Agri Services

Bayer Expert Guide

Potato Late Blight

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Introduction

The purpose of this Expert Guide is to help potato agronomists and growers understand and protect potato crops against late blight.

Its four chapters contributed by leading independent experts cover; blight population dynamics; integrated pest management; the characteristics of fungicides and; planning blight control strategy. The fifth and final chapter covers the role of Bayer's late blight fungicide Infinito.

Bayer Expert Guides are part of the company's Agri Services initiative to aid decision making so growers can realise the full potential of their crops, in yield, quality and profit. In addition to publications, Agri Services offers Apps, eLearning, pest and disease risk tools and the Four Seasons Farmers club.

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Blight Population Dynamics

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Late blight of potato is caused by the specialised, fungus-like pathogen *Phytophthora infestans*. In Great Britain it mainly survives between growing seasons in infected tubers; in outgrade piles, in groundkeepers or in infected seed. In spring, these produce infected shoots which sporulate and initiate infection in the next crop.

All disease begins with this primary inoculum but it is multiple cycles of stem and leaf infection that drive disease within the growing crop. Given the right conditions initial infection develops into an epidemic that can rapidly destroy crops.

Since the notorious Irish potato famine, late blight has been recognised as the greatest potential disease threat to potato crops and today no other disease demands such collective responsibility to safeguard potato production.

This chapter provides the essential biological understanding of the pathogen that control of late blight is based on. It explains the life cycle, the conditions that are conducive to disease development and the recent genetic development of the pathogen.

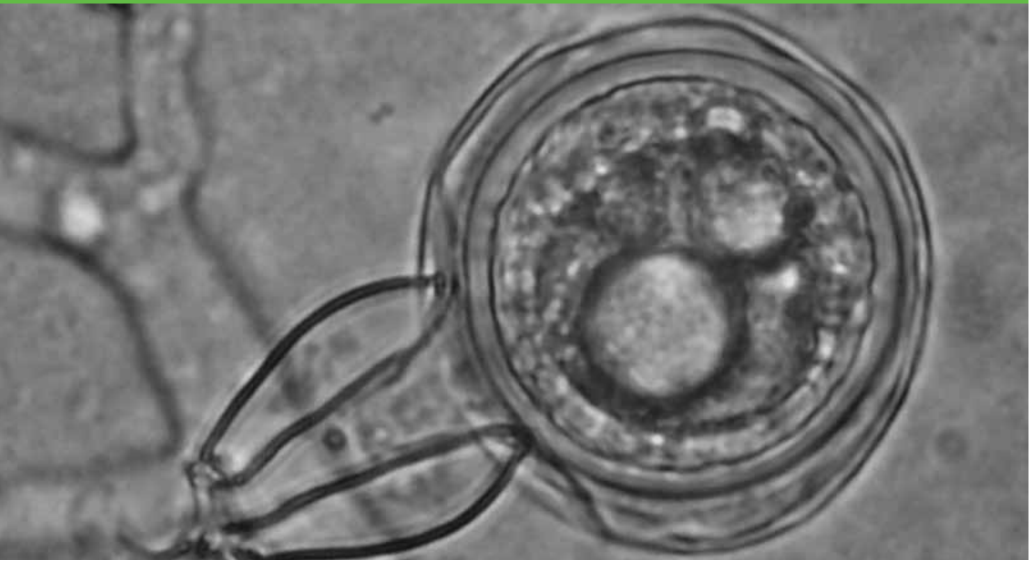


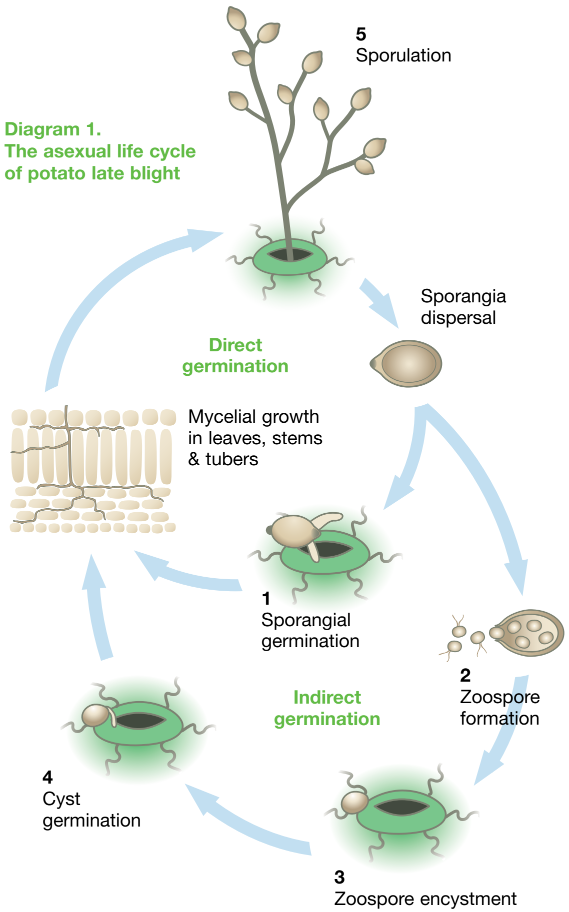
Photo © David Cooke

The Life Cycle

The late blight pathogen can reproduce sexually and asexually. Currently in Britain the initiation and spread of foliar infection and subsequent infection of tubers is almost entirely by asexual reproduction. Sexual reproduction has not yet been seen to be significant in disease spread in this country, but it is in other European countries so we have to be alert to the possibility here, understand the mechanism and its potential implications.

Foliar and stem infection via the asexual cycle

Diagram 1.
The asexual life cycle of potato late blight



The asexual life cycle (Diagram 1) begins with sporangia landing on a crop. Under warmer conditions, 18˚C or more, most sporangia germinate directly (1) forming a germ tube that penetrates the epidermal cells. Under cooler conditions most sporangia differentiate to form 10 to 12 motile zoospores that are released through the apex of the spore (2). They move in the water film on the plant surface and are attracted to suitable infection sites where they encyst (3), germinate and form germ tubes that penetrate the epidermis (4).

Unchecked, the pathogen will colonise the plant tissue, form visible lesions and begin to sporulate. Under humid conditions the pathogen forms spore-producing mycelium called sporangiophores that exit the plant through the stomata on the lower leaf surface (5).

This mycelium appears as a white downy growth on the margins of stem or foliar lesions and generates up to twenty thousand sporangia per square centimetre of lesion in a single day. Foliar lesions 1 can rapidly defoliate a potato crop but stem lesions 2 are also particularly damaging, as they are less susceptible to fungicides, can survive dry periods that can check leaf infections and, if they girdle the stem, will kill all the plant tissue above the lesion.

As the life cycle repeats, a focus of blight develops. From this, air-borne spores establish new infections and secondary foci are created. Spores may travel several kilometres and, provided they are not desiccated, or killed by ultraviolet exposure en route, remain viable and can cause infection in other crops.

The length of time from a spore landing on the plant until sporulation begins is termed the latent period. Under optimal conditions the latent period may be as short as three days and if left unchecked explains the explosive epidemic development.

Foliar lesion Photo © David Cooke

Stem lesion Photo © David Cooke

Tuber infection

As tubers form they become vulnerable to infection from sporangia and zoospores. The infection route is these spores being washed down through the soil, or down the stems themselves (Diagram 2), or coming into contact with tubers at lifting or grading.

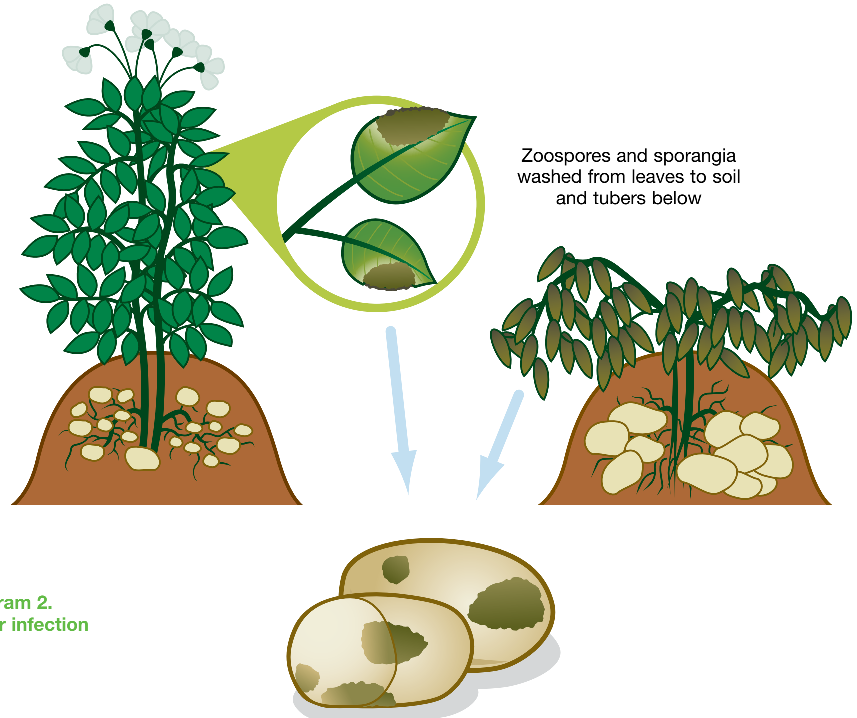


Diagram 2.
Tuber infection

Survival of sporangia in the soil depends on soil type, moisture content and to a lesser degree soil temperature. Under natural environmental conditions most sporangia die within 14 days but they have been found to survive underground for up to 21 days in the absence of green plant material.

Zoospores emerging from sporangia infect tubers and colonise the layer just under the skin. Most infection prior to harvest is through lenticels and eyes leading to tubers with firm chestnut or granular brown lesions just under the skin that spread inwards 3.

Frequently tuber blight provides an entry route for secondary infection by soft rotting bacteria that convert the flesh to a putrid semi-liquid state.

Early symptoms of tuber blight

Photo © Scottish Agronomy Ltd

The following factors increase the risk of tuber blight and a combination of several of them is required for tuber blight to occur;

- Haulm with foliar blight where risk increases with increasing levels of inoculum
- High risk weather that maximises spore production on haulm
- A temperature drop below 11°C that encourages formation of zoospores which are smaller, motile in water and therefore more likely to reach tubers
- Rainfall or irrigation of 5 mm or more that washes spores into soil
- High soil moisture content which favours tuber infection; lesion development increases from 40 to 80% field capacity
- Cracked ridges and shallow-set tubers effectively shortening spores' journey from leaf to tuber
- Sandy soils which zoospores can travel faster through than clay soils

The asexual form of *Phytophthora infestans* will not survive between seasons in the absence of live potato tissue so fully rotted tubers break the cycle. Conversely, infected tubers that survive can carry primary inoculum to re-start the cycle the following season. Infected tubers cause disease via sporangia formed on the tuber surface that are thought to contaminate the soil and splash onto the lower leaves of the developing crop or via latent infection of the developing sprouts that form sporulating lesions at or after crop emergence.

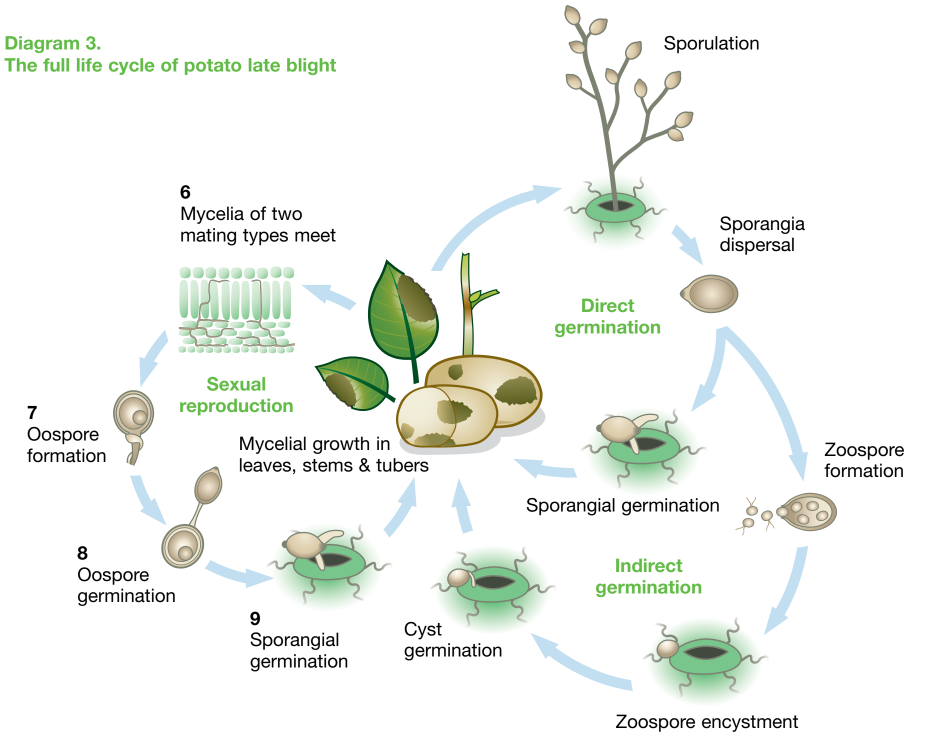
Oospores and the sexual life cycle

The phases of the life cycle described above are the result of asexual (i.e. clonal) reproduction. Such clonality can be an advantage to the pathogen as successful combinations of traits remain genetically fixed for months or even years. However, this limits the opportunities for genetic evolution which is a disadvantage over longer time scales.

The pathogen has two mating types termed A1 and A2 and, as illustrated in diagram 3 below, these opposing forms must co-infect and meet in plant tissue (6) to reproduce sexually. Until the 1970s this part of the life cycle could not occur in Europe as the A2 type was only found in Mexico, the pathogen's centre of origin. With the introduction and spread of the A2 mating type in Europe, both types may now co-infect plants and reproduce sexually, generating thick-walled oospores (7). These oospores enter the soil as the infected plant material rots down, remain viable for many years and then germinate (8) in the presence of a host plant to form sporangia (9) which re-start the life cycle.

Diagram 3 below combines the asexual and sexual life cycles of the late blight pathogen and shows how they drive disease development in leaves, stems and tubers.

Diagram 3.
The full life cycle of potato late blight



Each germinating oospore is genetically distinct and such 're-shuffling of the genetic pack' generates new combinations of traits. Through a process of natural selection those genotypes that are more aggressive, fitter, resistant to fungicide or more capable of overcoming host resistance than the existing pathogen population, will be more likely to spread and cause crop disease that is more difficult to manage.

The implications of oospores acting as a source of inoculum are potentially serious. In other parts of Europe, early infections from soil-borne oospores have proved difficult to manage. The role of oospores can be seen in the aerial photograph to the right 4 of a potato trial at Uppsala, Sweden. The black rectangle shows the location of a heavily blighted potato trial two years prior to the current crop and severe blight from the soil-borne inoculum has resulted in plant death.

In British crops, however, despite the prevalence of the A1 and A2 mating types, the incidence of oospore-borne outbreaks remains very low. One key factor is the length of the rotation between potato crops. In the absence of a susceptible crop the viability of dormant oospores declines and the reduced inoculum load thus decreases disease risk. Maintaining long rotations is therefore advisable for managing late blight as well as other soil-borne pests and pathogens.

Oospore infection Photo © Magnus Sandström

Research has also shown that the dominant 6_A1 and 13_A2 lineages, although fit and aggressive in their own right, are genetically weak parental strains and do not generate high numbers of viable oospores.

Nonetheless, growers should remain alert to the signs of soil-borne oospore inoculum, particularly in crops grown in fields that suffered severe blight infection when potatoes were last grown. Warm, wet conditions after planting stimulate co-ordinated oospore germination that can cause patches of sudden decline of the emerging crop.

Signs to look out for include the early appearance of multiple blight lesions on leaves in contact with the soil and patches of young plants dying off from stem blight that appears to start from the stem base or below the soil. This may occur in low-lying areas of the field where wet soil conditions favour pathogen activity. The picture to the right 5 shows what has become the signature symptoms of oospore-derived outbreaks in Finland; multiple lesions on lower leaves close to the soil surface.

Symptoms of oospore-derived blight

Photo © Asko Hannukkala and Ari Lehtinen

Conditions

Potato blight infection and spread is strongly influenced by the weather with periods of warm wet weather being optimal for the pathogen. There is a strict requirement for high humidity or free water on the host surface for pathogen spores to infect with temperature influencing the rate at which such infection occurs. Temperatures of 15 to 18˚C are considered optimal for pathogen infection and growth.

Once the infection hyphae have gained entry to the plant, dry cool conditions can be tolerated as the pathogen has access to water and nutrients from its host and can remain in a latent state. Subsequent lesion growth and disease spread will then occur with a return to warmer and wetter conditions. Once lesions have formed, the pathogen produces abundant spores with sporulation promoted by cool wet conditions, typically overnight. Drying of the crop the next morning promotes spore release and local dissemination and re-infection to form a disease focus. Longer distance spore dispersal from tens of metres to kilometres depends on wind speed. Cloud cover is an important factor in viable spore dispersal as exposure to ultraviolet light kills sporangia.

A set of meteorological conditions considered optimal for blight infection and spread were defined in the 1940s and modified by Smith in the 1950s. These ‘Smith Period’ risk criteria predict infection and spread if on each of two consecutive days the minimum air temperature is above 10˚C and the relative humidity is greater than 90% for more than 11 hours on each day. It is evident that the number of Smith periods corresponds well with disease occurence but there are concerns that the criteria should be changed to account for the current pathogen population.

Studies on contemporary lineages such as 13_A2 and 6_A1 have shown that infection can occur down to at least 6˚C and that although 11 or more hours of high humidity is optimal for infection, significant infection occurs with periods of only six to eight hours. Contemporary populations of the blight pathogen are more aggressive, require shorter infection windows and are able to move through life cycle stages more rapidly which makes them more difficult to manage. Potato Council funded work to improve the Smith criteria is underway which, coupled with technological advances in our ability to measure and report local meteorological conditions, will improve the precison of blight prediction in the future.

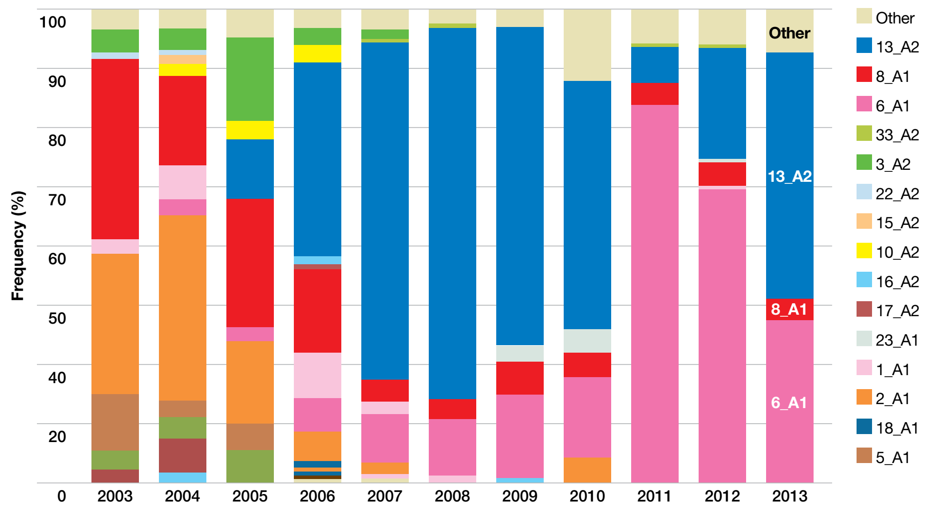
Genotypes

The potato late blight pathogen *Phytophthora infestans* is capable of rapidly generating billions of spores and spreading as genetically uniform genotypes. Genetic fingerprinting tools have allowed the tracking of such genotypes and shown some to have persisted for decades. The success of these genotypes is due to their traits of agressiveness; ability to infect and colonise host plant tissue and fitness; ability to spread within and between seasons. In a polycyclic disease such as potato late blight even slight changes in these traits can have a significant effect on their competitive ability.

The ability to overcome the resistance of commonly grown potato cultivars or having reduced sensitivity to key fungicides also shapes the population and affects the success of blight management. The Potato Council sponsored ‘Fight Against Blight’ campaign has supported blight sampling by disease scouts in British crops for more than a decade along with the identification of genotypes so the makeup and development of the blight population can be studied (Diagram 4).

State-of-the-art DNA fingerprinting, as used in criminal forensics, identified a genotype called 13_A2 (blue 13) that was first found in the Netherlands in 2004 and in Britain towards the end of the 2005 growing season. Over the next three seasons 13_A2 rapidly displaced other genotypes of the pathogen; growers were thus managing a quite different form of blight than in the past. Further characterisation of 13_A2 showed it was more fit and aggressive than other genotypes, could overcome some sources of blight resistance and was resistant to metalaxyl-M.

Diagram 4.
Potato Council sponsored blight monitoring shows changes in the GB *P. infestans* population



Over the 2009 and 2010 seasons the frequency of 13_A2 declined to be replaced with another fit and aggressive lineage, 6_A1 (pink 6) that was also first found in the Netherlands and first reported in Britain in 2004. Both these genotypes produce large lesions that remain biotrophic (grow on green living plant tissue) and sporulating for longer than other genotypes offering them a competitive advantage. There have been some indications that 13_A2 and 6_A1 differ in their response to environmental conditions. However it is proving difficult to generalise on studies of relatively few isolates tested under laboratory conditions, within such large populations of a pathogen as genetically adaptable as *P. infestans*.

Genetic fingerprinting of British and European samples recently presented on the EuroBlight web site (www.euroblight.net) indicates the prevalence of previously characterised genotypes such as 13_A2 and 6_A1 in some regions of Europe. However it also illustrates the diversity of genetically distinct types (termed ‘other’) which are more common in the north and eastern areas of Europe. These represent the genetically unique isolates from germinating oospores and such diversity that may be the source of the next generation of successful clonal genotypes.

2

Integrated Pest Management

Dr David Nelson, Branston Ltd

As part of the EU Sustainable Use Directive, the UK government is now legally required to demonstrate that growers are following Integrated Pest Management (IPM) practices. To achieve this, the NFU has developed an Integrated Pest Management Plan for the Voluntary Initiative scheme which replaces the Crop Protection Management Plan.

It has long been accepted that the principles of IPM are a cornerstone of good agricultural practice and offer significant opportunities to lower pesticide inputs and control costs. Although professional growers have been working to these principles for many years one look at the sources of blight infection on the Fight Against Blight website shows that as an industry there is still much to be done.

This chapter lists the eight principles of IPM, applies them to potato production and discusses in detail hygiene measures, varietal resistance and the use of decision support systems.

Photo © Scottish Agronomy Ltd

IPM Principles

The eight principles of IPM are:

1 Preventing or suppressing the disease or pest by good hygiene and variety resistance

2 Monitoring of disease incidence, forecasting or warning systems

3 Setting robust thresholds for intervention according to region or varieties

4 Prioritising the use of biological, physical or other non-chemical methods in favour of chemical methods

5 Pesticides applied should be specific for the target and have minimal side effects on non-target organisms and the environment

6 Reduced rates or partial applications are preferred where these can demonstrate efficacy and do not risk resistance development in the target disease

7 Where the risk of resistance has been identified, strategies which include the use of multiple pesticides with different modes of action are required

8 Pesticide usage and disease pressure should be professionally reviewed to monitor the success of plant protection measures.

While accepting these eight principles of IPM, some have little application in the control of potato blight. In view of the speed of disease spread and its devastating impact on crop output and the need for chemical intervention, methods which focus on disease prevention are vastly preferred to curative options.

Hygiene

Given the importance of preventing disease establishment, actions which inhibit or suppress blight by good hygiene and variety resistance are critical elements of control. In basic seed stocks the current tolerance for blighted tubers is 0.5% so the use of certified seed offers good protection from introducing blight on seed.

The key to good hygiene is preventing the carryover of disease from one year to the next, either in volunteers or waste potato dumps (Diagram 5). In both scenarios, any blight infected mother tubers may initiate a disease outbreak which spreads to neighbouring potato crops. Even if the mother tubers are not carrying blight, the plants they generate are growing without fungicide protection and provide an easy entry point for disease and its rapid spread.

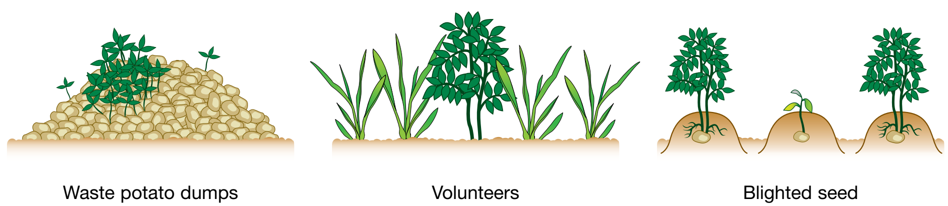
The importance of waste potato dumps as potential foci for potato blight has been recognised widely for many years. In the Netherlands, national blight control regulations were introduced almost 15 years ago including a requirement to cover dumps before 15 April with black plastic sheet throughout the growing season.

Similar recommendations are made in the UK and in addition the Potato Council advise minimising the amount of potatoes going into waste potato dumps by on-farm grading, better extraction of small stock feed tubers from any soil waste and keeping piles shallow to increase the chance of frost damage. If plastic sheeting is not an option, then it is advised that any green leaf or shoots are regularly destroyed by use of a desiccant such as diquat, followed late season by glyphosate.

Volunteer or groundkeeper potatoes are self-set tubers which have survived the winter from a previous crop and are then growing as a weed. Hard winters where the ground freezes to 10 to 20cm depth greatly reduces the survival of tubers and avoiding deep cultivations keeps more unharvested tubers exposed on the surface.

In some situations, farmers have been able to graze livestock on fields after harvest to clean up unharvested tubers. The viability of unharvested tubers can also be markedly reduced by a chemical approach using maleic hydrazide. Applied to the growing crop, it reduces the incidence and vigour of sprouting but permission should be sought before use as it is not permitted in all market sectors.

Diagram 5.
Sources of inoculum



Long rotations enable better control of volunteers and should not be tighter than one in five to prevent the development of many potato diseases. In the Netherlands and Nordic countries, despite acceptable volunteer control, close rotations of two to three years are linked with a higher frequency of sexual reproduction and the majority of crop infection now appears to originate from oospores.

Unfortunately, either mild winters or burial by ploughing ensure that volunteers often persist for many seasons and there is an increasing risk of emerging potato plants being carriers of blight and acting as a primary infection source.

While volunteers are usually well controlled in sugar beet and wheat crops, they are often neglected in un-cropped areas. These are a particular threat and a frequent origin of disease outbreaks in nearby potato crops. Volunteer control is made even more difficult as they can emerge over several weeks from spring to early summer.

Spot spraying volunteers in row crops

Photo © Tillett and Hague Technology Ltd

Computer vision targets plants out of place (red)

Photo © Tillett and Hague Technology Ltd

In field crops, volunteer potato control is best achieved by either mechanical inter-row cultivation or a targeted herbicide programme. Recently, technology which enables automated spot treatment has been developed by Tillett and Hague Technology Ltd for the control of volunteers in row crops 6.

This computer vision based system identifies a plant out of place and sprays a jet of herbicide into the central growing point 7. It could also be developed to control volunteers growing between rows in potato crops during the early post-emergence period.

Variety

Another key cultural approach to reducing disease ingress and spread is varietal resistance. Since the arrival of blight in Europe, blight resistance has been a target of many variety-breeding programmes. However, over time, the relative resistance of a variety to blight may change as there is a shift towards more aggressive and virulent genotypes. So although breeders have introduced new sources of resistance very few have persisted.

Currently, the level of blight resistance provided by commercially dominant potato varieties ranges from low (1-3) to medium (4-6). Over the past five years resistance ratings have generally slipped in response to new genotypes such as 13_A2, becoming dominant. Varieties such as Cara and Sante which previously had a blight resistance rating of 7 are now 5, while many others such as Estima have slipped to 4 (Table 1).

In a few situations, these changes in the blight population, have generated a slight improvement in varietal resistance with Saxon and Pentland Dell being examples in the UK.

Table 1.
GB plantings by variety 2014 and resistance ratings

Source: Potato Council

		Variety Database Resistance Ratings	
Variety	Area (Ha) 2014	Foliage blight	Tuber blight
Maris Piper	19,220	4	5
Markies	7,527	4	4
Maris Peer	5,611	5	7
Lady Rosetta	5,322	4	4
Estima	4,299	4	5
Melody	4,050	4	7
Harmony	3,388	4	4
Marfona	3,175	5	3
Hermes	2,724	3	4
King Edward	2,479	3	4

The scope for differences in variety resistance of just two to three points to reduce disease spread and fungicide requirements has been demonstrated in research by Dr Ruaridh Bain at SRUC. In a series of 13 trials between 2009 and 2011, moderately resistant varieties outperformed more sensitive varieties even when given just half of the recommended fungicide dose. Without a fungicide programme the results were less clear-cut as the rate of spread of the blight epidemic was accelerated across all variety blight groups.

Although not grown on any scale, a number of highly blight resistant varieties are available and used predominantly in the organic sector where there are very few fungicide options. Despite the introduction of genes from wild species, the durability of this blight resistance has often collapsed after just a few years of commercial trials in response to new blight populations.

In practice, most growers are still nervous about utilising variety resistance to extend spray intervals or reduce fungicide rates. Not only is it complicated to manage a range of blight control strategies but there is also a lack of reliable variety resistance information. Furthermore, variety performance could decline in relation to changing, more virulent blight populations.

A pragmatic approach is to use resistance ratings as a fallback under periods of very high disease pressure or when spray intervals have been stretched. It then makes sense to give priority to the spraying of varieties with the weakest resistance first and likewise target these with the strongest fungicide chemistry.

Blight resistance already plays some role in regional variety selection with the most susceptible types generally being grown more widely in regions of the UK with lowest overall blight pressure such as East Anglia.

Decision Support Systems

Blight monitoring and forecasting systems have made a very positive impact on blight control decision making and the sophistication of support systems continues to progress. In the UK, most growers already receive blight warnings from Blightwatch. Further information on the location and frequency of blight outbreaks is available from the 'Fight against Blight' (FAB) scheme on the Potato Council website (Diagram 6).

Such blight warnings are a useful aid to understanding historical disease pressure but more proactive advice is needed to ensure crops are protected in advance of risk periods. To achieve this, a number of companies provide Decision Support Systems (DSS) which interpret local weather forecasts to provide a five-day view of both blight pressure and spray windows. More sophisticated DSS, such as the Dacom blight forecasting system, also take account of information on crop growth stage, irrigation and the proximity of local disease outbreaks.

DSS are useful in guiding the timing and interval between blight sprays. In seasons with high and prolonged blight pressure there may be periods when tightening spray intervals to five days is essential for successful control. Such practice may well require product blight products to be alternated in order to remain compliant within label recommendations.

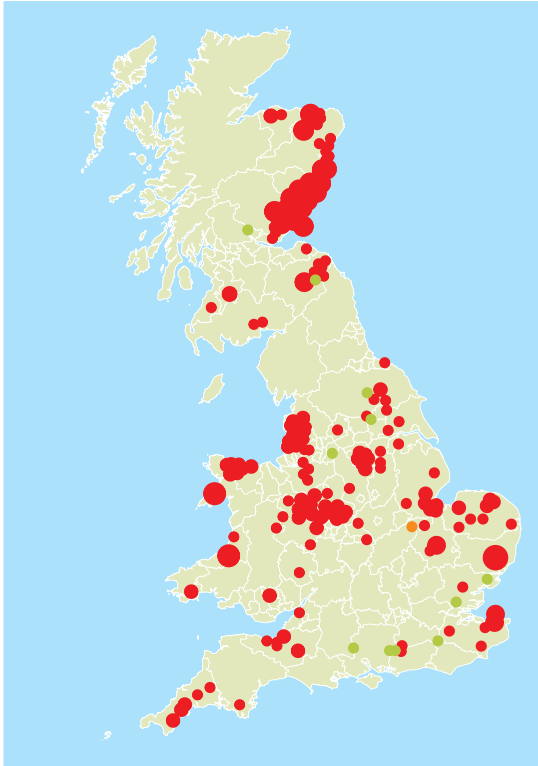


Diagram 6.
FAB 2013 blight incidents map

In other years, low blight pressure may persist over much of the growing season and there may be ample opportunity to extend intervals, use cheaper fungicides and possibly reduce rates. Importantly, DSS must foresee changes in local disease pressure and give opportunity to react. Blight pressure can change in hours and the ability to respond at any stage of the growing season is critical.

Further sophistication to DSS is promised by exciting new Potato Council funded research being undertaken at the James Hutton Institute by Dr Peter Skelsey. Investigations are seeking to develop a spatially explicit DSS which will combine historical, current and future risk of disease spread. It is seeking to refine the Smith criteria by improving our understanding of the precise environmental conditions conducive to particular blight strains.

In addition, it will map disease incidence and predict the direction and intensity of disease pressure. While the distance spores can travel is determined by both wind speed and atmospheric turbulence, the survival of detached sporangia is sensitive to the dosage of ultraviolet radiation received during transportation. This technique will use mapping technology to identify downwind potato crops at particular risk.

Threshold, Pesticides & Non-Chemical Controls

The concept of an acceptable disease threshold is rarely advisable within a blight control strategy as the rate of disease spread is often catastrophic. Such an approach could possibly be applied to a few very blight resistant varieties where the rate of disease spread is very slow and retrievable. However this could expose the crop to a high risk of tuber blight infection.

The use of reduced fungicide rates could be incorporated into blight control strategies but low confidence in varietal resistance, weather forecasting and local disease pressure encourage a conservative approach to risk management. In practice very few fungicide products advise variable application rates according to disease pressure and interval. As a result most growers prefer to maintain a regular seven-day spray interval and adjust the programme intensity through product choice.

The only non-chemical method to control the spread of blight is to harvest or defoliate blight hot spots.

Anti Resistance Strategy

While blight has demonstrated a tremendous ability to evolve and overcome varietal resistance it has been less effective at evolving resistance to fungicides.

The notable exception to this was the evolution of metalaxyl resistance which began during the 1980s. This systemic fungicide was used alongside the protectant mancozeb to offer extended protection from blight, especially during the early part of the growing season where it could protect new growth. Alongside other, similar phenylamide group active substances, exposure of blight to low concentrations of metalaxyl resulted in resistance development within a few years of the product's introduction. Efforts to reduce the number of applications met with limited success and phenylamide resistance became a more serious issue from 2006 onwards with 13_A2 being fully resistant and widespread. As a result phenylamide group fungicides now play a minor role in blight control strategy.

Excessive reliance on a single active substance also appears to have been responsible for driving fungicide resistance in the Netherlands during 2010/11. There was heavy reliance on fluazinam because of its low dose rate and a desire to comply with targets on pesticide use reduction. First concerns regarding its efficacy arose during late 2011 and it was found to be linked with the presence of the blight strain 33_A2 (green_33). As a result Dutch purchases of the leading fluazinam product fell by 78% between 2010 and 2012 and growers were recommended to either alternate or block a wider range of the major blight active substances. The frequency of 33_A2 is now very low and it has not been able to gain a foothold in the UK.

Generally UK growers have always favoured either the blocking or alternating of blight sprays to prevent over reliance on a single active substance or group of actives. Alternating blight products allows greater flexibility to tighten intervals under periods of highest blight pressure, and enables different modes of action to be exploited to build up protection against tuber blight.

Review

The success of your IPM strategy should be reviewed at the end of the season and fed into the farm audit report. The key elements of this review should be blight pressure, fungicide usage and blight incidence.

Blight fungicide inputs should be positively related to the blight pressure experienced over the growing season. Periods of the season with high blight pressure should have more intensive applications and some years will be markedly different to others. Any outbreaks of blight should be diagnosed in relation to both disease source and any inherent weakness in the fungicide control programme. This process is essential to monitor the success of crop protection measures and identify areas for improvement.

3
Characteristics of Late Blight Fungicides

Dr Huub Schepers. Wageningen University

Fungicides play a key role in the integrated control of late blight. The threshold for late blight is zero so blight control strategies are primarily preventive by spraying fungicides when weather conditions are conducive to blight and the crop is no longer fully protected by the previous spray.

The protection conferred by a spray decreases as its active substances degrade over time and as new unsprayed leaves grow. Spray timing and interval therefore depend on the characteristics of the fungicide, the growth of the crop, weather conditions and disease pressure.

EuroBlight, the potato late blight network for Europe, produces the EuroBlight Fungicides Table which summarises fungicides' characteristics to provide agronomists and growers with an independent scientific basis for selection. This chapter explains the characteristics listed on the EuroBlight table (www.euroblight.net) and thereby provides the understanding needed to select fungicides for blight control strategies.

Leaf blight	Tuber blight	New growth	Stem blight	Protectant	Curative	sporulant	fastness	Mobility	Year
			●	●◐	0	0	●	C	1900
2.0	0.0		●	●●	0	0	●◐	C	1961
			◐	●●	0	0	●●◐	C	1964
3.8	3.8	●●	●	●●●	0	0	●●●	C	2001
2.9			●	●●●	0	0	●●◐	C	1992
2.8			● 5	●●●	0	0	●●◐	C + C	2001
4.5	3.7		●	●●◐	0	?	●●●	C + C	2007
3.7		? 3	? 3	●●◐	0	0	●●●	C + C	2011
			●◐	●●	●●	●	●●◐	C + T	1996
4.0		●●	●◐	●●●	● 6	●◐	●●●	T	2005
4.0		●●	●◐	●●●	● 6	●◐	●●●	T + C	2005
3.7			●◐ 5	●●●	●◐	●	●●◐	T + C	200
			●◐	●●	●●	●	●●	T + C	197
			●◐	●●			●●	T + C	197

Effectiveness

Leaf Blight

Protection of leaves 8 against blight infection by either direct contact or via translaminar activity.

Leaf blight Photo © Scottish Agronomy Ltd

Tuber blight

Activity against tuber infection 9 as a result of fungicide application after infection of the haulm, during mid- to late-season i.e. where there is a direct effect on the tuber infection process. Three characteristics are important in preventing tuber blight;

- Killing spores that are washed from the leaves to the tubers
- Reducing lesion size causing fewer spores to be formed
- Anti-sporulant efficacy to reduce the number and viability of spores

Tuber blight Photo © Scottish Agronomy Ltd

New growth

The ratings for the protection of new growth indicate the protection of new foliage by systemic or translaminar movement or the redistribution of a contact fungicide. New growth consists of growth and development of leaves present at the time of the last fungicide application and/or newly formed leaves that were not present. Besides translaminar fungicides some new contacts that are taken up in the wax layer can protect new growth.

Stem blight Photo © Scottish Agronomy Ltd

Stem blight

Protection of stems 10 by either direct contact or via translaminar activity.

Biological Efficacy

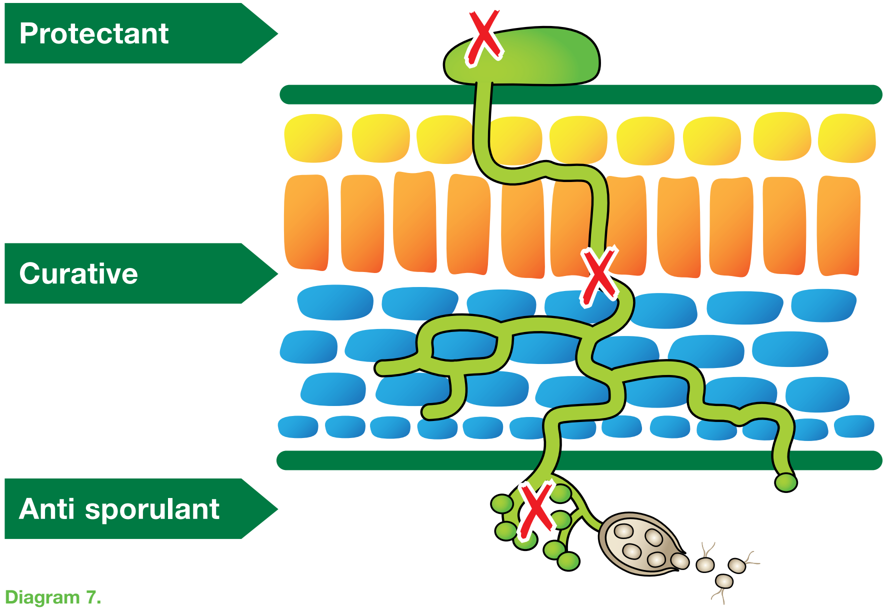


Diagram 7.
Biological efficacy of fungicides

Protectant

Spores killed before or upon germination or penetration. The fungicide has to be present on or in the leaf or stem surface before spore germination or penetration occurs.

Curative

The fungicide is active against the pathogen during the immediate post infection period but before symptoms become visible i.e. during the latent period.

Anti Sporulant

Lesions are affected by the fungicide decreasing sporangiophore formation and/or decreasing the viability of the sporangia formed.

Mobility

Contact

Contact fungicides are not taken into the plant and are therefore more vulnerable to erosion by wind, rain and sunlight.

Some new contacts are taken up in the wax layer. They protect where the spray has been deposited (Diagram 8) and can protect new growth.

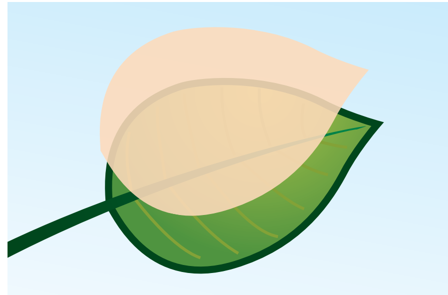


Diagram 8. Contact fungicide

Translaminar

Translaminar fungicides are taken up by the leaf and show limited redistribution from one leaf surface to the other (Diagram 9) e.g. from upper sprayed surface to lower unsprayed surface. They are only transported locally within the leaf and can provide partial protection of new growth.

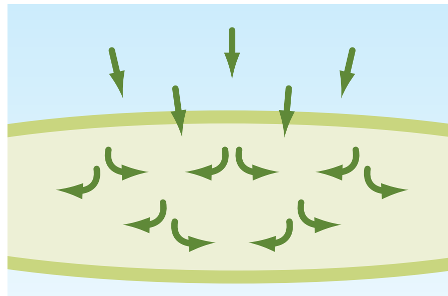


Diagram 9. Translaminar fungicide

Systemic

Systemic fungicides are taken up by the foliage and redistributed upwards by the xylem vessels (Diagram 10). They therefore have the potential to protect new foliage growth formed between fungicide applications.

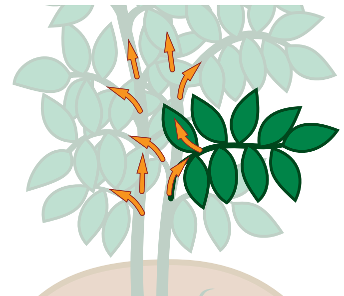


Diagram 10. Systemic fungicide

Often the mobility of a fungicide is used to justify its positioning in a strategy. However, biological efficacy should be the main driver of product choice. In this it is important to realise that all fungicides, whether they be contact, translaminar or systemic, are all protecting the plant. The contacts cannot penetrate plant tissues and therefore do not have curative or anti-sporulant efficacy.

A more detailed appreciation of the characteristics and properties of fungicides is needed to design an effective blight control strategy that is well adapted to the conditions of the particular potato crop. The EuroBlight blight ratings provide such information. Efficacy to control leaf and tuber blight is tested in EuroBlight field trials. Ratings of the other characteristics are decided by the Fungicides Sub-group – independent scientists and representatives from the crop protection industry – on the basis of available data.

Resistance management

The risk of resistance development is a combination of the inherent pathogen risk, the agronomic risk and the inherent fungicide risk. The Fungicide Resistance Action Committee (FRAC) rates the inherent risk of *P. infestans* developing resistance to fungicides as medium and the agronomic risk as high because of numerous sprays per season.

The inherent risk of the phenylamide fungicides (eg. metalaxyl-M) is rated as high. Shortly after their introduction in the 1980s, the late blight pathogen developed resistance. Resistance management consisted of three important measures; restricting the use to only several sprays per season; co-formulating with contact fungicides and; limiting the use to protectant sprays and not using it as an eradicant.

Depending on the mode of action of fungicides, resistance risk can be rated low or high (Table 2). Fungicides with a medium to high resistance risk need a resistance management strategy to prevent the development of resistance.

FRAC code	Active substance common name	UK fungicide name (example)	Resistance risk
4	metalaxyl-M	in Fubol Gold	High
22	zoxamide	in Electis	Low-medium
43	fluopicolide	in Infinito	Resistance not known
11	fenamidone famoxadone	in Consento in Tanos	High risk
21	cyazofamid amisulbrom	Ranman Top Shinkon	Medium-high
29	fluazinam	in Shirlan	Low
45	ametoctradin	Initium	Medium-high
40	dimethomorph mandipropamid benthiavalicarb	in Invader Revus in Valbon	Low-medium
27	cymoxanil	in Curzate	Low-medium
28	propamocarb	in Infinito	Low-medium
M1	copper	Wetcol	Low
M3	mancozeb	Dithane	Low
M5	chlorothalonil	Bravo	Low

Table 2. FRAC codes and resistance risk of the most important active substances for late blight control

Source: FRAC and FRAG-UK

Within FRAC, working groups discuss the monitoring results regarding the most important fungicide groups. The fungicide working groups on Carboxylic Acid Amines (CAA) - FRAC code 40 - and Quinone outside Inhibitors (QoI) - FRAC code 11 - have formulated use recommendations to manage fungicide resistance in late blight. For the other fungicides, FRAC recommends that resistance management is necessary but does not provide recommendations.

Carboxylic Acid Amines (CAA) Use Recommendations

- Apply CAA fungicides preferably in a preventive manner
- Apply a maximum of 50 % of the total number of intended applications for late blight control
- Alternation with fungicides having other modes of action is recommended in spray programs

Quinone outside Inhibitors (QoI) Use Recommendations

- Apply QoI fungicides according to manufacturer's recommendations
- Where QoI fungicide products are applied alone do not exceed one spray out of three with a maximum of three sprays per crop. Do not use more than two consecutive applications.
- Where QoI fungicide products are applied in mixtures (co-formulations or tank mixes) do not exceed 50% of the total number of sprays or a maximum of six QoI fungicide applications whichever is the lower. Do not use more than three consecutive QoI fungicide containing sprays.

In the UK a regional Fungicide Resistance Action Group is active. This FRAG-UK group combines the expertise of the industry with the independent sector to provide up-to-date information and advice on fungicide resistance. They translate the information that FRAC provides into recommendations for UK conditions. FRAG-UK has published a guideline to manage fungicide resistance (www.frac.info).

4

Planning Blight Control Strategy

Eric Anderson, Scottish Agronomy

A blight strategy is a plan of how you to intend to approach the protection of a potato crop against blight. It should contain IPM actions – based on the eight principles described in chapter 2 – and crop protection options to be deployed as the season unfolds. Here we focus on how to select crop protection options appropriate to crop growth stage and blight risk.

Previously the industry talked about a 'blight programme' rather than a 'blight strategy'. The change of phraseology acknowledges that coming up with a precise plan of sequenced sprays before seeing what the season brings is inflexible and potentially risky and/or wasteful.

Think of a blight programme as the result of a blight strategy. A programme is a record of the crop protection sprays applied that were selected from the blight strategy. It is a useful record to review in the light of the outcome to refine future seasons' strategies.

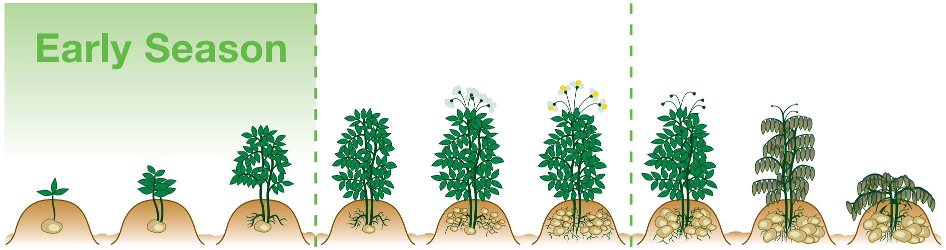
Potato crops grow through three distinct phases each of which has different needs for protection. In this chapter these needs are described and the development of blight strategy is discussed with reference to the characteristics of blight fungicides explained in chapter 3.

Photo © Bayer CropScience

Crop Growth Phases

In this chapter the planning of blight strategy is discussed with reference to three phases of crop growth; early, mid and late season. Early crop canopy development is from emergence to the end of the rapid growth phase when the canopy is complete. The crop then moves in to the mid season phase. When this ends is less clear-cut and depends on variety and target lifting date. Generally the transition from mid- to late-season is considered to be at the point where the crop is likely to need just two or three more sprays. Late season is from this point up to complete haulm destruction.

Early Season Protection



Previously the advice was to begin protection when plants met along rows or when the first warning of risk occurred, whichever was the earlier. With the possibility that blight populations may now be active at temperatures below the 10°C Smith criterion and that infection can begin without a Smith period occurring we have to be alert to local conditions from emergence. All it may take is soil moisture or humidity to initiate early season sporulation.

A major factor in successful blight control is to start early enough. The first spray should be applied either at the rosette stage, when there is sufficient crop to intercept the spray, or when there is a high risk period, whichever comes first.

At the rosette stage (11) 90% of a field's surface area is bare soil so for the first spray it is appropriate to go for an economical protectant option such as mancozeb or fluazinam. If there is a risk that blight has been introduced on seed then it is appropriate to use a fungicide with curative activity and also activity on zoospores e.g. Ranman Top (cyazofamid) or fluazinam in mixtures. A blight-infected seed stock carries a higher risk of non-emergence (blanking) or earlier expression of blackleg symptoms (12).

Thereafter, it will be necessary to protect rapid canopy growth with sprays that have good ratings for protection of new growth. Options currently are Ranman Top, Revus (mandipropamid), Amphore Plus (mandipropamid + difenoconazole), Consento (fenamidone + propamocarb) and Infinito (fluopicolide + propamocarb). Ranman Top and Revus are commonly used through rapid canopy growth because they bind strongly to the leaf wax layer and as buds open and develop leaf, they take small amounts of the chemical with them.

Infinito is equally well suited to this period but often retained for later in the season when its tuber blight and anti-sporulant activity are needed.

During rapid canopy growth spray intervals should not be extended beyond seven days, as by day eight there will be a very large area of new leaf vulnerable to infection should conditions become conducive to foliar blight.

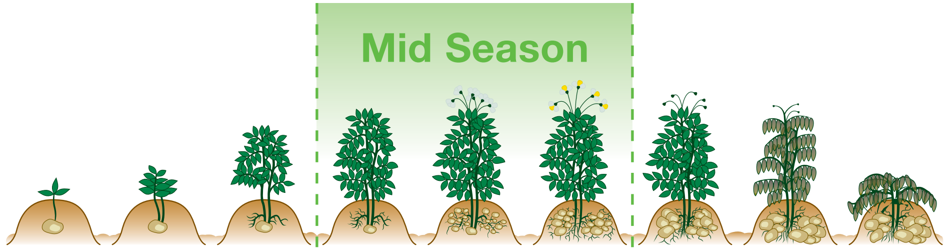
Rosette stage Photo © Scottish Agronomy Ltd

Early symptoms of blackleg

Photo © Scottish Agronomy Ltd

If forced to apply shortly after a high-risk period it is advisable to add a tank mix partner with anti-sporulant activity It is also important to use angled nozzles to maximise crop canopy spray penetration and coverage.

Mid Season Protection



Crops are most able to tolerate blight pressure during mid season, so this is the time to take advantage of periods of low risk to make savings with some economical protectant products: there are plenty to choose from. However, it is important not to reduce rates and to stick resolutely to seven-day intervals. And do not forget that risk of tuber infection begins at tuber initiation which can be from just two to three weeks after emergence. Even through a low-risk mid season period, including a couple of sprays with tuber blight activity will start building tuber protection and pay dividends later on.

If visual blight on stems or leaves is found in a crop, or one nearby your crop, products with anti-sporulant activity should be selected. Early infections on the lower stem are often overlooked but once spores from a stem lesion infect leaves, the disease becomes obvious.

Options with good ratings for foliar blight and anti-sporulant activity, with cymoxanil added where necessary for kickback are;

- Revus 0.6 L/ha + Sipcam C50 (cymoxanil) 0.24 kg/ha
- Infinito 1.6 L/ha
- Invader (dimethomorph + mancozeb) 2.4 kg/ha
- Ranman Top 0.5 L/ha + Sipcam C50 0.24 kg/ha
- Valbon (benthiavalicarb + mancozeb) 1.6 kg/ha + Zinzan

The aim is always to prevent the onset of foliar blight for as long as possible while acknowledging that prevention is unlikely in a high-pressure season and at some stage infection will get into the crop and have to be dealt with. Typically this occurs during the mid season phase of growth but in lower pressure years it can be staved off until late season.

Where blight is found to be active, the anti-sporulant activity of Infinito, Invader and Revus can be useful. It is the strong anti-sporulant action of the active substance propamocarb contained in Infinito that 'dries up' foliar infections. Propamocarb also comes in co-formulations with cymoxanil and their curative activity is even stronger than that of Infinito. However, they are not as 'rounded' and do not have sufficient foliar or tuber blight activity so should only be used in tank mixes with complimentary products.

Good control of established blight has been achieved from a tank mixture of full rate Ranman Top plus 2.0 L/ha Proxanil. This contains 50 g/L cymoxanil and 400 g/L propamocarb and offers stronger anti-sporulant activity than straight cymoxanil.

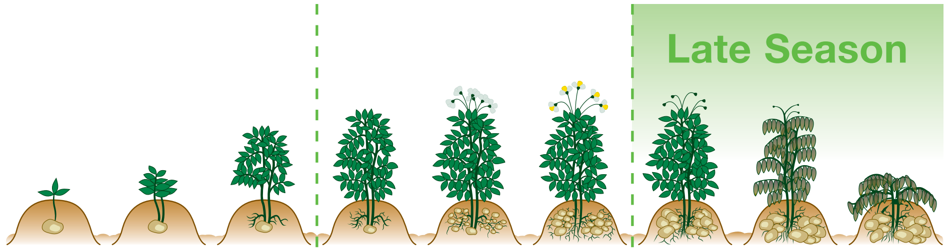
Fungicide products vary in their curativity or kickback. In general the kickback period will be shorter in very susceptible varieties where temperature is higher – 20 to 23°C rather than 10 to 15°C – and/or infection is caused by a more aggressive genotype. Because of the faster life cycle of the 6_A1 and 13_A2 blight genotypes, all products with curative activity are likely to have a shorter period to act than has been relied upon historically and may in practice afford significantly less than 24 hours kickback.

In a small study the curative fungicide activity of cymoxanil was reduced when an isolate (13_A2) with shorter latent and infection periods was compared with a less aggressive genotype (8_A1). This demonstrates that cymoxanil now has severe limits in its practical eradicant activity.

Straight dimethomorph is available as Morph (0.3 L/ha). Dimethomorph has an even shorter eradicant period than cymoxanil but it is persistent in the canopy for five to seven days versus three days for cymoxanil. Do not use Morph, Proxanil or straight cymoxanil without a tank mix partner.

Most product labels do not allow for an interval of less than seven days, however, by alternating products, intervals can be reduced to three to five days. The best advice is to maintain shortened intervals and alternate products with different modes of action until actively sporulating blight lesions dry up.

Late Season Protection



During the late season phase of growth the priority is protection of tubers so for the last two to three sprays, products with good tuber blight ratings should be used i.e. Infinito @ 1.6 L/ha or Ranman Top @ 0.5 L/ha. If blight escalates and is active in the crop anti-sporulant activity is needed in addition to tuber blight activity to reduce the amount of viable inoculum in the crop. Infinito is the one fungicide that offers both but the following tank mixes can also meet the need;

- Proxanil (cymoxanil + propamocarb) 2.0 L/ha plus Ranman Top @ 0.5 L/ha
- Revus 0.6 L/ha plus Shirlan (fluazinam) 0.4 L/ha
- Invader 2.4 kg/ha plus Ranman Top @ 0.5 L/ha

The rationale for these is that the first product listed brings anti-sporulant activity, the second brings tuber blight activity to the mix and one of them also has good foliar blight activity. Where conditions require intervals to be reduced below seven days, use different products sequentially.

On the rare occasion when either blight is not present in the crop or late season conditions are low risk, an economical option for tuber protection is fluazinam, however it is not a robust product for either foliar or tuber blight.

The propamocarb stewardship conditions of Tesco Nature's Choice limit its use to 4,500g/ha per annum. An application of Infinito at 1.6 L/ha delivers 1,000 g/ha. It is important to remember this, especially if it has been used at an earlier stage, to avoid exceeding the limit while focusing on tuber blight.

Continuing to keep crops growing when they have active foliar blight puts daughter tubers at a very high risk of infection. The rare exception is when there is no significant rainfall until after target tuber sizes are achieved and haulm is completely desiccated.

Blighted progeny tubers are more likely to rot away prior to harvest, especially if infection is earlier in the tuber bulking phase of the growing season and conditions favour secondary bacterial activity, i.e. soils are wet and warm. If blight infection of tubers is late in the growing season then the risk of secondary bacterial soft rot in store will generally be higher.

The harvesting process can be a very effective way of introducing tuber infection as the mechanical mixing of soil and tubers rubs spores into them. Key precautions to minimise risk of infection at harvest are;

- Wait until haulm has been dead for at least 14 days
- Ensure there is no re-growth after desiccation; it is particularly susceptible to blight infection
- Maintain appropriate spray intervals until all haulm is completely dead

5

The Role of Infinito

Nigel Adam, Bayer CropScience

Infinito is well established as an essential fungicide in European late blight control strategies. It is a co-formulation of fluopicolide and propamocarb; active substances which work hand in hand to protect every part of the potato plant – leaves, stems, tips and tubers – and attack the late blight pathogen at every stage of its life cycle.

Since its launch in 2006 Infinito has been a leader in the EuroBlight table and is unique in combining premier league ratings for effectiveness against foliar blight, tuber blight and anti-sporulant efficacy.

This chapter explains how Infinto's chemistry delivers these important fungicidal characteristics, with particular reference to the role of anti-sporulant activity in combating aggressive blight strains. It concludes with guidance on the best use of Infinito in blight strategies to achieve the ultimate in protection of potato crops.

Photo © Evington Morris

Mode of Action

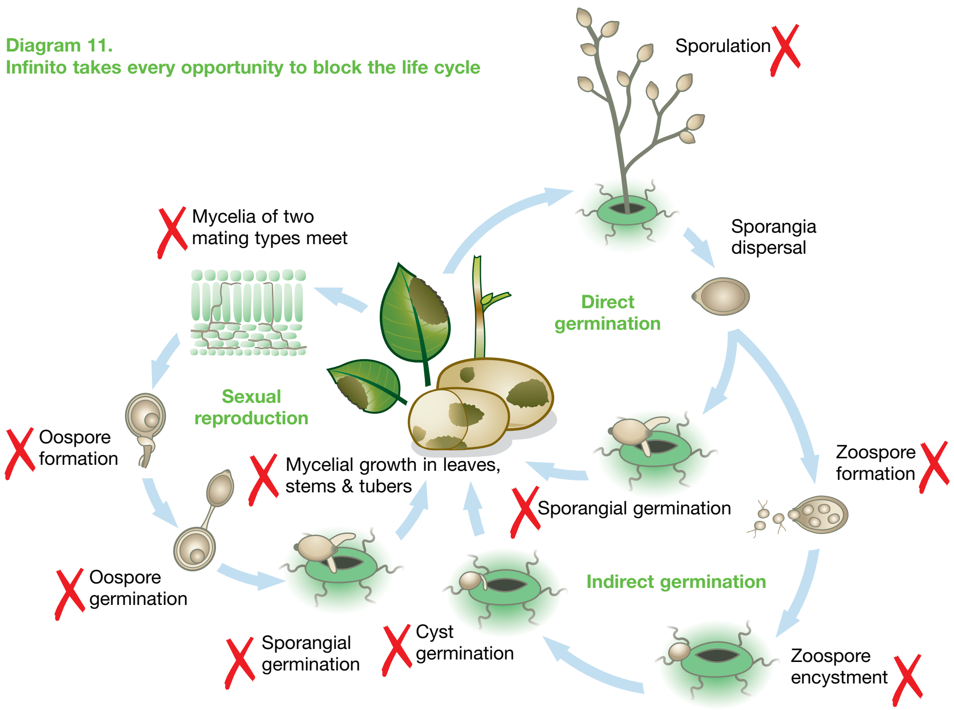
Fluopicolide is a strong protectant fungicide and has translaminar mobility. It works by disorganising the pathogen's cell structure, disrupting the formation of spectrin like proteins, believed to play a vital role in maintaining the pathogen's cytoskeleton stability. This novel mode of action is highly effective at all key stages in its life cycle. In particular, fluopicolide's activity against motile zoospores is dramatic. Under the microscope, it is seen to halt their movement immediately on contact and in less than a minute they burst.

Propamocarb is also a strong protectant fungicide and has systemic mobility. It disrupts the formation of fungal cell walls by interfering with phospholipid and fatty acid synthesis. This mode of action attacks a number of stages in the life cycle and crucially pushes the pathogen into direct germination which limits spore production to a tenth of its potential.

With the highly aggressive blight strains now dominating, every opportunity must be taken to block the life cycle. Infinito is effective at all key stages (Diagram 11): sporulation, zoospore and cyst formation, zoospore mobility, cyst germination and mycelial growth.

Activity on both direct and indirect germination of sporangia provides strong and reliable action against the disease, regardless of temperature. Its power to control mycelial growth also blocks the pathogen's sexual reproduction route by preventing the mycelia of different mating types from meeting.

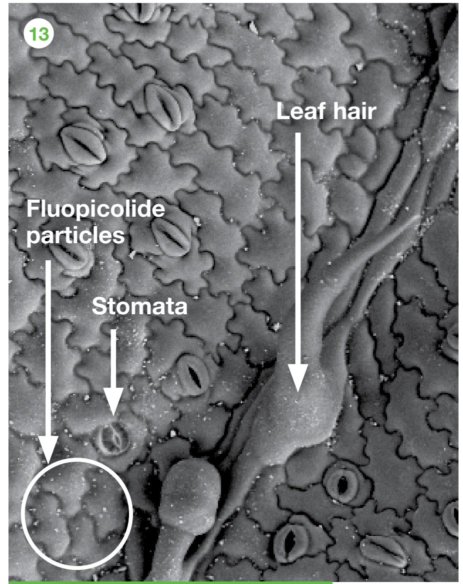
Diagram 11.
Infinito takes every opportunity to block the life cycle



Foliar Blight

The key to optimal yield and tuber quality is successful protection of leaves and stems. To keep building yield to full potential the canopy has to be kept healthy and complete. If disease can be kept out, spores cannot be produced, and the source of tuber infection – sporangia or zoospores washed down from the foliage above – is eliminated. Infinito provides the robust foliar protection and strong anti-sporulant activity needed to achieve this.

Infinito's formulation technology produces complete and even distribution of the product on leaves, stems, and petioles. Small droplets with excellent sticking properties cover the upper and lower surfaces of the leaf, un-hindered by leaf hairs. After drying, fluopicolide particles are evenly distributed to provide effective protection against the pathogen 13.



Even distribution of fluopicolide particles

Photo © Bayer CropScience

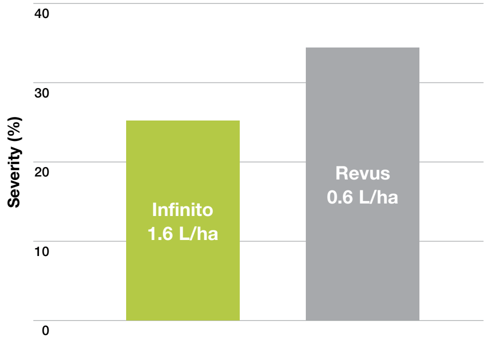
Full protection is achieved on the day of application. The propamocarb moves quickly into the leaves and stems taking some of the fluopicolide dissolved in the spray solution with it. The active substances have a complementary effect with the presence of propamocarb doubling the penetration of fluopicolide. Even a minute amount of the product is enough to control fungus developing within the leaf.

The even distribution of Infinito provides a reservoir of fungicide to protect the leaf surface against further infection and it continues moving into the leaf and stems throughout the spray interval to maintain a high level of protection. When applied to the upper surface of a leaf it quickly provides protection to the lower surface too, and when applied to the base or petiole of a leaf it moves forwards into the leaf tissue. This strong translaminar mobility ensures new growth is well protected throughout the spray interval.

Infinito adheres firmly to the leaf even when the surface is wet with dew or recent rainfall. Once dried on the leaf, the product remains fixed and resists wash-off by rain. Its behaviour on the plant is also independent of temperature and sunlight. Uptake is just as effective at low or at high temperatures and fluopicolide is very stable and resistant to degradation even under strong sunshine.

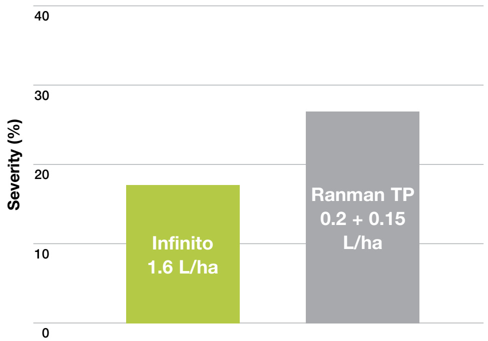
Infinito's control of foliar blight has been tested against other leading protectant products since 2002 in field trials spanning five European countries, including the UK.

Graphs 1 and 2 to the right show the results of product comparisons by programmes of sequential sprays at weekly intervals with the bars representing mean severity compared with complete defoliation of the untreated control.



Graph 1. Foliar blight prevention Infinito vs Revus

Source: Bayer CropScience 26 trials in Belgium, France, Germany, Netherlands and UK 2009-11.



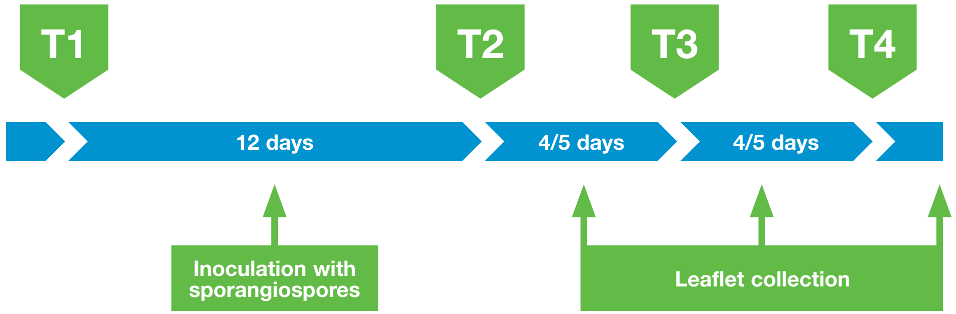
Graph 2. Foliar blight prevention Infinito vs Ranman

Source: Bayer CropScience 37 trials in Belgium, France, Germany, Netherlands and UK 2002-11.

Once blight infection gets into the canopy, anti-sporulant efficacy is vital in slowing down the spread of infection. In 2009 Wageningen UR conducted a trial in the Netherlands to study the impact of fungicides on spore production.

The crop was completely protected against late blight with cover sprays of mancozeb until mid to late flowering when a sequence of four test treatments was implemented (Diagram 12). A broadcast inoculation with sporangiospores was conducted six days before the second treatment to induce a late blight epidemic. Throughout the experimental period the canopy was sprinkler irrigated for four minutes per hour from 07:00 to 21:00 to maintain a humid microclimate.

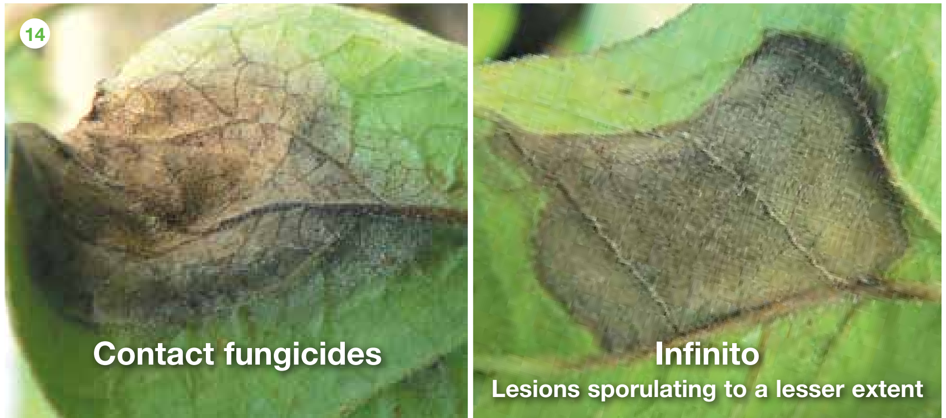
Diagram 12.
Experimental design



Leaflets with a single lesion were collected randomly in each plot one to three days after experimental treatments 2, 3 and 4, dipped in water to collect spores and spores were counted. The canopy was desiccated 18 days after the fourth test treatment and potatoes were harvested a fortnight later. Tubers were assessed for the presence of late blight infections and tuber blight was expressed as % incidence.

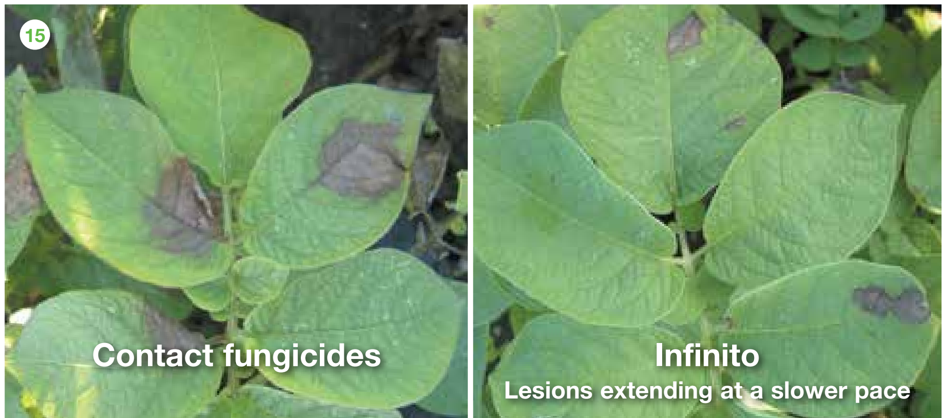
The broadcast inoculation set off a leaf blight epidemic which resulted in complete defoliation of the canopy in a period of 25 days. Leaf blight incidence ranged from 90-95% in plots treated with fours sprays of Dithane or Shirlan, to 20% in plots treated with Ranman and 5% in plots treated with Infinito.

Late blight lesions present in plots treated with Infinito differed in appearance from lesions treated with contact fungicides. Lesions in Infinito plots sporulated to a lesser extent compared with those in plots treated with Dithane, Ranman or Shirlan 14. Furthermore, lesions in plots treated with Infinito extended at a slower pace than those in plots treated with contact fungicides 15.



Appearance of late blight lesions

Photos © Bayer CropScience

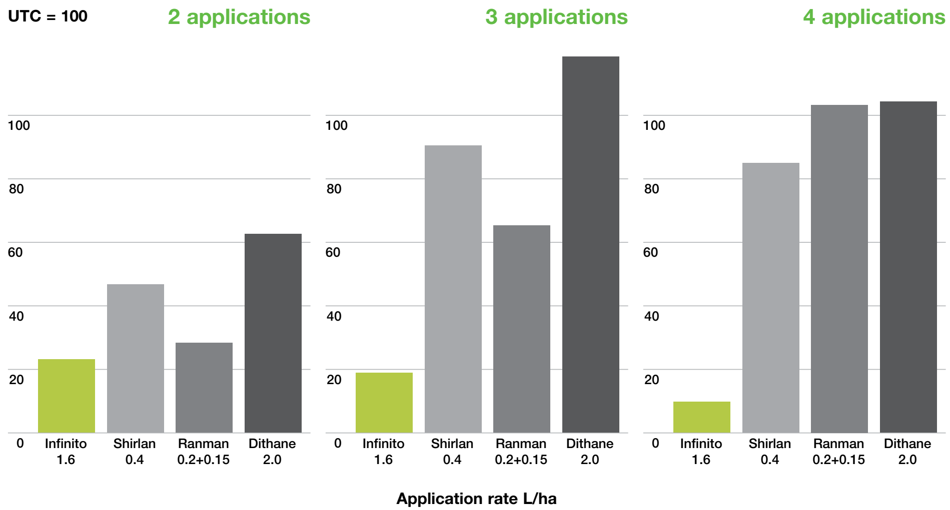


Growth of late blight lesions

Photos © Wageningen UR

Graph 3 below shows the evolution of spore production in time from the first to the third sampling, representing the impact of two, three or four test treatments. The sampling after two applications shows that all treatments had a considerable effect on spore production. The subsequent samplings show that the effect of Infinito on spore production per lesion persisted and improved after three and four applications.

Graph 3.
Spore production per lesion



Tuber Blight

The source of tuber blight, that causes yield loss at harvest and during storage, is sporangia and zoospores washed down from leaves and stems by rainfall and irrigation. So preventing tuber blight requires fungicides with strong anti-sporulant activity to eliminate these infection sources from the canopy before they can reach the soil.

Sporangia washed down to the soil at this time can remain viable for several weeks. Even during periods of rainfall Infinito will kill newly developed spores before they are washed down to the soil.

Diagram 13 to the right, illustrates Infinito's triple action targeting spore quantity, spore mobility and spore viability to provide the ultimate in tuber protection.

The performance of Infinito in protecting crops against tuber blight was investigated across 21 trials conducted by Bayer CropScience in the Netherlands from 2006 to 2011. Leaf blight epidemics were introduced via inoculation of guard rows and plots received a programme of sequential Infinito sprays at weekly intervals. The average incidence level of tuber blight was 29% in the untreated control, 6% for Shirlan, 1% for Ranman and 0.5% for Infinito.

Tuber infection of just 0.5% has been found to cause rot and storage problems so these results further underline the need use Infinito as part of a comprehensive strategy to protect crops against tuber blight.

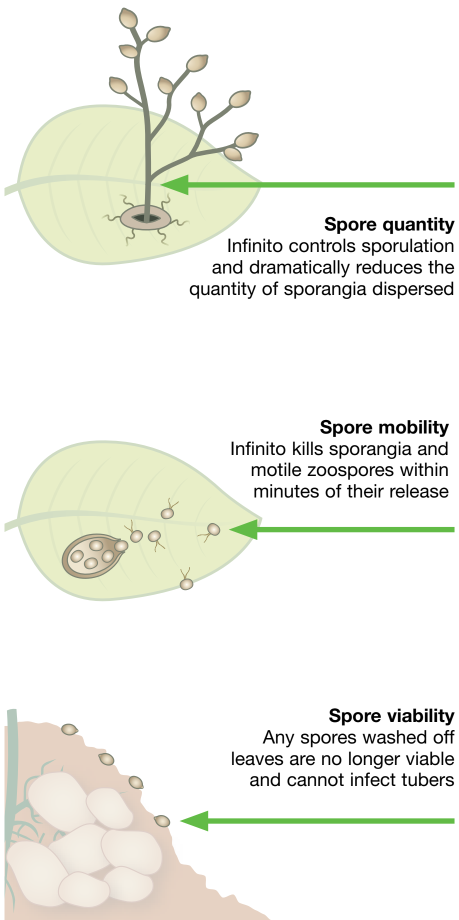


Diagram 13.
Infinito's anti-sporulant action

Best Use

In the fight against today's blight strains Infinito is widely considered as a 'must have' in any blight strategy. To get the most from its foliar and tuber blight efficacy and anti-sporulant mobility it is best used through the stage of crop growth when the risk of foliar blight is high and/or when conditions are conducive to tuber infection. Generally this means from canopy compete onwards.

A sound strategy is to plan to incorporate sprays of Infinito in alternation with complimentary fungicides from canopy complete until complete haulm destruction (Diagram 14). Not all Infinito sprays need be aimed at high-risk periods. It has been recognised that tuber protection is optimised by building it up from shortly after tuber initiation.

This approach is far more effective than waiting until blight is active in the canopy and spores are being washed down to the soil below before introducing fungicides with tuber blight activity. Using Infinito from canopy complete onwards in this way will build in the strongest possible backbone of tuber protection.

Diagram 14.
Positioning Infinito in a blight strategy

Combining the complimentary modes of action of two active ingredients, Infinito has a solid inbuilt anti-resistance mechanism. Although fluopicolide has no cross-resistance with other fungicides, pro-active anti-resistance management is an essential part of best practice in blight control. The number of applications recommended is therefore limited to four.

To obtain the best protection against all strains of late blight use Infinito at 1.6 L/ha at 7-day spray intervals in programmes with fungicides from different chemical classes.

Disclaimer

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