## Introduction

Many diseases challenge the yield, quality and hence profitability of barley and so need to be controlled effectively.

In the UK, barley crops range from September-sown 6-row feed varieties to spring-sown 2-row varieties for malting. Regardless of variety, sowing date, location or market, disease management in barley aims to maximise grain numbers by protecting tillering and ear formation.

Barley is fundamentally different to wheat and different approaches are therefore required to manage disease.

This guide aims to provide barley growers with up-to-date information on diseases that affect their crop and options for control.

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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 four UK governments within the EU-wide framework.

EU member countries can prescribe stricter standards than the EU minimum. Thus 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 none 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.

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 or 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.

Farmers must declare any use of farm-saved seed to the British Society of Plant Breeders (BSPB). All varieties are eligible for farm-saved seed payment. 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.
Seed sampling, testing and treatment

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.

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 (see table below for number of samples required).
- Thoroughly mix all samples from a lot in a clean bucket; divide to create a composite sample for testing. Alternatively, consider employing a trained agronomist to undertake sampling.

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 test (TZ) is recommended. However, this does not detect chemical damage and could over-estimate germination after pre-harvest glyphosate.

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.
- Test for seedling blights if seedbeds potentially cold.

<table>
<thead>
<tr>
<th>Regulatory standards and advisory thresholds</th>
<th>Regulatory standard</th>
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<td>Method</td>
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<tr>
<td>Loose smut Ustilaginoidea f.sp. hordei</td>
<td>Embryo extraction</td>
<td>48 hours</td>
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<tr>
<td>Leaf stripe Pyrenophora graminea</td>
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<td>Net blotch Pyrenophora teres f. sp. teres</td>
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<tr>
<td>Ergot Claviceps purpurea</td>
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<td>Covered smut Ustilaginoidea hordei</td>
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<td>Seedling blights Microdochium nivale</td>
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<td>Fusarium graminearum Cochliobolus sativus</td>
<td>Agar plate</td>
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<td></td>
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<td>7–10 days</td>
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Primary samples required for given lot sizes

<table>
<thead>
<tr>
<th>Lot size (tonnes)</th>
<th>Primary samples required</th>
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<td>10</td>
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<td>20–30</td>
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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.

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.
- Conditions that slow germination (eg cold, overcompacted or waterlogged seedbeds) increase seedling transmission.

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.
- Soil-borne infection.
**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.

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**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.

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**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.

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**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, surrounded by a yellow halo, on both sides of the leaf. 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.
- Wet weather at flowering.
Rhynchosporium
– *Rhynchosporium secalis*

**Symptoms**
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. Typical symptoms on leaves are pale water-soaked lesions that develop into typical brown necrotic patches with dark margins.

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

**Risk factors**
– Varietal susceptibility.
– Wet weather.
– Proximity to debris from previous barley crops.

*See also page 12.*

**Seed treatment – To treat or not to treat**

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<td><strong>Germination test</strong></td>
<td><strong>Considering sowing untreated?</strong></td>
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<tr>
<td><strong>Does loose smut exceed 0.5% or 2% if farm-saved seed?</strong></td>
<td><strong>Is grain damaged, eg heat, glyphosate?</strong></td>
</tr>
<tr>
<td><strong>Does leaf stripe exceed 2%?</strong></td>
<td><strong>DO NOT USE FOR SEED</strong></td>
</tr>
<tr>
<td><strong>Does net blotch exceed 10%?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Do seedling diseases exceed advisory standards (page 4)?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Very low risk of seed-borne disease. Consider sowing seed untreated.</strong></td>
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*Leaf stripe, net blotch and seedling disease can all be determined from the same agar plate test.*
### Seed treatment – Options

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<td></td>
<td>loose smut</td>
<td>leaf stripe</td>
</tr>
<tr>
<td>carboxin, thiram</td>
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<td>Deter Bayer</td>
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<td>sithiofam</td>
<td>Latitude Monsanto</td>
<td>winter</td>
<td>✓</td>
<td>✓</td>
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</table>

* Products expire 30 May 2011
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 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).

**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.

**Crop development and growth – definitions**

<table>
<thead>
<tr>
<th>Development</th>
<th>Changes in crop structure, controlled by temperature accumulated since sowing and daylength. Development is not affected by disease.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth</td>
<td>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.</td>
</tr>
</tbody>
</table>

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.

**Yield increases as grain number/m² increases**

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

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

\[
\text{Yield increases as grain number/m}^2 \text{ increases}
\]
Winter barley spray timing

<table>
<thead>
<tr>
<th>Ear number</th>
<th>Tiller production</th>
<th>Tiller loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain number per ear</td>
<td>Spikelet production</td>
<td>Spikelet loss</td>
</tr>
<tr>
<td>Canopy size</td>
<td>Green canopy production</td>
<td>Canopy senescence</td>
</tr>
<tr>
<td>Grain growth</td>
<td></td>
<td>Grain filling</td>
</tr>
</tbody>
</table>

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

### Winter barley spray timing

**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.**

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

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

**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.**

**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.**
Spring barley spray timing

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 numbers 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.
**Foliar diseases – Rhynchosporium**

*Rhynchosporium secalis*

Visible levels of disease of 1-2% at GS31-32 will result in an economic loss if left untreated. UK survey data indicates that in 2005 farm crops had 0.6% Rhynchosporium on leaf 2 at GS75, which equates to a national yield loss worth £4.8 million (at £100/t) despite treatment.

**Life cycle**

In winter barley, symptoms can occur in autumn as random patches as a result of infection from rain splash 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 with rain splash spores during wet and windy weather.

**Risk factors**

- Cool, wet weather favours the disease, hence it is most common in the north and west UK.

Disease sources are seed, trash, volunteers and airborne spores.

**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 triazole, 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 boot stage (GS49) – a mixture of chlorothalonil or SDHI with a triazole should be considered.

The HGCA barley disease management guide 2011
**Foliar diseases – 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 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**
- **Seedling infection**
- **Airborne spores from cereal hosts**
- **Lesions on dead lower leaves**
- **Spread to upper leaves**
- **Conidia**
- **Under stress – symptoms on upper leaves**

Ramularia is seed-borne, spreading to new leaves without visible symptoms. Symptoms usually appear when the crop is stressed. Then spores are released following a period of leaf wetness. Although these spores can cause secondary infections, they 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. Some spring varieties show better resistance, eg Decanter, NFC Tipple and Belgravia.

**Cultural**
- Prevent N stress/deficiency.

**Fungicides**
Current seed treatments have little effect on disease development.

Triazoles, eg prothioconazole and epoxiconazole, applied at the boot stage before symptoms appear, provide effective control and protect upper leaves. Using a triazole in mixture with boscalid, isopyrazam, bixafen or chlorothalonil achieves the best control. Strobilurins are no longer effective due to fungicide resistance.
Foliar diseases – Net blotch

*Pyrenophora teres*

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.

UK survey data indicates that in 2005 farm crops had an average infection of 0.85% on leaf 2 at GS75 which equates to a national yield loss of £6.8 million (at £100/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**

HGCA Recommended Lists provide resistance ratings for winter barley varieties, but data is limited for spring types. 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 triazole prothioconazole and the SDHI fungicides boscalid, isopyrazam, or bixafen remain the most effective.

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

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.
Foliar diseases – 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) can occur in April–June leading 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.

UK survey data indicate that between 2001 and 2005 farm crops had an average of 0.3% on leaf 2 at GS75 which equates to a national yield loss of £2.4 million a year (at £100/t) despite treatment.

**Life cycle**

- **Pustules of brown uredia erupt from the leaf releasing uredospores**
- **Slow disease development in spring – infection by wind-borne uredospores**
- **Most rapid spread occurs at high temperature, late in the season**
- **Teliospores produce basidia and basidiospores. Aecidal stage found on alternate host (Ornithogalum) but rare in UK**
- **Late in the season black telia form on leaf surface**
- **Overwinters on volunteers**

**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 varietal resistance can break down so any extensive outburst will require fungicide treatment.

**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, triazoles 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.
Foliar diseases – Yellow rust

*Puccinia striiformis f.sp. hordei*

**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**
- **Spring**: Early infection of plants by wind-borne uredospores.
- **Summer**: Pustules erupt releasing uredospores. Disease spread by wind dispersal.
- **Autumn**: Teliospores produce basidia and basidiospores (no alternate host known).
- **Late in the season**: Black telia form on leaves.

**Risk factors**
- Susceptible varieties.
- Cool, wet weather in an early spring before fungicides applied.

**Control**

**Varieties**
Effective varietal resistance means yellow rust is rare nowadays.

**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, triazoles 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.

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

*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**
UK survey data indicate that between 2001 and 2005 farm crops had an average of 0.3% on leaf 2 at GS75 which equates to a national yield loss worth £2.4 million a year (at £100/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 in 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.

**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, cyfluconazole) 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 both short-term knockdown and longer-term protection.

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

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. Popular malting barley varieties are however susceptible and control relies on protectant and eradicant fungicides.

In some varieties adult plant resistance, which starts to become effective during stem extension, reduces infection on upper leaves.
Stem-base diseases – 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**

Conidia splash from debris to young plants. Ascospore infection of autumn sown crops

‘Eyespot’ lesion on stem base

Lesions cause whiteheads and sometimes lodging

Sexual stage on straw debris may result in long distance spread of ascospores

**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 *The wheat disease management guide*, HGCA 2011).

**Control**

**Varieties**

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

**Cultural**

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

**Fungicides**

Several fungicides (eg prothioconazole, boscalid and epoxiconazole, and cyprodinil) are effective against both *Rhynchosporium* and eyespot when used at stem extension (GS31-32).
Ear diseases and mycotoxins

Ear diseases

Specific ear and grain diseases (e.g., Botrytis, Fusarium, Microdochium nivale, and sooty moulds including Alternaria and Cladosporium) are encouraged by wet weather during flowering and grain filling.

Foliar diseases (e.g., 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 (e.g., loose smut) can affect the ear. Seed treatments control these diseases.

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 few fungicides are approved for use after ear emergence.

Ergot

Claviceps purpurea

Ergot can develop in the ear of any cereal crop, but it is less common in barley than 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 man 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 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, HGCA (2010)).

HGCA has also produced a Fusarium mycotoxin risk assessment tool to help identify wheat crops at risk (www.hgca.com/mycotoxins). 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. These mycotoxins are produced by different fungi, e.g. Fusarium langsethiae, which are favoured by drier conditions, so risk factors are different for T-2 and HT-2 compared 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).

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.
Virus diseases – Barley yellow dwarf virus (BYDV)

Caused by an aphid-borne luteovirus

Infected plants cannot be cured, so methods to prevent infection and limit spread are necessary.

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

BYDV is transmitted by the grain aphid and the bird cherry aphid. Grain aphids feed on cereal crops and grasses all year round. 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, and tends to be restricted in cold winters to milder coastal areas.

Risk factors
Risk in winter crops is greatly increased by:
– early crop emergence.
– mild winters
– sowing after grass
Spring-sown crops can also be infected, but substantial yield loss is rare.

Control
The only control option is to prevent infection and reduce its spread.

Cultural
Good stubble hygiene, or a gap of five weeks between ploughing and sowing, will help prevent transmission via the ‘green bridge’ (ie aphids on grass weeds and volunteers).

Natural enemies include spiders, ground beetles and parasitoid wasps. Grass banks and uncultivated field margins encourage natural enemies, but can also provide a refuge for infective aphids. Therefore, the overall benefit may be unclear.

Chemical
Chemical control aims to prevent wingless second and third generation aphids spreading disease within the crop.

Development time for each generation depends on temperature. It requires an accumulated sum of 170 day-degrees above 3°C to produce a generation (the ‘T-sum 170’). Treatments timed to coincide with the production of second generation aphids in a crop, ie at T-sum 170, are most cost-effective because they control the maximum number of aphids before any secondary spread can occur. The T-sum 170 is calculated from either the time of emergence of the crop or from the end of the protection afforded by seed treatment (six weeks from sowing).

Treatments at T-sum 340 are sometimes justified on early-emerged crops where winged aphid immigration continued after the T-sum 170 spray was applied.

Early emerged crops are most at risk of BYDV infection. Decisions on whether to treat crops emerging in September must be made by the start of October. The treatment window is wider for later-emerging crops.
Virus diseases – Soil-borne mosaic viruses

**Barley yellow mosaic virus**  
**Barley mild mosaic virus**

These virus diseases, very common in Britain 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**

- **Polymyxa graminis** forms intercellular plasmodia and resting spores.
- Virus particles multiply in the plant causing leaf chlorosis and stunting.
- Yellow stunted plants in patches in winter and spring.
- Symptoms fade as temperature rises.
- Resting spores in roots.
- **Polymyxa graminis** zoospores, carrying virus particles, infect root hairs in autumn/winter.

**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 HGCA Recommended List).

**Cultural**  
Cleaning cultivation equipment between fields will reduce the risk of the virus spreading.
Assessing disease risk – The basis

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 ‘field resistance’, ie the ability of the crop to resist or avoid infection.

Crop management
The diagram below summarises the effect of various crop management practices on disease risk. For example, a dense crop, early sown using min-till following barley would be at very high risk of Rhynchosporium.

<table>
<thead>
<tr>
<th></th>
<th>Rhynchosporium</th>
<th>Ramularia</th>
<th>Net blotch</th>
<th>Rusts</th>
<th>Mildew</th>
<th>Eyespot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early sown</td>
<td>↑↑</td>
<td>↑↑</td>
<td>↑↑</td>
<td></td>
<td></td>
<td>↑↑</td>
</tr>
<tr>
<td>High N/dense crop</td>
<td>↑</td>
<td>↓↓</td>
<td>↑↑</td>
<td>↑</td>
<td>↑</td>
<td>↑↑</td>
</tr>
<tr>
<td>Min-till, if following barley</td>
<td>↑↑</td>
<td></td>
<td>↑↑</td>
<td>↑</td>
<td>↑</td>
<td>↑↑</td>
</tr>
</tbody>
</table>

Disease inoculum
Key sources of inoculum differ for each disease. However, they generally include seed, trash, soil, volunteers, and airborne spores and are primarily governed by frequency of previous cropping, either in the same field or the vicinity.
Assessing disease risk – Weather and region

Rhynchosporium
- Favoured by cool, wet conditions

Ramularia
- Favoured by wet June and July

Net blotch
- Favoured by wet and humid conditions
- Regional distribution varies with seasons

Brown rust
- Favoured by warm temperatures (15–22°C) and dew formation

Mildew
- Favoured by mild, humid conditions

Eyespot
- Favoured by spring rainfall
Assessing disease risk – Varieties

HGCA Recommended List trials assess disease susceptibility and yield across the UK each year. These provide a clear guide of the strengths and weaknesses of different varieties and help in selection of varieties with resistance to diseases prevalent in specific regions.

Robust fungicide programmes are used in RL trials to maximise varietal potential. Comparing treated and untreated yields provides a useful indication of total yield response to fungicides.

Varieties with larger differences between treated and untreated yield will usually need higher fungicide inputs to achieve their yield potential.

In both winter and spring barley 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.

On the 1 – 9 scales high figures indicate that a variety shows the character to a high degree (eg high resistance). [ ] = limited data.

The BaYMV column refers to winter barley resistance to barley yellow mosaic virus strain 1.

Source: HGCA Recommended Lists 2011/12
Assessing disease risk – 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 (as indicated by high resistance ratings on the HGCA Recommended List).

– Diversifying the varieties grown so they are not all susceptible to the same mildew race, using the Variety Diversification Scheme.

Choosing varieties to grow together

1. Select a first-choice variety and find its Diversification Group (DG).
2. Go to the selection matrix and find this DG under ‘Chosen DG’ on the left-hand side of the table.
3. Read across the table to find the risk of spread of mildew for each companion DG.

<table>
<thead>
<tr>
<th>Diversification group</th>
<th>Winter varieties</th>
<th>Spring varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>DG1</td>
<td>DG10</td>
<td>Propino, Panther, Quench, Shuffle, Concerto, Moonshine, NFC Tipple, Publican, Belgravia, Westminster, Summit, Garner, Waggon, Scout</td>
</tr>
<tr>
<td>DG10</td>
<td>Saffron, Boost</td>
<td>DG14</td>
</tr>
<tr>
<td>DG14</td>
<td>Cassata, Winsome, Flagon, Purdey, Pearl, Retriever, KWS Cassia, Florentine, Suzuka, Volume, Element, Escadre, Pelican</td>
<td></td>
</tr>
<tr>
<td>DG0</td>
<td>DG10</td>
<td>DG14</td>
</tr>
<tr>
<td>DG0</td>
<td>DG10</td>
<td>DG14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variety diversification scheme for barley mildew, 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chosen</td>
</tr>
<tr>
<td>DG</td>
</tr>
<tr>
<td>DG</td>
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<tr>
<td>DG</td>
</tr>
<tr>
<td>DG</td>
</tr>
<tr>
<td>DG</td>
</tr>
</tbody>
</table>

4. Wherever possible choose combinations of varieties marked ‘L’. A combination marked ‘M’ is a lower risk than one marked ‘H’.

5. If there is a choice of varieties in a companion DG, give preference to those with higher resistance ratings (see 1-9 ratings on HGCA Recommended List).

Source: UK Cereal Pathogen Virulence Survey, funded by HGCA and Defra
### Fungicide activity against major diseases

Performance is scored according to whether spray is applied before (protectant) or after (eradicant) disease becomes established. In high disease pressure situations, effective eradication will be difficult with any fungicide.

<table>
<thead>
<tr>
<th>Chemical group</th>
<th>Active ingredient</th>
<th>Activity rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rhynchosporium</td>
</tr>
<tr>
<td>Amidoxine</td>
<td>cyflufenamid</td>
<td>★★★★</td>
</tr>
<tr>
<td>Anilinopyrimidine</td>
<td>cyprodinil</td>
<td>★★★</td>
</tr>
<tr>
<td>Benzophenone</td>
<td>metrafenone</td>
<td>★★★★</td>
</tr>
<tr>
<td>Chloronitrile</td>
<td>chlorothalonil</td>
<td>★★★</td>
</tr>
<tr>
<td>Imidazole</td>
<td>prochloraz</td>
<td>★</td>
</tr>
<tr>
<td>Morpholine</td>
<td>fenpropimorph</td>
<td>★★★</td>
</tr>
<tr>
<td></td>
<td>fenpropidin</td>
<td>★★★</td>
</tr>
<tr>
<td>Quinolene</td>
<td>quinoxyfen</td>
<td>★</td>
</tr>
<tr>
<td>Quinazolinone</td>
<td>proquinazid</td>
<td>★★★</td>
</tr>
<tr>
<td>Spiroketalamine</td>
<td>spiroxamine</td>
<td>★★★★★</td>
</tr>
<tr>
<td>Strobilurin</td>
<td>azoxystrobin</td>
<td>★</td>
</tr>
<tr>
<td></td>
<td>picoxystrobin</td>
<td>★★★★</td>
</tr>
<tr>
<td></td>
<td>pyraclostrobin</td>
<td>★★★★</td>
</tr>
<tr>
<td></td>
<td>trifloxystrobin</td>
<td>★</td>
</tr>
<tr>
<td>Strobilurin mixtures</td>
<td>prothioconazole + fluoxastrobin</td>
<td>★★★★★</td>
</tr>
<tr>
<td></td>
<td>kresoxim-methyl + epoxiconazole</td>
<td>★★★★</td>
</tr>
<tr>
<td></td>
<td>kresoxim-methyl + fenpropimorph</td>
<td>★★★★</td>
</tr>
<tr>
<td>SDHI** mixtures</td>
<td>boscalid + epoxiconazole</td>
<td>★★★★</td>
</tr>
<tr>
<td></td>
<td>isopyrazam + cyprodinil</td>
<td>★★★★</td>
</tr>
<tr>
<td></td>
<td>bixafen + prothioconazole</td>
<td>★★★★★</td>
</tr>
<tr>
<td>Triazole</td>
<td>cyproconazole</td>
<td>★</td>
</tr>
<tr>
<td></td>
<td>epoxiconazole</td>
<td>★★★</td>
</tr>
<tr>
<td></td>
<td>flusilazole</td>
<td>★</td>
</tr>
<tr>
<td></td>
<td>metconazole</td>
<td>★</td>
</tr>
<tr>
<td></td>
<td>propiconazole</td>
<td>★</td>
</tr>
<tr>
<td></td>
<td>prothioconazole</td>
<td>★★★★</td>
</tr>
<tr>
<td></td>
<td>tebuconazole</td>
<td>★</td>
</tr>
</tbody>
</table>

*Spots not associated with any known fungi, but which can be reduced by fungicide treatment.
**Succinate Dehydrogenase Inhibitor
### Active ingredients for barley disease control

<table>
<thead>
<tr>
<th>No</th>
<th>Active ingredient</th>
<th>Example products – single ai</th>
<th>Example products – more than one ai</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>azoxystrobin</td>
<td>Amistar</td>
<td>Amistar Opti, Amistar Pro, Priori Xtra</td>
</tr>
<tr>
<td>2</td>
<td>bixafen</td>
<td>Only available in mixtures</td>
<td>Siltra Xpro</td>
</tr>
<tr>
<td>3</td>
<td>boscalid</td>
<td>Only available in mixtures</td>
<td>Chord, Deuce, Splice, Totem, Tracker, Venture</td>
</tr>
<tr>
<td>4</td>
<td>chlorothalonil</td>
<td>Bravo 500, Joules</td>
<td>Alto Elite, Amistar Opti, Cherokee, Credo, Mida, Octolan, Zimbrair</td>
</tr>
<tr>
<td>5</td>
<td>cyflufenamid</td>
<td>Cyflamid</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>cyproconazole</td>
<td>Centaur</td>
<td>Alto Elite, Alto Extra, Cherokee, Furlong, Menara, Octolan, Priori Xtra, Radius, Sphere</td>
</tr>
<tr>
<td>7</td>
<td>cyprodinil</td>
<td>Kayak, Unix</td>
<td>Acanto Prima, Bontima, RADIUS</td>
</tr>
<tr>
<td>8</td>
<td>epoxiconazole</td>
<td>Epic, Ignite, Opus, Rubric</td>
<td>Brustus, Capalo, Ceando, Chord, Cloister, Covershield, Deuce, Diamant, Eclipse, Ennobe, Envoy, Gemstone, Icarus, Landmark, Mantra, Opera, Opponent, Opus Team, Seguris, Splice, Totem, Tracker, Venture</td>
</tr>
<tr>
<td>9</td>
<td>fenpropidin</td>
<td>Tern, Instinct</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>fenpropimorph</td>
<td>Corbel</td>
<td>Amistar Pro, Capalo, Colstar, Diamant, Eclipse, Ensign, Jenton, Mantra, Opera Team, Orka, Pluton</td>
</tr>
<tr>
<td>11</td>
<td>fluoxastrobin</td>
<td>Only available in mixtures</td>
<td>Fandango, Jaunt, Maestro</td>
</tr>
<tr>
<td>12</td>
<td>flusilazole</td>
<td>Capitan 25, Genie 25, Lyric, Punch 25, Sanction 25</td>
<td>Charisma, Coltrast, Contrast, Harvestan, Medley, Mida, Plun, Punch C</td>
</tr>
<tr>
<td>13</td>
<td>isopyrazam</td>
<td>Only available in mixtures</td>
<td>Bontima, Seguris</td>
</tr>
<tr>
<td>14</td>
<td>kresoxim-methyl</td>
<td>Only available in mixtures</td>
<td>Covershield, Ensign, Landmark, Mantra, Opponent</td>
</tr>
<tr>
<td>15</td>
<td>metconazole</td>
<td>Caramba, Caramba 90, Juventus, Sunorg Pr</td>
<td>Brustus, Icarus</td>
</tr>
<tr>
<td>16</td>
<td>metrafenone</td>
<td>Attenzo, Flexity</td>
<td>Capalo, Ceando, Cloister</td>
</tr>
<tr>
<td>17</td>
<td>picoxy-strobin</td>
<td>Galileo</td>
<td>Acanto Prima, Credo, Furlong, Zimbrai</td>
</tr>
<tr>
<td>18</td>
<td>prochlorozine</td>
<td>Mirage 40 EC, Poraz</td>
<td>Agate, Bumper P Ennobe, Monkey, Vareon</td>
</tr>
<tr>
<td>19</td>
<td>propiconazole</td>
<td>Anode</td>
<td>Bumper P, Cherokee, Cogito, Menara</td>
</tr>
<tr>
<td>20</td>
<td>proquinazid</td>
<td>Justice, Talius</td>
<td>Vareon</td>
</tr>
<tr>
<td>21</td>
<td>prothioconazole</td>
<td>Proline, Proline 275</td>
<td>Cello, Fandango, Helix, Jaunt, Maestro, Mobius, Proximo, Siltra Xpro, Spiral, Zephyr</td>
</tr>
<tr>
<td>22</td>
<td>pyraclostrobin</td>
<td>Comet, Comet 200, Flyer, Platoon 250, Tucana, Vivid</td>
<td>Covershield, Diamant, Envoy, Gemstone, Jenton, Opera, Opponent</td>
</tr>
<tr>
<td>23</td>
<td>quinoxyfen</td>
<td>Apres, Erysto, Fortress</td>
<td>Orka</td>
</tr>
<tr>
<td>24</td>
<td>spiroxamine</td>
<td>Torch, Torch Extra</td>
<td>Cello, Helix, Sage, Spiral</td>
</tr>
<tr>
<td>25</td>
<td>tebuconazole</td>
<td>Folicur</td>
<td>Agate, Cello, Cogito, Monkey, Proximo, Sage, Silvacur, Vareon</td>
</tr>
<tr>
<td>26</td>
<td>trifloxystrobin</td>
<td>Swift</td>
<td>Jaunt, Mobius, Sphere, Zephyr</td>
</tr>
</tbody>
</table>

**Product | No | Product | No**
---|---|------------------|---
Acanto Prima | 7, 17 | Jaunt | 11, 21, 26
Agate | 18, 25 | Jenton | 10, 22
Alto Elite | 4, 6 | Joules | 4
Alto Extra | 6 | Justice | 20
Amistar | 1 | Juventus | 15
Amistar Opti | 1, 4 | Kayak | 7
Amistar Pro | 1, 10 | Landmark | 8, 14
Anode | 19 | Lyric | 12
Apres | 23 | Maestro | 11, 21
Attenzo | 16 | Mantra | 8, 10, 14
Bontima | 7, 13 | Medley | 12
Bravo 500 | 4 | Menara | 6, 19
Brutus | 8, 15 | Mida | 4, 12
Bumper P | 18, 19 | Mirage 40 EC | 18
Capito 25 | 8, 10, 16 | Mobius | 21, 26
Caramba | 15 | Monkey | 16, 25
Caramba 90 | 15 | Octolan | 4, 6
Ceando | 8, 16 | Opera | 8, 22
Cello | 21, 24, 25 | Opponent | 8, 14, 22
Centaur | 6 | Opus | 8
Charisma | 12 | Opus Team | 8, 10
Chord | 3, 8 | Orka | 10, 23
Cloister | 8, 16 | Platoon 25 | 22
Cognito | 19, 25 | Pluton | 10, 12
Colstar | 10, 12 | Poraz | 18
Capitan 25 | 12 | Prior Xtra | 1, 6
Caramba | 15 | Proline | 21
Charisma | 3, 8 | Proline 275 | 21
Chord | 8, 16 | Proximo | 21
Cloister | 12, 18 | Plun | 21
Cogo | 19, 25 | Prof | 21
Covershield | 8, 14, 22 | Puro | 21
Credo | 4, 17 | Puro Team | 21
Cytamid | 5 | Prover | 21
Deuce | 3, 8 | Rubric | 8
Diamant | 10, 12 | Sago | 24, 25
Eclipse | 8, 10 | Sanctioin 25 | 12
Ennobe | 8, 18 | Seguris | 8, 13
Ensino | 19, 24 | Siltra Xpro | 2, 21
Envoy | 8, 22 | Silvacur | 25
Epic | 8 | Sphere | 6, 26
Erysto | 23 | Spiral | 21, 24
Fandango | 11, 21 | Splice | 3, 8
Flexity | 8 | Sunorg Pro | 15
Flyer | 16 | Swift | 26
Folicur | 22 | Talus | 20
Fortress | 25 | Terr | 9
Furlong | 6, 17 | Torch | 24
Galileo | 17 | Torch Extra | 24
Gemstone | 8, 22 | Totem | 3, 8
Genie 25 | 12 | Tracker | 3, 8
Harvestan | 12 | Tucana | 22
Helix | 21, 24 | Unis | 7
Icarus | 8, 15 | Vareon | 18, 20, 25
Ignite | 8 | Vareon | 18, 20, 25
Instinct | 9 | Vareon | 18, 20, 25
Zephyr | 21, 26 | Zephyr | 21, 26
Zimbrai | 4, 17 | Zimbrai | 4, 17

The HGCA barley disease management guide 2011
Determining appropriate dose

Fungicides are rigorously tested in HGCA-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.

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.

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 the Fungicide performance tool on the HGCA website: www.hgca.com/diseasecontrol

The dose-response curve

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.
Fungicide performance curves

All curves based on 2009-2010 data
Fungicide performance curves

Brown rust curves based on 2008-2009 data
Mildew and Ramularia curves based on 2009-2010 data
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 strobilurins) means the risk of resistance occurring is greater than with older ones (eg chlorothalonil) with less specific activity.

**Resistance to strobilurins** is widespread in barley pathogens. However, the effectiveness of fungicides against different pathogens varies:
- powdery mildew and Ramularia – strobilurins no longer effective.
- net blotch – still some activity, especially from pyraclostrobin and picoxystrobin.
- Rhynchosporium – resistance has been detected in France but not in the UK.
- rusts – no resistance has been detected and control remains effective.
- *Microdochium nivale* – resistance is now widespread in the UK.

**Triazole resistance** results in reduced efficacy over seasons.
- powdery mildew – the first disease to develop triazole resistance. Some of the newer triazoles 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.

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

**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 (www.pesticides.gov.uk/rags.asp)
## 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.

<table>
<thead>
<tr>
<th>Spray timing</th>
<th>Rationale</th>
<th>Product choice and dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>Rarely necessary unless extensive disease affects overwintering capability or in high risk snow rot crops.</td>
<td>Use doses at 30–40%. If possible avoid triazoles to minimise resistance risk. Powdery mildew – fenpropimorph, spiroxamine, fenpropidin Brown rust – fenpropimorph, spiroxamine, fenpropidin Rhynchosporium – cyprodinil, fenpropimorph, spiroxamine, fenpropidin Net blotch – cyprodinil Snow rot – epoxiconazole</td>
</tr>
<tr>
<td>T0 GS23-30 Early spring</td>
<td>Useful time to start control of established disease on susceptible varieties. Yield responses vary, depending on disease pressure.</td>
<td>Use doses at 30–40%. If possible avoid triazoles to minimise resistance risk. Powdery mildew – fenpropimorph, spiroxamine, fenpropidin Brown rust – fenpropimorph, spiroxamine, fenpropidin Rhynchosporium – cyprodinil, fenpropimorph, spiroxamine, fenpropidin Net blotch – cyprodinil</td>
</tr>
<tr>
<td>T1 GS30-32 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.</td>
<td>Use dose of 40–60% for triazole. For other fungicides in mixture use at 30–50% dose. Rhynchosporium – prothioconazole, epoxiconazole, boscalid (in mixture), bixafen, isopyrazam, strobilurin, cyprodinil, chlorothalonil Net blotch – triazole, strobilurin, cyprodinil, boscalid, bixafen, isopyrazam Powdery mildew – fenpropimorph, spiroxamine, metrafenone, proquinazid, cyfluconamid Eyespot – boscalid (in mixture), cyprodinil, prothioconazole</td>
<td></td>
</tr>
<tr>
<td>T2 GS39-49 Good timing to protect upper leaves against brown rust, Ramularia and net blotch. Rhynchosporium risk will be lower except in wet summer. Take care if using eradicant mildew fungicides, since they sometimes reduce green leaf area. 40% of yield response comes here. Higher responses occur where late brown rust or Ramularia and where later harvests (ie north UK).</td>
<td>Use dose of main fungicide at 30–50%. Use other fungicides in mixture at 30–50%. Rhynchosporium – triazole, strobilurin, cyprodinil, boscalid, bixafen, isopyrazam Net blotch – triazole, strobilurin, cyprodinil, boscalid, bixafen, isopyrazam Ramularia – prothioconazole, epoxiconazole, chlorothalonil, boscalid, bixafen, isopyrazam Brown rust – triazole, most strobilurins, boscalid, bixafen, isopyrazam</td>
<td></td>
</tr>
<tr>
<td>GS59 Only use if no spray at GS39-49. Protection from ear disease (not malting barley). Fungicides choice is more limited.</td>
<td>Fusarium – prothioconazole, epoxiconazole, and some strobilurins</td>
<td></td>
</tr>
</tbody>
</table>
# Fungicide decision guide – 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.

<table>
<thead>
<tr>
<th>Spray timing</th>
<th>Rationale</th>
<th>Product choice and dose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T0</strong> GS12-22</td>
<td>Powdery mildew present on susceptible variety and timing coincides with herbicide application.</td>
<td><strong>Powdery mildew</strong> – fenpropimorph, spiroxamine, metrafenone, proquinazid</td>
</tr>
</tbody>
</table>
| **T1** GS25-31 | Good timing to protect against Rhynchosporium, brown rust, net blotch and mildew. 40% of yield response to fungicides comes from treatments applied now. | **Rhynchosporium** – prothioconazole, epoxiconazole, boscalid (in mixture), strobilurin, cyprodinil, chlorothalonil, bixafen, isopyrazam  
**Net blotch** – triazole, strobilurin, cyprodinil, bixafen, isopyrazam  
**Powdery mildew** – fenpropimorph, spiroxamine, metrafenone, proquinazid, cyflamid  
**Eyespot** – boscalid (in mixture), cyprodinil, prothioconazole |
| **T2** GS39-49 | Best timing to protect upper leaves from disease. 60% of yield response to fungicides comes from treatments applied now. | **Rhynchosporium** – triazole, strobilurin, cyprodinil, bixafen, isopyrazam  
**Net blotch** – triazole, strobilurin, cyprodinil, bixafen, isopyrazam  
**Ramularia** – prothioconazole, epoxiconazole, chlorothalonil, boscalid (in mixture), bixafen, isopyrazam  
**Brown rust** – triazoles, most strobilurins, bixafen, isopyrazam |
### Further information

HGCA publications and details of HGCA-funded projects are all available on the HGCA website – www.hgca.com

#### HGCA Guides

**HGCA Recommended Lists for cereals and oilseeds**, HGCA (annual)

- **G34** Guidelines to minimise the risk of fusarium mycotoxins in cereals, HGCA (2010)

- **P05** Nozzle selection chart, HGCA (2010)

**G41** The encyclopaedia of cereal diseases, HGCA/BASF (2008)

- **G30** The barley growth guide, HGCA (2006)

- **G14** Pest management in cereals and oilseeds, HGCA (2003)


#### HGCA Topic Sheets

- **PP15** Fungicide performance in oilseed rape, HGCA (2010)

- **TS104** Managing fusarium mycotoxin risk in wheat – changes for harvest 2009, HGCA (2009)

- **TS97** Ramularia leaf spot in barley, HGCA (2007)

- **TS57** Necrotic spots in barley: causes and control, HGCA (2002)

#### HGCA Project Reports

- **PR415** Investigation of Fusarium mycotoxins in UK barley and oat production (2007)

- **PR431** Impact and interactions of *Ramularia collo-cygni* and oxidative stress in barley (2008)

- **PR436** Understanding fungicide mixtures to control Rhynchosporium in barley and minimise resistance shifts (2008)

- **PR455** Appropriate fungicide doses on winter barley: producing dose-response data for a decision guide (2009)

- **PR457** Understanding ergot risk in spring barley (2009)

- **PR463** Managing *Ramularia collo-cygni* through varietal resistance, seed health and forecasting (2010)

- **PR470** Targeting winter and spring barley disease management (2010)
Current projects

3187 United Kingdom Cereal Pathogen Virulence Survey (UKCPVS)

3370 Rhynchosporium on barley: understanding the relationship between barley varietal resistance, fungicide resistance and the influence of seed-borne infection

3441 Control of Ramularia leaf spot (CORACLE)

3453 Integrated strategy to prevent mycotoxin risks

3458 Improving resource use efficiency in barley through protecting sink capacity

3462 Fungicide performance information for barley growers

3479 Study of Fusarium langsethiae infection of cereals

3517 Improved tools to rationalise and support stewardship programmes for SDHI fungicides to control cereal diseases in the UK

3685 Occurrence and subsequent expression of two seed-borne diseases in Northern Ireland’s barley seed stock

Websites

Information on the efficacy of individual products will be updated annually with a range of online resources. Always consult the HGCA website for the latest versions.

HGCA – www.hgca.com

- Fungicide performance tool www.hgca.com/diseasecontrol
- Fusarium mycotoxin risk assessment (www.hgca.com/mycotoxins)
- RL Plus (www.hgca.com/varieties/r-plus)
- The UK Cereal Pathogen Virulence Survey
- Variety diversification scheme for yellow rust
- The Encyclopaedia of Cereal Diseases (www.hgca.com/cde)

British Society of Plant Breeders – www.bspb.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
Liaison – https://secure.fera.defra.gov.uk/liaison
Fungicide Resistance Action Committee (FRAC) – www.frac.info
NIAB-TAG – www.niab.com
SAC – www.sac.ac.uk/crops
Science and Advice for Scottish Agriculture – www.sasa.gov.uk
The Voluntary Initiative – www.voluntaryinitiative.org.uk
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