POTATO LATE BLIGHT MANAGEMENT IN ORGANIC AGRICULTURE

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Introduction

Late blight caused by the fungus *Phytophthora infestans* is one of the most serious diseases of potato worldwide and can completely destroy a crop, resulting in 100% yield loss. In the 1840s, it caused the Irish Potato Famine that killed a quarter of a million people through starvation and caused another million or so to immigrate to the United States (Arneson, 1998). Currently, it causes substantial economic losses in both conventional and organic potato production systems throughout the EU (Elad, Kohl, and Shtienberg, 2002). A range of chemical fungicides with different modes of action offer the most effective control of late blight. However, when environmental conditions favour spread of the disease, frequent applications will be needed and they may not be completely effective. In organic agriculture, copper compounds are currently the only fungicides permitted for blight control, but not in all countries. These were due to be prohibited from March 2002 under EU legislation, but this has been delayed. Until the end of 2005, use of copper is restricted to a maximum of 8 kg of elemental copper/ha/year, then 6 kg per year thereafter, with the aim of completely phasing it out when effective alternative control methods are developed. The proposed ban on the use of copper fungicides in organic farming in the EU will substantially increase the risk of blight in organic production and consequently increase economic losses of farmers, unless suitable alternative blight management strategies are developed. Since EU policies are aimed at supporting an expansion of organic production these are required urgently. Such approaches are being investigated in an EU-funded research programme known by the acronym **Blight-MOP: Blight**-development of a systems approach for the **M**anagement of late blight in EU **O**rganic **P**otato production to maintain yield and quality and hence commercial viability in the absence of copper fungicides. It involves seven countries (Denmark, France, Germany, Netherlands, Norway, Switzerland, and UK) and thirteen research centres and runs from 2001 to 2005. The system approach involves integrated use of (i) resistant varieties and diversification strategies (ii) existing agronomic strategies (iii) alternative treatments that can replace synthetic and copper based fungicides and (iv) use of existing blight forecasting systems to optimise control treatments.

Late blight disease agent and symptoms

The late blight fungus attacks potato leaves, stems and tubers. Asexually produced spores (sporangia) spread through the crop by wind and rain splash and the disease progresses very rapidly when temperatures exceed 10°C and relative humidity is over 75% for 2 days or more. At temperatures above about 15°C, spores can infect leaves directly but at lower temperatures, the spores germinate to produce 10-12 motile zoospores, each of which can swim in water films and infect the leaves. The fungus overwinters as mycelium in potato tubers infected during the previous season by spores that were washed through the soil. As

Symptoms of potato late blight infection

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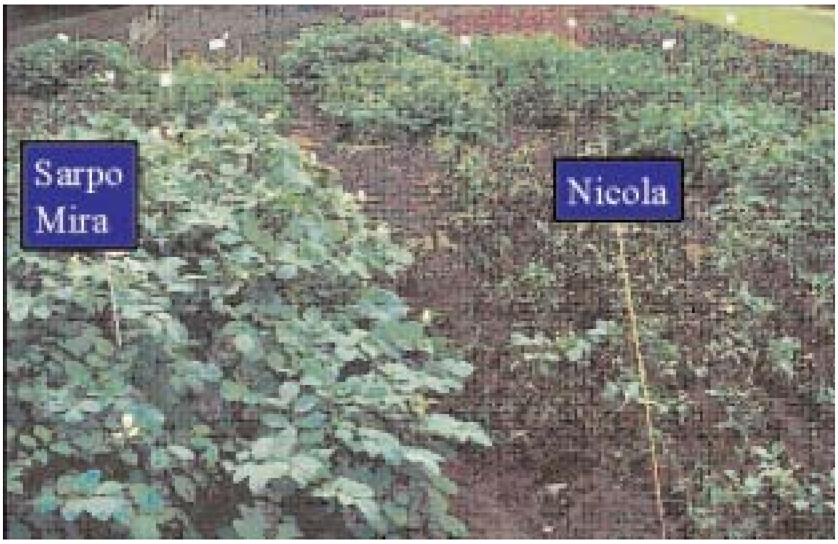
temperatures increase in spring and the infected tuber begins to grow, the mycelium within it grows to produce an infected plant on which spore-bearing lesions develop. These spores infect newly planted potato crops and the disease cycle begins again. The first sign of infected tissue is brown spots on the leaves often surrounded by a halo of chlorotic (yellowed) tissue. During moist weather, a white cottony growth will develop on the margins of the lesions on the underside of the leaves (but in dry weather such as experienced in August 2003, infected areas quickly turn dark brown and brittle and the disease is arrested). Infected stems and petioles will turn dark brown or black. Stem blight lesions may appear before or after leaf lesions and are important sources of further infection. Their origins seem to be unclear, but they may arise from infection within the mother-tuber that moves up the stem. Alternatively, spores from foliar lesions higher up the plant may be transported downwards and become lodged within the axils of leaves lower down the canopy where they germinate and penetrate the stem. As mentioned previously, tubers may become infected by spores washing through the soil profile. These develop brown to purple lesions followed by a brown rot. When harvested and put into store, blight-infected tubers may lead to serious losses of marketable yield because of invasion with secondary rotting pathogens, especially bacteria.



Differences in varietal resistance to late blight

The late blight pathogen originates from central Mexico. Here there is a highly diverse sexual population with both A1 and A2 mating types present. Until about 25 years ago, only the A1 mating type was present worldwide. Sexual reproduction was impossible because the compatible A2 mating type was absent except in Mexico. Since then however, the A2 type has been found in most potato growing regions of the world and was first detected in Europe in 1981 (Roman, Grunwald and Fry, 2000). Sexual reproduction between A1 and A2 mating types produces resting spores or oospores. Oospores have thick walls and are very resistant to desiccation and microbial attack. They can survive in the soil for several years free of potato host-tissue and are a source of infection for healthy crops in the absence of blight-infected tubers. Their true significance is unclear and varies from country to country depending on the distribution and frequency of the A1 and A2 mating types. However, sexual reproduction leads to more diverse populations than asexual reproduction, which coupled with the spread of more virulent strains of the pathogen in recent years has made the disease even more problematic.

Late blight management strategies

Late blight management principles are the same for both organic and conventional production, but the scope for fungicide use is severely limited in organic crops. Non-chemical blight management depends on the integration of different measures that help to avoid, prevent or delay the onset of the disease or reduce the rate of infection (Clarke, 2003). Used alone, they may not give satisfactory control, but each can make an important contribution, and in combination interact to give improved efficacy.

As infected tubers are one of the main sources of infection, blight-free seed should be planted. Waste potatoes on dumps and volunteers are major sources of inoculum early in the season and, as they tend to develop and produce foliage well ahead of the planted crop, should be destroyed before the new crop emerges. However, eradication is extremely difficult. Disease forecasts based on weather conditions and current infection patterns will help growers to assess the risk of an outbreak and take appropriate action. Crops should also be monitored regularly for development of infection with the disease to facilitate timely defoliation and reduce the risk of tuber blight infection

Varietal resistance

Potato varieties differ in their susceptibility to both foliage and tuber blight. Varieties with race specific (highly effective resistance based on R-genes) and race non-specific resistance (partial resistance/tolerance) to late blight are available. However, if the same resistant varieties are used frequently in the same geographic area, new races or more aggressive strains of the fungus develop that overcome their resistance. Partial resistance, based on a number of genes that work together rather than a single major resistance gene, slows the progression of the disease, imposes less selection pressure on the fungus and is more durable. Results from the BLIGHT-MOP research project showed that resistant varieties grown to organic standards under different environmental conditions gave particularly effective prevention of foliage and tuber blight. Although yields of resistant varieties were not always higher than more susceptible varieties, they would decrease the source of inoculum significantly. It was also clear that copper fungicides gave limited benefit in the most resistant varieties. Whilst more resistant varieties are available than some of the most popular ones grown organically, uptake is very much dependent on their market acceptability.

Diversification strategies

Evidence suggests that blight epidemics can be prevented or at least delayed by adopting diversification strategies. These include growing varieties with different forms of resistance as mixtures or in alternating rows, or growing potatoes in beds alternating with beds of other crops such as cereals to provide physical barriers to spore dispersal. BLIGHT-MOP studies showed that the effects of mixtures of potato varieties and alternating rows of susceptible and resistant varieties on the onset or amount of infection of the foliage with blight were variable. However, it was clear that the success of such approaches will be highly dependent on the choice of varieties grown in combination and severity of disease infection, but may be beneficial as part of an integrated blight management system. An interesting observation was that the yield per unit area of varieties grown in some mixtures was higher than equivalent yield of the same varieties grown as monocultures, not because blight was decreased, but because resources for growth were better utilised – an important objective in organic systems. However, growing varieties in mixtures may increase costs of establishment, harvest and handling of crops and may offset potential advantages in terms of disease prevention or yield.

Furthermore, acceptability of mixed varieties may be limited for the discriminating fresh and processing markets for human consumption because of varietal differences in quality characteristics. These may be less important for starch manufacture however. Intercropping potatoes with beds of grass/clover or spring wheat showed some reduction in blight in some situations but overall, yield was unaffected.

Agronomic strategies

Agronomic management strategies in organic crops may affect levels of foliage and/or tuber blight. On the other hand, they may encourage early tuber growth so that acceptable yields are obtained before blight intervenes. Crop nutrition and soil fertility can influence disease development in the crop. For example, high inputs of nitrogen can cause excessive haulm growth and delay natural senescence, thereby increasing the risk of blight and decreased yield. Early planting and/or pre-sprouting (chitting) seed usually results in earlier bulking. Higher yields are achievable earlier, before blight infection occurs, than from late planted or un-sprouted seed but the advantage may decrease as the season progresses and blight infection is delayed. Wider plant spacing may speed up bulking rates to meet market specification more quickly before blight destroys the crop. Yield of potatoes is very responsive to irrigation when water supply is limited. However, irrigation can increase incidence of foliage blight and also tuber blight by washing spores down to progeny tubers and should be avoided in the presence of active blight or in periods of high risk (e.g. Smith Periods). If blight symptoms appear, foliage should be destroyed by flailing or flailing and burning with a propane–gas burner to help prevent spread to the tubers. Harvest should be delayed for at least 3 weeks after defoliation to allow tuber skins to set and blight spores on tops to die off. In summary, BLIGHT-MOP experiments testing agronomic treatments have shown that: there were no differences in blight infection between plant populations and spacing covering the normal commercial range although total and graded yields were affected because of large effects on numbers of stems and tubers; effects of planting date and chitting on blight were small and yield differences were due to effects on the duration of tuber bulking; blight was unaffected by manurial treatments i.e. levels of nitrogen or potassium or nitrogen to potassium ratios, but fertility management influenced yield in some cases. However, there was an indication that potatoes grown after grass/clover or lucerne had more blight infection than after spring wheat; irrigation had greater effects on yield than on blight infection; defoliation mechanically and/or by heat treatment decreased the number of blight sporangia per plant but had no effect on tuber blight, although seasonal conditions were not highly conducive for the development of tuber infection.

Pre-sprouted (chitted) seed tubers

Alternative treatments

Various alternative treatments including microbial antagonists and plant or compost extracts have been developed for the control of fungal pathogens. They may have direct antifungal effects or stimulate competitor micro organisms and/or induce plant resistance. Compost extracts (compost teas), which are filtrated solutions of mixtures of compost materials and water, have shown promising results

Compost extract (“tea”) maker

Leaf bioassays of micro-organisms for late blight control

against crop diseases (Brinton, Trankner & Droffner, 1996; Goldstein, 1998) but the mechanisms of effects seem to vary depending on the host/pathogen relationship and the mode of application. Biological control of late blight with bacteria and fungi that are antagonistic to late blight but harmless to crops has been studied for many years (Jindal, Singh, & Meeta, 1988). So far, BLIGHT-MOP experiments have shown some beneficial effects of compost extracts on potato blight control in laboratory assays but not in the field, although the use of adjuvants may improve field performance. Some micro organisms, plant extracts and existing products have also shown promise, but more investigations are needed to find the most effective and consistent alternative treatments and to formulate them to achieve optimum results.

Conclusions

There are large regional differences in the impact of late blight on organic potato production in the EU and there is a widespread view that a copper fungicide ban will have serious consequences for organic potato production unless effective alternatives are available. There is no single, alternative treatment available that offers the level of control given by copper fungicides. Consequently, successful management of late blight in organic systems will rely on an integration of resistance management and diversification, agronomic and alternative treatment strategies into existing organic potato production systems specifically adapted to particular regions to sustain economically viable potato production. To this end, the BLIGHT-MOP research programme is still underway and currently evaluating integrated management systems in each of the seven countries involved.

Clearly, the challenges for managing blight in crops grown according to organic standards are even greater than in conventional ones where fungicide programmes play a key role in delaying the epidemic. Systems of production will be needed that are designed for particular situations and prevailing conditions and the level of success in delaying or slowing the rate of spread of the disease may vary from system to system. This demands a much more flexible approach than in conventionally grown crops, where variety choice, agronomic management, crop protection protocols and production standards are very specific in order to meet the demands of particular market outlets.

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Keywords

Defoliation, Fungicide, Infection, R-gene, resistance, sprouting, Variety.

References

Arneson, P.A. (1998): Late blight. Cornell University, Ithaca, NewYork. http://ppathw3.cals.cornell.edu/OLplpath/profiles/Lateblit/pa2300t0.htm.

Brinton, W.F., A. Trankner & M. Droffner (1996): Investigations into liquid compost extracts. *Biocycle* **37 (11),** 68–70.

Clarke, B. (2003): Bold strategy to defeat potato blight. Science on your Doorstep series, Eastern Daily Press 1st March 2003. http://www.nrp.org.uk/enews/edpblight.htm

Elad, Y., J. Kohl & D. Shtienberg, (2002): Screening of plant extracts, micro-organisms and commercial preparations for biocontrol of *Phytophthora infestans* on detached potato leaves. *Bulletin Oilb/Srop* **25,** 391–394.

Goldstein, J. (1998): Compost suppresses disease in the lab and on the fields. *BioCycle*, November 1998. 62–64.

Jindal, K. K., Singh, H., & Meeta, M. (1988): Biological control of *Phytophthora infestans* on potato. *Indian Journal of Plant Pathology,* **6,** 59–62.

Roman, K. V.; Grunwald, N. J. & W.E. Fry, (2000): Promoting international collaboration for potato late blight disease management. *Pesticide Outlook*, October 2000, 181–184

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Other articles on disease control in potatoes appeared in issues **9(6)**, **11(6)** and **15(1)**