



Managing the risk of late blight

www.potato.org.uk/blight

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Glossary

Clonal lineage Individuals in a clonal lineage of the late blight pathogen are genetically identical and descended from a genetically identical ancestor. Produced by asexual reproduction.

Determinate/indeterminate Ranges from 1 to 4, where a determinate variety has a short haulm longevity with a score of 1 and an indeterminate variety has a very long haulm longevity with a score of 4.

Genotype If individuals of the pathogen are the same genotype they have the same genetic make up.

Germ tube At higher temperatures sporangia germinate to produce a germ tube directly. The germ tube is involved in the infection of host tissue.

Kickback Fungicides with curative activity which can cure blight in the early stages of development.

LERAP Local Environment Risk Assessment for Pesticides.

Mating type There are two for *P. infestans*, named A1 and A2. Sexual reproduction between individuals requires them to be different mating types.

Motile zoospores A zoospore is a small asexual spore that uses a flagellum (tail) to swim in moisture.

Oospore A thick-walled, long-term survival spore produced from sexual reproduction.

Pathogen An agent that causes disease, especially a living microorganism.

Phytophthora infestans The Latin name for the pathogen that causes late blight.

SMART test The SMART test allows you to evaluate when there is sufficient soil moisture for the application of Reglone. It is a simple in-field test that will quickly indicate whether it is safe to desiccate with full rate Reglone, a reduced rate split application or, in some cases, to use an alternative method. In any situation (even SMART Fail) Syngenta will support the application of 1.0L/ha Reglone.

Sporangia/sporangium An asexual cell, or organ, producing spores. It's in the form of sporangia that the blight pathogen is spread in air currents.

Sporulation The formation of spores.

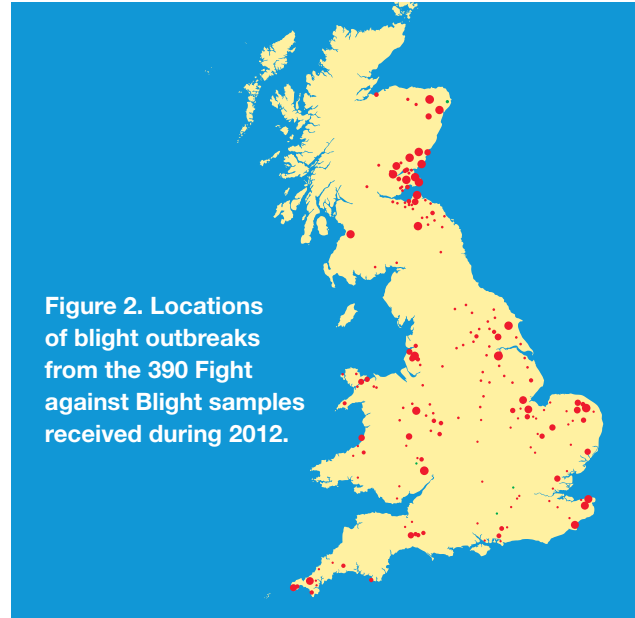
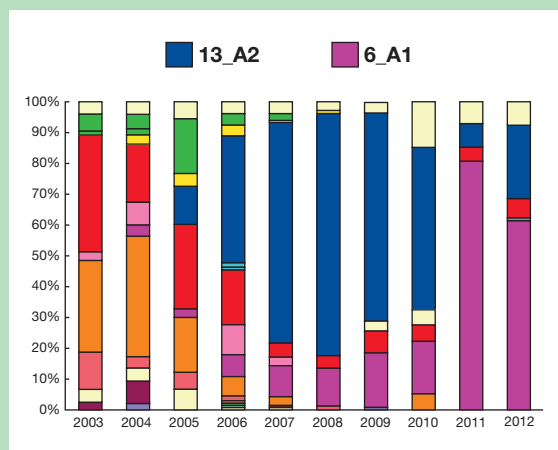
13_A2/6_A1 The new, more aggressive genotypes of *P. infestans*.

Managing the risk of late blight

This guide has been written to help identify the various areas where late blight control can be managed and to give practical advice to keep blight out of a crop, or minimise the impact if an infection does occur. An important factor to remember is, not to develop a blight programme at the start of the season, but a blight strategy. This will then help to adjust timings and choice of product to best suit the conditions as they develop.

Potato Council fund the annual monitoring of the pathogen population which led to the discovery that 13_A2 and now 6_A1 have now become the dominant strains within GB (see figure 1), with 13_A2 causing more outbreaks in England and Wales, and 6_A1 in Scotland. These strains are both more aggressive and fitter than the older A1 genotypes that used to dominate. The knowledge of these changes has helped to adapt the notes within this guide and also direct new research into the implications of the change. One such implication is the use of Smith periods, it is now known that the two dominant genotypes are capable of infecting at temperatures below 10°C, and high humidity periods of less than eleven hours. Whilst research is on-going to improve the accuracy of blight risk predictions using spatially explicit models that account for infection, sporulation and spore dispersal of current pathogen population in relation to weather forecast data, it is still important to be aware of Smith periods alerts, as they still provide a good broad picture of risk periods. It is also useful to view the 'near misses' on the blightwatch website (www.blightwatch.co.uk) to better adapt to the weather element of late blight management.

Figure 1. Changes in blight genotypes over a 10 year period.



In Europe, especially the Scandinavian countries, there is evidence of sexual recombination between the A1 and A2 mating types. This is a real threat to GB potato crops as this could lead to many novel genotypes that have the potential of being even more aggressive than 13_A2 and 6_A1. To date there is evidence of some sexual recombination but these lines have quickly disappeared or have stayed at relatively low levels meaning they are not aggressive or fit enough to compete. So we still have a largely clonal population to deal with. The level of each genotype will fluctuate seasonally, possibly in part, dependant on the weather conditions early in the season, but the monitoring for possible oospore outbreaks is on-going and important to allow a more proactive approach to changing blight control.

The work of Blight Scouts and Blight Monitors on allotments continues to play a pivotal role in both the monitoring of outbreaks and the supply of samples available for research. Without the hard work of these people Potato Council couldn't run the Fight against Blight campaign. See figure 2.



If anyone in your organisation would like to help in the Fight against Blight by becoming a Blight Scout, please email gary.collins@potato.ahdb.org.uk to request a sampling kit.

Gary Collins
Potato Council, technical executive.

1: Outgrade piles

Outgrades should not be left in potato boxes because they are difficult to treat and may become difficult to remove once well sprouted. Minimise the size of any pile. Piles should include only material that cannot be fed to cattle, such as rots and greens. Over/undersized tubers and surface defects should have a market.

Mapping late blight outbreaks, as part of the Fight against Blight Campaign, has demonstrated that outgrade piles remain a significant source of blight for crops.

In addition to blight, outgrade piles can act as a source of aphid-borne virus and other diseases. **Uncontrolled outgrade piles of whatever size can cost you money.**

Whether there is obvious blight or not, all outgrade piles should be dealt with. Fungicide and aphicide programmes can be jeopardised by a failure to tackle outgrade piles. Blighted plants release millions of air-borne spores that can travel, and remain viable, for miles under dull and damp conditions. However, the closer an outgrade pile is to a crop, the greater the risk of crop infection.

Best practice is to adopt a zero tolerance approach to sprouting and production of green foliage on outgrade piles by taking action early; preferably covering with black plastic sheeting. See figure 3.

If sheeting is not used early and the outgrade pile has been allowed to sprout, you should spray the pile as soon as possible with Reglone (Diquat) or glyphosate.

Always read the pesticide product label for glyphosate use or be in possession of the EAMU for Reglone use.

Cover the pile with black plastic sheeting and ensure that the edges are sealed to prevent the escape of spores and reduce the impact of wind or the likelihood of animals tearing the sheeting.

Reglone now has an Extension of Authorisation for Minor Use (EAMU) (formerly known as a SOLA) in the UK for use on outgrade piles. **You must be in possession of, and have read, the full EAMU (20111882)** which can be downloaded from the following website: <https://secure.pesticides.gov.uk/offlabels/>

If Reglone or glyphosate treatment is used alone without sheeting then it is likely that repeated herbicide applications will be required because of the delayed emergence from tubers at depth in the pile. This is a good reason to level off the outgrade pile, prior to any haulm being produced. In addition to improved health and safety during application, the period of emergence will be considerably reduced and fewer herbicide treatments will be required. In a shallower pile, an additional advantage is that any frost will kill more of the tubers. Tubers are killed by 50 hours or more at a temperature below -2°C.

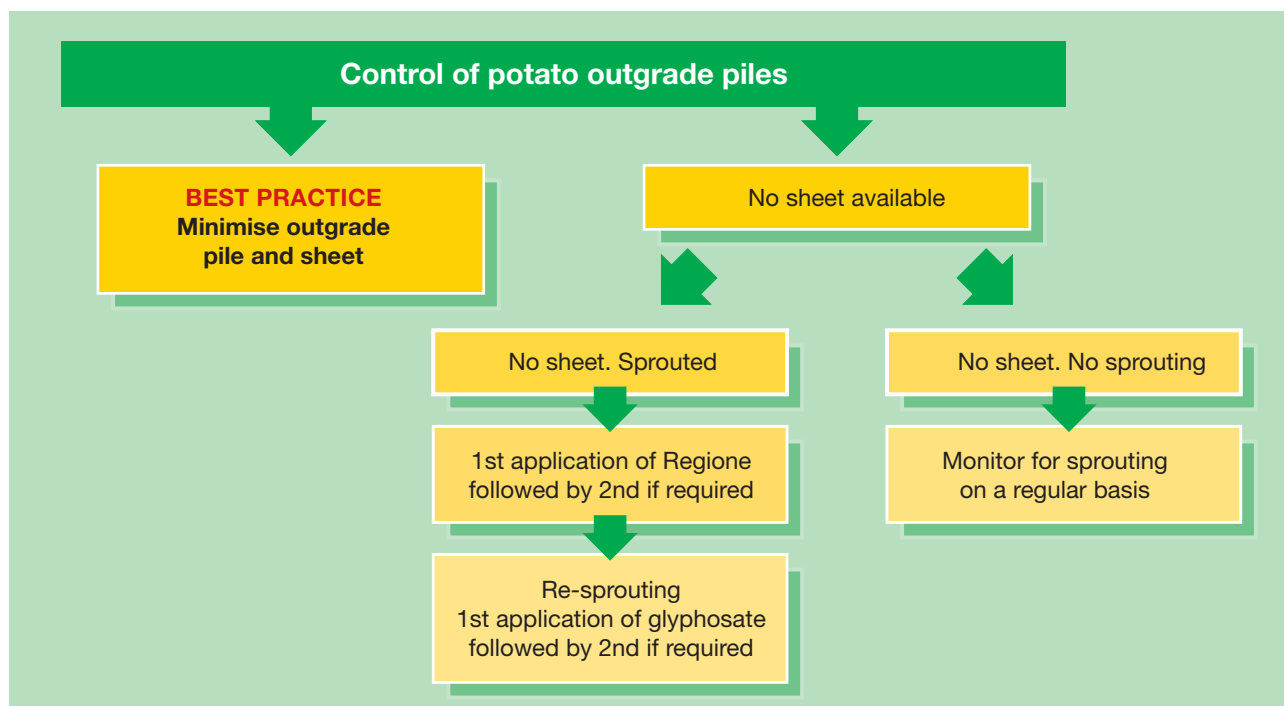


Figure 3. Best practice for control of outgrade piles.

Applying glyphosate to established haulm is a high-risk strategy. Potato Council-funded work at SRUC has shown that blight spores continue to be released during the slow haulm kill with this herbicide. It is not good practice to mix Reglone and glyphosate, as the Reglone can inhibit the systemic movement of glyphosate to the tubers. Glyphosate is much slower acting than Reglone and treated haulm can still pose a blight risk.

You should check outgrade piles regularly throughout the growing season and encourage neighbours to control their outgrade piles.

Research carried out by SRUC has shown that blighted tubers may not always show blight symptoms. It is, therefore, best to assume blight is present in the outgrade pile and to use Reglone as the preferred chemical for a quicker haulm kill.

Location of outgrade piles

Outgrade piles should be accessible but well away from your own, and your neighbour's, potato crops and farm buildings. Try to locate piles on land not intended for any crop, especially any potatoes in the future.

Don't risk polluting watercourses. Locate piles away from ditches, rivers, groundwater, etc. Outgrade piles should not be placed on a non-permeable surface. There is a risk of point source pollution of water courses from the breakdown of tubers and any chemical used to control haulm growth.

If you require any specific advice about your own situation, please contact your BASIS registered agronomist.

Agricultural waste management regulations

Since 2005, the composting, storage, and disposal of plant tissue and other organic wastes on land at the farm where they are produced requires an exemption under the waste management regulations in England, Wales and Scotland.

Summary of best practice to minimise effects of outgrade piles

- **Minimise the number of tubers being put in the outgrade pile**
- **Keep the outgrade pile low to increase any frost kill and reduce delayed emergence from depth**
- **Sheet and check regularly**
- **If sheeting is not an option, use Reglone when green material is first seen, as blight infections may not be visible. Reglone provides quick haulm desiccation**
- **When new growth is seen, apply Reglone for the second time. For subsequent new growth use applications of glyphosate**
- **Both Reglone and glyphosate are only effective on green material**
- **Remember sheeting is best practice because this has a zero tolerance for green material.**



Don't let outgrade piles get to this stage.

Photo source: Scottish Agronomy Ltd

Further information is available at:

- **England Wales Environment Agency** www.environment-agency.gov.uk/business/sectors/32777.aspx
- **Scotland Scottish Environment Protection Agency (SEPA)** www.sepa.org.uk/land/agriculture/agricultural_waste_guidance.aspx

2: Seed health

There is no survey information on the percentage of crop outbreaks in GB that originate from infected seed. However, a survey in The Netherlands, reported at the EuroBlight Workshop by Bert Evenhuis from Wageningen, identified that infected seed was responsible for around 36% of outbreaks between 1999 and 2005.

A single seed tuber with blight symptoms in every 100 tubers can produce at least two primary infection sources per hectare. In the right conditions this could start a blight outbreak in your crop.

The amount of inoculum arising initially from a seed-borne infection may be limited compared with that from a large outgrade pile. However, the seed-borne inoculum is already within the crop making spread less dependent on warm, humid weather. Also, the infection may not be spotted until it becomes more advanced.

Seed cutting can increase the spread of blight and the risk of an early outbreak.

Regular and open communication between you and your seed supplier is very important.

When it comes to blight, there are several points worth checking:

- Where your seed was grown
- What had been the blight risk in that area. This can also be checked from the Potato Council's outbreak mapping service
- Information on blight from your supplier's inspection reports.

Carry out a washup test (see opposite) as soon as possible after seed is delivered.

Be aware that refrigerated storage, for example 3°C, is likely to prevent the expression of tuber blight symptoms but the blight pathogen can remain viable. When assessing blight on seed stored under long-term refrigeration, the seed sample should first be incubated at around 15°C for at least two weeks, to allow subclinical blight to manifest itself as visible symptoms.

Seed grade	Tuber blight tolerance
Pre-basic	0.2%
SE, E, A	0.5%

Using your own farm-saved seed?

- Check last year's records for blight infection in your crops
- Don't save seed from crops known to have had a blight infection
- Carry out regular washup tests (see opposite)
- Classified seed tolerances should be used as a guide
- Carry out more than one test
- **Treat farm-saved seed with particular caution, because it has no certification and may have numerous other health risks.**



Source: SECSR

Clearly, the higher the incidence of seed tuber blight, the greater the risk of spread to the growing crop. However, it is difficult to be too specific about the risk associated with different severities of seed tuber blight. Seed tubers with obvious symptoms will be detected and not planted. Tuber infections that are barely visible or latent are a greater threat. The risk of blighted seed producing infected haulm will be modified by factors, such as soil moisture content between planting and crop emergence, and the depth of soil cover over the seed.

Latently infected seed can be detected using PCR diagnostics. However, the test is not generally available because of insufficient information on sampling and the level of risk associated with different incidences of seed infection.

Comments regarding the difficulty in determining the risk of blight spread from seed with different severities of blight apply also to the impact of varietal resistance. Clearly, tuber resistance will influence the size of blight lesions on tubers at any one time. However, just because varietal resistance is high, does not necessarily mean that there is a lower risk of spread from seed of that variety. The blighted seed tuber needs to decay slowly enough so that it remains a source of viable blight inoculum at or after crop emergence.

Some of the laboratories that offer diagnostic testing

Sutton Bridge Crop Storage Research

Glyn Harper: 01406 359413,
glyn.harper@potato.ahdb.org.uk

Cambridge University Farm

David Firman: 01223 335088
david.firman@niab.com

Food and Environment Research Agency (Fera) Plant Clinic

Helpline: 01904 462324
plantclinic@fera.gsi.gov.uk

SRUC, Aberdeen

Daan Kiezebrink: 01224 711206,
daan.kiezebrink@sruc.ac.uk

SRUC, Edinburgh

Fiona Burnett: 0131 535 4133
fiona.burnett@sruc.ac.uk

NIAB

Jane Thomas: 01223 342200
jane.thomas@niab.com

Make every effort to reduce the risk from seed-borne blight

Carrying out washups is simple and highly effective

Step 1

Collect a **minimum** of 100 randomly selected tubers from each seed stock. With **classified seed** this should be done as soon as you receive the seed. This way, you can quickly communicate the findings to your supplier. If you are using farm-saved seed, collect samples several times throughout the storage period. Remember, just because you cannot see blight infected tubers at store loading does not mean that there is no infection there.

Step 2

Wash samples and carefully inspect each tuber. The main sites for infection of blight are the eyes, lenticels and any damage caused by handling.

It may be necessary to cut tubers to see blight. This is an ideal opportunity to look for other defects.

Step 3

Wherever possible, do not plant stocks of seed where blight has been detected due to the risk of it becoming a primary source of infection under the right conditions. This is described as good practice within most assurance protocols. However, classification for tuber tolerances allow 0.2% or 0.5% infection. If you have any doubts contact your agronomist.

Step 4

Soft rots may mask tuber blight symptoms. If you need further clarification, consider sending a suspect sample to a laboratory for diagnosis (listed left).

3: Planting

Plan a field in advance of planting the potato crop. Not doing so could lead to unnecessary problems later.

Site selection

The following factors should be considered prior to planting.

1. External sources of infection – outgrade piles, volunteers

It is important when selecting a field for growing potatoes to think of external sources of infection. Try to stay as far away as possible from outgrade piles and fields that may have uncontrolled volunteers.

2. Sources of infection within the field – oospores

There is no strong evidence that oospores are initiating blight outbreaks in GB. However, the risk of an oospore-derived outbreak is greater where a potato crop is grown on too short a rotation, where the previous potato crop had blight. Research in The Netherlands has shown

that oospores can remain viable in a sandy soil for 48 months and in a clay soil for 34 months. In recent years in GB, approximately one fifth of blight outbreaks have contained both mating types of the blight pathogen. It is, therefore, possible for oospores to have been produced. The best way to minimise the risk of an oospore-derived outbreak (see photos in section 5 for signs of potential oospore infection) is to avoid short rotations, especially if it is known that the previous potato crop was blighted, or blighted volunteers were observed in the intervening years.

Currently, there is no test available for soil-borne oospores of late blight. Information on whether both the A1 and A2 mating types were present in any outbreak will probably be available if samples of blight were submitted through the Potato Council's Fight against Blight campaign (www.potato.org.uk/blight).

3. Water courses

Identify where watercourses are in relation to the potato field. Certain blight fungicides and herbicides carry a LERAP category B rating. This requires a buffer zone of between 1 and 5 metres, depending on the LERAP assessment. Some insecticides added to blight fungicide



Source: Gary Naylor Photography

also have an arthropod buffer zone carrying a mandatory 5 metre buffer to non-crop land. This may affect blight fungicide spraying options later in the season (also see page 19).

4. Trees

Potatoes planted beside trees can often act as hotspots for blight spread, due to the creation of a sheltered, more humid microclimate which is ideal for the production of spores as plants are slower to dry after rain. If possible, leave land in close proximity to trees unplanted or consider crops other than potatoes.

5. Permanent objects – telegraph poles/electricity pylons

Planting too close to poles and other permanent objects can leave areas of the crop with poor fungicide coverage. Leave enough room for the sprayer to cover all around the object, at a safe distance. Areas between objects may be wide enough to plant but may not be wide enough to spray. **If you can't spray it – don't plant it.**

6. Temporary objects – irrigation pipes

Plan where header/feeder pipes will be in relation to sprayer access. This may influence the way the field is planted.

Field hygiene

This is a very important area and is often forgotten about at planting because of busy workloads.

Small quantities of tubers are often discarded in corners of fields or on unplanted headlands when changing to different varieties during planting. Seed boxes can often be left on unplanted headlands for storage and can contain unused tubers. If left throughout the season, any resulting plants will not receive any fungicide spray. These plants can be as big a source of infection as any more-distant outgrade pile.

Action

Ensure all boxes are properly emptied

When changing variety, empty all unused tubers from the planter into a box and remove from the field



Source: Blackthorn Arable

Plants on field margin missed by spray application.

Planter setting

Beds may be eroded later in the season through excess rainfall or irrigation, leaving very little soil cover, resulting in a higher risk of zoospores being washed down into the soil and infecting tubers. To reduce this:

- **Check wheel widths** on both planter and tractor. Make sure they are at the correct spacing and not running on the edge of beds
- Cultivate **deeply enough** to supply enough tilth for adequate soil cover
- Make sure tubers are planted in the middle of the ridges with adequate soil cover both above and to either side of the tubers
- Check **planter ploughs/discs** for wear. Replace if worn
- **Avoid shallow planting** – avoiding this makes it more difficult for inoculum to travel from any infected seed through the soil and onto the foliage. It will also make it more difficult for any blighted tubers to produce a plant that becomes infected and acting as a primary infection source.

4: Volunteer control (Groundkeepers)

Volunteer potato plants growing from overwintering, infected tubers can act as a primary infection source in some seasons. However, generally, they can allow the blight pathogen to multiply and produce large amounts of spores on their unprotected foliage throughout the growing season.



Source: Scottish Agronomy Ltd

In recent years, many of the volunteer outbreak samples submitted through the Potato Council's outbreak mapping service have contained both mating types of the blight pathogen. Clearly, there is a risk that unprotected volunteers can allow oospores to be formed and to contaminate some fields between potato crops.

Volunteer potatoes can also act as a reservoir, or a host, for free living nematodes, Spraing, PCN, *Rhizoctonia*, Black scurf, Black dot, Powdery scab, aphids and aphid-transmitted potato viruses. In seed crops, the presence of volunteer potatoes can lead to downgrading if threshold levels for variety deviations are exceeded at crop inspection (0% for PB, 0.05% for SE and E grades) (SASA, 2009). Volunteer potatoes are also a significant problem in other crops such as carrots, parsnips and

leeks. Figure 4 shows the variable effects of volunteer potatoes in a subsequent crop.

Cultural methods of control

Cultural control and herbicides form a two-pronged attack on volunteer potatoes, but practical and commercial considerations will dictate the limits to which cultural methods can be used.

- Don't grow tubers of a size that cannot be harvested
 - Have a good even tilth, with no compaction
 - Ensure even planting at the desired density, using tightly graded seed of even vigour
 - Use an appropriate fertiliser rate and have properly scheduled irrigation, if used
 - Ensure that haulm desiccation is well timed to give good separation of the haulm and tubers
 - Ensure good control of PCN and *Rhizoctonia*
 - Set harvesters, including web size, to minimise the return of tubers to the soil
 - Reduce web rod spacing (account for the balance between work rate and over-filling webs)
 - Set share depth and angle of primary web to avoid cutting tubers
- Target easy lifting conditions for most efficient pick-up of tubers
- Cultivations – where possible, establish following crop without ploughing
 - Maximise effect of frost kill and scavenging animals
 - This is not always possible after wet lifting conditions, therefore, follow with a competitive crop (eg wheat, barley).

Potential scale of the volunteer problem	Evidence from trials
Potentially higher plant population from volunteers than commercial seed rates	Typical ware crop seed rate: 40 to 50 thousand per hectare, from volunteers can be as high as 300 thousand per hectare
Return of true potato seed is high for many varieties but the incidence of volunteers from this source is low, possibly due to the use of residual herbicides	5 to 15 berries per plant @ 50 to 150 seeds per berry equals tens of millions of seeds per hectare, with a high viability of at least 60%
Tubers that are left in the soil tend to be small	70% are in the 10 to 30mm size range
Progeny tuber numbers can vary	Trials show between 0 and 4 tubers per plant
Volunteers tend to emerge and senesce over long periods making it very difficult to achieve good control with one herbicide application	Trials show volunteers start to emerge in April and can senesce from June through to September
Tubers can be killed when subjected to frost	Tubers are killed by 50 hours or more below -2°C

Figure 4. The variable effects of volunteer potatoes.

Herbicides for the control of volunteer potatoes

There are several issues that must be considered with herbicide use:

- residual herbicides are not always effective because food reserves in the tuber are too large
- a long period of emergence by the volunteers requires repeated applications of contact herbicides
- the timing of herbicide use can be restricted by the constraints of crop growth stage
- selective herbicides are never completely effective – good haulm control may not prevent production of viable daughter tubers
- spray coverage of volunteers can be limited by the growing crop.

Herbicide products

Cereals

- Selective herbicides such as fluroxypyr (eg Starane 2) and sulfonyleureas (eg Ally Max SX) give haulm suppression and a variable effect on daughter tuber viability
- Consider adding fluroxypyr to sulfonyleureas to improve control – although the best option is straight fluroxypyr at 2.0L/ha. This rate can be used in winter cereals. In spring cereals, the maximum dose per crop is 0.75L/ha (NB Straw treated with high doses of fluroxypyr may contain residues which could damage following crops. Read the label before use)
- Glyphosate (eg Roundup) applied pre-harvest has performed well in trials to control volunteer potatoes. However, many volunteers can germinate early and pose a blight risk before spray timings for glyphosate in cereals. Check with end user, eg maltsters, that pre-harvest glyphosate is allowed
- Glyphosate can also be applied post-emergence on to the stubble but before frost has killed regrowth. Check the product label to make sure that the rate of glyphosate will be sufficiently high to be effective. Avoid glyphosate damage to sensitive seed potato crops. Consult the Potato Council leaflet “Spraying glyphosate? Watch out for seed potato crops!” see www.potato.org.uk/publications/glyphosate-damage-seed-potatoes.

Sugar beet

- Clopyralid (eg Dow Shield) tends to give good control of volunteer potatoes but is best used in programmes along with ethofumesate (eg Nortron Flo),

Summary of control strategies

Consider the following

- Optimise tuber size distribution
- Apply maleic hydrazide e.g. Source II or Fazor (except on seed, first earlies or crops grown under fleece), check supplier protocol for use
- Set the harvester web to lift smaller tubers, where possible
- Keep returned tubers near the soil surface
- Follow the potato crop with a competitive crop
- Treat volunteers more than once because no single herbicide treatment is entirely effective.
- Use selective herbicides in following crops, eg fluroxypyr, sulfonyleureas and clopyralid
- Use pre-harvest glyphosate
- Clean up stubbles with glyphosate
- Other volunteers in crops can obscure the potato volunteers, eg winter oilseed rape and maize.

phenmedipham (eg Betanal Flo) and triflusaluron-methyl (eg Debut) to give better results on both the haulm and in the control of progeny tuber vigour. Good results can be achieved with multiple applications.

Oilseed Rape

- Clopyralid can be used for early season control although crop competition and latest application timings make control difficult
- Pre-harvest glyphosate can be used if volunteers are present but the crop canopy is likely to shade the volunteers so control is not achieved.

Carrots

- The use of Guillotine in carrots as an Extension of Authorisation of Minor Use (EAMU) has been shown to give control of volunteer potatoes when used in mix with linuron
- Experimental work, funded by the Potato Council and collaborators Garfords, using machine vision to target a non-selective herbicide such as glyphosate has proved successful in controlling volunteer potatoes in carrots.

Fallow ground

Glyphosate applied to fallow ground has performed well in trials in helping to reduce volunteer potatoes. However, this tends to work best later in the season, which can leave unprotected foliage on which blight can sporulate. Control can be reduced **at lower rates**.

5: Oospore outbreaks

Why is it important to identify and analyse outbreaks possibly derived from oospores?

The consequences of late blight becoming a soil-borne pathogen have been highlighted in many articles. Oospores create the potential for earlier epidemics, with blight being more difficult to control with fungicides and increased risks of insensitivity to fungicides and varietal resistance being overcome. In addition, the dramatic increase in pathogen diversity that would result from widespread infections from oospores has the potential to introduce genotypes that are more aggressive and fitter than the new genotypes that have recently become dominant in GB. The challenge to the industry from the currently prevalent genotypes 13_A2 and 6_A1 is a stark reminder of the possible consequences of the widespread occurrence of oospores in GB soils.

The aim in this section of the guide is to help identify blight outbreaks that could have been initiated by oospores. Recent changes in the late blight population have increased the likelihood of both mating types occurring together and, therefore, increased the possibility of sexual reproduction and the threat of an additional source of within-crop infection from oospores.

Oospores have been present in some continental European countries for a few years. **From the 2010**

season in Britain, a greater number of new genotypes were associated with some of the blight outbreaks, which could be due to oospore-derived infections.

Oospores are known to survive for up to 48 months in light soils.

There are similarities in blight symptoms arising from oospores and infected seed and the descriptions below help to discriminate the two. If oospores are suspected to be present, it is important to remove samples of leaf blight and send to Fera as part of the Fight against Blight campaign (please contact Gary Collins on 07879 676932 if you are not a blight scout but suspect an oospore outbreak). Once blight is confirmed, the samples will be sent to the James Hutton Institute (JHI) for genotype testing which will help to establish the source of infection, and monitor changes in the blight population.

What are typical symptoms of seed tuber-borne and oospore-derived outbreaks?

These are described in figure 5 below. In the field, the key differences between the two types are the size of the initial outbreak, the size and number of lesions per leaf (leaflet) and the health of the seed tubers. The initial outbreak size from a seed source is likely to be small because only a small proportion of blighted seed tubers produce haulm with symptoms.

	Oospore-derived outbreak	Outbreak originating from seed
1. Field symptoms		
Early season infections	Likely	Likely
Most lesions (leaf or stem) at soil level or the base of the plant	Yes	Yes
Multiple plants in a patch blighted as soon as symptoms develop	Yes	No
Many small lesions per leaf (leaflet)	Yes	Much less likely
Blighted mother tuber observed	No	Yes
Infected stems are substantially shorter than symptomless stems	Yes	Yes
Infected groundkeepers close to the focus	No	No
Known local external source	No	No
2. Subsequent laboratory analysis		
Many rare late blight genotypes	Yes	No
Both mating types present in same patch of blight	Yes	Much less likely
Oospores observed in lesions	Yes	Much less likely

Figure 5. Signatures of outbreaks of blight from oospores and infected seed.

Signatures of outbreaks of blight from oospores and infected seed

If an outbreak is spotted early enough, an experienced agronomist may be able to deduce the type of primary inoculum based on the distribution of symptoms in the crop and the predominant lesion types. As the disease spreads, establishing the source of the inoculum becomes far more difficult. Discriminating outbreaks resulting from oospores is much more challenging and we have no confirmed cases in the UK on which to base our descriptions.

However, this guide provides images and descriptions of typical symptoms. Despite some general guidelines, this is not an exact science and the specific symptoms may vary according to site-specific conditions, such as variety and weather.

There is currently no soil test to detect oospores in fields. However, the risk of an oospore-derived outbreak is greater where:

1. a potato crop was grown in the field within the last 4 years
2. the previous potato crop was blighted
3. two different mating types of late blight were present in the outbreak in the previous crop.

Typical seed-borne infection

Typical symptoms of a seed tuber-borne outbreak. The basal stem lesion is progressively moving up the stem infecting and killing leaf petioles as it develops.



Source: Dr. Jean-Luc Genet, DuPont de Nemours (France) SAS

Typical soil-borne oospore infection

Typical symptoms of multiple lesions on lower leaves close to the soil surface have proved a signature of 'oospore-derived' outbreaks in Finland.



Source: Asko Hannukela and Ari Lehtinen (Finland)

Severe infection and stunting of young plants typical of suspected 'oospore-derived' sources of infection in which the lower leaves close to the soil were first to become infected.



Source: Jens G. Hansen (Denmark)

The preferred situation for the GB potato industry is the absence of oospores. The best method of minimising the risk of oospore-derived outbreaks is to ensure that rotations are long and clean of blight. Remember, oospores may also be formed in outgrade piles and on volunteers so, as always, control of these remains important. If there are any such oospore-borne outbreaks, it is very important that the industry is fully aware of them. The key role of detecting and confirming these outbreaks is through the Fight against Blight (www.potato.org.uk/blight) campaign.

6: Spray application technique

Key messages on spraying technique

- The key principle for all applications: a sufficient dose, in sufficient concentration and applied evenly on the target
 - Spraying for potato blight can be a compromise between treating the entire crop on time and achieving optimum crop coverage
 - Timing is more important than fungicide product choice or perfect coverage. During marginal weather, the use of air-induction nozzles may help to keep to the correct interval. However, good coverage is essential – particularly to prevent tuber blight
- Avoid extending intervals between applications during high blight risk. One day early is better than one day late, although this is restricted by some product labels
 - During the phase of rapid growth, good coverage of the growing point is essential
 - Treat all parts of a potato crop. Missed areas will become infected and create a high disease pressure. Avoid planting parts of fields where spraying is difficult (eg around telegraph poles)
 - Ensure your sprayer is in good condition and has been NSTS tested. Pay attention to detail when setting up and calibrating your sprayer. Check nozzle flow rates and spray patterns along the boom



Source: Gary Naylor Photography

- Set the boom height at 50cm above the top of the crop when using 110° conventional flat fan nozzles. Increased boom heights substantially increase the risk of drift and reduce the ability of the spray to penetrate the crop canopy. If the boom is too low, then the spray pattern will not be uniform and areas of the crop will be under-dosed.

Nozzle selection can influence efficiency of application and water volume used

- In early crop development, lower water volumes can provide adequate cover
- As full canopy is reached, higher water volumes tend to give better cover, 150-300L/ha is considered optimal with conventional nozzles
- The effectiveness of different water volumes has not been well tested with different fungicides
- Blight fungicides are best applied in a medium spray quality (but check specific product label)
- High water volumes (greater than 300L/ha) can increase chemical run-off
- Nozzles selected for reducing drift (3 star nozzles) to fulfil LERAP requirements may give suboptimal coverage and coarse droplets may not penetrate the canopy effectively. When treating crop that is adjacent to a water body, conduct a LERAP and select a nozzle that will minimise the buffer zone width. Use an air-induction nozzle, noting the operating pressure, boom height and forward speed relevant to the LERAP rating. When possible, treat only the 12.0m wide strip adjacent to the water body with the drift reducing nozzle
- Angled nozzles can give better canopy cover at all stages but particularly up to and including full canopy, from which point the crop starts opening up allowing easier canopy penetration. When using angled nozzles, it is important to keep the boom as low as possible and less than 50cm from the top of the crop. Angling nozzles alternately backwards and forwards will reduce the risk of drift and give good spray distribution and penetration within the canopy
- Nozzles with a smaller spray fan angle (such as 80° rather than 110°) can be used at boom heights of greater than 500mm but will generate a coarser spray. If using such nozzles, check that the spray quality is medium.

Spraying for blight requires:

- PA1 and PA2 certificates. This is a legal requirement for sprayer operators
- COSHH assessment
- appropriate Personal Protective Equipment (PPE)
- the label to be read and adhered to
- LERAP requirements understood and followed as necessary
- awareness of requirements under Production Protocols (Nature's Choice has some restrictions on product use)
- an understanding of customer's product restrictions
- the sprayer to be tested annually through the National Sprayer Testing Scheme.

7: Spray programme

Fungicides have a key role to play in the control of blight. The timing of application and choice of fungicide product depend on a number of factors, including disease risk, weather conditions, fungicide mode of action, resistance management issues and, not least, the stage of growth of the crop.

Independent information on the relative effectiveness of different blight fungicides is available in the Euroblight fungicide comparison table. This can be viewed through the blight hub www.potato.org.uk/blight

Protection against leaf blight, curative activity, tuber protection and rain fastness are among the properties rated. It is important to read the caveats to the table.

Each year, Potato Review provides updated information about many fungicide products (www.potatoreview.com/potato-review-fungicides).

The aim should be to use blight fungicides protectively, that is, apply them before blight infects the crop. Starting the spray programme early enough and maintaining the correct spray intervals for the prevailing risk during the season are just as important as the choice of fungicide. Risk assessment means having as accurate a picture as possible of local blight outbreaks, recent high-risk periods and forecasted periods of high-risk. In this document, it

is only possible to give a summary of some of the issues involved. Growers should discuss recommendations applicable to specific crops/locations with an agronomist.

There is evidence that fungicide programmes are more effective where there is a proactive, flexible approach that matches products with appropriate properties to what is specifically required at the time of application, such as curative activity, rain fastness, persistence of protection and tuber protection. With this approach, the most effective fungicides are used when the risk is highest. The results of recent experiments argue against having a blight fungicide programme planned in advance of the season.

Another factor influencing fungicide product selection is the stage of crop development. There are essentially four phases of growth.

Phase 1:

Crop emergence to the start of rapid haulm growth

- The widespread prevalence of new genotypes (6_A1 and 13_A2) of late blight, which have substantially shorter latent periods and can,



Source: Gary Naylor Photography

therefore, build up more quickly, requires an earlier start to the fungicide programme. Crops grown from seed stocks known, or suspected, to have significant seed tuber infection require an earlier start to the fungicide programme

- Previously, some growers used the cheapest fungicides until ground cover by the crop was sufficient to intercept a high proportion of the spray. This approach is riskier with the more aggressive genotypes currently dominating the GB population
- Fungicide coverage from any one individual spray application is not 100%. Where crop growth is particularly rapid, the spray interval may need to be reduced to 7 days or below.

Phase 2:

Rapid haulm growth

- The new leaf and stem tissue produced between fungicide applications needs to be protected
- New haulm tissue is produced more quickly at higher temperatures and, therefore, the amount of new growth requiring protection will be greater. The protection of new growth is more challenging for later-planted crops because they normally experience higher temperatures during this growth phase
- The two main strategies to protect new growth are either to use partially systemic fungicides, eg propamocarb + fenamidone (Consento), or some of the new generation contact fungicides, eg mandipropamid (Revus) or cyazofamid (Ranman Top) at short intervals
- The prevalence of genotype 13_A2, which combines greater aggressiveness with insensitivity to phenylamide fungicides, has resulted in the manufacturers of products containing phenylamide fungicides, eg Fubol Gold, currently recommending a limited number of applications per crop. However, many agronomists no longer recommend products containing phenylamides.

Phase 3:

Stable canopy

- The end of rapid haulm growth is more clearcut for determinate than indeterminate varieties

- Products with tuber blight activity should be considered as part of the programme, eg Electis, Infinito, Percos, Ranman Top, Shinkon and Shirlan
- For the slower growing haulm during this phase there is a wide range of fungicides available. Fungicide choice will be dictated by what is required at the time of application, over and above good tuber protection, eg curative activity or rain fastness.

Phase 4:

Start of senescence to haulm destruction

- Products with good tuber blight activity should continue to be used
- Fungicide protection should continue until complete haulm death.

Intervals between applications

Fungicide timing is critical. For protectant fungicides, the optimum timing is just before high-risk weather conditions so that protection is optimised during the elevated risk. This, of course, means that fungicide applications can only be most effective when used in conjunction with a system that forecasts periods of high-risk weather.

Curative fungicides have a limited kickback period if applied soon after infection. This period is unlikely to exceed 24 to 48 hours. Kickback can be useful if application intervals are extended slightly due to adverse weather conditions. The active ingredients bentiavalicarb (Valbon), cymoxanil (various products), dimethomorph (eg Invader), mandipropamid (Revus) and propamocarb (various products) have curative action. See the blight hub for a link to the Euroblight fungicide table (www.potato.org.uk/blight). This property can be useful in any of the above four phases of crop growth.

Curative activity is diminished under conditions that favour rapid development of the pathogen after infection, such as higher temperatures. More aggressive genotypes of late blight colonise leaf and stem tissue more quickly and therefore kickback will be less effective against the genotypes that currently dominate.

There is increasing evidence that the 10-day and 7-day interval, generally recommended for low and high-risk,

respectively, do not always allow current fungicides to effectively control the most aggressive of the new late blight genotypes, 13_A2 and 6_A1.

- Observing the minimum interval between applications of the same product is a legal requirement and this is stated on the product label
- The use of some fungicide products at 7-day intervals is limited to specific risk circumstances. Product labels should be checked for details
- Under conditions of high blight pressure, such as when infection is present in the crop, reducing the interval between applications below 7 days may be necessary. This can be achieved by alternating effective active ingredients.

Decision support systems

Decision support systems are an invaluable aid to assessing blight risk and deciding on spray application timings. Two examples of internet-based warning systems that are available in GB are www.potato.org.uk/blight (the Fight against Blight section of the Potato Council website provides access to interpolated Smith Period values and the locations of verified outbreaks) and www.syngenta-crop.co.uk (BlightCAST forecasts Smith Periods in the next 5 days). Plant Plus, and a more limited version of Plant Plus called Forecast Xtra, are also available in Britain.

Tuber blight

- Tuber infection during the growing season is mainly caused by motile zoospores, which are produced in the cooler temperatures of late summer and early autumn. Spores of late blight produced on infected foliage are washed into the ridges by rainfall. Zoospores can move between the soil particles to infect the progeny tubers
- Adequate depth of soil cover over progeny tubers is important to minimise the risk of tuber infection
- Tuber blight control using fungicides effective against this phase of the disease should be considered from tuber initiation
- Tuber infection is almost invariably associated with leaf or stem infection, especially lesions in the bottom of the canopy
- Even a little blight on the haulm under favourable conditions for the pathogen can produce sufficient inoculum to result in significant tuber infection

- Tuber blight can develop within a few weeks of the first signs of foliar blight
- Good control of leaf and stem blight will indirectly reduce the risk of tuber blight.

Resistance management strategies

Avoid overreliance on a single FRAC resistance group.

Guidance on strategies to avoid or reduce the risk of fungicide resistance is continually reviewed by the agrochemical industry through the Fungicide Resistance Action Committee (FRAC) (www.frac.info), or by the UK Fungicide Resistance Action Group (FRAG). FRAC are regional committees throughout Europe comprising representatives from the agrochemical industry. FRAG includes representatives from the Chemicals Regulation Directorate (CRD) and researchers working on fungicide resistance, as well as representatives of the agrochemical industry.

To reduce the risk of insensitivity to fungicides it is advisable to select products with different chemical modes of action during the growing season. This can be as formulated mixtures, tank mixes or the alternation of products with different chemical modes of action (alternation of single applications or blocks). Specific advice for individual fungicide products is given on the product labels. However, in figure 7, fungicides in the same row have active ingredients that are in the same FRAC resistance group and, therefore, have the same chemical mode of action. For co-formulations the active ingredient listed first is in the resistance group.

For further information on resistance management, see the Potato Council/Fungicide Resistance Action Group (FRAG-UK) publication entitled *Potato late blight: Guidelines for managing fungicide resistance* (www.potato.org.uk/blight) or product labels. The restrictions that form part of anti-resistance strategies for a product comprise number of applications, proportion of the intended total number of applications in the programme, the number of consecutive applications and the product must be used in a tank mix with a fungicide with a different mode of action.

Rain fastness

- Rainfast times range from 15 minutes to 3 hours
- Consult the label, supplier or the Euroblight fungicide comparison table for advice on rain fastness.

Adjuvants

- Seek technical advice before tank mixing adjuvants with blight fungicides. Specific adjuvants can improve the efficacy of some blight fungicides. For example, the adjuvant ZinZan is essential for full efficacy of Valbon.

LERAP (Local Environment Risk Assessment for Pesticides)

- Fungicide product choice may be influenced by the aquatic buffer zone distance specified by CRD to a product for potatoes. In the current interim scheme there are four product types (the two established A and B categories plus two new ones) – see figure 8.

Further information

Further information is available at www.pesticides.gov.uk

FRAC resistance group	DISEASE: Late blight	DISEASE: Early blight	DISEASE: Other
11 Quinone outside inhibitor (QoI) fungicides	Consento (fenamidone + propamocarb) Tanos (famoxadone + cymoxanil)	Signum (pyraclostrobin + boscalid) Olympus (azoxystrobin + chlorothalonil)	Amistar (azoxystrobin) (soil treatment for black dot and black scurf)
21 Quinone inside inhibitor (Qil) fungicides	Ranman Top (cyazofamid) Shinkon (amisulbrom)		
29 Uncouplers of oxidative phosphorylation	Shirlan (fluazinam)		
40 Carboxylic acid amides (CAA) fungicides	Invader (dimethomorph+ mancozeb) Morph (dimethomorph) Hubble (dimethomorph + fluazinam) Revus (mandipropamid) Valbon (benthiavalicarb + mancozeb)		

Figure 7. FRAC resistance groups for some main potato fungicides.

Product type	Buffer zone distance (metres)	Reducible with a LERAP assessment
Category 'A'	5	No
Category 'B'	5	Yes
Not categorised	5 ^a	Yes
Not categorised	6-20 ^a	No

Figure 8. Buffer zones for different product types in the interim LERAP scheme.

^a Product labels will give clear information on the distance for the product/potato crop combination.

8. The contribution of varietal resistance to control

Fungicide protection is more effective where the number of spores challenging the crop has been suppressed. Non-fungicidal control measures, such as dealing with outgrade piles or planting high quality seed, reduce the amount of late blight inoculum available.

Varietal resistance is no exception; it minimises the number of spores by limiting successful infections, and also by restricting spore numbers produced per unit area of lesion. The benefit of growing a variety rated just one higher on the 1 to 9 scale is shown below.

It is helpful to express the advantages of varietal resistance in terms of properties of late blight fungicides.

Figure 8. Foliar blight in King Edward compared with Saturna. Plots treated at 7-day intervals with fungicide.



King Edward (foliar resistance rating 3)

Saturna (foliar resistance rating 4)

Photo source: SFUC

Varietal resistance gives 100% ‘coverage’ because it is ‘systemic’ in the haulm; this ‘coverage’ is maintained throughout the season. Resistance is not prone to weathering and is completely rainfast. Haulm resistance provides indirect protection against tuber blight because more resistant leaves limit the number of spores that can be washed down into the soil (resistance in the tubers protects them directly but it should be noted that the tuber resistance of some varieties is not always correlated with their foliar resistance).

Varietal resistance to late blight is considered in the risk assessments of many decision support systems that have been developed in continental Europe and elsewhere. Varietal resistance is a key component of integrated control because fungicide inputs can be reduced on varieties that are more resistant, without compromising blight control. Recently completed research has shown that such integrated control is feasible under GB conditions. The trials were conducted under high to very high-risk weather conditions over three growing seasons and the more aggressive pathogen genotypes 13_A2 or 6_A1 were responsible for the epidemics.

The control of foliar blight using varietal resistance-based integrated control was, in general, very effective (see figure 9 below) when tested either during rapid canopy or stable canopy development. There were relatively few instances in which integrated control resulted in significantly less effective control of foliar blight than the reference treatment. Reduced inputs of fungicide should not be considered until plants have at least 10 leaves because there is evidence that the resistance of leaves is related to leaf position, with the basal leaf being the most susceptible. Fungicide distribution within the canopy

	Significantly more effective	More effective	Less effective	Significantly less effective
a. Integrated control during rapid canopy				
%	65.4	29.8	1.2	3.6
b. Integrated control during stable canopy				
%	40.9	41.7	8.3	9.1

Figure 9 Efficacy of varietal resistance-based integrated control versus a standard 7-day spray fungicide treatment of a variety rated 3 for foliar blight resistance. The standard reference treatment was King Edward treated with 1.6L/ha of Infinito every 7 days. The varietal resistance-based integrated control treatments were the more resistant varieties Markies, Cara and Sarpo Mira treated with less fungicide input. The reduced fungicide input was achieved by using combinations of fungicide product, spray interval and fungicide dose that delivered less fungicide protection than the reference treatment. Two examples are given in Figure 10.

should take account of this, by starting early with good spray penetration.

The efficacy of integrated control is well illustrated in Figure 10. The control of foliar blight was significantly better for the more resistant varieties even when they were treated with a less effective fungicide, at either a reduced rate or with an extended interval.

The same experiments demonstrated that, in general, for the same total fungicide input it was more effective to apply less fungicide more frequently, than have fewer applications with greater fungicide input for each application.

The negative impact of late blight genotype 13_A2 on varietal resistance ratings is well publicised and appears to partially undermine the effectiveness of varietal resistance-based integrated control. However, a recent study has demonstrated that the resistance ratings for intermediate varieties, eg Ambo (6) and Cara (5), are relatively higher when well protected by fungicide and, therefore, varieties with these levels of resistance contribute more to disease control in conventional potato production than suggested by their current published ratings.

The resistance of a variety is not necessarily durable. The use of resistant varieties to help control blight requires frequent testing using current pathogen genotypes to confirm ratings. A sexually reproducing pathogen population increases the risk of a variety's resistance being overcome. Taking all possible steps to prevent sexual reproduction in the GB late blight population will make it simpler to have accurate current ratings for varieties. It is possible to frequently test the main varieties against current genotypes if the population comprises only a few pathogen genotypes but this task becomes impractical where there is a very large number of unique pathogen genotypes.

If resistance-based integrated control is not used by a grower then the greater resistance of some varieties will, at the very least, offer some background protection.

With more resistant varieties, the timing of fungicide application is not quite so critical. During periods in the growing season when it is difficult to apply fungicide to all crops at the planned time, then consider treating the more susceptible varieties first.

Current resistance ratings for varieties are available on the British Potato Variety Database on the Potato Council website (www.varieties.potato.org.uk).

Figure 10 The control of foliar blight was less effective with a susceptible variety treated with an effective chemical (1) compared to more resistant varieties treated with a less effective fungicide, at either a reduced rate (2) or with an extended interval (3).



1. King Edward treated with Infinito (1.6L/ha) @ 7 days



2. Cara treated with Shirlan (0.3L/ha) @ 7 days



3. Markies treated with Shirlan (0.4L/ha) @ 10 days

The EuroBlight ratings for full label rates of Infinito and Shirlan are 3.8 and 2.9, respectively.

Photo source: SFRUC

9: Irrigation

Irrigation increases humidity within the crop canopy and prolongs leaf surface wetness. Such conditions encourage blight to sporulate, spread and infect potato plants. Crop growth can also be more rapid in irrigated crops. Such rapid growth, particularly early in the growing season, could leave a greater percentage of the foliage under-protected. Inevitably, there will also be a dilution of fungicide loading on the foliage due to rapid growth and some reduction through wash off. The extent of wash off will vary with fungicide product.

Irrigated crops should be sprayed with fungicide at intervals appropriate for high-risk conditions. Management of irrigation is crucial to help reduce the associated risk of blight.

Irrigation frequently prevents fungicide application for several days because the application of significant amounts of water results in ground conditions unsuitable for sprayers.

- Ideally, fungicide application should be made prior to irrigation. This ensures that protection is maximised when high-risk conditions prevail during and after irrigation. Good rain fastness is the property of a fungicide that indicates how little of it is washed from the foliage as a result of rainfall or irrigation within a few hours of fungicide application. Many modern fungicides have very good rain fastness (www.potato.org.uk/blight). These should be used prior to irrigation.
- Applying overhead irrigation to blighted crops can increase the risk of tuber infection considerably, because inoculum on the haulm is washed into the soil and onto progeny tubers. The proportion of the tubers at risk will be directly related to the area of crop affected by haulm blight. For example, if blight is limited to one patch then only tubers in and close to that patch are at increased risk. The sooner irrigation is applied after weather conducive to the production of large numbers of sporangia and the lower the temperature of the crop, the higher the risk of tuber blight infection.



Source: Gary Naylor Photography

Figure 11 The germination of sporangia to produce zoospores or germ tubes in relation to temperature for two new genotypes (13_A2 and 6_A1). Similar responses to temperature were obtained for six older genotypes (data not shown).

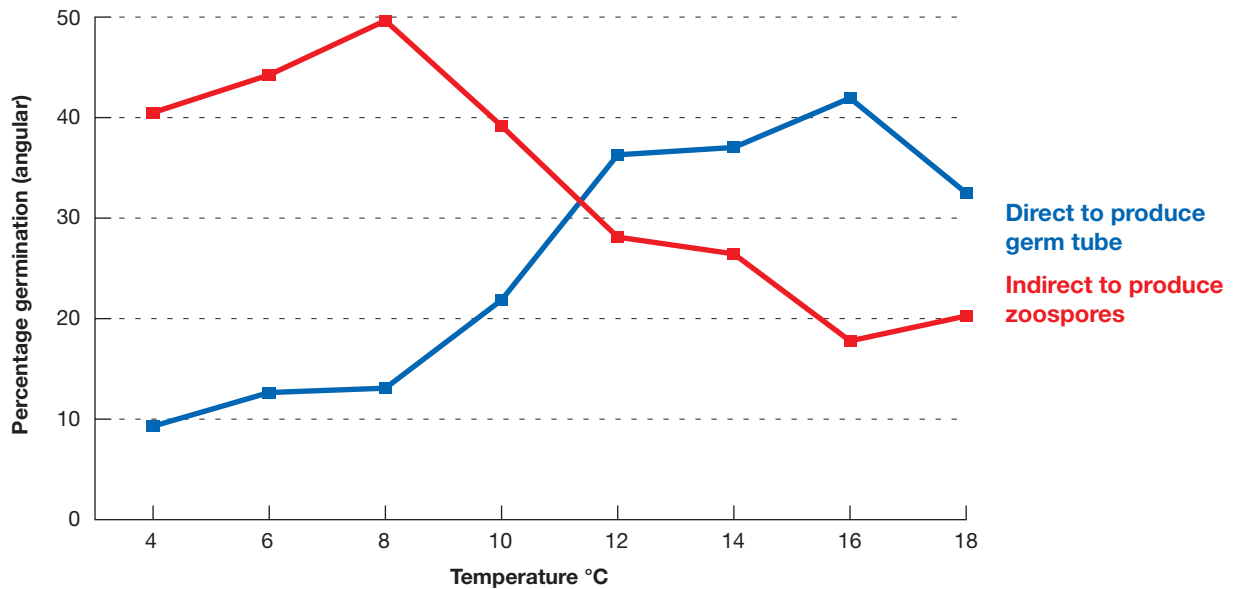


Figure 11 above shows the large effect of air temperature on the percentage of sporangia producing zoospores (as a result of indirect germination of sporangia). A temperature drop encourages the formation of zoospores. Zoospores are much more likely to cause tuber infection because they are smaller and are more likely to travel down through the spaces between soil particles. They can also swim in soil moisture.

Sporangia can infect tubers but the risk of this in crops is lower unless the protection of tubers given by good soil cover is breached through ridge cracking under dry conditions or soil erosion. Another way in which the protection afforded by depth of soil can be bypassed is where the action of the wind has rocked stems sufficiently to create vertical gaps between the sides of stems and the surrounding soil. Both zoospores and sporangia can be easily washed down these channels.

Rain gun and boom irrigation

- Ideally, allow a dry gap of 6 to 8 hours between fungicide application and irrigation to ensure rain fastness
- Make use of irrigation scheduling to ensure that the crop is only irrigated when water is required. If soils are too wet this will encourage blight infection.

Trickle irrigation

- Trickle irrigation is less of a risk than a rain gun or boom irrigation because it does not wet the foliage and it does not wash spores from the haulm into the soil
- Although trickle irrigation does not wet the foliage directly it is likely to increase the humidity within the crop canopy. Increasing the soil moisture content also increases the risk of tuber infection by any spores in the soil.

Irrigation pipes

- Work out in advance where you will need to put header/feeder pipes in relation to where you will need to have access with your sprayer. Time spent moving pipes can be lost spraying time
- Use pipe ramps or bury the pipes where pipes will obstruct sprayer access
- Between irrigation events, move irrigation equipment well away from the crop so as not to compromise sprayer boom access and crop coverage.

For more information on how irrigation may affect blight control please contact an agronomist.

10: Responding to a crop infection

Successful blight control is preventing the disease from appearing in the crop. However, in some seasons this can be very difficult and it's necessary to deal with a blight infected crop.

No fungicide currently on the market can be regarded as totally effective at preventing blight.

However, any infection requires immediate action.

Reaction time to infection

- All blight fungicides are protectants. Products containing bentiavalicarb, cymoxanil, dimethomorph, mandipropamid and propamocarb have limited curative (kickback) activity. Generally, the period of curative activity is 1 to 2 days after infection. However, the length of this period depends on the fungicide, the resistance of the variety, the prevailing temperature and the aggressiveness of the genotype of late blight
- The latent period is the time between infection and new blight spores being produced on the leaf. In recent research, the latent period depended on the genotype of blight and ranged from 4.5 to 5.5 days for most genotypes tested at a constant 13°C, whereas the range was 3 to 4 days for most genotypes at 18°C. If symptoms are present, eradicating these lesions with fungicides will be very difficult. However, fungicides applied in this situation can limit the production of viable spores (anti-sporulent), cure very early infections and protect healthy leaves, stems and tubers.



Source: SRUC

Key identification points for leaf blight:

1. browning of veins on lower surface of leaf and
2. white, fluffy pathogen growth at the advancing edge of the lesion (most obvious under warm, humid conditions).

Control methods

- Do not use any product with a label stating that it is not to be used in the presence of blight
- If necessary, alternate products to maintain appropriate spray intervals, being mindful of resistance management issues and label recommendations
- Use fungicides with different modes of action to reduce the risk of fungicide resistance
- Always include products with curative activity when spraying infected crops
- Consider using formulated products, or tank mixes, to obtain anti-sporulant activity (to reduce the sporulation on active lesions) and curative activity
- If the crop has met a market specification in terms of tuber size and yield potential, it would be prudent to destroy the foliage immediately to reduce the risk of tuber infection and also the risk to neighbouring crops.

Removing hot spots of infection

- Destroy or remove any hot spot found in the field

Size of the hot spot	Action
Single plant or a few plants	Remove and destroy infected plants
Patch	Desiccate with Reglone (Diquat) applied through a knapsack sprayer
Large area/field	Desiccate using Diquat applied through a ground sprayer

- Always desiccate a few metres beyond the outside edge of the blighted area. This is because these plants will have been challenged by the greatest number of spores and probably will already have non-visible symptoms.

Desiccation treatments that kill the haulm quickly are preferred to reduce the risk of further disease spread (see Haulm Destruction section). Where desiccation is slow, the desiccated area needs to be protected by fungicides until the haulm is completely dead.

- When destroying infected foliage, do not flail, because this could increase the spread of spores
- Report all outbreaks to the Potato Council blight mapping service through a registered Blight Scout.

Note: Growers who wish to desiccate blighted patches of a seed crop entered in a classification scheme need to discuss the situation with the classification scheme authorities before taking action.

Dealing with hot spots that occur later, when there is a risk of tuber infection

- Tuber blight becomes an issue once progeny tubers have formed. Fungicide products with activity against the production and viability of zoospores should be used
- It remains important to use fungicides with curative activity, anti-sporulant activity and good protection of haulm. For tuber blight, see the Euroblight table at www.potato.org.uk/blight.

There is a high-risk that some of the progeny tubers in the blighted patch will already be blighted. Either remove them once the patch has been desiccated or mark the patch and harvest them separately.

Water volume

- Ensure that fungicide coverage is adequate
- In some situations, it will be necessary to use more than 200 litres of water per hectare to ensure that the spray penetrates into the bottom of the crop
- Adjust forward speed so that, together with appropriate water volumes, good coverage and penetration of the canopy is achieved.

Weather

- Several days of hot, dry weather will greatly limit further development of the disease. These conditions not only restrict sporulation but, if they persist, can also result in many diseased leaves being shed
- However, the pathogen can remain viable in stem lesions and develop rapidly from these when warm, humid conditions return.



Irrigation

- The risk of tuber infection due to local circumstances and environmental conditions should be considered (see section 9 on irrigation) before blighted crops are irrigated
- Irrigation can help produce the humid conditions within the canopy that encourage sporulation and infection
- Irrigation water can wash zoospores into the soil, leading to an increased risk of tuber blight.

Protected crops

Early crops grown under plastic or fleece are frequently among the first crops in which blight outbreaks are reported. These crops are generally at a higher risk of blight than non-covered crops because fungicides can't be applied until the sheeting is removed. Currently, there are no label or off-label approvals for blight fungicides to be applied to potato crops through fleece.

A higher humidity is most likely when ground cover and haulm growth are more extensive. When a crop with some blight has the fleece or plastic removed, there is potential for much inoculum to spread to neighbouring crops. To minimise the risk of spread the cover should be removed if possible on dry and sunny days. Such weather, during and after removal will limit the distance that a large number of viable spores can travel. Fungicide applications should start as soon as the covers are removed. Consult your agronomist about fungicide choice.

For information on the specific properties of fungicides, such as curative activity, refer to the EuroBlight fungicide ratings table on the Potato Council website (www.potato.org.uk/blight) or information provided by the manufacturers.

11: Haulm destruction

Desiccants minimise the risk of further development of foliar blight and of tuber infection by killing the haulm and therefore limiting the production of spores.

Some desiccant treatments have a limited direct effect on the blight pathogen. For example, gas burner heat treatments will kill any blight spores exposed to the heat. Some treatments will only kill established blight lesions slowly, eg those on the stems. This is especially true where penetration of the crop is limited. In this situation, one or more additional blight fungicide sprays are required.

Principles

- The blight pathogen requires green plant tissue in order to develop and produce spores
- The haulm needs to be protected from blight. In seed and dual purpose crops, protection from virus infection is required until there is no green haulm left. The

fungicide protection required after the desiccant is applied will depend on how quickly the desiccant acts

- Blighted regrowth greatly increases the risk of tuber infection
- Ensure that the desiccant programme is sufficient to prevent regrowth of the haulm after treatment
- Check crops for regrowth
- Where regrowth occurs it will be necessary to apply more desiccant and also further fungicide treatment may be required
- Regrowth is most likely where the crop is being desiccated earlier than planned or too much nitrogen was applied
- The generally recommended safe harvest interval to minimise the risk of tuber infection during harvest is a minimum of 14 days after the haulm is completely dead
- Stem tissue will be slower to desiccate than leaves, therefore, stems remain a source of inoculum for tuber infection for longer.



Source: Gary Naylor Photography

Desiccants

Ensure that the volume of water used to apply the desiccant is appropriate to penetrate into the lower part of the canopy. This is particularly important if only one application of desiccant is being made to the crop. Consider the use of angled nozzles to aid coverage. Avoid the use of low drift bubble jets because the droplet size is too big.

Diquat, carfentrazone-ethyl, glufosinate-ammonium and pyraflufen-ethyl

- Environmental factors affect the speed of desiccation with these products
- Diquat works best in humid overcast conditions, carfentrazone-ethyl and glufosinate-ammonium in warmer, direct sunlight
- Diquat can only be used following a SMART test to determine soil moisture around the tubers. Do not use Diquat if the soil moisture deficit around the tubers is more than 25mm. However, Syngenta supports the use of 1L/ha of Reglone under any soil conditions
- All of these desiccants require fungicide protection to continue after application
- There are certain application restrictions on some of these products that should be checked prior to use.

Application

Any measures that improve coverage of the haulm with desiccant will increase the rate of desiccation and, therefore, reduce the risk of further development of blight. The following measures can speed up the rate of haulm desiccation.

- Sequences of desiccation treatments allow more desiccant to be targeted onto the stem after the initial application removes the top layers of leaves. Diquat should be used to open the crop, followed by carfentrazone-ethyl, glufosinate-ammonium or pyraflufen-ethyl to target the stems. On an erect crop it may be necessary to use a split dose of Diquat
- Flailing, if done well, allows greater deposition of a follow-up desiccant onto the stems. Flail to leave 15-20cm of stem for optimal control of follow up desiccant and avoid regrowth. If regrowth occurs spray with Diquat, be aware of the total dose. Note: total

dose for Reglone is 5.0L/Ha, other Diquat products are 4.0L/Ha

- Alternative types of application technology can improve the distribution of desiccant within the crop canopy, such as an angled nozzle

Note: with Quickdown there is a need to add an adjuvant such as Toil.

Heat treatment

Defoliation using gas burners will kill any of the blight spores that are exposed to the heat and dry up leaf lesions. However, this treatment may not kill stem lesions because insufficient heat may penetrate into the stem.

Flailing

The risk of spreading blight spores during the flailing of crops that have some foliar blight can be reduced if:

- carried out within 5 days of applying a good anti-sporulant blight fungicide
- carried out under conditions that will reduce the viability of any blight spores that are released into the air, that is, hot, dry, sunny conditions, with low relative humidity
- five to seven days prior to flailing, the crop is treated with Diquat. This will limit the production of blight spores by drying up lesions.

If flailing is to be followed by a desiccant, then ensure that the pulverised haulm is deposited in the bottom of the furrow. If it is left on top of the ridge then it will reduce the amount of desiccant that reaches the stem bases.



Source: Grimme UK

12: Harvest

Weather and soil conditions at lifting and also harvesting techniques can influence the risk of tuber infection and therefore the storability of a crop.

Rain/irrigation

- While growers have no control over rainfall, irrigating too close to desiccation may increase the number of blight spores that are washed from the haulm into the soil to infect tubers. Tuber infection arising from spores already in the soil is generally more likely when soils are wetter
- Where practical, avoid harvesting blighted stocks during periods of wet weather. Harvesting under dry conditions will reduce the spread of blight from any infected tubers to healthy ones and also reduce the risk of associated secondary bacterial soft rotting. Harvested tubers that get wet must be thoroughly dried as soon as possible. Harvesting under dry conditions will also speed up the dry curing phase upon entry to store, which may help reduce infection.

Haulm destruction

- Do not harvest the crop until all of the haulm, including the stems, has been dead for a minimum of 14 days. This will considerably reduce the risk of tuber infection from any infected haulm during harvest and viable spores in the soil
- It is commonly advised that the harvest of blighted stocks should be delayed as long as possible after desiccation to allow blighted tubers to rot prior to harvest. The success of this approach will depend on soil temperature and moisture content during the delay period. Blighted tubers may decay only slowly if soils are dry and cool

- If a blighted crop is harvested before healthy ones, then ensure that the harvesting machinery is thoroughly cleaned to prevent cross-contamination by the blight pathogen and also soft rot bacteria. Blighted tubers are predisposed to breakdown caused by soft rot bacteria such as *Pectobacterium atrosepticum* (one of the causes of blackleg), therefore, the incidence of bacterial soft rots is likely to be higher in blighted stocks.

Damage

Blight spores do not require wounds to infect tubers, they can infect through lenticels and eyes. However, at harvest most lenticels will be closed and, therefore, any reduction in damage that breaches the tuber skin will reduce the number of entry points for blight.

Removal of blighted tubers prior to store loading

As many blighted tubers as possible should be picked off the harvester to minimise potential problems in store. However, it will not be possible to spot tuber blight lesions that developed from more recent infections.

Tuber return

Try to harvest as many tubers as possible to minimise groundkeepers. Volunteers are an important potential source of inoculum for the infection of subsequent crops grown in close proximity.

For more information on blight control at harvest, consult a BASIS-registered advisor.



Source: Gary Naylor Photography

13: Storage

Blight in-store – the general points

Tuber blight in-store can lead to major losses. While blight is a serious disease, the main concern with storing a stock containing blight-infected tubers is the threat from secondary bacterial soft rot.

Planning storage

When planning storage of a crop where blight may be present, it is crucial to include an assessment of risk. The risk assessment for storage suitability should take into consideration the following:

Prior to harvest

- Blight on haulm
- Significant rainfall on crops with blighted haulm, particularly after warm, humid conditions
- Cracked soil/exposed tubers.

During harvest

- Crops where desiccation of blighted haulm is slow or regrowth becomes blighted
- Harvest before all haulm is dead
- Tubers become wet during harvest
- Poor lifting conditions.

Other factors to consider include:

- known daughter tuber infection (from wash-up assessment)
- capability to dry and cool the crop
- prolonged store loading
- intended market
- planned storage temperature.

Note: Varieties with a lower resistance to tuber blight will be at higher risk for a given set of conditions.

Washup

To find out what crops are suitable for longer-term storage, carry out a washup of samples of the unharvested crops. For an accurate assessment of risk, tubers should be sampled, washed and assessed for blight on the same day. This will not only help assess risk for storage soft rots but will also help with the marketing of the crop.

Carrying out washups is simple and highly effective. Here's how:

Step 1

Collect a **minimum** of 100 randomly selected tubers from each field (this can be combined with test yield digs). Ideally, this should be done throughout the growing season and should be carried out right up to harvest and throughout the storage period. Remember, just because you cannot see blight-infected tubers at store loading, this does not mean that there is no infection there.

Step 2

Wash samples and carefully inspect each tuber. The main sites for infection of blight are the eyes, lenticels and any damage caused by handling.

It may be necessary to cut tubers to see symptoms of blight. This is an ideal opportunity to look for other defects (see page 30).

Step 3

Soft rots may mask tuber blight symptoms. If you need further clarification, consider sending a suspect sample to a laboratory for diagnosis (listed on page 7).

Tuber blight symptoms

Tuber blight symptoms are not all expressed at once but develop over a period of time. The point at which symptoms develop is affected by many factors including:

- the time of tuber infection
- the temperature of tubers after lifting
- how tubers are handled
- variety.

Under ambient temperatures, tubers infected prior to lifting should show symptoms within a week or two of harvest. It is likely that a high proportion of infected tubers will be showing symptoms within two months. There is also some evidence that blight can spread on rare occasions in-store from diseased to healthy tubers. For this to happen requires the storage conditions to be damp and warm, to encourage spores to be produced.

Early visible symptoms of foxy red-brown discolouration.



More advanced symptoms on the tuber surface and brown discolourations of the tuber flesh.



Photo source: Scottish Agronomy

Photo source: SBCSR

Blighted tubers are particularly prone to bacterial soft rot and so crops with greater than 1% blighted tubers should preferably not be stored. However, if they have to be stored they should be well ventilated and kept separate and, ideally, be marketed as early as possible. If tuber blight is suspected:

- **Consider whether to store.** A maximum of 1% tuber infection is widely regarded as the threshold for storing crops. Crops with greater than 1% infection are regarded as very high-risk crops
- **Ventilation is key.** After lifting, ventilation should be positive – ie air should pass through the crop not around boxes. Drying tubers at harvest and keeping them dry and cool will minimise the risk of sporangia being produced in the store and being spread during handling. No fungicides applied to the harvested crop will control blight or soft rots in-store
- **Cool tubers as soon as possible.** Only cure high-risk stocks if damage levels are high and wound healing is necessary or scuffing levels are high or if CIPC treatment is required
- **Keep tubers dry.** Doing so throughout storage will minimise soft rotting (but not eliminate it) and will help to dry up any rots before they spread
- **Monitor crops.** Regular quality-control wash-ups throughout storage (minimum 100 tubers) will help identify potential problems earlier. Temperature probes placed throughout the crop are essential to spot any

temperature rise early, which could indicate localised secondary rotting

- **Be prepared to unload.** If soft rotting develops and spreads in-store, losses can multiply rapidly.

Storage of very high-risk crops

If the decision is taken to store a stock with more than 1% of blighted tubers, special measures will be required:

- Continual, positive ventilation is required to keep the crop dry and mummify existing soft rots to slow the disease development in the crop
- Keep the holding temperature as low as possible for the particular crop, bearing in mind the intended market. Some compromise is likely to be required in processing crops as the rate of breakdown will be greatest at warm storage temperatures
- Monitoring should be carried out every day during the storage period. Checks will only take a matter of minutes. Look for evidence of soft rotting and check for temperature hotspots
- Try to maintain easy access to the most high-risk crops and be prepared to empty the store quickly if the crop starts to break down
- Don't handle blighted stocks during storage unless soft rotting becomes a problem. Resist the temptation to grade seed stocks more than once and wait until the planned grading time to remove blighted tubers. Repeated grading at intervals is only likely to spread the disease to healthy tubers
- Take care to avoid condensation at all times as some tubers may not have mummified fully and any wetness could start breakdown and spread of disease through the stock in-store or during subsequent handling
- Grading equipment should be cleaned after use for high-risk crops to avoid the contamination of other stocks.



Blighted tubers are prone to secondary infection by soft rot bacteria. This is a very serious development as an individual soft rotted tuber can rapidly affect neighbouring tubers.

Photo source: SBCSR

For more information on storage, please consult your local advisor or phone the Potato Council Storage Advice Line on 0800 02 82 111.

READ THE PESTICIDE LABEL BEFORE USE. USING A PRODUCT IN A MANNER THAT IS INCONSISTENT WITH THE LABEL MAY BE AN OFFENCE. FOLLOW THE CODE OF PRACTICE FOR USING PLANT PROTECTION PRODUCTS.

The (COSHH) Control of Substances Hazardous to Health Regulations may apply to the use of pesticides at work.

For more information on specific products, please consult your agronomist or a BASIS registered advisor.

Always consult appropriate buyer protocols before using any pesticides.

For the latest Potato Council levy-funded research please visit www.potato.org.uk/knowledge-hub and search by the project number (eg R449) under research projects in the keyword search.

Potato Council funded projects

- 807/242 Blight – New Active Ingredients in GB
- R274 Survey of GB Late Blight Populations
- R293 Matching Blight Fungicides to Cultivar Resistance
- R424 Matching Blight Fungicides and Cultivar Resistance (LINK)
- R423 Blight Population Changes
- R449 Effectiveness of Mineral Oils

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4. NPTC – www.nptc.org.uk/
5. Chemicals Regulations Directorate
6. Health & Safety Executive – COSHH
– www.coshh-essentials.org.uk/
7. Health & Safety Executive – COSHH, a brief guide to regulations
– www.hse.gov.uk/pubns/indg136.pdf
8. Crop Protection Association Best Practice Guides – Protective Equipment
– www.cropprotection.org.uk

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Front cover photograph

- Gary Naylor Photography

Other relevant Potato Council publications

- Store Managers' guide
- Managing the risk of blackleg and soft rot
- Irrigation and water use best practice guide

Available from publications@potato.ahdb.org.uk.

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