Introduction

This updated *Wheat disease management guide* brings together the latest information on controlling economically important wheat diseases. Foliar, stem-base, root and ear diseases are covered. The guide now includes a section on ensuring good seed health – particularly relevant if you are home-saving seed.

Reliance on repeated fungicide sprays has increased the pressure for development of fungicide resistance. Some important mode of action groups have lost activity against major diseases. The guide describes how to account for varietal resistance when making spray decisions.

Most energy, greenhouse gas and economic costs are invested in crop establishment and nitrogen application, in order to grow green canopy. It is important to prevent diseases destroying green area before it can re-pay the investment during grain filling.

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 *Septoria tritici* is now *Mycosphaerella graminicola*). However, in some cases the original scientific names have become widely used to describe the diseases they cause (eg Septoria tritici or Septoria leaf blotch) – distinguished from Latin names by not being in italics. In general the most widely used common names are given in this guide.

<table>
<thead>
<tr>
<th>Most recent name</th>
<th>Previous name</th>
<th>Commonly called</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mycosphaerella graminicola</strong></td>
<td><em>Septoria tritici</em></td>
<td><em>Septoria tritici</em></td>
</tr>
<tr>
<td><strong>Stagonospora nodorum</strong></td>
<td><em>Septoria nodorum</em></td>
<td><em>Septoria nodorum</em></td>
</tr>
<tr>
<td>or <em>Phaeosphaeria nodorum</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Blumeria graminis</strong></td>
<td><em>Erysiphe graminis</em></td>
<td><em>Powdery mildew</em></td>
</tr>
<tr>
<td><strong>Puccinia triticina</strong></td>
<td><em>Puccinia recondita</em></td>
<td><em>Brown rust</em></td>
</tr>
</tbody>
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**Further information**

The *HGCA/BASF Encyclopaedia of Cereal Diseases* (2008) illustrates and describes symptoms and life cycles of common and less frequently found diseases.  
www.hgca.com/cde
Certified seed
All seed bought and sold in the UK must be certified. Wheat quality standards (including varietal and species purity, germination, loose smut and number of pieces of ergot) are prescribed in the Cereal Seed Regulations which are issued as statutory instruments by the UK governments within the EU-wide framework. These prescribe minimum quality standards but also allow member countries to set stricter standards.

In the UK, ‘HVS’ (Higher Voluntary Standard) seed is certified to higher standards for varietal and species purity, ergot contamination and loose smut. HVS seed is sold at a premium over EU standard seed.

Seed can be certified at various stages as a variety is commercialised. Certified seed of the second generation (C2) is the normal category for commercial crop 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, currently rare in UK wheat, and ergot but there are none for seed-borne bunt or fungal seedling blights. Although not a requirement of certification, in practice most certified seed is treated; which diseases are controlled depends 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.

Farmers must declare any use of farm-saved seed to the British Society of Plant Breeders (BSPB). Most varieties are eligible for payment; the list is available at www.bspb.co.uk. Payments must be made via a registered processor or directly to BSPB. Payments for previously zero rated varieties will be refunded immediately but declarations of these varieties are subject to verification by BSPB.

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

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 seed-borne diseases.
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 bunt contamination.
- Keep grain intended for sowing separate from larger grain bulks.
- Only use seed from one field to reduce variability within a seed lot.
- Sub-divide 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.

**Primary samples required for given lot sizes**

<table>
<thead>
<tr>
<th>Lot size (tonnes)</th>
<th>Primary samples required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 5*</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>20–30</td>
<td>40</td>
</tr>
</tbody>
</table>

*Seed treatment should only be used where necessary but with small seed lots it may be cheaper to treat than to sample and test for seed-borne diseases.

**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 low germination caused by disease damage, but gives a good indication of potential germination after treatment for seedling blights.

**Seed health testing**

- Never sow untreated seed without testing for seed-borne diseases, particularly bunt and Microdochium seedling blight.
- Test for ergot, loose smut, Septoria seedling blight and Fusarium graminearum if a problem is suspected.

**Regulatory standards and advisory thresholds**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Method</th>
<th>Duration</th>
<th>Results given as</th>
<th>Regulatory Standard</th>
<th>Advisory threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunt</td>
<td>Wash</td>
<td>48 hours</td>
<td>Spores per seed</td>
<td>A</td>
<td>Treat if 1 spore/seed or more</td>
</tr>
<tr>
<td></td>
<td>Molecular test</td>
<td>48 hours</td>
<td>Either over or under 1 spore/seed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microdochium seedling blight</td>
<td>Agar plate</td>
<td>7–10 days</td>
<td>% infection</td>
<td>A</td>
<td>Treat if over 10% infection</td>
</tr>
<tr>
<td></td>
<td>Molecular</td>
<td>48–72 hours</td>
<td>Either over or under 10% infection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Septoria and Fusarium seedling blights</td>
<td>Agar plate</td>
<td>7–10 days</td>
<td>% infection</td>
<td>A</td>
<td>Treat if over 10%</td>
</tr>
<tr>
<td>Ergot</td>
<td>Visual 500g or 1000g search</td>
<td>24 hours</td>
<td>Number of pieces in 500g or 1000g</td>
<td>Maximum pieces: 3 pieces/500g – minimum standard</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Molecular test</td>
<td>48–72 hours</td>
<td>Either over or under infection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loose smut</td>
<td>Embryo extraction</td>
<td>48 hours</td>
<td>% infection in 1000 embryos (advisory) or 2000 embryos (certification)</td>
<td>Maximum infection: 0.5% – minimum standard</td>
<td>0.2% – HVS</td>
</tr>
</tbody>
</table>

Treat for seedling blights when sum of infection levels exceeds 10%.

At present seedling blight caused by Cochliobolus sativus is a low risk in UK wheat.
Seed-borne diseases

Bunt *Tilletia tritici*

**Symptoms**
Symptoms appear after ears emerge. Plants are often stunted and sometimes have yellow streaks along the flag leaf. Infected ears are dark grey-green with slightly gaping glumes. Bunt balls replace all grains and, if broken, release millions of black spores smelling of rotten fish.

**Importance**
Bunt occurs at low levels in some seed stocks. Contaminated grain may cause rejection.

**Life cycle**
Spores on the seed surface germinate with seeds. After invading shoots and growing points, the fungus grows within the plant until ear emergence when bunt balls replace grain. The spores contaminate healthy grain during harvest, transport and storage. Spores can land on soil or spread by wind to neighbouring fields. Soil-borne spores can invade seedlings very early in germination.

**Risk factors**
Seed-borne infection:
- Seed repeatedly sown without a fungicide treatment.
- Seedbed conditions leading to slow emergence.

Soil-borne infection:
- Very short time between harvesting first wheat and sowing second wheat.
- Dry soil conditions between harvesting and sowing.

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Microdochium seedling blight

*Microdochium nivale and majus*

**Symptoms**
The most common symptom of a serious attack is poor establishment. The fungus can also cause root rotting, brown foot rot, leaf blotch and, in combination with *Fusarium* species, ear blight.

**Importance**
In most years Microdochium seedling blight occurs on wheat seed and is the most important cause of seedling blight in the UK. Sowing untreated seed with high levels of infection causes very poor crop establishment leading to yield loss.

**Life cycle**
Inoculum (spores) are found in soil and on infected seed. Spores, released when seedling blight or stem-base browning occurs, are splashed up the plant and ultimately infect the ear.

**Risk factors**
- Wet weather during flowering.
- High level of seed infection.
- Untreated seed sown into poor seedbeds.
- Late-sown crops.

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Septoria seedling blight

*Phaeosphaeria nodorum*

**Symptoms**
The most common effect is poor plant establishment. Symptoms are so similar to those of Microdochium seedling blight that only laboratory analysis can distinguish them. Septoria nodorum is more commonly associated with necrotic blotching of leaves and glumes.

**Importance**
Effects of Septoria seedling blight are usually less severe than Microdochium seedling blight. However, at high levels crop establishment can be badly affected.

**Life cycle**
While the disease can survive on plant debris, most infections result from seed-borne inoculum.

**Risk factors**
- High seed infection levels.
- Untreated seed sown into poor seedbeds.
- Cool, wet soils.
Seed-borne diseases

**Fusarium seedling blight**

*Fusarium graminearum*

**Symptoms**
Poor plant establishment is the most common effect together with root rotting, brown foot rot and ear blight.

**Importance**
At present *Fusarium graminearum* is the only *Fusarium* species that causes significant seedling losses in the UK.

**Life cycle**
Inoculum occurs mainly on crop debris, but can be seed-borne. Spores are splashed up the plant to infect ears.

**Risk factors**
- High levels of seed infection.
- Sowing untreated seed into poor seedbeds.
- Maize in the rotation.

**Ergot**

*Claviceps purpurea*

**Symptoms**
A hard, purple-black sclerotium, up to 2cm long, replaces some grains in the ear.

**Importance**
Yield is hardly affected but ergot is highly poisonous to man and animals, so contaminated grain will be rejected or require cleaning. Standards for number of ergot pieces exist for certified seed.

**Life cycle**
At or near harvest, ergots fall to the ground, or are spread with contaminated seed. They remain dormant until the following summer, when they germinate and produce spores, encased in sticky ‘honeydew’. Spores spread by wind to open grass and cereal flowers nearby. Rain splash or insects carry spores to other flowers, leading to further infection.

**Control**
No fungicide is effective against ergot. In the absence of host crops, ergots decay over 12 months. Check weed grasses and field margins for ergot. Consider ploughing between host crops and break crops. Control cereal volunteers and grass weeds.

**Risk factors**
- Any factor that slows germination and emergence, eg poor seedbeds.
- Extended periods of warm, moist weather.

**Loose smut**

*Ustilago nuda f. sp. tritici*

**Symptoms**
The ear is usually completely replaced by black fungal spores. Sometimes ears are partly affected. Spores are released as soon as the ear emerges leaving a bare ear rachis with total grain loss. Blackened ears are so obvious that very low incidences appear severe.

**Importance**
Seed certification and resistant varieties have minimised seed-borne infection.

**Life cycle**
The fungus is present inside the embryo. As seed germinates the fungus grows within the plant and infects the ear at an early 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.

**Risk factors**
- Cool, moist conditions during flowering.
- Infected neighbouring crops.
- Seed repeatedly sown without treatment.
Seed treatment – To treat or not to treat

Certified seed

Farm-saved seed

Germination test

85% plus

78–84%

Under 78%

Considering sowing untreated?

Is heat damage present?

DO NOT USE FOR SEED

Does bunt exceed 1 spore/seed?

NO

Do combined seedling diseases exceed 10%?

NO

YES

YES

Very low risk of seed-borne disease. Consider sowing seed untreated.

Treat seed with an appropriate product (see page 9)

Test seed for bunt and Microdochium seedling blight. Test for Septoria seedling blight if Septoria nodorum present in the growing crop.

Test seed for bunt and Microdochium seedling blight.
# Seed treatment – Product choice

<table>
<thead>
<tr>
<th>Active ingredient</th>
<th>Product</th>
<th>Seed-borne diseases</th>
<th>Other diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Bunt</td>
<td>Seedling blights</td>
</tr>
<tr>
<td>carboxin, thiram</td>
<td>Anchor Ch</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>clothianidin</td>
<td>Deter By</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>clothianidin, prothioconazole</td>
<td>Redigo Deter By</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>difenconazole, fludioxonil</td>
<td>Celest Extra Sy</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>fludioxonil</td>
<td>Beret Gold Sy</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>fludioxonil, flutriafol</td>
<td>Beret Multi Sy</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>fludioxonil, tefluthrin</td>
<td>Austral Plus Sy</td>
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<td>✓</td>
</tr>
<tr>
<td>fluquinconazole</td>
<td>Galmano By</td>
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<td>✓</td>
</tr>
<tr>
<td>fluquinconazole</td>
<td>Jockey Solo Bs</td>
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<td>✓</td>
</tr>
<tr>
<td>fluquinconazole, prochloraz</td>
<td>Galmano Plus By</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>fluquinconazole, prochloraz</td>
<td>Jockey Bs</td>
<td>✓</td>
<td>✓</td>
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<tr>
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<td>✓</td>
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<td>ipconazole</td>
<td>Rancona 15ME Ch</td>
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<td>✓</td>
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<td>prothioconazole</td>
<td>Redigo By</td>
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<td>✓</td>
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<td>Kinto Bs</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>silthiofam</td>
<td>Latitude Mo</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Key to company:**
- Bs=BASF
- By=Bayer CropScience
- Ch=Chemtura
- Mo=Monsanto
- MA=Makhteshim-Agan
- Sy=Syngenta

- ✓ label recommendation
- ✓ some known activity, but no label recommendation
Foliar diseases – Impact on yield formation

Most foliar diseases accelerate senescence of the top three leaves and so reduce yield. Fungicide sprays during canopy growth prevent green leaf area loss during grain filling.

**Construction phase**

**Canopy growth:** Canopy expansion accelerates in April/May as temperatures rise and large upper leaves emerge. The maximum green area of leaves and stems (measured as green area index – GAI) is reached as ears emerge, just before grain filling begins.

**Stem reserve accumulation:** During stem extension, stored soluble carbohydrates accumulate in the stem.

Applying sprays during this critical phase – at T1 (GS32) and T2 (GS39) – limits disease progress and protects emerging upper leaves, so maximising photosynthesis later.

**Production phase**

**Grain filling:** In this six to seven week period, up to 80% of yield comes from photosynthesis. On bright days, yield typically increases by 0.2t/ha/day. In this phase, stem reserve relocation accounts for 20% of grain filling.

A fungicide at full ear emergence may help prevent premature leaf loss.

Flag leaf and ear contribute 65% of total yield
Foliar diseases – Infection and development

Initial infection
Infection usually results from spores moving into the crop. When this occurs depends on the disease. For example by spring, Septoria tritici is present on the lower leaves of most crops.

Disease development
Infection is followed by a ‘latent period’ when the fungus grows within the leaf but the leaf exhibits no symptoms.

The cycle of leaf emergence, infection, latent period and symptom expression applies to all foliar diseases. The latent period varies considerably between pathogens and is affected by temperature. At higher temperatures, latent periods are shorter.

Septoria tritici has a very long latent period (14–28 days). Many modern fungicides can control disease after a leaf becomes infected but only for about half of the latent period. In the summer, Septoria tritici may have a latent period of 14 days, but fungicides provide eradicant control for only about seven days. Although there may be no symptoms on a leaf, infection may be so far into the latent period that no fungicide at any dose will control the fungus.

Importance of spray timing and latent period

Infection from within crops
As stems extend and upper leaves emerge, the crop tends to grow away from the disease. Newly emerged leaves always appear free from Septoria tritici between GS32 and GS39. However, the crucial final three leaves are at risk as soon as they emerge. By this stage, most inoculum comes from within the crop and spore movement from other fields is much less important. Rusts and powdery mildew have very short latent periods and can be found before leaves have fully expanded. In the absence of fungicide use, the final severity of disease is determined by variety and weather.
Foliar diseases – Spray timing

Foliar treatments
To ensure adequate protection of the key yield forming leaves, fungicide treatments should be targeted to leaf emergence, rather than growth stage. Full emergence of leaf 3 usually coincides with GS32 but this can vary between crops. Very early sowing can lead to leaf 3 emerging as late as GS33, but leaf 3 may emerge at GS31 in late-sown crops. Thus, leaf emergence is the best guide for decisions on spray timings. With practice, this can be assessed quickly in the field. Growth stages provide a second best option.

Spray window
The ‘spray window’ for effective disease control on a particular leaf layer is relatively narrow. The optimum spray timing is when a leaf has just fully emerged.
- Spraying too early, when the leaf is not fully emerged, results in insufficient spray on the leaf and thus poor control.
- Spraying too late means the disease is already established and results in poor control, especially with protectant fungicides.

Main timings
T1 timing – Leaf 3 emerged (usually coincides with GS32, but can be as early as GS31 or as late as GS33).
T2 timing – Flag leaf emerged (GS39)
Applying both T1 and T2 sprays at optimal timings gives effective disease control on the top three leaves – those most important in grain filling.

Additional timings
T0 timing – Usually two to four weeks earlier than T1.
Instances where a T0 spray may be considered include:
- to delay Septoria tritici development
- where mildew, yellow or brown rusts are active
- when eyespot requires earlier treatment.
T3 timing – Ear spray
May be used to control ear diseases and ‘top-up’ foliar disease control on the flag leaf on susceptible varieties under high disease pressure.

Effects of spray timing on disease control
The optimum T1 spray gives maximum disease control on leaf 3, and provides some protection for leaf 2.
The optimum T2 spray gives maximum disease control on the flag leaf and eradicates any latent infections on leaf 2 that have escaped earlier sprays.

The figures above were produced from trials. Sprays were applied at frequent intervals across a range of growth stages. Each curve shows the level of control achieved on each of the top three leaves for the spray timings from GS31 to GS59. The interval between T1 and T2 is important. Disease control on upper leaves will be lost if the interval extends beyond three weeks, especially when diseases with short life cycles, e.g. rusts or powdery mildew, are active.
**Foliar diseases – Septoria tritici**

*Mycosphaerella graminicola*

*sometimes known as leaf blotch*

### Symptoms

In autumn and winter, brown oval leaf spots (lesions) occur on older leaves which contain the diagnostic small black fruiting bodies (pycnidia). Several lesions may turn large areas of leaf brown. In spring and summer, lesions are usually rectangular and confined by leaf veins. Leaf lesions are often surrounded by areas of leaf yellowing or death. During rapid development, water-soaked lesions gradually turning brown may be present.

### Importance

Septoria tritici is the most damaging foliar disease of UK wheat, causing significant yield loss every year. Infection occurs in all crops. Unusually dry weather throughout May and June may reduce losses. Higher rainfall areas in the south and west are most at risk.

National survey data over the past ten years indicates that crops had an average of 5.3% Septoria tritici on leaf 2 at GS75, despite treatment, representing an annual yield loss worth £49 million (at £100/t).

### Life cycle

Airborne spores disperse in autumn/winter from previous wheat stubbles. These ascospores infect leaves to produce leaf spots from mid-autumn onwards and then spread by rain splash and physical contact between leaves.

### Risk factors

- Susceptible varieties.
- Early sowing.
- Rainfall: high risk Septoria periods occur during ‘splashy’ or prolonged rain, especially in May and early June. Mild winters and wet, windy conditions in early spring increase risk.

### Control

#### Varieties

The HGCA Recommended List contains varieties with resistance ratings from 5 to 8 so a fungicide treatment is likely to be necessary in most instances. However, a lower dose is required for effective control on more resistant varieties.

#### Cultural

Avoid very early sowing of susceptible varieties.

#### Fungicides

Control relies on using robust rates of azole fungicides at T1 and T2, in mixture with a fungicide of a different mode of action; usually an SDHI (bixafen, isopyrazam or boscalid) and/or chlorothalonil.

Resistance to strobilurin products is widespread and they are unlikely to be effective.

Some systemic seed treatments (eg fluquinconazole) may give limited early control.
**Foliar diseases – Septoria nodorum**

*Phaeosphaeria (Stagonospora) nodorum*
sometimes known as leaf and glume blotch

**Symptoms**
On leaves, symptoms are mainly oval brown lesions with a small yellowish halo. Pale brown, rather than black, pycnidia distinguish Septoria nodorum from Septoria tritici. The indistinct brown pycnidia may be only visible when lesions are held up to the light. Under high disease pressure, leaf symptoms can include small purplish-brown spots.

On ears, symptoms are typically purplish-brown blotches on glumes.

**Importance**
Although Septoria nodorum is widespread, it is now rare for severe attacks to occur; when they do it is usually associated with high rainfall at ear emergence (e.g. south-west Britain). Here yield losses in untreated crops may exceed 50%.

**Life cycle**
The pathogen survives in crop residues, volunteers and wild grasses. It can be seed-borne. Airborne ascospores from wheat stubbles spread infection to newly-emerged crops.

Secondary spread occurs when pycnidiospores, produced within leaf spots, are dispersed by rain splash.

Symptoms appear within 7–14 days. The disease can develop very rapidly in warm temperatures (20–27°C) with long periods (6–16 hours) of high humidity.

**Risk factors**
- Susceptible varieties.
- High rainfall during and after ear emergence.
- South-west and coastal locations.

**Control**

**Varieties**
The HGCA Recommended List contains varieties with resistance ratings from 4 to 9. Resistant varieties are preferred in high risk areas.

**Cultural**
Ploughing or cultivation to bury crop residues after harvest may provide some control.

**Fungicides**
T1 and T2 sprays applied to control other diseases usually control Septoria nodorum on the leaves. When risk is high, a T3 protectant ear spray is important.
Foliar diseases – Yellow (stripe) rust

*Puccinia striiformis*

**Symptoms**
Groups of yellow pustules forming stripes between veins are the main symptoms. Under hot, dry conditions – or after fungicide use – pustules may be difficult to detect.

In spring, small patches (foci) of leaves with scattered yellow pustules precede rapid spread throughout the field. Ears can also be affected.

**Importance**
New races developed in 2009; as a result over 30% of the 2010 crop was rated 4 or less for yellow rust. Severe epidemics can occur where large areas of susceptible varieties are grown. In untreated susceptible varieties, yellow rust can reduce yields by over 50%. However, well-timed fungicide sprays are usually very effective so annual losses are small.

Outbreaks often occur in coastal areas from Essex to the Borders and central England.

**Life cycle**
Epidemics are associated with mild winters that enable the pathogen to overwinter in crops and volunteers. Cold winters with severe frosts restrict its survival.

In early spring distinct foci may occur; secondary spread is through airborne spores as well as leaf-to-leaf contact. Cool (10–15°C), damp weather, with overnight dew or rain, provides optimum conditions for disease development.

UK weather conditions are unlikely to limit development in spring or early summer. Symptoms appear 7–14 days after infection so leaf tips may show symptoms before leaves fully emerge. Hot, dry weather with temperatures over 25°C limit development.

**Risk factors**
- Large variation between years in epidemic risk.
- Overwinter survival is critical.
- Problems occur after mild winters and on susceptible varieties.
- Cold winters with several frosts below -5°C reduce survival.
- New races continue to develop that overcome the major gene resistance of some new varieties.

**Control**

**Varieties**
Varieties with resistance ratings of 7 and 8 on the HGCA Recommended List give effective control and may be less prone to sudden loss of resistance than varieties with a rating of 9. The wheat yellow rust diversification scheme is designed to help growers choose combinations of varieties in such a way as to reduce the risk of crop loss due to disease spreading from one variety to another.

**Cultural**
Control volunteers that provide a ‘green bridge’ between harvest and emergence of new crops.

**Fungicides**
Azole and most strobilurin products are very effective, some SHDIs also have good activity.

Systemic seed treatments (eg fluquinconazole or triadimenol) may delay epidemic development where risk is high.
**Foliar diseases – Brown (leaf) rust**

*Puccinia triticina*

**Symptoms**
Most commonly seen as tiny orange-brown pustules scattered over leaves. During autumn and winter few pustules, confined to older leaves, may be seen. While the pustules can be a similar colour to those of yellow rust, they usually have a chlorotic halo.

Late in the season brown rust can become very severe and cause leaf death. Leaf sheaths and ears are also affected. Black spots occur on maturing crops when pustules produce a second, teliospore stage.

**Importance**
There is large seasonal and geographic variation in brown rust severity. The disease is more common in southern and eastern England on susceptible varieties.

National survey data over the past ten years indicates farm crops had an average of 0.15% brown rust on leaf 2 at GS75, representing an annual yield loss worth £1.4 million (at £100/t). In 2007, a season when brown rust was prevalent, the cost was £11.2 million.

**Life cycle**
Brown rust overwinters in crops and on volunteers. It spreads by means of airborne spores. Cold winters may reduce its survival.

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 appear in 5–6 days at optimum temperatures. The disease is active over a wider range of temperature (7–25°C) than yellow rust.

**Risk factors**
- Seasonal weather – the disease is normally most active when June and July temperatures are high. (However, in 2007 above average spring temperatures led to unusually early epidemics.)
- High humidity is necessary for epidemic progress.
- Susceptible varieties.
- Early sowing.
- New races continue to develop that overcome the major gene resistance of some new varieties.

**Control**

**Varieties**
Resistant varieties provide good control. Varieties on the HGCA Recommended List have ratings from 3 – 9. These can change over time as new races of brown rust appear. Most current UK wheat varieties are very, or moderately, susceptible, but some have good resistance.

**Cultural**
Control volunteers that provide a ‘green bridge’ between harvest and emergence of new crops. Susceptible varieties should not be sown early in September.

**Fungicides**
Products containing azoles, strobilurins and SDHIs are very effective. In a programme, treatment intervals should not exceed three to four weeks; they should be substantially shorter under high disease pressure.

Systemic seed treatments (eg fluquinconazole) may help delay epidemics developing where risk is high. However, seed treatments are likely to provide less control of brown rust than yellow rust.
Foliar diseases – Tan spot

Pyrenophora (Drechslera) tritici-repentis

Symptoms
Tan spot symptoms are variable. Small tan, or brown, flecks develop into pale-brown oval spots with dark centres. These lesions sometimes have a chlorotic halo. Numerous lesions can coalesce into large necrotic areas. Symptoms are very similar to those of Septoria nodorum and diagnosis relies on spore identification.

Importance
Tan spot is still a minor UK disease, but appears to be becoming more common. Some severe cases have occurred in recent years. It is a major problem in Sweden, Denmark, Germany and France, and it is perhaps surprising that tan spot is not more widespread in the UK.

Life cycle
Like Septoria nodorum, tan spot is trash-borne and favoured by minimum tillage. Ascospores produced on stubble, probably in spring, introduce the disease into crops. Leaf lesions appear in 7–14 days and produce splash-dispersed asexual spores.

High temperatures (20–28°C) and rain causing long periods of leaf wetness are ideal for tan spot development.

Risk factors
- Minimum and non-inversion tillage.
- Long periods of wet weather from GS32 onwards.

Control

Varieties
Resistance ratings are not currently available.

Cultural
Ploughing or cultivation to bury infected crop residues.

Fungicides
Fungicidal control is difficult due to the short latent period.

Strobilurin resistance in tan spot has been confirmed elsewhere in Europe, and is likely to be present in the UK.
Foliar diseases – Powdery mildew

**Blumeria graminis**

**Symptoms**
White fluffy colonies of pustules often occur on leaves from autumn onwards. On yellowing leaves, pustules retain a distinctive ‘green island’. Severe mildew can cover almost the entire leaf surface and develop on ears and stems.

Later in the season, pin-head sized, black fruiting bodies (cleistothecia) that produce sexual spores (ascospores) may be found on the white colonies.

**Importance**
Mildew can develop over a wide range of conditions but is sporadic, often affecting crops under stress. Although very visible, it generally reduces yield much less than other foliar diseases. Damaging attacks can occur anywhere in the UK, but yield losses rarely exceed 10%.

National survey data over the past ten years indicates that farm crops had an average of 0.2% mildew on leaf 2 at GS75, representing an annual yield loss worth £1.9 million (at £100/t), despite treatment.

**Life cycle**
Airborne conidia, produced on crops or volunteers, enable mildew to spread widely. Warm (15–22°C), breezy conditions with short periods of high humidity favour infection. New pustules are produced in 5–14 days.

Temperatures over 25°C and rain can inhibit development. Sexually-produced spores provide a mechanism for summer survival when leaf growth has slowed.

**Risk factors**
- Susceptible variety.
- Sheltered fertile sites.
- High nitrogen.
- Warm dry, but humid, weather.

**Control**

**Varieties**
Most recommended varieties show moderate resistance although Claire, Conqueror and Solstice are rated 4 on the HGCA Recommended List.

**Cultural**
Avoid excessive nitrogen fertilisation.

**Fungicides**
Fungicides with specific activity against mildew are required where powdery mildew is a particular threat. Some treatments, applied at T0 or T1, provide long-term protection. Fungicide resistance is known to affect the performance of various fungicide groups (eg strobilurins, azoles, morpholines).

The HGCA/BASF Encyclopaedia of Cereal Diseases (www.hgca.com/cde) provides information on disease identification.

CropMonitor (www.cropmonitor.co.uk) provides information on disease prevalence and risk.
Root diseases – Take-all

*Gaeumannomyces graminis* var. *tritici*

**Symptoms**

Take-all can infect plants at a low level without causing obvious symptoms. However, moderate or severe infection reduces the number of active roots over winter, which restricts canopy growth. Infection of the crown (adventitious) roots in the spring and early summer restricts water and nutrient uptake, resulting in patches of whiteheads (bleached ears) as grain fills.

**Importance**

Take-all is the major cause of ‘second wheat syndrome’ when yields of second wheat crops are frequently 10–15% less than those of first wheats.

Take-all is usually most severe in the second to fourth successive cereal crop, but generally yields recover to some extent in continuous cereals – ‘take-all decline’.

Take-all causes most damage on light soils where loss of active roots has a large effect on water and nutrient uptake.

Even on chalky boulder clay soils with high water holding capacity, losses of 10% are common in second and third wheat crops. On less well-bodied soils yield losses can be much higher, so it may be uneconomic to grow second or subsequent wheat crops.

**Risk factors**

- High pH increases disease risk.
- Severe attacks can also occur in acid patches. Poor drainage, low nutrient status and particularly early sowing and light, puffy seedbeds, encourage the disease.
- Cereal volunteers and grass weeds, especially couch, in break crops will carry the disease through to following cereals.

**Control**

**Cultural**

Control relies largely on rotation and good soil management and husbandry. Reducing the severity in second and subsequent wheats is achieved by delaying drilling compared with first wheats, and maintaining good soil structure and nutrient levels.

**Varieties**

All varieties are susceptible to take-all but some are more tolerant in the presence of disease. The HGCA Recommended List yields for second wheats give some guidance to choosing the most suitable varieties for second and subsequent sowings. Yield responses reflect take-all tolerance and eyespot resistance. Varieties known to perform well as second wheats include Duxford, Grafton, JB Diego, Ketchum, KWS Santiago and Oakley.

**Fungicides**

Seed treatments, based on silthiofam and fluquinconazole, can help to reduce the effects of take-all, particularly when used in conjunction with cultural control measures. Seed treatments do not alter the optimum sowing date, but can delay the take-all epidemic, and reduce the yield penalty from sowing second wheats early.

Azoxystrobin or fluoxastrobin applied at T1 timing can help suppress take-all.

**Seed treatment does not alter optimum sowing date**


[www.hgca.com/publications](http://www.hgca.com/publications)
Stem-base diseases

Stem-base diseases can be difficult to distinguish, particularly early in the season when treatment decisions are made. Identification is necessary because eyespot is much more important than sharp eyespot (*Rhizoctonia cerealis*) and Fusarium foot rot. During stem extension, lesions caused by Fusarium and sharp eyespot are generally confined to the outer leaf sheath. Some fungicides give incidental sharp eyespot control but specific treatment is difficult to justify.

Eyespot

*Oculimacula acuformis (R type)*

*Oculimacula yallundae (W type)*

**Symptoms**

Eyespot affects the stem base of winter wheat from autumn onwards. Lesions appear as red-brown blotches. Mixed R and W type eyespot infections occur in most UK crops. Symptoms may disappear as leaf sheaths die off during spring growth, but can reappear later.

**Importance**

Eyespot reduces yield and quality by restricting water and nutrient uptake. Yield losses may be large, particularly in early-sown crops. Severe eyespot can cause lodging from weakened stems. Even without lodging, severe eyespot can reduce yield by 10–30%.

**Risk factors**

Eyespot development in crops is difficult to predict. The need for control can be based on estimating disease risk using local experience of incidence and weather. The visible presence of eyespot at stem extension is not the only indicator of risk. Risk is increased by ploughing, a preceding wheat or cereal crop in the rotation, heavy soils, and early sowing. There is a strong weather influence on disease development. Wet spring weather increases risk.

**Control**

**Varieties**

Eyespot-resistant varieties on the HGCA Recommended List include Battalion, Beluga, Cassius, Cocoon, Grafton, Istabraq, Humber, KWS Target and Stigg.

**Fungicides**

Good control is difficult to achieve and may be affected by the type of eyespot present. Many treatments only reduce severity.

Prothioconazole or boscalid (the latter in mix with epoxiconazole), control both eyespot and Septoria tritici well – a useful option at T1. Higher doses are usually required for eyespot control. Specific eyespot treatments should be applied at GS30-31 if high risk justifies early treatment.

Yield response to foliar disease control usually exceeds response from eyespot treatment. However, delaying treatment until GS32 – for better disease control on leaf 3 – may compromise eyespot control, especially if disease levels are high on susceptible varieties.

Some control may be achieved at GS37 if eyespot has not penetrated the stem base.

Estimating your eyespot risk

With funding from HGCA, SAC devised an eyespot risk model, summarised below, to help winter wheat growers.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Level</th>
<th>Risk points</th>
</tr>
</thead>
<tbody>
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<td>Sowing date</td>
<td>Before 6 October</td>
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<td></td>
<td>After 6 October</td>
<td>0</td>
</tr>
<tr>
<td>Eyespot infection at GS31–32</td>
<td>Under 7% tillers infected</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Over 7% tillers infected</td>
<td>10</td>
</tr>
<tr>
<td>Mean rainfall (mm) in March/April/May</td>
<td>Under 170mm</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Over 170mm</td>
<td>5</td>
</tr>
<tr>
<td>Tillage</td>
<td>Minimum tillage</td>
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</tr>
<tr>
<td></td>
<td>Plough</td>
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<tr>
<td></td>
<td>Heavy</td>
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<tr>
<td>Previous crop</td>
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<tr>
<td></td>
<td>Other cereal</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td>15</td>
</tr>
</tbody>
</table>

* add a further 5 points for brash and limestone soils

Use the table to estimate your total risk points. This approach gives you the flexibility to decide on the level of risk that you will accept.

Interpreting your total risk points

Threshold if you accept minimum risk

Threshold if you accept higher risk

Increasing need for treatment
Ear diseases

Diseases can affect grain quality by reducing grain filling, leading to low specific weights and shrivelled grain. Infections of *Fusarium* and *Microdochium* species may result in mycotoxins. Sooty moulds, and similar diseases, may affect grain appearance causing rejection for milling.

**Foliar diseases that affect the ear**

*Septoria nodorum* is potentially the most damaging to yield. In south-west England, foliar and ear infections can cause yield losses of up to 70%.

*Yellow rust*, in severe cases, infects ears.

*Brown rust* can also affect ears.

*Powdery mildew*, although very obvious on ears, does not cause large yield losses.

**Specific ear diseases**

*Sooty moulds* are caused by a mixture of fungi, mainly *Cladosporium* and *Alternaria* species, which grow on glume surfaces in wet weather or on prematurely ripened ears. They cause little yield loss but can discolour grain, which affects marketability, particularly for milling.

*Fusarium ear (or head) blights* are caused by a range of *Fusarium* species and *Microdochium nivale* and *Microdochium majus*. In recent years, there has been concern about the link between ear blights and the formation of mycotoxins.

In UK wheat, the main mycotoxin-producing species are *Fusarium culmorum*, *Fusarium graminearum* and *Fusarium avenaceum* which all produce similar symptoms. The presence of ear blight is not a good indicator of likely mycotoxin risk in UK crops.

Legislation imposes a limit for deoxynivalenol (DON) in grain for human consumption of 1250 parts per billion. In most years few UK grain samples have exceeded this limit.

Risk of mycotoxin formation can increase if:
- maize preceded the wheat crop
  - *NB* ploughing maize residues reduces risk
- wet weather occurred during flowering.

Fungicide treatment can help reduce ear blight and mycotoxin risk provided the recommended rate is used as near to infection time as possible.

**Seed-borne ear diseases**

Details of diseases such as bunt, ergot and smut can be found at pages 6 and 7.

**Control of ear diseases**

Sprays applied after ear emergence:
- top-up protection for flag leaf and leaf 2 against foliar disease
- protect the newly-emerged ear against foliar diseases
- protect against specific ear diseases
- limit mycotoxin accumulation.

Sprays applied around GS59 can help maintain canopy size and prolong its duration by protecting leaf and ear green area against disease. For ear blight control, spray during anthesis (GS61-65).

The T3 ear spray should be considered where it is necessary to ‘top-up’ disease control on the flag leaf and/or to protect the ear from disease. If no T3 spray is planned, it is important not to delay the T2 spray. Delaying the T2 spray to allow part of the ear to emerge will lead to poorer foliar disease control on the critical flag leaf and leaf 2.
**Barley yellow dwarf virus (BYDV)**

**Symptoms**
In wheat, infections cause leaf yellowing and stunting, initially confined to single plants scattered randomly in a field. Distinct circular patches develop later 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. Substantial yield loss is rare in spring-sown crops.

**Life cycle**
BYDV is transmitted by the grain aphid and the bird cherry aphid. Grain aphids fly into crops during late summer and autumn, spreading disease. The LT50 (lethal temperature for 50% mortality) for grain aphid is -8°C. The bird cherry-oat aphid is more frost-susceptible, with an LT50 of 0.5°C.

**Risk factors**
- Early crop emergence.
- Mild winters.
- Sowing after grass.

**Control**
Control measures aim to prevent infection and reduce spread.

**Cultural**
Good stubble hygiene and an interval of five weeks between ploughing and sowing help prevent transmission via the ‘green bridge’ (ie aphids on grass weeds and volunteers).

**Chemical**
Insecticidal seed treatments can provide four to six weeks’ protection for early-sown crops in high risk areas. 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. 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.

**Soil-borne cereal mosaic virus (SBCMV)**

**Soil-borne wheat mosaic virus (SBWMV)**

The viruses are transmitted by the soil-borne organism *Polymyxa graminis* and can remain viable in soil for at least 15 years. The viruses are spread by any movement of soil infested with *Polymyxa graminis* containing SBCMV or SBWMV particles.

**Symptoms**
Symptoms vary from pale green to prominent yellow streaks on leaves and leaf sheaths, accompanied by moderate to severe stunting. Infections usually occur in distinct patches that increase in size in successive years.

**Importance**
Mosaic virus is present in the UK but symptoms are not commonly found.

**Control**
Once land is infected by SBCMV or SBWMV, the only practicable means of control is to grow resistant varieties. Claire and Hereward have been shown to have resistance.
Assessing disease risk – The basis

Crop protection decisions need to be taken as upper leaves emerge, well before visible disease develops on yield-forming leaves. To estimate the likelihood of disease development, it is necessary to consider the balance between disease pressure and the field resistance of the crop.

The severity of future disease depends on disease pressure (determined by the amount of disease inoculum and weather) and the variety’s genetic ability to resist that pressure.

Disease forecasting is not very precise – it is sufficient to decide if risk of disease development is nil, low, moderate or high.

A higher fungicide dose is needed when disease pressure is high and varietal resistance is low. Conversely, a resistant variety facing low disease pressure may not require any treatment.

Disease inoculum

Disease lesions on lower leaves are the most common source of spores to infect upper leaves emerging during stem extension. Hence, if a particular disease cannot be found during field walking then the risk is low and no treatment is needed. Inspect the crop again one or two weeks later. However, if disease is visible, even at small amounts on lower leaves, the potential risk is high. Whether disease develops subsequently on upper leaves depends on varietal resistance, crop management and weather.

Crop management

The diagram below summarises the effect of various crop management practices on disease risk. For example, the highest risk of rusts would occur with:

- a susceptible variety
- established using min-till – which may allow infected volunteers to survive
- with high N uptake leading to a dense canopy.

<table>
<thead>
<tr>
<th>Crop management</th>
<th>Septoria tritici</th>
<th>Septoria nodorum</th>
<th>Brown rust</th>
<th>Yellow rust</th>
<th>Powdery mildew (in spring)</th>
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</thead>
<tbody>
<tr>
<td>Early sown</td>
<td>↑↑</td>
<td>↑</td>
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<td>↓*</td>
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<tr>
<td>Min-till after wheat</td>
<td>↑</td>
<td>↑</td>
<td>↑↑</td>
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<td>↑</td>
</tr>
</tbody>
</table>

Key

- ↑↑ Increased risk
- ↑ Small increase in risk
- ↓↓ Decreased risk
- *mildew tends to proliferate in spring on late-sown crops
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 yields 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 (tolerance)
- diseases have differing effects on yield
- fungicide effects not entirely linked to control of visible disease, eg canopy ‘greening’ or growth regulatory effects.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Mildew</th>
<th>Yellow rust</th>
<th>Brown rust</th>
<th>Septoria nodorum</th>
<th>Septoria tritici</th>
<th>Eyespot</th>
<th>Fusarium ear blight</th>
<th>Yield response to fungicide treatment (t/ha)</th>
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</table>

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

Source: HGCA Recommended Lists 2011/12
Assessing disease risk – Varieties

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.

Resistance for a given variety to a particular disease is rated on a 1–9 scale (1=very susceptible; 9=immune) in the HGCA Recommended Lists.

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

Understanding disease resistance and the effects of disease pressure can explain why disease levels on the same variety may vary between fields and years.

High nitrogen uptake encourages rapid development of rusts and powdery mildew. In such crops even moderately resistant varieties can suffer high levels of disease.

Early drilling (early September) puts crops at higher risk to most diseases and moderately resistant varieties can suffer high levels of disease.

Types of resistance

Race non-specific resistance is effective against all fungal races and is not subject to sudden failure. Therefore, the ratings provide a guide to the relative resistance of this type of variety that is unlikely to change quickly. Although control is not complete, it can be as effective as fungicides. This is the main type of resistance available against Septoria tritici.

Race-specific resistance can provide complete protection (rating 9) against rusts or powdery mildew. But new ‘races’ of the fungus may develop which can overcome this form of resistance, leading to sudden loss of control.

Race-specific resistance to rusts and powdery mildew will no longer be effective if a virulent race of the fungus emerges. When such a change occurs, the level of varietal susceptibility then depends on its underlying race non-specific resistance.

For example, Robigus and Consort were both rated 9 for brown rust in the 2007/08 HGCA Recommended List. However, a new race has evolved and therefore ratings have been reduced to 7 and 3 respectively in the 2009/10 list.

Fungicide dose and variety

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

Fungicide dose and wheat price

The optimum fungicide dose changes little with wheat price. As the graph above illustrates, if wheat price increases from £80 to £160/tonne then the optimum triazole dose increases by 20%.

Actual dose required varies less with grain price than with disease pressure and variety resistance. Under moderate disease pressure the optimum dose of triazole for a disease-susceptible variety is more than that required for the more disease-resistant one.
Septoria tritici – favoured by mild and wet conditions

Septoria nodorum – favoured by high rainfall at ear emergence

Yellow rust – overwinter survival critical to risk. Mild winters and susceptible cultivars increase risk

Brown rust – favoured by above average temperatures, usually most active in June/July

Tan spot – favoured by wet weather, high temperatures and non-inversion tillage

Powdery mildew – favoured by humid weather
Fungicides – New fungicides and resistance management

Succinate Dehydrogenase Inhibitors (SDHIs)
Since last season two new SDHIs have been approved for use, bixafen (in Aviator Xpro and other products) and isopyrazam (in Seguris). SDHIs inhibit a different enzyme in the mitochondria of fungi to azoles. The new generation have excellent efficacy on Septoria tritici, and a broad spectrum of foliar disease control. They are at medium/high risk of fungicide resistance so should always be used in mixtures (see below).

Resistance
Resistance occurs when a pathogen population becomes so insensitive to a fungicide that its field performance is impaired. Resistance can arise rapidly and completely so that control is lost in a single step. Alternatively, if resistance develops gradually, the pathogen population becomes progressively less sensitive. Initially, field performance may not be affected except under very high disease pressure and with susceptible varieties.

Septoria tritici
Sensitivity to triazoles has declined slowly since the mid-90s, but efficacy of epoxiconazole and prothioconazole disease pressure and with susceptible varieties. becomes progressively less sensitive. Initially, field resistance develops gradually, the pathogen population so insensitive to a fungicide that its field performance is impaired. Resistance can arise rapidly and completely so that control is lost in a single step. Alternatively, if resistance develops gradually, the pathogen population becomes progressively less sensitive. Initially, field performance may not be affected except under very high disease pressure and with susceptible varieties.

Yellow and brown rust
Although shifts in sensitivity to triazoles were reported in the 1990s, field performance has been maintained. No resistance has been found to morpholine or strobilurin fungicides, since the mid 1980s, and strobilurin fungicides, since 2003.

Powdery mildew
With rapid growth and many disease cycles each season, there is an inherently high resistance risk with this disease. High levels of resistance to strobilurins in mildew mean these fungicides are ineffective. After an initial shift, the sensitivity to morpholines and triazoles has stabilised and they still provide partial control.

Quinoxyfen-resistant isolates are now widespread in the UK. In 2009 and 2010, low levels of isolates resistant to metrafenone were detected in parts of Europe.

Septoria nodorum
Strobilurin resistance has been reported in mainland Europe and may be affecting fungicide performance in the UK.

Eyespot
Reduced sensitivity to prochloraz and cyprodinil has been known in parts of Europe for several years. There is no evidence of any sensitivity shift to cyprodinil in the UK. Some triazoles and boscalid achieve good control.

Reducing resistance risk: the role of mixtures
Azole and SDHI-based fungicides, are at risk of resistance development. These fungicides should be used in a way which slows resistance, to avoid future loss of efficacy.

Using mixtures of fungicides with different modes of action and good efficacy, is key to reducing resistance risk and achieving good control.
For this reason, SDHI fungicides are only available in mixtures with fungicides of a different mode of action. Azole fungicides are available as single active substance products, but should not be used alone.

For the major diseases, basing the programme on azole + SDHI mixtures should provide some mutual protection from the risk of resistance development against both the components.

For Septoria tritici control, in most circumstances, adding chlorothalonil to azole or azole + SDHI mixtures aids efficacy, reduces the risk of resistance development, and should prolong their usefulness. However, if T2 sprays are delayed, the addition of chlorothalonil may slightly reduce triazole or SDHI / triazole eradicant activity. Therefore, where infections are already established and full eradicant activity is needed, chlorothalonil should be omitted.

For rust control, adding a strobilurin fungicide to an azole or azole + SDHI mixture may improve control and reduce the risk of resistance development. Only two strobilurin sprays can be applied in any season.

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)
# Fungicides – Activity chart

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<th>Mildew</th>
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<th>Septoria tritici</th>
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**Choosing fungicides**

Fungicides should be matched to the primary disease risk, which depends mainly on variety, sowing date, location and local weather. Often fungicide mixtures with different properties, from different fungicide groups, are most effective.

Fungicide resistance can dramatically affect fungicide performance, so new information should be taken into account when planning fungicide programmes.

To help select the appropriate dose see the Fungicide performance tool www.hgca.com/diseasecontrol

**Key**

★★★★ Excellent  ★★★★ Very good  ★★★ Moderate  ★★ Poor

* Ear blight caused by Fusarium culmorum or Fusarium graminearum.
  + Performance against Septoria nodorum may be reduced by recent resistance.
### Fungicides – Active ingredients and products

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Foliar diseases – Fungicide dose

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 yield loss from a given level of disease) and fungicide effectiveness also modify the appropriate dose.

To help select an appropriate dose, see the HGCA website: www.hgca.com/diseasecontrol
Fungicide performance curves

*Aviator Xpro tested contained 150g/l of prothioconazole and 75g/l of bixafen. Aviator235 Xpro as available in the UK contains 160g/l prothioconazole with 75g/l bixafen.

**Only available in mixture

*** Seguris was tested as a formulated product in 2010, and as a tank mix in 2008 and 2009.

The HGCA wheat disease management guide 2011
Fungicide performance curves

Yellow rust

Brown rust

Mildew

2008-2009 data

2008-2009 data

2006-2009 data

Aviator Xpro  Brutus  Comet  Cyflamid  FireFly  Flexity  Isopyrazam  Opus  Proline  Talius  Tern  Torch

The HGCA wheat disease management guide 2011
### Decision guide – T0, T1 and T2

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<th>Spray timing</th>
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| **T0** | Treatment combined with PGR before T1 may be appropriate in high disease years on susceptible varieties. Any yellow rust found should be controlled immediately. Controlling brown rust, mildew and eyespot may be economic where disease risk is high and on susceptible varieties. Treatment may slow early rust epidemic development and reduce disease pressure at T1 and T2. Check crops in early spring for yellow rust, brown rust, mildew and eyespot. Low doses – quarter to half label recommended dose – are appropriate. Timing for eyespot and brown rust control – 2–3 weeks before T1 applications. For Septoria tritici control, sprays are largely for insurance. Chlorothalonil applied three weeks before T1 applications would be adequate. | **Rusts** – triazoles, strobilurins  
**Mildew** – cyflufenamid, fenpropidin, metrafenone, proquinazid, quinoxyfen, spiroxamine  
**Eyespot** – boscalid + epoxiconazole, cyprodinil, flusilazole, metrafenone, prochloraz, prothioconazole  
**Septoria tritici** – chlorothalonil |
| **T1** | Primarily aimed at controlling Septoria tritici on recently-emerged final leaf 3 and sometimes diseases on leaf 4. Varieties susceptible to Septoria tritici (rated 5 or less on the HGCA Recommended List) should be targeted as high priority. Check growth stage and leaf emergence carefully at this time. Spraying too early or too late will give poorer disease control. Sprays applied for Septoria tritici will normally also control rusts. Eyespot risk should be assessed. Strobilurins add to disease control and increase yield due to greening effects. | **Base spray on a triazole/chlorothalonil mixture, possibly with the addition of SDHIs. Use doses between half and three-quarters of label recommended dose to ensure eradicant control of Septoria tritici. The triazole choice and dose is particularly important. Septoria tritici – chlorothalonil, triazoles, SDHIs  
Rusts – morpholines, spiroxamine, strobilurins, triazoles, SDHIs  
Mildew – cyflufenamid, cyprodinil, fenpropidin, metrafenone, morpholines, proquinazid, quinoxyfen, spiroxamine, SDHIs  
Eyespot – boscalid + epoxiconazole, cyprodinil, flusilazole, metrafenone, prochloraz, prothioconazole** |
| **T2** | This is the most important spray as yield responses to flag leaf sprays are consistently profitable. This spray is aimed at controlling disease on the top two leaves, which contribute approximately 65% of yield. Apply when most flag leaves on main tillers have emerged. Varieties prone to Septoria tritici (rated 5 or less on the HGCA Recommended List) should be targeted for treatment first as delaying flag leaf sprays will be costly. Spray timing is less critical on more resistant varieties. Doses between half and full label recommended dose are usually appropriate. Higher triazole doses are needed on Septoria tritici susceptible varieties under high disease pressure. Lower doses are appropriate on disease-resistant varieties under low disease pressure. Use triazole/SDHI mixture to ensure good eradicant control of Septoria tritici and prolong green leaf area of the top two leaves. Add chlorothalonil on Septoria tritici susceptible varieties in protectant situations. | **Septoria tritici** – chlorothalonil, triazoles, SDHIs  
**Rusts** – morpholines, spiroxamine, strobilurins, triazoles, SDHIs  
**Mildew** – cyflufenamid, fenpropidin, metrafenone, morpholines, proquinazid, quinoxyfen, spiroxamine, SDHIs |
### Decision guide – T3

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<th>Spray timing</th>
<th>Rationale</th>
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| **T3** Ear spray | The ‘ear’ spray targets ear diseases, but also gives additional control of disease on the top two leaves – important in high disease seasons and on disease-prone varieties. On Septoria tritici susceptible varieties, ensure triazole applied for ear diseases is also active against Septoria tritici. In disease-resistant varieties, an ear spray may not be necessary. Brown rust, yellow rust and Septoria nodorum can be damaging if ears are affected. Wet weather during flowering can lead to Fusarium ear blight and possibly mycotoxins and discoloured grain. Control of ear blight is difficult and costly as high doses must be applied close to the infection period. Avoiding mycotoxins is more important for wheat intended for human consumption. Growers should use the HGCA Fusarium risk assessment tool and treat accordingly. Sooty moulds, which result in discoloured grain, have little effect on yield but can be important in milling varieties. | Choose a triazole-based product or mixture with specific activity against ear diseases. This also provides broad-spectrum eradicant control on upper leaves. Consider adding a strobilurin where grain filling is likely to be prolonged or where brown rust is a risk. A quarter to a half label dose is appropriate for additional disease control. A minimum of half dose is necessary for Fusarium control. **Preferred active ingredients specifically for ear disease control:**  
  - **Septoria nodorum** – azoxystrobin, dimoxystrobin, epoxiconazole, prothioconazole, pyraclostrobin, trifloxystrobin.  
  - **Fusarium ear blight** – epoxiconazole plus dimoxystrobin, metconazole, prothioconazole, tebuconazole.  
  - **Sooty moulds** – azoxystrobin, dimoxystrobin, pyraclostrobin, tebuconazole. |

For the latest information on fusarium mycotoxins and the risk assessment, see: [www.hgca.com/mycotoxins](http://www.hgca.com/mycotoxins)
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)
G39 The wheat growth guide, HGCA (2008)
G31 Take-all in winter wheat – management guidelines, HGCA (2006)
G14 Pest management in cereals and oilseeds, HGCA (2003)

HGCA Topic Sheets, Information Sheets and Project Progress
PP15 Fungicide performance in oilseed rape, HGCA (2010)
TS96 Options for low volume spraying of winter wheat, HGCA (2007)
TS95 Foliar disease control in wheat, HGCA (2007)
TS80 Determining eyespot risk in winter wheat, HGCA (2004)
TS73 Testing winter wheat for seed-borne disease, HGCA (2003)
TS72 Sampling wheat seed for seed-borne disease, HGCA (2003)
TS56 Managing ergot in crops, HGCA (2002)

HGCA Project Reports
PR418 Controlling soil-borne cereal mosaic virus in the UK by developing resistant wheat cultivars (2007)
PR432 Understanding the basis of resistance to Fusarium head blight in UK winter wheat (2008)
PR439 Fungicide doses in sequences and mixtures for winter wheat (2008)
PR444 Appropriate Doses Network: up-to-date information on fungicide performance for wheat growers (2008)
PR456 Towards a sustainable whole-farm approach to the control of Ergot
PR459 Monitoring risks of mycotoxin contamination caused by fusarium head blight pathogens in winter wheat (2009)
Current projects

3187 United Kingdom Cereal Pathogen Virulence Survey (UKCPVS)

3453 Integrated strategy to prevent mycotoxin risks

3479 Study of Fusarium langsethiae infection of cereals

3480 Identification and characterisation of resistance to the take-all fungus in wheat (PhD)

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

3570 Cephalosporium leaf stripe – an emerging threat to wheat crops in short rotations

3573 Improved modelling of fusarium to aid mycotoxin prediction in UK wheat

3625 Identification, prevalence and impacts of viral diseases in UK winter wheat crops (PhD)

3713 Identification and characterisation of azole sensitivity shifts in Irish and UK populations of Mycosphaerella graminicola sampled from HGCA fungicide performance winter wheat trials

3729 Development of novel methods for detecting and quantifying viable inoculums of Oculimacula yallundae and O. acuformis (PhD)

3730 Value of resistance genes for controlling Septoria tritici in high-yielding wheat varieties (PhD)

3734 New fungicide performance in winter wheat

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/r1-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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HGCA is the cereals and oilseeds division of the Agriculture and Horticulture Development Board.

Acknowledgements

This guide was funded by HGCA as a knowledge transfer project and is based on research funded by HGCA and Defra. It was written by Dr Neil Paveley, Jonathan Blake and Dr Peter Gladders, ADAS; and Valerie Cockerell, SASA.

HGCA is grateful to many experts who have commented on draft versions of the guide, including:
Dr Denise Ginsberg, ADAS; Dr Peter Mercer and Dr Louise Cooke, AFBI; Nigel Adam and Nigel Godley, Bayer CropScience; Steve Waterhouse, BASF; Bill Clark, Broom’s Barn; Dr Penny Mapleston, BSPB; Malcolm Tomkins, Chemtura Europe Ltd; Reuben Morris, Cropwise; David Roberts, Dow AgroSciences; Patrick Goldsworthy, Goldsworthy Associates; Dr Simon Edwards, Harper Adams University College; David Stormonth, Interfarm; Steven Burgner, Dr Victoria Foster, Professor Graham Jellis, Dr Clare Kelly, Dr Jim McVittie, HGCA; Dr Rosemary Bayles and Dr Kerry Maguire, NIAB; Dr Oliver Macdonald, PSD; Dr Simon Oxley, SAC; Huw Phillips, Scottish Agronomy; David Ranner, Syngenta; Mark Taplin, independent agronomist; and David Houghton and Julian Hasler, farmers.

Edited by Dr Clive Edwards, HGCA and Geoff Dodgson, Chamberlain.

2011 Updates: Pinstone Communications Ltd.
Photographs: ADAS, Scottish Agricultural College, Dalton Seeds, SASA