



Barley disease management guide

Introduction

This *Barley disease management guide* brings together the latest information on controlling economically important barley diseases. It covers foliar, stem-base, root and ear diseases.

Fungicide activity and performance

Annually updated information on fungicides is available as a separate information sheet. This includes:

- Seed treatment options
- Fungicide activity against major barley diseases
- Active ingredients for barley disease control
- Fungicide dose-response curves

cereals.ahdb.org.uk/publications



Further information

The *Encyclopaedia of Cereal Diseases* (2008) illustrates and describes symptoms and life cycles of common and less frequently found diseases.
cereals.ahdb.org.uk/cde



For information about fusarium mycotoxins, visit
cereals.ahdb.org.uk/mycotoxins

For the AHDB Recommended Lists for cereals and oilseeds and the latest variety information, visit
cereals.ahdb.org.uk/varieties



Neonicotinoids – On 24 May 2013, restrictions on the use of the clothianidin, imidacloprid and thiamethoxam neonicotinoid insecticides were adopted by the European Commission. The restrictions apply from 1 December 2013, visit
cereals.ahdb.org.uk/neonics

Seed production and certification

Certified seed

All seed bought and sold in the UK must be certified. Barley quality standards (including varietal and species purity, germination, loose smut and ergot) are prescribed in Cereal Seed Regulations issued by the UK within the EU-wide framework.

EU member countries can prescribe stricter standards than the EU minimum. The UK sets a Higher Voluntary Standard (HVS) with higher standards for varietal and species purity, ergot and loose smut. HVS seed is sold at a premium.

Seed can be certified at various stages as a variety is commercialised. Second generation certified seed (C2) is the category normally bought for commercial production.

Certification and seed-borne disease

The Cereal Seed Regulations state: “Harmful organisms which reduce the usefulness of the seed shall be at the lowest possible level.” Standards exist for loose smut and ergot contamination but not for leaf stripe, net blotch, covered smut, or seedling blights that are seed-borne. Although not a requirement, most certified seed is treated. The diseases controlled depend on the treatment.

Naming of fungal diseases

Latin names of pathogenic fungi are agreed by international convention and these can change over time as new scientific evidence emerges (eg *Rhynchosporium* is now *Rhynchosporium commune*).

Farm-saved seed

Quality seed can be grown and processed on farm. The aim should be to meet at least the minimum certified seed standards. Static units of mobile contractors can process seed on farm. Alternatively, it can be processed off farm.

Note: by law, farm-saved seed cannot be sold, shared or bartered.



Any use of farm-saved seed must be declared to the British Society of Plant Breeders (BSPB). All varieties are eligible for farm-saved seed payment; the list is available at www.bspb.co.uk. This must be paid via a registered processor or directly to BSPB. Payments for zero-rated varieties will be refunded immediately.

Organic seed production

Organic certified seed must meet the same quality standards as conventionally produced seed. No conventional seed treatments should be used on organic certified or farm-saved seed. All seed considered for organic production should be tested for germination and seed-borne diseases.

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Seed sampling and testing

By law, seed must be officially sampled and tested before it can be certified. Sampling and testing are also important for grain intended for farm-saved seed. The value of any seed test is limited by the sampling methodology used. It is vital to collect a representative sample of grain.

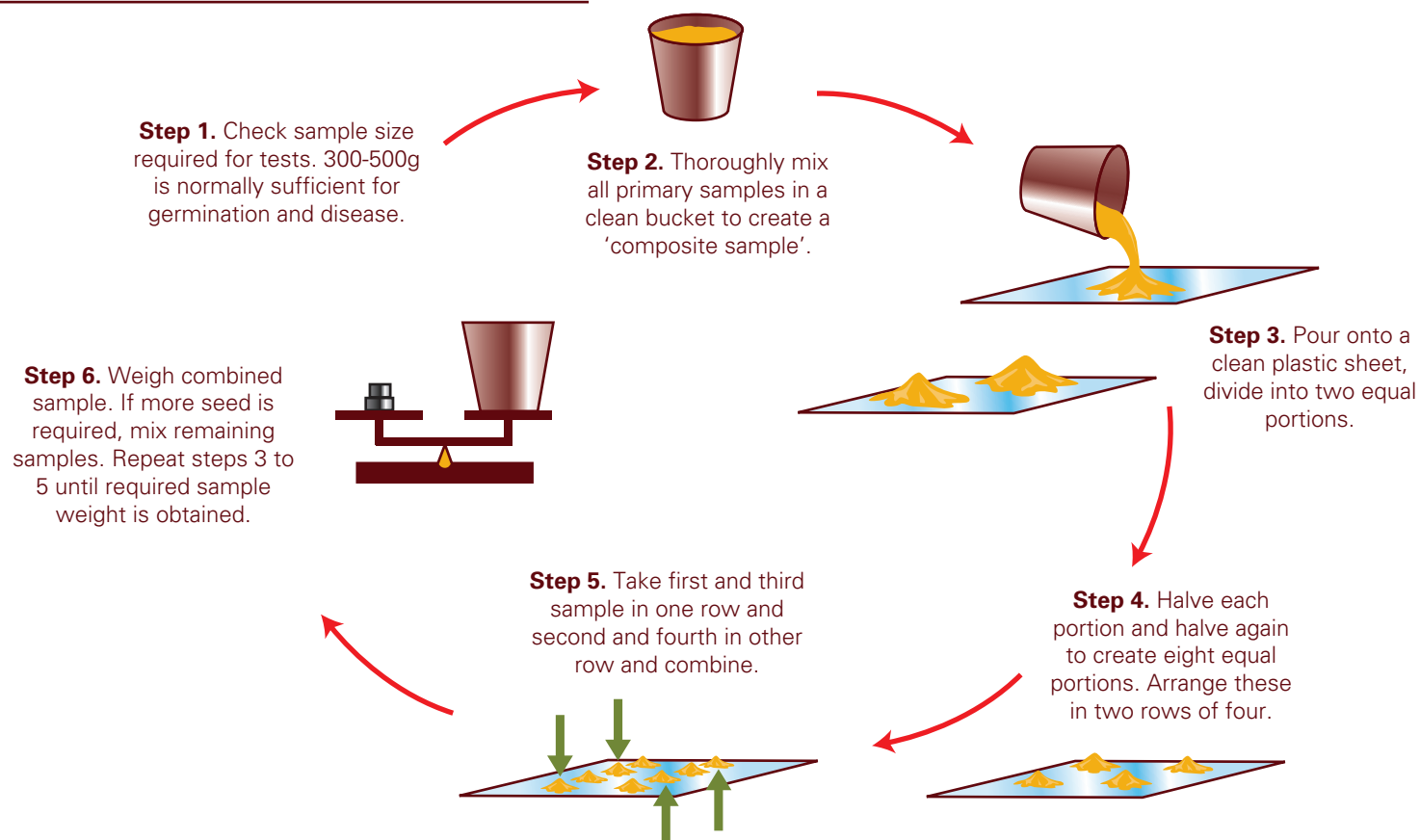
Sampling

- Sample grain before cleaning or drying, ideally with a single or multi-chamber stick sampler
- Wash equipment with water and detergent, before and between lots, where there is a risk of covered smut contamination
- Keep grain intended for sowing separate from larger grain bulks
- Only use seed from one field to reduce variability within a seed lot
- Subdivide seed lots over 30 tonnes into smaller lots
- Sample across the bulk or trailer at different depths (each sample taken is a primary sample)
- Thoroughly mix all primary samples in a clean bucket to create a 'composite sample' and divide for testing

Primary samples required for given lot sizes

Lot size (tonnes)	Primary samples required
<5	Treat as not economic to test
5	10
10	20
20-30	40

Figure 1. Preparing samples for testing



Cleanliness and hygiene

Wash all sampling equipment prior to starting sampling and between lots using water, detergent and a brush. Dry equipment or allow it to dry before use.

Equipment

The single chamber sampler (or “deep bin probe” or “Neate sampler”) collects one primary sample at a time. Screw-on extensions can be used if the depth of grain in the bulk is greater than the length of the sampler.

The multi-chamber sampler usually has three or more chambers; all seed collected in this one sampling action equals one primary sample. It can be used to sample grain up to two metres deep and is suitable for most trailers. A piece of plastic guttering is useful for collecting samples from this type of sampler.

If you do not have access to appropriate equipment, have your grain sampled by a trained agronomist.

Germination testing

Low germination, due to disease, sprouting, drying, mechanical or chemical damage, is a major cause of poor quality in UK seed. Where time is limited, the tetrazolium (TZ) test is recommended. However, this does not detect chemical damage and could over-estimate germination if pre-harvest glyphosate is used.

Seed health testing

- Never sow untreated seed without testing for seed-borne diseases, particularly loose smut, leaf stripe and net blotch (where not previously present).
- Test for ergot, covered smut and *Fusarium graminearum* if a problem is suspected.

Regulatory standards and advisory thresholds

Disease	Method	Duration	Results given as	Regulatory S standard A dvisory threshold
Loose smut <i>Ustilago nuda</i> f. sp. <i>hordei</i>	Embryo extraction	48 hours	% infection in 1000 embryos (advisory) or 2000 embryos (certification)	Maximum infection: A S 0.5% – minimum standard S 0.2% – HVS
Leaf stripe <i>Pyrenophora graminea</i>	Agar plate Molecular	7–10 days 48 hours	% infection Presence/Absence	A Treat if over 2% A Treat if present
Net blotch <i>Pyrenophora teres</i> f. sp. <i>teres</i>	Agar plate Molecular	7–10 days 48 hours	% infection % infection	A Treat if over 15%
Ergot <i>Claviceps purpurea</i>	Visual 500g or 1000g search	24 hours	Number of pieces in 500g or 1000g	Maximum pieces: A S 3 pieces/500g – minimum standard S 1 piece/1000g – HVS
Covered smut <i>Ustilago hordei</i>	Wash	24 hours	Spores/seed	A Treat if present
Seedling blights <i>Microdochium nivale</i> <i>Fusarium graminearum</i> <i>Cochliobolus sativus</i>	Agar plate Agar plate Agar plate	7–10 days 7–10 days 7–10 days	% infection % infection % infection	A Treat if over 30% A Treat if over 10% A Treat if over 30%

Seed-borne diseases

Loose smut

– *Ustilago nuda*

Symptoms

Loose smut is easily recognised as the ear is usually completely replaced by black fungal spores. Sometimes ears are partly affected. Spores are released as the ear emerges, leaving a bare ear rachis with total grain loss. As blackened ears are so obvious, the disease can appear severe, even at very low incidence.



Importance

The disease is well controlled in certified seed stocks but relatively common in farm-saved seed. Incidence varies between seasons and cultivars. High levels are associated with increasing areas of susceptible varieties and inappropriate seed treatment choice.

Life cycle

The fungus is present inside the seed embryo. When seed germinates, the fungus grows within the plant and infects the ear at an early development stage. Eventually, spikelets are replaced with masses of fungal spores which are released at ear emergence. Spores spread by wind to nearby open flowers and infect developing grain sites on healthy plants. The fungus lies dormant within the embryo of the seed until the seeds are sown.

Risk factors

Weather conditions during flowering influence how long florets remain open and hence susceptibility to infection. Cool, moist conditions pose a higher risk.

Most loose smut inoculum originates within diseased crops; however, spread from neighbouring crops can significantly reduce seed quality.

Seed repeatedly sown without a systemic fungicide seed treatment poses a risk.

i See also page 19.

Leaf stripe

– *Pyrenophora graminea*

Symptoms

Successive leaves on infected plants show long narrow stripes, often pale green at first, becoming yellow and dark brown. Stripes are first seen on seedling leaves. Some leaves split along the stripes giving a shredded appearance. The first symptoms may be sudden yellowing of plants as the flag leaf emerges. Leaf stripe reduces plant efficiency by reducing green area. It can result in ear blindness, ie no harvestable grain.

Importance

Relatively rare in the UK but potentially serious, causing yield loss and reducing grain quality. It can multiply significantly if seed is saved and re-sown without treatment.

Life cycle

The fungus is present in the seed coat and on the seed surface. As seedlings start to grow, the fungus invades the coleoptile, penetrating to the first leaf. The fungus grows through successive leaf sheaths, producing the characteristic symptoms on each leaf until it infects the ear, which often remains in the leaf sheath.

Spores produced on infected leaves are spread by wind to developing seeds. The seed is susceptible to infection from anthesis through to soft dough.

Risk factors

- Seed repeatedly sown without a fungicide seed treatment
- Conditions that slow germination (eg cold, overcompacted or waterlogged seedbeds) increase seedling transmission
- Spread of inoculum from neighbouring infected crops can significantly reduce seed quality

i See also page 19.



Covered smut

– *Ustilago hordei*

Symptoms

The disease is not obvious until ear emergence when infected grains are replaced by a mass of black fungal spores. Partially affected ears are common. Infected grains appear to be covered in a thin transparent membrane which is easily broken.



Importance

The disease is rare in UK barley but can be found in crops grown repeatedly from untreated seed. There is normally a total loss of grain from affected plants.

Life cycle

Spores present on seed surface or in soil infect via the coleoptile and first leaf as seedlings emerge. The mycelium develops within growing points and colonises developing ears. When the ear emerges it contains a massive amount of black spores held within a transparent membrane. The disease cycle is completed at harvest when smutted heads are threshed, releasing spores on to soil or seed. The membrane covering spores generally prevents release until harvest.

Risk factors

- Seed repeatedly sown without a fungicide seed treatment
- Soil-borne infection

Rhynchosporium

– *Rhynchosporium commune*

Importance

Rhynchosporium colonises seed tissues and can be detected by molecular and other methods. Under favourable conditions, it can be transmitted from infected seed to seedlings.



Seed-borne inoculum can contribute to the start of epidemics. Yield loss is associated with early infections.

i See also page 12.

Seedling blights

- *Microdochium nivale*
- *Fusarium graminearum*

Symptoms

The most common symptom of a serious attack is poor plant establishment. Other symptoms include brown lesions on stem base, leaf blotch and ear blight.

Importance

Unlike wheat, poor seedling establishment in barley due to *Microdochium nivale* is rare. Very high infection levels may cause seedling blight when seed is sown in cold seedbeds. Losses are not as high as those seen for wheat. *Fusarium graminearum* has the potential to cause seedling losses in barley but is currently rare.

Life cycle

Inoculum is mainly found on crop debris (*F. graminearum*) and soil (*M. nivale*) or from seed infection. The resultant seedling blight or stem-base browning releases spores which are splashed up the plant ultimately infecting the ear.

Risk factors

- High level of seed infection
- Untreated seed or seed without appropriate treatment
- *M. nivale*: early-sown spring barley
- *F. graminearum*: maize in the rotation

Seedlings with blight



Seedling blight, foot rot and leaf spot

- *Cochliobolus sativus*

Symptoms

Early symptoms include brown roots and coleoptiles which can cause seedling blight but more usually infected plants grow to maturity. Affected plants show brown spotting on lower leaves. Severe infections can cause stem-base rotting and poorly-filled ears.

Importance

Cochliobolus sativus is traditionally a disease of hotter climates than that of the UK but seedling losses and leaf spotting can occasionally occur.

The disease is rare on winter barley but is more often recorded on spring barley. Some varieties are more susceptible than others. Infections tend to be higher in organic compared to conventional systems.

Life cycle

The soil and seed-borne fungus survives on debris and grass weeds. It sometimes causes seedling blight. More usually it infects roots but the plant survives. Leaf spotting and stem-base infections produce splash-borne spores to infect seed in ears.

Risk factors

- Any factors that slow germination and emergence
- Poor seedbeds
- Extended periods of warm, moist weather

Net blotch

- *Pyrenophora teres* f. sp. *teres*
- *Pyrenophora teres* f. sp. *maculata* (spot form)



Symptoms

Symptoms can be similar to leaf stripe infection in emerging crops – the first leaf has a single stripe extending the full length of the leaf. Later leaves develop more characteristic lesions.

Importance

Seed-borne inoculum is usually much less important than infected stubble, though infected seed can start early foliar epidemics which may damage yield.

Risk factors

- High level of seed infection
- Varietal susceptibility

i See also page 14.

Ramularia leaf spot

- *Ramularia collo-cygni*



Symptoms

Ramularia shows no visible symptoms at the seedling stage. Identification within seed and leaves requires molecular diagnostics. Symptoms occur when leaves are stressed. Square brown lesions develop on the middle or tips of leaves, which are clearly visible on both sides of the leaf. The lesions are surrounded by a yellow halo. Symptoms are similar to the spot form of net blotch but the rectangular shape is typical of ramularia leaf spot.

Importance

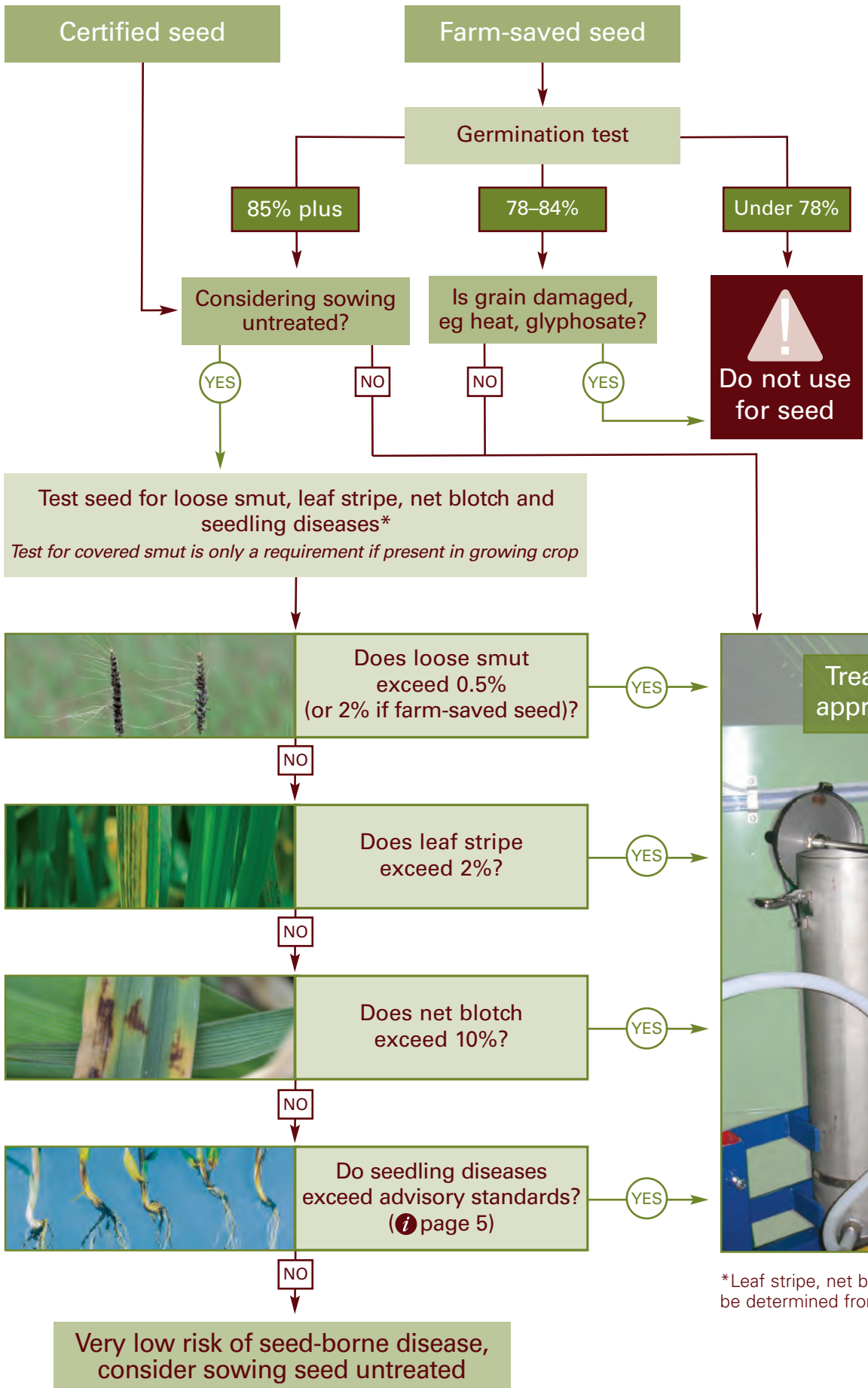
Seed-borne inoculum is considered a major disease source.

Risk factors

- High level of seed infection
- Varietal susceptibility
- Prolonged spells of leaf wetness April-June
- Stress, including waterlogging

i See also page 13.

Seed treatment



i For a list of seed treatment options, see the Information Sheet, *Fungicide activity and performance in barley*, which will be updated annually.



*Leaf stripe, net blotch and seedling disease can all be determined from the same agar plate test.

Foliar and stem-base diseases

When to treat

Disease control should aim to keep the crop healthy during the growth stages that are most important for yield.

Yield components

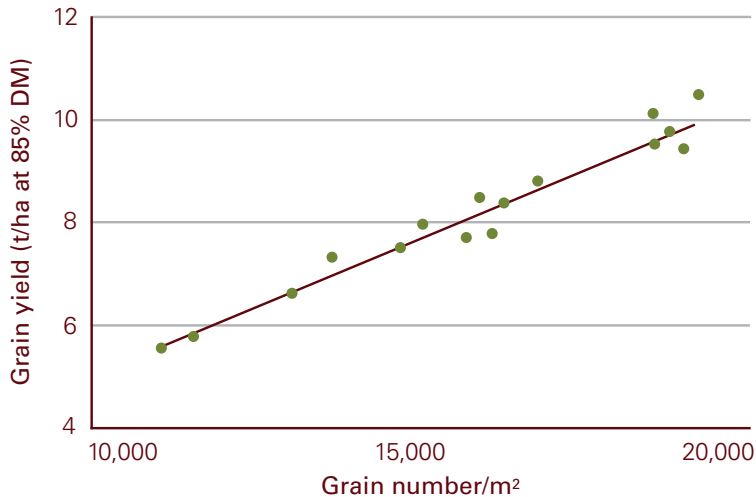
The three components of grain yield are:

- Number of ears per unit area (determined by the number of fertile shoots that survive)
- Grain numbers per ear (determined by spikelet production and survival)
- Average grain weight (thousand grain weight, determined by grain development and filling)

$$\text{Grain yield} = \text{grain number/m}^2 \times \text{average grain weight}$$

$$\text{Grain number/m}^2 = \text{ears/m}^2 \times \text{grains/ear}$$

Yield increases as grain number/m² increases



Crop development and growth – definitions

Development—changes in crop structure, controlled by temperature accumulated since sowing and daylength. Development is not affected by disease.

Growth—changes in crop size or weight, resulting from photosynthesis in green leaves, stems, ears and awns. Growth is affected by disease. Disease management aims to protect yield-forming parts of the plant.

Phases of development

It is crucial to protect crops against disease during those phases of development when ears/m² and grains/ear are being determined. The same development processes occur in winter and spring barley but at different dates, reflecting sowing times.

Vegetative development

After germination, the stem apex initiates new leaves and tillers until reproductive development (formation of ears and spikelets) begins. Thereafter, the initiated leaves expand and emerge until the final (flag) leaf emerges – GS37–39. Most tillers have emerged by the start of stem extension; however, some may continue to expand and emerge later.

Reproductive development

The start of reproductive development depends on sowing date and variety. For instance:

- In a late September/early October sown crop it can occur in early February when the crop has 6 or 7 emerged leaves
- In a February/March sown spring crop it can occur when the crop has 4 or 5 emerged leaves

In this phase, spikelets are initiated. Each one can develop one floret and grain. In two-row barley, spikelets form on each side of the ear in threes but only the central one develops a fertile floret. In six-row barley, all three spikelets develop fertile florets. The maximum number of spikelets occurs around GS30–31.

Survival of tillers and spikelets is favoured by good light interception, photosynthesis and growth during stem extension.

Potential grain size and dry matter storage capacity are determined by ovary development during booting, as well as by endosperm development in the two or three weeks after ear emergence.

Winter barley spray timing

Ear number	Tiller production	Tiller loss	
Grain number per ear	Spikelet production	Spikelet loss	
Potential grain size			
Canopy size	Green canopy production		Canopy senescence
Grain growth			Grain filling

Emergence	Start of tillering	GS23	GS30	GS31	GS32	GS39	GS49	GS59	Harvest
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Autumn



Substantial tillering can occur in the autumn after early drilling and/or during a mild winter. An autumn spray to such crops may give small, but significant, yield responses. Where plant populations are moderate or high the potential to increase ear numbers is greater.

An early spring treatment is more likely to produce an economic response.

T0 Early spring



Early spring treatments protect against foliar diseases that can limit growth during tiller and spikelet production.

T1 Stem extension



Treatments at the start of stem extension provide protection during the period of tiller and spikelet mortality. Yield responses are mostly due to increased grain numbers and tend to be greater than responses to treatment during booting (GS45–49) or in early spring.

T2 Flag leaf emergence and booting



Treatments around flag leaf emergence can significantly increase grain number/m², probably by increasing grains/ear by reducing spikelet mortality during booting.

Treatment at booting may extend canopy duration, increase dry matter available for grain filling and increase grain storage capacity leading to higher thousand grain weight (TGW). Later applications, towards the end of booting, have more effect through TGW. Optimum ramularia control will be achieved by fungicide application at booting.

i For more information, see Cereal growth stages – a guide for crop treatments cereals.ahdb.org.uk/publications



Winter six-row barley responds similarly to two-row barley with T1 sprays producing most yield effect through increased grain number/m².

Spring barley spray timing

Ear number	Tiller production	Tiller loss	
Grain number per ear	Spikelet production	Spikelet loss	
Potential grain size			
Canopy size	Green canopy production		Canopy senescence
Grain growth			Grain filling

Emergence	GS12	GS22		GS25	GS31		GS39	GS49	GS59	Harvest
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Early spring



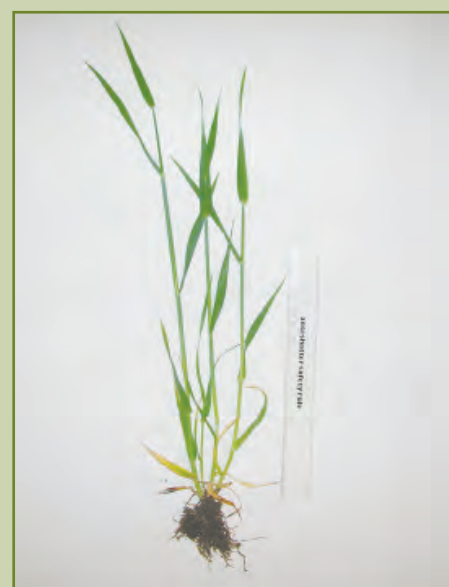
Early mildew control may be needed on very susceptible varieties using a protectant fungicide.

T1



The main timing for maximum tiller and spikelet survival provides protection through to T2 application because spring varieties develop at a faster rate than winter ones.

T2



This is the optimum time to protect crops against late-developing rhynchosporium, as well as ramularia leaf spot, brown rust and net blotch. The aim is to maximise TGW and specific weights and minimise screenings. Growers who omit a T1 spray may use an earlier timing (GS37–39).

Disease management in spring barley aims to provide early protection of developing tillers and spikelets and then to protect grain development and filling. Timing is influenced by sowing date and disease risk of site and variety. Early-sown crops (eg January/February) may be treated like winter barley, whereas crops sown later may only require one or two sprays.

Key points for both winter and spring barley:

- Barley yields are usually limited by grain number per unit of ground area
- Foliar diseases can reduce tiller numbers
- Barley is less able than wheat to recover from early disease effects on tillering
- Disease management must start early to protect tillering and the developing ears and spikelets
- Season-long protection maximises grain storage capacity
- For difficult to control diseases, eg rhynchosporium, early fungicide application may prevent epidemics developing
- Fungicide treatment may be beneficial to yield even if no visible disease develops

Foliar diseases – Rhynchosporium

Rhynchosporium

Rhynchosporium commune



Symptoms

Initially, pale grey water-soaked lesions appear, commonly at the leaf base close to the stem. These lesions expand into pale, irregular patches with dark brown margins across the foliage.

Importance

Rhynchosporium remains the most damaging disease of barley in the north and west.

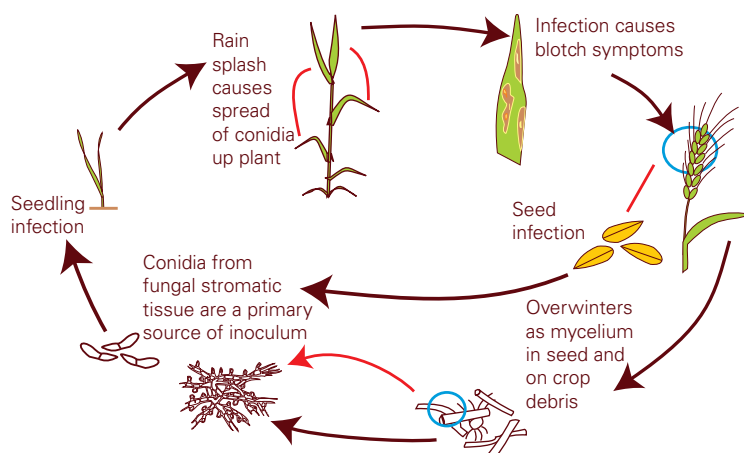
Visible levels of disease of 1–2% at GS31–32 will result in an economic loss if left untreated. CropMonitor national survey 2005 data* indicated that crops had 0.7% rhynchosporium on leaf 2 at GS75, which equates to a national yield loss worth £7.2 million (at £150/t) despite treatment.

Life cycle

In winter barley, symptoms can occur in autumn as random patches as a result of infection by rain-splashed spores from crop debris, previous stubble and volunteers. Widespread infection can occur in January/February as a consequence of seed-borne infection which initially develops inside the leaves and roots without symptoms showing.

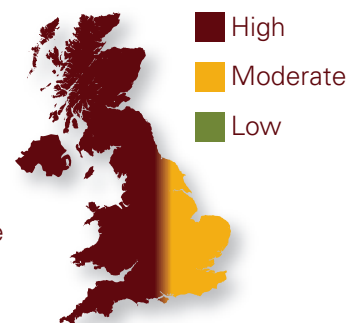
Symptom expression can be high at tillering stages of growth in winter barley. Infection of upper leaves can also occur in a wet summer. Spores on upper leaves may spread to ears and affect seed.

In spring barley, it is rare to see symptoms until after tillering. Symptoms spread to the upper leaves during a wet summer. Crops adjacent to affected winter barley crops may become infected by rain-splashed spores during wet and windy weather.



Risk factors

- Disease sources are seed, trash, volunteers and airborne spores
- Cool, wet weather favours the disease, hence it is most common in the north and west of the UK



Control

Varieties

- Select resistant varieties in high-risk areas
- Avoid seed from affected crops

Cultural

- Minimise barley trash and volunteers
- Avoid early sowing (December–February) of spring varieties
- Use clean seed stocks
- Avoid excessive N uptake

Fungicides

In autumn, control should only be considered if early symptoms cause extensive leaf damage.

In early spring (March–GS30), if symptoms occur, a fungicide application will help control disease until the main fungicide timing (GS31–32).

At GS31, an effective azole in mixture with a strobilurin or SDHI fungicide is a good foundation for disease management and in most crops will be the first treatment. For additional eradication, a morpholine can be included in the mixture.

Later protection of upper leaves is needed if weather is wet between flag leaf emergence (GS39) and ear emergence (GS59) – a mixture of an azole with an SDHI and chlorothalonil should be considered. Alternatively, a mixture of an azole with strobilurin and chlorothalonil should be considered.

*Last available CropMonitor survey data: 2005

Foliar diseases – Ramularia

Ramularia

Ramularia collo-cygni



Symptoms

Small brown 'pepper spot' lesions on the upper side of leaves develop into dark-brown rectangular lesions with yellow margins – easily mistaken for net blotch, particularly if lesions coalesce. Lesions develop most on the middle of leaves exposed to the sun and can be seen on upper and lower surfaces. Symptoms also occur as small brown flecks on awns and stems.

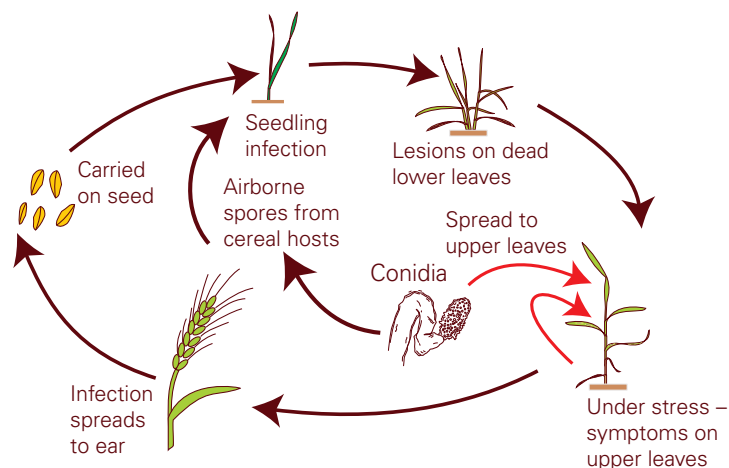
Ramularia symptoms develop rapidly and can occur on dying leaves throughout the season, but most commonly occur on upper leaves after ear emergence.

Importance

Increasingly important in the north of the UK but becoming more common in the south, on winter and spring barley.

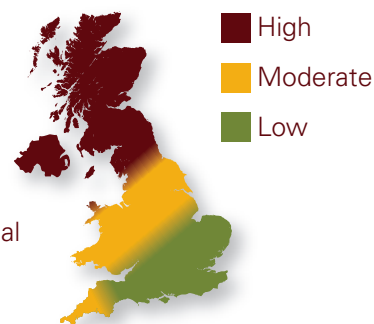
Life cycle

Ramularia is seed-borne, spreading to new leaves without visible symptoms. Symptoms usually appear when the crop is stressed. Spores are then released following a period of leaf wetness. These spores can cause secondary infections and are important for seed infection.



Risk factors

- Disease sources are seed, trash and airborne spores
- Stress, eg waterlogging, poor nutrition or physiological stress
- Leaf wetness in spring



Control

Varieties

The main economic loss is in spring malting barley where the varieties preferred by the market are not disease resistant. Resistance ratings for ramularia are available in the AHDB Recommended List for spring barley.

Cultural


- Prevent N stress/deficiency

Fungicides

Current seed treatments have little effect on disease development.

Azoles, eg prothioconazole and epoxiconazole, applied at the boot stage before symptoms appear, provide effective control and protect upper leaves. Using an azole in mixture with an SDHI fungicide and chlorothalonil achieves the the best control.

Strobilurins are no longer effective due to fungicide resistance.

 For more information, see Information Sheet 47.
cereals.ahdb.org.uk/publications



Foliar diseases – Net blotch

Net blotch

Pyrenophora teres



Symptoms

Symptoms can vary depending on source of infection:

- **Seed:** brown stripes spread from the base of leaves in seedlings and tillering plants
- **Spores** from crop debris or neighbouring plants: long, brown lesions with a mottled or netted appearance develop

Leaf tissue surrounding lesions may be yellow and can occur anywhere on the leaf. Lesions differ in size. Small lesions appear as individual spots which can easily be mistaken for ramularia. Diagnosis may require microscopic examination.

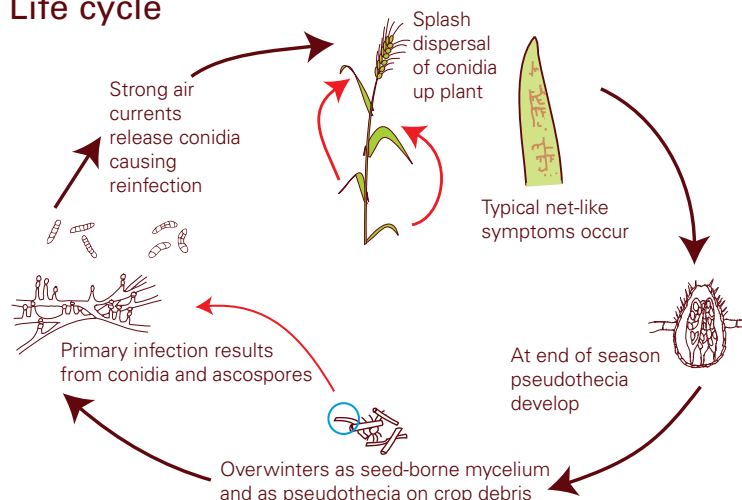
Symptoms can be extensive in winter but affected leaves die back and new leaves in spring can be symptom-free. The most serious symptoms usually occur on upper leaves in summer on unprotected susceptible varieties.

Importance

Net blotch is a serious disease of barley causing large yield losses when left uncontrolled. Infections from trash-borne inoculum pose the biggest threat to yield.

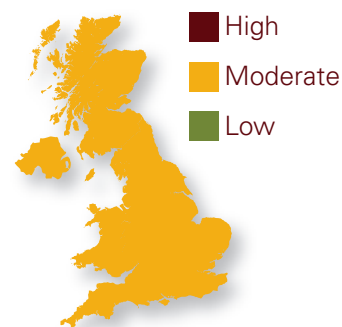
CropMonitor national survey 2005 data* indicated that crops had an average of 0.8% on leaf 2 at GS75 which equates to a national yield loss of £10.2 million (at £150/t) despite treatment.

Life cycle



Risk factors

- Disease sources are seed, trash, volunteers and airborne spores
- Mild, wet weather
- Second barley crops, especially after minimum tillage



Control

Varieties

Resistance ratings for net blotch are available in the AHDB Recommended List for winter barley varieties. A resistant variety will reduce risk substantially.

Cultural

- Minimise previous crop debris
- Apply appropriate treatment on infected seed
- Manage N to avoid excessive concentrations in plants

Fungicides

Seed treatments protect against seed-borne inoculum. Seed testing can be used to assess the need for seed treatment.

Susceptible crops are at risk from late infections, so fungicides should be used to protect upper leaves. The azole prothioconazole and the SDHI fungicides remain the most effective. Cyprodinil is active against net blotch and offers an alternative mode of action.

Insensitivity to strobilurins is now widespread but most strobilurins show some activity even where resistance is widespread.

*Last available CropMonitor survey data: 2005

Foliar diseases – Brown rust

Brown rust

Puccinia hordei



Symptoms

Small brown spore pustules may form on leaves. Symptoms can occur at any time during the season and are usually scattered randomly. Lesions reduce green leaf area.

In winter barley, symptoms can occur in autumn and winter if conditions are mild. However, affected leaves die off and do not always lead to high disease incidence in spring.

Favourable conditions (high temperatures and overnight dews) in April–June can lead to extensive symptoms on the upper leaves in susceptible varieties.

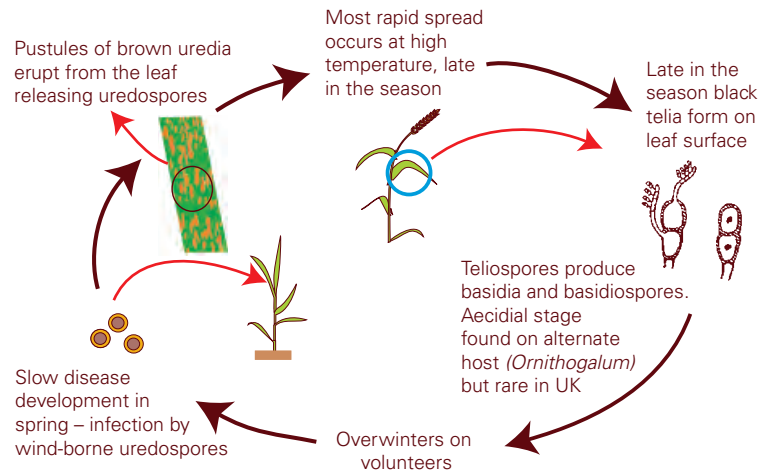
Importance

Infections threaten green leaf area and hence yield. Infections of the ear can also reduce quality.

CropMonitor national survey 2005 data* indicated that crops had an average of 0.2% on leaf 2 at GS75 which equates to a national yield loss of £3.6 million (at £150/t) despite treatment.

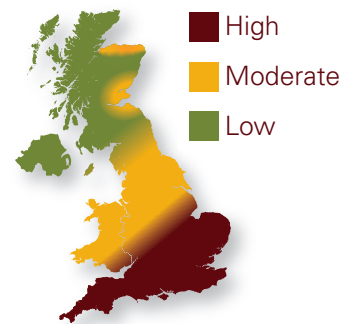
Life cycle

Brown rust can only survive on live leaf tissue, so overwinters in crops and on volunteers. It spreads by means of airborne spores. Optimum conditions are days with high temperatures (15–22°C) followed by overnight dews. Surface moisture on leaves is essential for spore germination. Symptoms can occur 5–6 days after infection at optimum temperatures.



Risk factors

- Disease sources are volunteers and airborne spores
- Humid, warm weather, especially in April to June



Control

Varieties

Resistant varieties reduce disease risk but new races are continually evolving and varietal resistance can break down quickly.

Cultural

- Control volunteers to remove 'green bridge' in autumn and spring
- Manage N to avoid excessive concentrations in plants

Fungicides

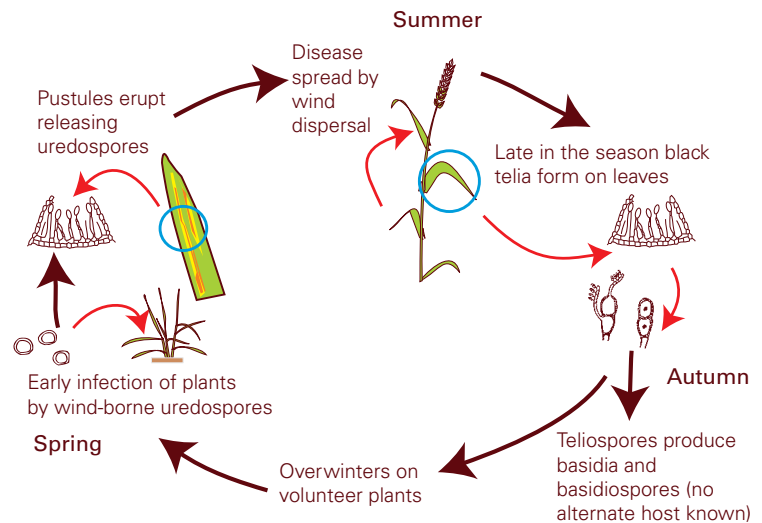
Protecting against infection is far more successful than eradicating established disease. Most strobilurins, azoles and SDHIs remain effective. Mixing a morpholine with one of these fungicide groups helps eradicate established disease. However, eradication is difficult when ideal weather conditions for the disease occur.

*Last available CropMonitor survey data: 2005

Foliar diseases – Yellow rust

Yellow rust

Puccinia striiformis f. sp. *hordei*



Risk factors

- Susceptible varieties
- Cool, wet weather in an early spring before fungicides applied

Control

Varieties

Effective varietal resistance means yellow rust is now rare.

Cultural

- Control volunteers to remove 'green bridge' in autumn and spring
- Manage N to avoid excessive concentrations in plants

Fungicides

As with brown rust, fungicides will protect against yellow rust provided treatments are applied before the disease becomes well established.

Most strobilurins, azoles and SDHIs remain effective. Once disease is established, adding a morpholine to fungicide treatments will help to eradicate the disease, but effective eradication is a challenge when weather conditions are ideal for the disease.

Symptoms

In autumn, yellow/brown spore pustules can occasionally appear, randomly distributed on leaves.

They can easily be mistaken for brown rust. In spring, yellow pustules develop in distinctive lines. Without treatment, symptoms on susceptible varieties can be extensive.

Importance

Yellow rust is rare and has not been included in national surveys.

Life cycle

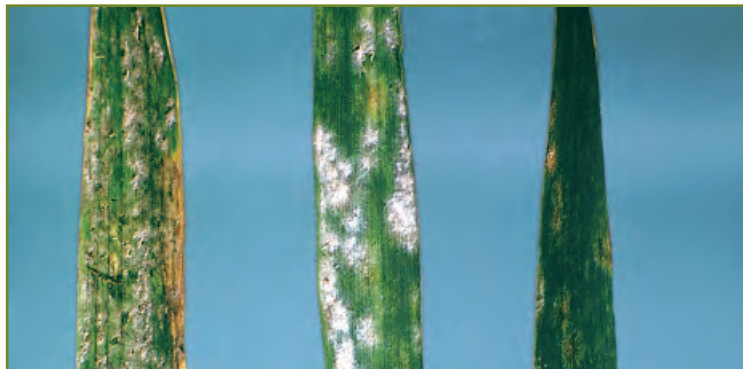
Mild winter weather enables the disease to survive on crops and volunteers.

Cool (10–15°C) temperatures, and prolonged periods when the leaves are wet, provide optimum conditions. Symptoms occur 7–14 days after infection. Hot, dry weather can stop disease development.

Foliar diseases – Powdery mildew

Powdery mildew

Blumeria graminis f. sp. *hordei*



Symptoms

Powdery mildew produces white fluffy fungal growth on leaves, stems and ears. Individual pustules merge under favourable conditions to cover much of the leaf and stem surfaces. Leaf yellowing is associated with infection. Late in the season, small black fungal bodies develop within pustules to produce airborne spores.

In winter barley, symptoms can occur in autumn or winter under mild conditions. However, autumn infection can be reduced by winter frosts, thus spring infection may not be severe.

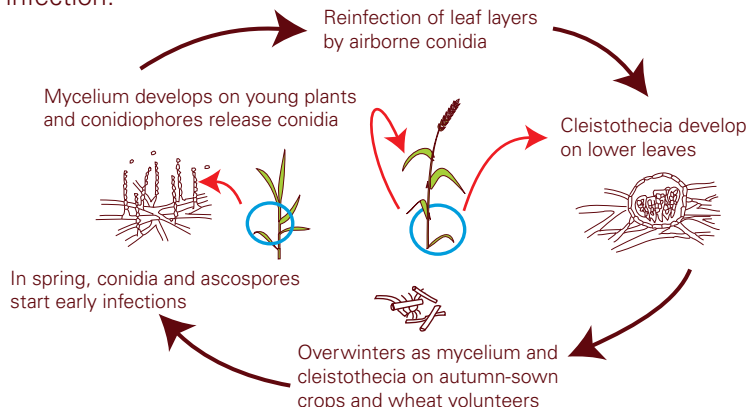
Spring barley is most affected at leaf emergence and tillering but symptoms can develop as early as GS11 (first leaf unfolded).

Importance

CropMonitor national survey 2005 data* indicated that crops had an average of 0.4% on leaf 2 at GS75 which equates to a national yield loss worth £3.6 million (at £150/t) despite treatment.

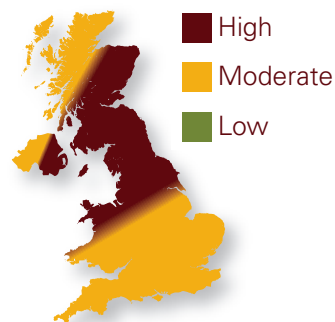
Life cycle

The fungus can only grow on living plants. It spreads from winter crops to spring crops and to volunteer barley via airborne spores. New pustules are produced 5–14 days after infection.



Risk factors

- Disease sources are volunteers and airborne spores
- Warm (15–22°C), breezy conditions with short periods of high humidity favour infection
- Temperatures above 25°C and rain can inhibit the disease



Control ⓘ See also page 22.

Varieties

The risk of mildew can be substantially reduced by growing varieties with good mildew resistance (see AHDB Recommended Lists for cereals and oilseeds).

In spring barley, varieties with effective resistance provided by the 'mlo' gene should be grown where possible. Some mildew can develop on these varieties, particularly on seedlings during dry conditions; however, resistance has proved reliable and effective over the past ten years. Older varieties no longer on the AHDB Recommended List may still be susceptible and control will rely on protectant and eradicant fungicides.

In some varieties adult plant resistance, which starts to become effective during stem extension, reduces infection on upper leaves.

Cultural

- Manage N to avoid excessive concentrations in plants
- Control volunteers to remove 'green bridge' in the autumn and spring

Fungicides

In winter barley, control in autumn or winter is rarely warranted.

During rapid growth at tillering in the spring, powdery mildew can cause yellowing and loss of tillers. Early control is, therefore, essential on susceptible varieties to protect the crop from yield loss.

Several fungicides (eg metrafenone, proquinazid, cyflufenamid) give effective protection when applied before symptoms become extensive. Morpholines can provide eradication and short-term control, but poor protection. Mixing a protectant with a morpholine will eradicate and protect. Cyflufenamid provides short-term knockdown and longer-term protection.

Other fungicides (eg SDHIs, prothioconazole and cyprodinil) provide some protection but activity is limited once disease is established. Strobilurins no longer control mildew due to widespread resistance.

*Last available CropMonitor survey data: 2005

Stem-base diseases – Eyespot

Eyespot

Oculimacula acuformis
O. yallundae



Symptoms

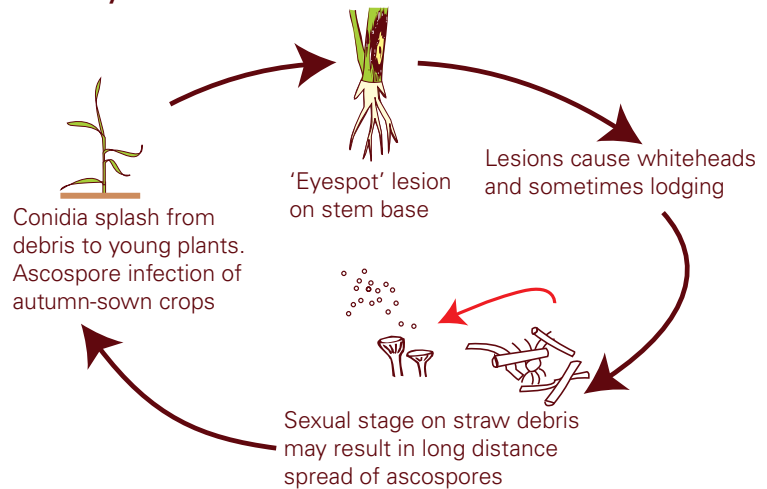
True eyespot appears as brown marks at the stem base on winter barley. These develop into typical 'eye-shaped' lesions which weaken straw and impede water and nutrient uptake.

Eyespot can be confused with sharp eyespot and fusarium.

Importance

Losses due to true eyespot are less in barley than in wheat. Other stem-base diseases seldom damage yield.

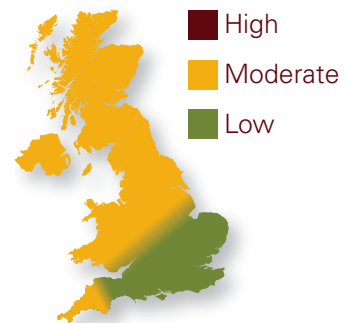
Life cycle



Risk factors

- Disease sources are trash and airborne spores
- Early sowing and high rainfall in spring increase eyespot risk

A risk forecast developed for winter wheat provides a useful indicator of risk for barley, since the same fungi are involved in both crops. However, the calculations have not been tested for barley (see Topic Sheet 111).



Control

Varieties

Varietal resistance to stem-base diseases is not assessed on barley.

Cultural

A two-year break from cereals will reduce eyespot risk but a break of just one year will have little effect.

Fungicides


Several fungicides (eg prothioconazole, boscalid and cyprodinil) are effective against eyespot when used at stem extension (GS31–32).

Ear diseases and mycotoxins

Ear diseases

Specific ear and grain diseases (eg botrytis, fusarium, *Microdochium nivale* and sooty moulds including alternaria and cladosporium) are encouraged by wet weather during flowering and grain filling.

Foliar diseases (eg powdery mildew, rhynchosporium, rusts, net blotch and ramularia) can spread to the ears and awns. These diseases are best managed by protecting upper leaves with a foliar fungicide.

Seed-borne diseases (eg loose smut) can affect the ear. Seed treatments control these diseases.  See also pages 6–8.

For feed barley varieties, delaying the last fungicide until the ear is fully emerged, or applying an additional ear spray may help. However, for malting barley, check the latest application time of the fungicide, since choice is limited.

Ergot

Claviceps purpurea

Ergot can develop in the ear of any cereal crop but is less common in barley than in open-flowered triticale or rye. Crops with secondary tillers are more susceptible. Ergot is common in weed grasses and field margins, which should be checked for its presence.

As ergot is highly poisonous to humans and animals, contaminated grain will be rejected. No fungicide is effective against ergot.

In the absence of host crops, ergots which fall to the ground usually decay over a 12 month period. Control is helped by ploughing between host crops and break crops combined with good control of cereal volunteers and grass weeds.

Check crops just before harvest to decide if ergot infested areas should be harvested separately.



Mycotoxins

Levels of mycotoxins (toxic chemicals produced by specific fungi that infect crops) are much lower in the UK than in mainland Europe and rarely exceed current EU limits.


Fusarium species, that affect ear and grain, are the main mycotoxin producers in winter and spring barley.

Mycotoxin risk, while lower than in wheat, should be considered particularly if barley is commonly grown in rotation with maize with minimum tillage (see *Guidelines to minimise risk of fusarium mycotoxins in cereals*).

AHDB Cereals & Oilseeds has also produced a fusarium mycotoxin risk assessment tool to help identify wheat crops at risk. This is a useful aid for assessing barley risk too.

Legal limits have been set for certain mycotoxins in barley grain intended for human consumption (1250ppb DON (deoxynivalenol) and 100ppb zearalenone). No limit for T-2 and HT-2 mycotoxins has been set (at the time of printing). T-2 and HT-2 are produced by different fungi, eg *Fusarium langsethiae*, which are favoured by drier conditions, so risk factors are different to those for DON.

EU guidelines apply for mycotoxin levels in barley intended for animal feed (8,000ppb DON and 2,000ppb zearalenone – lower for certain classes of stock).

 For the latest information on fusarium mycotoxins and the risk assessment, see: cereals.ahdb.org.uk/mycotoxins



Grain quality

Early infections (pre-GS31) of foliar diseases can reduce photosynthetic area and restrict tillering leading to lower yields with N content above the 1.85% specified by many malting barley buyers.

Smaller grains and increased screenings, which may lead to price penalty or rejection in both feed and malting markets, can result from foliar disease infections after GS39.

Use of fungicides to protect against disease can increase grain specific weight and reduce screenings, as well as increasing yield.

Virus diseases – Barley yellow dwarf virus

Barley yellow dwarf virus (BYDV)

Symptoms

Infections cause leaf yellowing and stunting, initially confined to single plants scattered randomly in a field but later developing into distinct circular patches as secondary spread occurs.



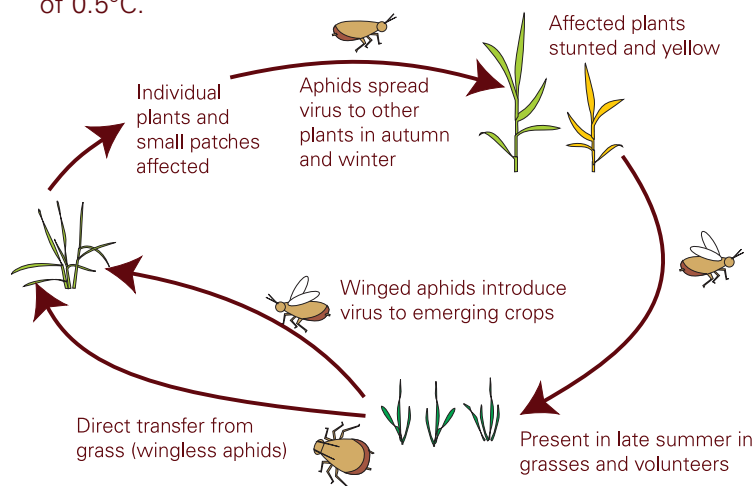
Importance

BYDV is most damaging when young plants are infected in autumn. Economic loss from a severe infection can make the crop unprofitable.

Life cycle

The main vectors of BYDV are the grain aphid and the bird cherry-oat aphid. During late summer and autumn, winged aphids migrate between hosts, so this is when the disease is most likely to be introduced to crops.

The LT50 (lethal temperature for 50% mortality) for grain aphid is -8°C , so they can survive through the winter in some years and even increase in numbers during mild spells. The bird cherry-oat aphid is more frost-susceptible, with an LT50 of 0.5°C .



Risk factors

- Early-sown winter crops
- Late-sown spring crops
- Mild conditions in autumn and winter
- 'Green bridge' transmission, ie from weeds and volunteers

Control

Control measures aim to prevent infection and reduce aphid spread by controlling aphid vectors.

Cultural

If high levels of aphid-infested grasses, especially annual meadow grass, are present in the stubble, a desiccant herbicide or ploughing may be beneficial to remove this green bridge. However, the risk of infestation by winged aphids in the autumn is lower following minimum tillage, and more so if the straw is left, compared to ploughing. Delaying sowing so that crops emerge after the end of the aphid migration (usually early November) will also reduce BYDV risk but this is not always practical.

If a spring barley crop follows a mild winter or is in a milder area, it may be worthwhile choosing a moderately resistant variety (see the AHDB Recommended List for spring barley).

i AHDB Aphid News provides information about when aphids migrate. The newsletter identifies the first autumn migrations and can aid decisions on spraying against BYDV vectors.

With this information, insecticides should be used more rationally, treatments timed better and harm to beneficial insects reduced. This will lower the risk of selection for insecticide resistance by reducing unnecessary or wrongly timed sprays.

Visit cereals.ahdb.org.uk/pests for more information.

Chemical

Insecticidal seed treatments can provide four to six weeks' protection for early-sown crops in high-risk areas. Cereals sown between January and June cannot be treated with thiamethoxam, clothianidin or imidacloprid but treatment is permitted at other times. An aphicide spray can prevent wingless second and third generation aphids spreading disease within the crop.

Development time for each generation depends on temperature. An accumulated sum of 170 day-degrees above 3°C is necessary to produce a generation (the 'T-sum 170'). Treatments are timed to coincide with the production of second generation aphids in a crop, at T-sum 170. The T-sum 170 is calculated either following emergence or the end of seed treatment protection.

Treatments at T-sum 340 may be justified where aphids continue to fly after the T-sum 170 spray.

Resistance

Kdr resistance associated with pyrethroid insecticides has been found in grain aphids. It is important that full recommended pyrethroid field rates are used. If control remains poor, a pyrethroid-based product should not be used again.

Virus diseases – Soil-borne mosaic viruses

Soil-borne mosaic viruses

Barley yellow mosaic virus
Barley mild mosaic virus



These virus diseases, very common in autumn-sown crops, are transmitted by the soil-borne *Polymyxa graminis*.

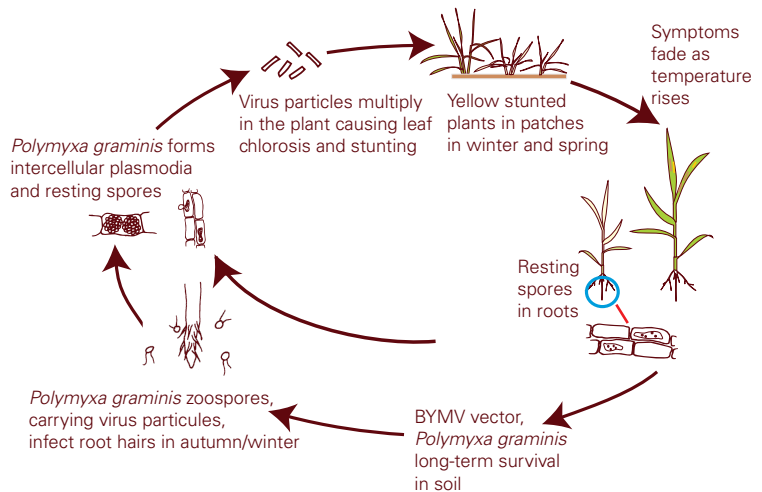
Symptoms

Affected plants are stunted and pale. Leaves typically have pale yellow streaks, especially in early spring, which are replaced by dark brown flecking and brown or purple leaf tips later in the season. Infections usually occur in distinct patches that increase in size in successive years.

Importance

Once present in the soil, it can persist in the absence of a cereal crop for more than 25 years. Yield within infected patches of a field can be reduced by up to 50%. As patches are quite visible, it is easy to over-estimate affected areas. However, overall yield can be reduced substantially as patches spread in successive crops.

Life cycle



Risk factors

- Previous infection, that can persist for 25 years
- Soil movement, especially during cultivations spreading within and between fields

Control

Disease cannot be controlled once plants are infected, so methods to prevent transmission and limit spread are required.

Varieties

Winter barley varieties resistant to both mosaic viruses are available (see AHDB Recommended List).

Cultural

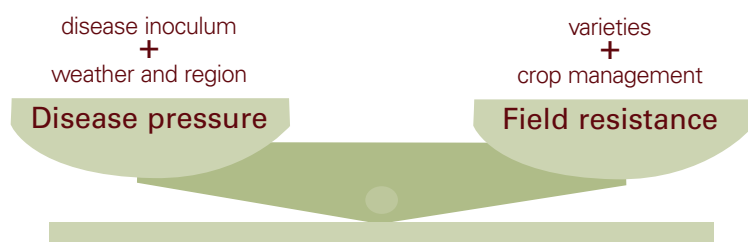
Cleaning cultivation equipment between fields will reduce the risk of the virus spreading.

Assessing disease risk

Disease pressure must be balanced against field resistance

Yield responses from some fungicide treatments can occur even where visible disease is at very low levels. Once infection is established and visible, yield may already be affected and disease will be difficult to control.

Avoiding yield loss requires early decision making based on risk assessments. The likelihood of infection – ‘disease pressure’ – has to be balanced against the ability of the crop to resist or avoid infection – ‘field resistance’.



Disease inoculum

Key sources of inoculum differ for each disease. However, they are primarily governed by frequency of previous cropping, either in the same field or the vicinity.

Crop management

The diagram below summarises the effect of various crop management practices on disease risk.

	Rhynchosporium	Ramularia	Net blotch	Rusts	Mildew	Eyespot
Early-sown	↑↑	↑↑	↑↑			↑↑
High N/ dense crop	↑	↓↓		↑↑	↑↑	
Min-till, if following barley	↑↑		↑↑	↑	↑	↑↑

Key ↑↑ Increased risk ↑ Small increase in risk ↓↓ Decreased risk

Varieties

AHDB Recommended List trials assess disease susceptibility and yield across the UK each year, helping growers select varieties with resistance to diseases prevalent in specific regions.

Robust fungicide programmes are used in these trials to maximise varietal potential. Comparing treated and untreated yields provides a useful indication of total yield response to fungicides. Varieties with large differences will usually need higher fungicide inputs to achieve their yield potential.

The susceptibility of varieties to each disease is partly reflected in the yield response to fungicides.

Other factors may affect varietal yield response:

- Differing yield sensitivity to disease
- Diseases have differing effects on yield
- Fungicide effects not entirely linked to control of visible disease, eg canopy ‘greening’ or growth regulatory effects

Variety diversification

Mildew can spread between barley varieties that are susceptible to the same race of the pathogen. The risk of severe and widespread infection may be reduced by:

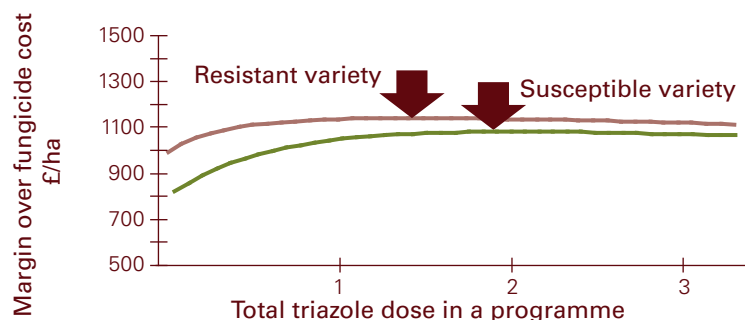
- Growing varieties with good resistance to mildew (see AHDB Recommended Lists for cereals and oilseeds).
- Diversifying the varieties grown so they are not all susceptible to the same mildew race

The UK Cereal Pathogen Virulence Survey, funded by AHDB Cereals & Oilseeds, produces a regularly updated diversification scheme for mildew in barley. The most recent version can be found from cereals.ahdb.org.uk/ukcpvs

Disease resistance

Some varieties are highly resistant to disease and may not require fungicide treatment if disease pressure is low. Even under high disease pressure a moderate fungicide input may be sufficient. Other varieties are very susceptible, requiring high fungicide input to reach their yield potential.

It is important to take disease resistance into account before deciding on an appropriate fungicide dose.



Choice of a more disease-resistant variety can significantly reduce the total fungicide input needed.

Resistance to fungicides

'Fungicide resistance' occurs as populations of a pathogen adapt to a fungicide. The specific mode of action of some modern fungicides (eg SDHIs) means the risk of resistance occurring is greater than with older ones with less specific activity (eg chlorothalonil).

Resistance to strobilurins

Resistance to strobilurins is widespread in barley pathogens; however, the effectiveness of strobilurins against different pathogens varies:

- Powdery mildew and ramularia – strobilurins no longer effective
- Net blotch – still some useful activity, especially from pyraclostrobin and picoxystrobin
- Rhynchosporium – resistance has been detected in France but not in the UK
- Rusts – there have been reports of small numbers of barley brown rust isolates with reduced sensitivity to strobilurins but they remain rare and field performance is good
- *Microdochium nivale* – resistance is now widespread in the UK

Azole resistance

Azole resistance results in reduced efficacy over seasons.

- Powdery mildew – the first disease to develop azole resistance. Some of the newer azoles, eg prothioconazole, provide useful control.
- Rhynchosporium – insensitivity is developing across most of the UK, with Northern Ireland less affected. Higher doses are required to control less sensitive strains.

Prothioconazole continues to show useful activity against both powdery mildew and rhynchosporium but should be used in mixture with an effective partner.

Quinoxifen resistance

Quinoxifen resistance may be reflected in poor activity against powdery mildew. Alternative fungicides include metrafenone and proquinazid.

SDHIs

Resistance to SDHIs has been confirmed in non-cereal pathogens and mutations in the target site genes of net blotch have been detected in the field, although field performance has not yet been detected in the UK. SDHIs are, however, considered to be at high risk of resistance development (FRAG-UK). SDHIs should always be used in a mixture with at least one fungicide from an alternative mode of action that has similar efficacy and duration, such as an azole.

Good resistance management is based on limiting the level of exposure of the target pathogen to the fungicide

- Fungicide input is only one aspect of crop management and other control measures should always be used, such as good hygiene through disposal of crop debris and control of volunteers which may harbour disease
- Always aim to select varieties exhibiting a high degree of resistance to diseases known to be prevalent in your area, in addition to the main agronomic factors you desire
- Avoid growing large areas of any one variety, particularly in areas of high disease risk where the variety is known to be susceptible
- Only use fungicides in situations where the risk or presence of disease warrants treatment
- Use a dose that will give effective disease control and which is appropriate for the cultivar and disease pressure
- Make full use of effective fungicides with different modes of action in mixtures or as alternative sprays
- Ensure that mixing partners are used at doses that give similar efficacy and persistence
- Monitor crops regularly for disease and treat before the infection becomes well established
- Avoid repeated applications of the same product or mode of action and never exceed the maximum recommended number of applications

For more information on resistance management, see the Fungicide Resistance Action Group – UK website (<http://www.pesticides.gov.uk/guidance/industries/pesticides/advisory-groups/Resistance-Action-Groups/frag>)



Foliar diseases – Fungicide dose

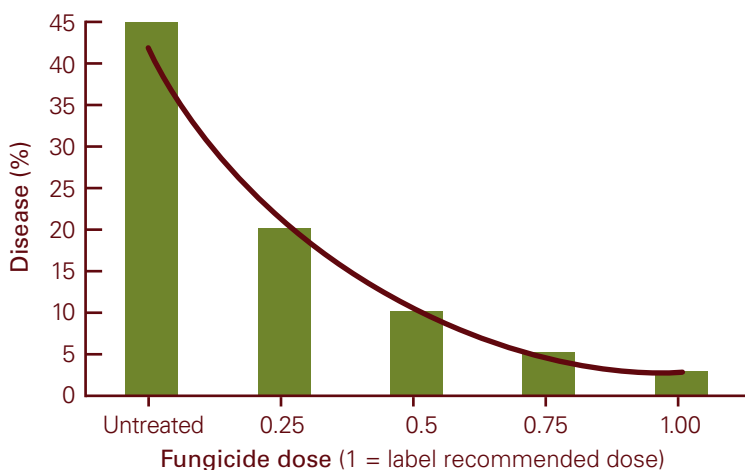
Determining appropriate dose

Fungicides are rigorously tested in AHDB Cereals & Oilseeds-funded trials. Each year, a single spray is applied at a range of doses on varieties which are highly susceptible to each major disease, and at sites where disease pressure is high. Disease levels are observed a few weeks later.

Performance of individual active ingredients can be assessed by comparing dose-response curves. These show average performance measured across a range of sites, seasons and leaf layers.

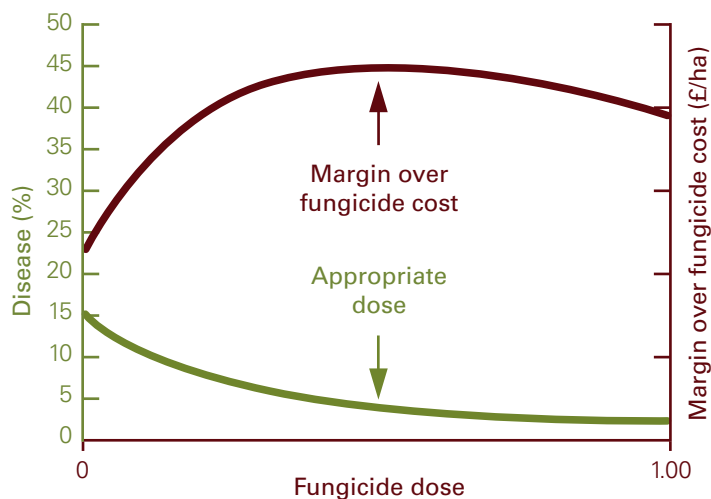
Disease severity in untreated crops depends on local disease pressure and varietal resistance. In treated crops, severity also depends on fungicide dose applied.

The dose-response curve



Fungicide dose and margin

Fungicide spray cost increases with dose applied, while yield loss, to some degree, is proportional to the amount of disease present. The figure below plots fungicide dose against margin and identifies when the return from a higher dose would not be economically justified.



The appropriate dose depends on disease risk and predicted yield loss and is defined as that point where margin is maximised.

Below the appropriate dose, profit is seriously reduced by ineffective disease control.

Maximising profit may mean accepting a small amount of disease in the crop despite treatment.

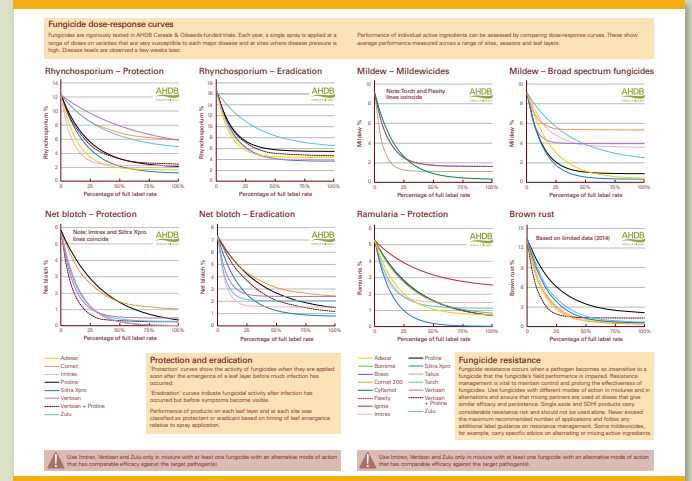
How disease and variety affect appropriate dose

Differing disease pressure is a major reason for varying appropriate doses between different crops. Clearly, higher disease pressure and disease susceptibility justify higher inputs.

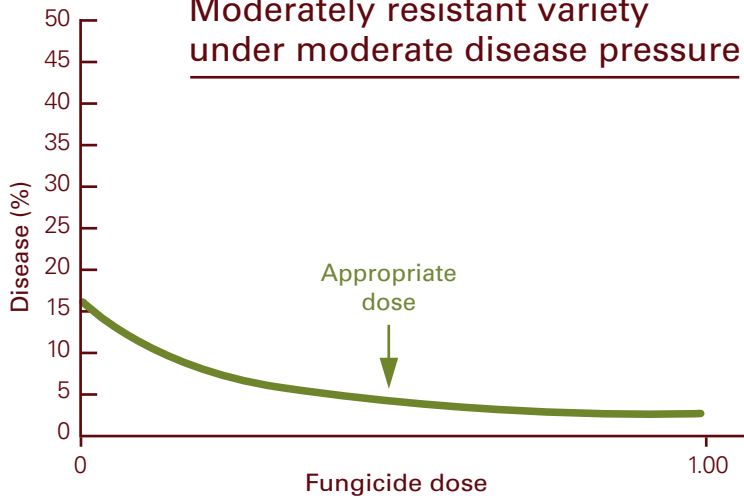
However, crop tolerance to disease (ie the yield loss from a given level of disease) and fungicide effectiveness also modify the appropriate dose.

To help in selecting the appropriate dose, see cereals.ahdb.org.uk/disease

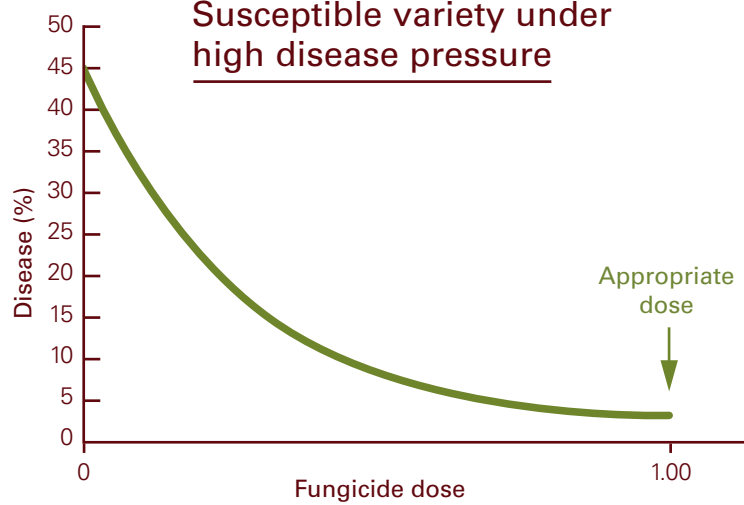
For the latest dose-response curves, see the Information Sheet, *Fungicide activity and performance in barley*, which is updated annually.



Moderately resistant variety under moderate disease pressure



Susceptible variety under high disease pressure



Fungicide decision guide

Winter barley While there are four key timings when a spray may be used, most winter barley crops are adequately protected by T1 and T2 sprays.

Spray timing	Rationale	Product choice (adjust dose to suit risk)
Autumn/ Winter	Rarely necessary unless extensive disease affects overwintering capability or in high-risk snow rot crops.	If possible, avoid azoles to minimise resistance risk. Powdery mildew – morpholine, cyprodinil Brown rust – morpholine Rhynchosporium – morpholine, cyprodinil, chlorothalonil Net blotch – cyprodinil Snow rot – epoxiconazole
T0 GS23–29 Early spring	Useful time to start control of established disease on susceptible varieties. Yield responses vary, depending on disease pressure.	If possible, avoid azoles to minimise resistance risk. Powdery mildew – morpholine, cyprodinil Brown rust – morpholine Rhynchosporium – cyprodinil, morpholine, chlorothalonil Net blotch – cyprodinil
T1 GS30–31	Main fungicide timing to control all foliar and stem-base diseases. 60% of response to fungicide is achievable at this timing. Target will be to eradicate established disease and provide protection until the next timing.	Rhynchosporium – prothioconazole, epoxiconazole, SDHI, strobilurin, cyprodinil, chlorothalonil Net blotch – azole, strobilurin, cyprodinil, SDHI Powdery mildew – morpholine, proquinazid, cyflufenamid, SDHI/azole mixtures may also provide some protection Eyespot – boscalid, cyprodinil, prothioconazole Brown rust – azole, most strobilurins, SDHI
T2 GS39–59	Good timing to protect upper leaves against brown rust, ramularia and net blotch. 40% of yield response comes from this timing. Rhynchosporium risk is lower except in wetter western regions and in wet summers. Higher yield responses can occur where late brown rust or ramularia epidemics occur and where harvest is later (ie north UK). Take care if using eradicant mildew fungicides, since they sometimes reduce green leaf area.	Rhynchosporium – azole, strobilurin, cyprodinil, SDHI, chlorothalonil Net blotch – azole, strobilurin, cyprodinil, SDHI Ramularia – prothioconazole, epoxiconazole, chlorothalonil, SDHI Brown rust – azole, most strobilurins, SDHI Fusarium – prothioconazole, epoxiconazole, tebuconazole, metconazole

Spring barley There are three key timings at which a spray might be considered. Most spring barley crops are adequately protected by one or two sprays applied at T2 and/or T1.

Spray timing	Rationale	Product choice (adjust dose to suit risk)
T0 GS12–22	Powdery mildew present on susceptible variety and timing coincides with herbicide application.	Powdery mildew – morpholine, proquinazid, cyflufenamid
T1 GS25–31	Good timing to protect against rhynchosporium, brown rust, net blotch and mildew. 40% of yield response to fungicides comes from this timing.	Rhynchosporium – prothioconazole, epoxiconazole, strobilurin, cyprodinil, chlorothalonil, SDHI Net blotch – azole, strobilurin, cyprodinil, SDHI Powdery mildew – morpholine, proquinazid, cyflufenamid, SDHI/azole mixtures may also provide some protection Eyespot – boscalid, cyprodinil, prothioconazole Brown rust – azole, most strobilurins, SDHI
T2 GS39–59	Best timing to protect upper leaves from disease. 60% of yield response to fungicides comes from this timing.	Rhynchosporium – azole, strobilurin, cyprodinil, SDHI, chlorothalonil Net blotch – azole, strobilurin, cyprodinil, SDHI Ramularia – prothioconazole, epoxiconazole, chlorothalonil, SDHI Brown rust – azole, most strobilurins, SDHI

Further information

AHDB Cereals & Oilseeds information

Publications and details of projects funded by AHDB Cereals & Oilseeds are all available at cereals.ahdb.org.uk

Information on the efficacy of individual products is updated annually with a range of online resources. Always consult the AHDB Cereals & Oilseeds website for the latest information.

Guides

AHDB Recommended Lists for cereals and oilseeds (annual)

- G67 Barley growth guide (2015)
- G62 Encyclopaedia of pests and natural enemies in field crops (2014)
- G34 Guidelines to minimise the risk of fusarium mycotoxins in cereals (2014)
- P05 Nozzle selection chart (2010)
- G49 Cereal growth stages – a guide for crop treatments (2009)
- G41 The encyclopaedia of cereal diseases, AHDB/BASF (2008)
- G63 Wheat disease management guide (2016)

Information Sheets

- IS42 Controlling aphids and virus diseases in cereals and oilseed rape (2015)
- IS40 Risk assessment for fusarium mycotoxins in wheat (2015)
- IS33 Ergot in cereals (2014)
- IS21 Ramularia leaf spot in barley (2013)
- TS106 Rhynchosporium control programmes (2011)

Current AHDB Cereals & Oilseeds-funded projects

- 3517 Improved tools to rationalise and support stewardship programmes for SDHI fungicides to control cereal diseases in the UK
- 3573 Improved modelling of fusarium to aid mycotoxin prediction in the UK
- 3751 United Kingdom Cereal Pathogen Virulence Survey (UKCPVS)
- 3773 Identification and characterisation of *Rhynchosporium* genes activating barley resistance
- 3779 Monitoring of Mycotoxins and other contaminants in UK cereals used in malting, milling & animal feed
- 3800 Consequences of intensification or integration of fungicide use for resistance management and sustainable disease control
- 3801 Assessing the resistance risks associated with systemic fungicide seed treatments
- 3804 Supporting UK malting barley with improved market intelligence on grain skinning
- 214-0006 Fungicide performance in wheat, barley and oilseed rape

Project Reports

- PR549 Integrated strategy to prevent mycotoxin risk: Inspyr (2015)
- PR541 Assessing the impact of the restrictions on the use of neonicotinoid seed treatments (2015)
- PR539 Impact of climate change on disease in susceptible arable crop systems: CLIMDIS (2015)
- PR524 Improving resource use efficiency of barley by protecting sink capacity (2013)
- SR23 Study of *Fusarium langsethiae* infection in UK cereals (2013)
- RR77 Implications of the restriction on the neonicotinoids: imidacloprid, clothianidin and thiamethoxam on crop protection in oilseeds and cereals in the UK (2013)
- PR500 Improving risk assessment to minimise fusarium mycotoxins in harvested oats and malting barley (2012)
- PR486 Role of inoculum sources in *Rhynchosporium* population dynamics and epidemics on barley (2012)
- PR482 Screening for QoI resistance in UK populations of *Rhynchosporium secalis* (2011)
- PR470 Targeting winter and spring barley disease management (2010)
- PR463 Managing *Ramularia collo-cygni* through varietal resistance, seed health and forecasting (2010)
- PR457 Understanding ergot risk in spring barley (2009)
- PR431 Impact and interactions of *Ramularia collo-cygni* and oxidative stress in barley (2008)

Other information

British Society of Plant Breeders – www.bspp.co.uk

Chemicals Regulation Directorate – www.pesticides.gov.uk

CropMonitor – www.cropmonitor.co.uk

Crop Protection Association – www.cropprotection.org.uk

Food Standards Agency – www.food.gov.uk

Fungicide Resistance Action Committee (FRAC) – www.frac.info

Fungicide Resistance Action Group (FRAG-UK) – www.pesticides.gov.uk/guidance/industries/pesticides/advisory-groups/Resistance-Action-Groups/frag

Insecticide Resistance Action Committee (IRAC) – www.irac-online.org

Insecticide Resistance Action Group (IRAG) – www.pesticides.gov.uk/guidance/industries/pesticides/advisory-groups/Resistance-Action-Groups/irag

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