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Blight-MOP: Development of a systems approach for the management of late blight (caused by *Phytophthora infestans)* in EU organic potato production

Period: 01/03/01 – 31/12/05

Co-Ordinators: Prof. C. Leifert
Dr. S. J. Wilcockson

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Note: Letters shown in brackets under Chapter 3 to 8 are the initials of Partners undertaking the work described. Please refer to Chapter 1, Table 1 for full names and addresses of Partners.

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This report has been compiled by Dr S.J. Wilcockson, UNEW, Assistant Project Co-ordinator, by editing contributions from the project partners. If there are errors, omissions or misrepresentations – sincere apologies are extended.

In the first instance, all enquiries and requests for additional information should be directed to:

Dr Steve Wilcockson
University of Newcastle upon Tyne
Nafferton Ecological Farming Group
Nafferton Farm
Stocksfield
Northumberland
NE43 7XD
United Kingdom

Telephone: +44 (0) 1661 830222
Fax: + 44 (0) 1661 831006

e-mail: s.j.wilcockson@ncl.ac.uk

Executive Summary

Blight-MOP

Late blight (caused by *Phytophthora infestans*) is the most devastating fungal disease affecting organic (and conventional) potato production in the EU. It kills the foliage and usually results in losses of yield which can be very large when infection is severe and occurs early in the season. The disease may be transmitted to the tubers which become unmarketable and these can lead to complete deterioration of the stored crop if put into storage with healthy tubers. To a great extent, conventional production systems rely upon frequent applications of synthetic fungicides with different modes of action for late blight control, but this is seldom completely successful. However, in organic systems, the availability of chemical fungicides is currently restricted to those which are 'considered to be traditional organic farming practices': these include copper hydroxide, copper oxychloride (tribasic), copper sulphate and cuprous oxide that have a protectant action and are reasonably effective. Their use is restricted by national legislation and organic certifying authorities and pressure has been mounting to withdraw them not only because of possible adverse effects on wildlife, the environment and human health but also their incompatibility with organic production principles. This led to a proposed ban on the use of copper fungicides for control of late blight in organic farming in the EU from March 2002 which had potentially serious implications for the potato crop. The resultant losses of yield and hence income in the absence of copper-based fungicide sprays were expected to threaten the economic viability of both organic potato enterprises and/or whole organic farming businesses in many areas of the EU in the medium to long term until effective, alternative methods are developed.

In the meantime, two major approaches were adopted. One was to set a limit to the amount of copper-based fungicides permitted for application: until 31 December 2005, the maximum application was restricted to 8kg of elemental copper/ha/year for annual crops, declining to 6kg/ha/year from 1 January 2006 (but this could be changed at any time in the light of developments in viable alternatives or should there be proposals for withdrawal under the EC Review programme for existing active substances). Another was to promote further research to identify and develop effective alternative late blight control methods and strategies without the undesirable effects associated with copper-based fungicides.

The **Blight-MOP** project – 'Development of a systems approach for late **Blight** (caused by *Phytophthora infestans*) **M**anagement in EU **O**rganic **P**roduction systems' was initiated in March 2001 to achieve this aim and maintain yield and quality and hence commercial viability of organic potato crops without the use of copper fungicides. Such an approach involves integrated use of (i) resistant varieties (ii) existing agronomic strategies (iii) alternative treatments that can replace synthetic and copper-based fungicides (iv) use of existing blight forecasting systems to optimise control treatments and to maximise synergistic interactions between (i), (ii), (iii) and (iv).

The specific objectives were to:

1. Assess the socio-economic impact of late blight and 'state-of-the-art' blight management practices in EU organic potato production systems
2. Assess varietal performance in organic production systems in different EU regions and interactions with local blight populations
3. Develop within field diversification strategies to prevent/delay blight epidemics
4. Optimise agronomic strategies for the management of late blight
5. Develop alternative control treatments to copper-based fungicides that comply with organic farming standards
6. Evaluate novel application and formulation strategies for copper- free/alternative and copper-based late blight treatments
7. Integrate optimised resistance management, diversification, agronomic and alternative control treatment strategies into existing organic potato management systems

To pursue these objectives, experiments were conducted over 4 seasons from 2001 to 2004 under organic cropping system conditions in seven countries (Denmark, France, Germany, Netherlands, Norway, Switzerland and United Kingdom) spanning a wide range of aerial, soil, production and marketing environments. The rate and severity of the late blight epidemics in 2001, 2002 and 2004 gave a rigorous test of the different components of the integrated management system which gave broadly similar effects in the three years. In 2003, the very hot, dry summer (and August in particular) severely restricted the disease making it difficult to evaluate the efficacy of treatments in some regions, but in others where infection did occur the general trends were similar to those observed in other years.

Assessment of the socio-economic impact of late blight and state-of-the art management in European organic potato production systems

Further expansion in organic potato production in the EU is likely because of increasing consumer demand, but as a consequence, crop profitability and price premiums, which are variable from country to country and season to season, could come under further pressure. Late blight is a major problem for the majority of growers, but the seriousness and impact varies from year to year and region to region. Farmers use a high diversity of strategies to stabilise yields and income, but not all use available technology. Copper-based fungicides are relied upon in many cases for late blight control to maintain yields (which are ~ 50 to 80% of conventional yields) but up to two thirds of growers have used alternatives to copper-based fungicides, but generally without success. In countries where the use of copper-based fungicides is still permitted almost two-thirds of growers expect a decrease in and serious consequences for, organic potato production. Not surprisingly, in Scandinavian countries and the Netherlands where use of copper-based fungicides is already prohibited little change is anticipated. Region-specific optimization and integration of technologies should improve yields and yield stability in organic potato production substantially and some growers could achieve this simply by adopting existing production strategies i.e. ‘state of the art’ technology or improving efficiency.
To secure production and supply and decrease dependency on copper-based fungicides, key factors needing further development, exploitation and evaluation under various regional conditions were considered to be

- Crop resistance management strategies
- Agronomic strategies
- Soil fertility management
- Novel crop protection strategies.

Dissemination of the resulting know-how and novel technologies will increase the success of organic potato production considerably and exploit the benefits of the research programme.

Variety performance

In France, Norway, Switzerland and the United Kingdom, resistant varieties consistently gave most effective control of foliage and tuber blight compared with diversification and agronomic strategies and alternative treatments to copper-based fungicides. Resistant varieties did not invariably outyield susceptible ones but a consistent benefit was assumed to be a decrease in disease inoculum and consequently the risk of infection within and between crops. In the United Kingdom, the fungicide copper oxychloride was applied to both resistant and susceptible varieties, but the improvement in blight control and yield in the most resistant varieties was relatively small. This indicated that growing resistant varieties is the most effective strategy to reduce or eliminate the need for copper-based fungicides in organic cropping systems whilst maintaining production. It was estimated that reductions of between about 16.5 and 50% of current levels copper fungicide applications could be achieved by growing them instead of susceptible varieties to the maximum extent that the market could absorb. However, in commercial practice this potential advantage will only be realised if the resistant varieties are acceptable for the ‘organic’ market and substitute for the susceptible but more popular varieties that are grown currently.

Unfortunately, as blight resistance has little or influence on market acceptability for most consumers at present, growers will be reluctant to grow resistant varieties if their economic returns are threatened or unless use of copper-based fungicides is prohibited. Uptake of new, more resistant varieties could also be delayed by the lengthy process involved in breeding, evaluation, seed multiplication, production, storage and marketing. Nevertheless, breeding new varieties resistant to foliage and tuber blight for organic, low-input and conventional systems of production remains a major objective. Marketing them as 'ecologically-friendly' varieties that require little or no protection with fungicides may counteract market resistance. Shifts in regional/national late blight populations towards increased pathogenicity with more resistant cultivars in production seems unlikely but virulence to new R-genes bred into new cultivars cannot be ruled out completely.

Diversification strategies

Usefulness of mixtures of potato varieties for reducing the impact of blight depended on the level of resistance of varieties in combination. In some cases, yield was increased in mixtures independently of effects on blight infection where ecological interactions between the constituent varieties resulted in improved resource capture and utilisation, which is important in organic systems. Alternating rows of susceptible and resistant varieties had a relatively small impact on the disease. Intercropping potatoes with grass/clover or spring wheat reduced blight in small plots grown perpendicular to the main wind direction, but yields were unaffected. Wheat was more effective at reducing blight than where either grass/clover or potatoes were grown as the adjacent crop. Unfortunately however, this advantage was offset by competitive effects at the boundary between the taller wheat and shorter potatoes which decreased the yield of potatoes. In commercial practice, it would be more difficult to manage crops grown as mixtures or alternating rows of different varieties or in beds separated by intercrops than as a single variety occupying a large area on a field-scale.
Compatibility of companion varieties in terms of nutrient requirements, maturity, storage requirements etc.; rotational considerations with intercrops and the need to separate mixed varieties prior to marketing for most purposes would need to be addressed. Nevertheless, such diversification approaches may be useful as part of a combined control strategy under low to moderate late blight disease pressure.

Agronomic strategies

Pigs effectively removed volunteer potatoes as a source of blight inoculum to infect subsequent potato crops in the same or neighbouring fields. However, soil compaction leading to establishment problems in the following cereal crop and detrimental effects on pig-meat quality were potential problems. This technique is restricted to farms with access to pigs, the necessary management skills and suitable soil types. Rotational position of potatoes is an important component of fertility management. Potatoes grown immediately after fertility building grass/clover or Lucerne crops were more infected with blight than after spring wheat but yield was not affected because of improved fertility. Although it was anticipated that improved fertility would increase the blight infection because of more prolific foliage growth, the type or level of manures applied prior to planting or their N:K ratio had no effect on disease, but improved crop growth and yield because of more optimal nutrient supply. Fertility management should be optimised to exploit direct effects on growth and yield rather than to influence late blight infection. It should be particularly effective in improving and stabilising yields since nutrient supply is generally sub-optimal in organic production systems. However, availability of organic manures and environmental legislation are potential limitations. Effects of planting date and pre-sprouting (chitting) on blight were small and insignificant but early planting and/or chitting extended the bulking period before the disease appeared leading to higher total and graded yields in 2001 and 2002 (but not 2003 because of premature senescence). Achieving an early start to tuber bulking by these techniques is a very important strategy and already used by many growers. Plant density and spacing had no effect on blight over a wide range of populations from 30000 to 80000 tubers planted/ha but large effects on total and graded yields. This is not an effective component strategy for managing late blight but essential for achieving market specifications in terms of tuber size. Irrigation increased yield compared with natural rainfall but did not increase the incidence of blight. Furthermore, optimised water application with reference to an objective scheduling system allowed less water (approximately half) to be used than with a traditional system based on experience and maintained yield without increased risk of late blight. The extent to which this effective yield enhancing strategy can be used depends on the local climate and the availability of water and irrigation equipment. Defoliation mechanically and/or by heat treatment prior to harvest to avoid the infection of tubers decreased the number of blight sporangia per plant but had no effect on tuber blight or the duration of the safe interval between defoliation and harvest. As conditions did not favour development of tuber blight, it was not possible to conclude which method would be most effective, but the combined 'flail and burn' technique is very promising in terms of effectiveness and cost and also applicable in conventional as well as organic systems of production.

Alternative treatments

Extracts of manure-based composts gave a degree of control of blight in potato leaf assays but it was far less than that of copper-based fungicide controls. Compost extracts applied alone had no effect on blight in the field, but one autoclaved extract with an adjuvant gave limited control and slightly higher yields in an experiment in 2003. Similarly, some micro-organisms, plant extracts and existing products showed promising effects on blight control in the laboratory but much less so under field conditions. Efficacy of a range of commercial and novel anti-fungal compounds was unaffected by dose rate or formulation. Overall, copper-free compounds had either no or limited effects on blight compared with standard copper-based fungicides at applied at normal rates but low doses of copper products were almost as effective. Underleaf spraying gave more uniform application of sprays but did not improve blight control with either copper-based fungicides or alternatives and timing of application is likely to be more important than method.

It seems that acceptable levels of blight control could be achieved by using lower doses of copper-based fungicides than those which are currently permitted, especially where applications are made according to decision support systems. Acceptable control may be achieved at rates of the order of 2 kg/ha/year of elemental copper, but further research is needed to test this and the most effective application strategy (timing and amounts) where such reduced rates are to be used. Where current national legislation and organic standards allow, this approach may offer an interim solution to the late blight problem in organic potatoes until fully effective and acceptable alternatives become available.

Integrated Systems Approach

In 2004, integrated strategies for late blight management were designed to incorporate the most effective components identified in the previous seasons' experiments. These were site specific and applied on MODEL ('Research') and 4 LINK (Commercial) farms in each of the 7 participating countries. For the MODEL farms, up to 5 individual components, beginning with the most effective, were added progressively to the CULBMS (Currently Used Late Blight Management System) = C0, i.e. C0+C1; C0+C1+C2; C0+C1+C2+C3; C0+C1+C2+C3+C4; C0+C1+C2+C3+C4+C5 to achieve additive and/or synergistic effects. On the LINK farms, the CULBMS (C0) was compared with a single, 'optimised' late blight management system based on a number of the most effective components. Combining components into an integrated system usually, but not always, improved the physical (marketable yield) and financial (cost/benefit) performance of the potato crop compared with the CULBMS. In general, the efficacy of late blight control was less than where copper-based fungicides were used, but copper did not always improve yields. This approach confirmed that in some circumstances, critical appraisal of the CULBMS should identify where improvements can be made. In some cases, the CULBMS may already be optimised but in others, there is scope to become more efficient, simply by adopting current 'state of the art' technology. There is no single blueprint and the integrated system must be designed for a specific situation because of differences from country to country and farm to farm. Adoption of the systems approach at the level of the individual grower, the country and the EU will narrow the gap between the output of the potato crop grown with and without copper-based fungicides.

At community, national and farm level, success of this approach depends on researchers, advisory and extension services effectively communicating relevant, up-to-date information via technical publications, workshops, demonstrations and conferences to stimulate and support uptake of the technology for organic and conventional systems. On-farm experimentation and further research are required to develop some of the less advanced strategies; identify combinations of component strategies that positively interact and match the requirements of the individual farm.

Achieving the optimum system is likely to take several years in most cases and will need to be re-evaluated and modified in the light of changes in technological, political, climatic, environmental and economic conditions, but in the meantime it could be by the incorporation of a lower-input programme of copper-based fungicides in the system. By working closely with farmers, Research Institutes and individuals involved in Blight MOP will facilitate the implementation of these results. Better management of late blight with less dependency on copper-based fungicides will sustain the production and profitability of organic potato growing in Europe for the benefit of all stakeholders and meet an important objective of EU organic farming policy. There may be additional benefits from applying principles to other crops grown in organic systems that receive copper-based fungicides.

Overall benefits that accrue from the Blight-MOP project in the context of 'Quality of Life and Management of living Resources' include:

1. Improvements to the quality of life through sustainable production and rational utilisation of natural resources, based on a multidisciplinary approach and focussing on societal demands for sound environmental practices
2. Involvement of end users (producers and consumers)
3. Results and information dissemination strategy for end users
4. Solutions for conversion to such (organic) systems and means to overcome existing obstacles
5. Development of technico-economic references and support to EU-legislation
6. Increased production of organic food at EU and national level
7. Avoidance of potentially detrimental effects of agricultural practices on the environment and food safety and decreased risk of adverse effects of pesticide handling, storage and disposal etc.
8. Increased employment in the agriculture and associated sectors of industry and educational and training opportunities for students and existing agricultural practitioners
9. Competitiveness in a global market

Beneficiaries are:

Society at European and national level
Environment
Government decision makers
Organic, low input and conventional producers at both EU and member state level
Consumers