicamba	174 b	140 b	142 b	40 a	16 c	24 c	10.7ab	24.8 c	109.0 c

*Values in each category not marked with same letter are significantly different by $DNMRT_{0.05}$.

B) Weed community

In grass control plots the presence of graminaceous plants and sedges such as quack grass, yellow nutsedge and foxtail were reduced. Lambsquarters was the most dominant broadleaf species. In nicosulfuron treated plots, the species present were mostly yellow foxtail; quack grass and yellow nutsedge with few broad leaves present. In the control corn plots, the weeds showed vigorous growth. Among the grasses, yellow foxtail and quack grass were initially present at higher levels but eventually yellow foxtail became dominant. It should be mentioned that grasses and broad leaves species were monitored but not evaluated.

Table 2. Effect of nitrogen rate and herbicide on broad leaf weeds.

Treatment	**Number of weeds (Plant m^{-2})**			**Visual rate (%)**			**Weed dry weight (g)**		
Nitrogen (kg ha^{-1})	6 Jun	25 Jun	27 Jul	6 Jun	25 Jun	27 Jul	6 Jun	25 Jun	27 Jul
60	30 a*	18 a	14 a	9 a	8 a	9 a	2.1 a	69.2 a	90.2 a
120	35 a	13 a	14 a	8 a	9 a	10 a	1.5 a	51.6 a	98.4 a
250	43 a	18 a	14 a	10 a	10 a	12 a	8.9 a	51.7 a	114.3 a
Herbicide									
Weedy check	44 a	26 a	24 a	11 a	19 a	20 a	1.1 a	93.1 a	220.2 a
Nicosulfuron	28 a	21 a	18 ab	6 b	4 c	7 c	8.2 a	72.9 ab	68.4 c
Dicamba	39 a	17 a	13 a	10 a	12 b	14 b	4.3 a	55.1 b	113.8b
Nicosulfuron + dicamba	33 a	3 b	1 c	7 b	1 c	1 d	3.1 a	2.2 c	1.4 d

*Values in each category not marked with same letter are significantly different by $DNMRT_{0.05}$.

Among the broad leaves, lambsquarter was the most dominant species but weeds such as Canada thistle, and milkweed were also present. Interestingly, in some plots where leafy spurge was highly present, yellow foxtail was not dominant and corn plants were in better condition. In the few plots where sowthistle was the dominant species, neither corn nor other weeds were in good condition. Although Banvel had some herbicidal effect on sowthistle, both sowthistle and quack grass could compete to other weeds and wherever they were present other weeds were not common. Sowthistle and leafy spurge may have allelopathic effects on weeds.

A significant difference was observed in the weed communities in the June 6, 2001 evaluations (Table 1). Since the distribution of grassy weeds within experimental plots was patchy thus, at greater densities it influenced the outcome (Swanton et al., 1999b) for example, the dry weight in the first evaluation.

In Nicosulfuron treated plots the differences in the number of weeds, visual rating, and dry weight were more pronounced in 2^{nd} and 3^{rd} evaluations (Table 1). The grasses were controlled effectively and where the number of grasses was high, the corn plants were vigorous enough to out competition the grass weeds. This was obviously due to the herbicide's ability to reduce grassy weed growth.

The effect of herbicide on broadleaf weeds was more apparent towards the end of the season. Using the combined broad leaf and grass herbicide had a better effect on weeds. Broadleaf control herbicides resulted in good control of broad leaves but grass plants were healthy and fresh. Where sowthistle and leafy spurge were present, grasses were reduced considerably. However, wherever only leafy spurge was present, corn plants grew better.

Table 3. Effect of nitrogen rate and herbicide on total weeds.

Treatment	Number of weeds (Plant m^{-2})			Visual rate (%)			Weed dry weight (g)		
	6 Jun	25 Jun	27 Jul	6 Jun	25 Jun	27 Jul	6 Jun	25 Jun	27 Jul
Nitrogen (kg ha^{-1})									
60	272 a*	176 a	184 a	52 a	41a	43 a	13.1a	136.0 a	226.9 a
120	252 a	177 a	175 a	49 a	41 a	42 a	10.3a	121.6 a	234.1a
250	259 a	191a	159 a	50 a	42 a	41 a	18.2a	145.8 a	276.3 a
Herbicide									
Weedy check	265 ab	188ab	196a	54a	64b	57b	8.6a	201.8a	390.4a
Nicosulfuron	258 ab	168b	140b	47a	14c	24c	17.0a	90.9b	113.2b
Dicamba	314 a	226a	213a	54a	70a	63a	16.9a	218.0a	333.4a
Nicosulfuron +dicamba	207 b	143b	143b	47a	17c	25c	13.0a	26.9c	107.4b

*Values in each category not marked with same letter are significantly different by $DNMRT_{0.05}$.

The effect of herbicides on total weed control indicated that using a combination of Dicamba and Nicosulfuron was the best treatment under the Montreal conditions (Table 3). Grasses were not demolished completely, but broad leaves were controlled effectively. This may be due to higher translocation of these herbicides (Kalany & Glenn, 2000). However, Augero-Alverdo *et al.* (1991), Augero-Alverdo & Appleby (1991) and Harts & Wax (1996) depicted antagonism among the broad leaf and grass herbicides.

In conclusion we might say that in the conditions studied, corn responds effectively to herbicides and increased nitrogen rates. It is noteworthy that controlling grasses with Nicosulfuron and Agral was more effective than total weed control. Corn grew better at higher rate of nitrogen but this was not true of the weeds.

We conclude that combination of Nicosulfuron and Dicamba was the best treatment for weed control in corn, but it may not result in better corn yield. However, due to variation climatic factors, a one-year study is not enough to obtain a definite conclusion. Further investigation of total weed control and grassy weed control is needed to clarify this and to justify recommendations on this basis of this research.

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