


Wheat disease management guide

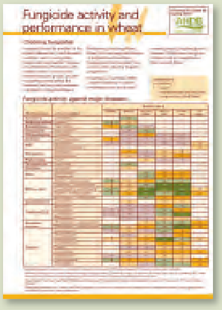
CEREALS & OILSEEDS

Updated February 2016

Introduction

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

Fungicide activity and performance



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

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

cereals.ahdb.org.uk/publications

Further information

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

For fusarium mycotoxin risk assessment tools and information, visit
cereals.ahdb.org.uk/mycotoxins

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

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

Seed production and certification

Certified seed

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

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

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

Certification and seed-borne disease

The Cereal Seed Regulations state: "Harmful organisms which reduce the usefulness of the seed shall be at the lowest possible level." Standards exist for loose smut, currently rare in UK wheat, and ergot but there are no standards for bunt or fungal seedling blights. Although not a requirement, most certified seed is treated. The diseases controlled depend on the treatment.

Naming of fungal diseases

Latin names of pathogenic fungi are agreed by international convention and these can change over time as new scientific evidence emerges (eg *Septoria tritici* was changed to *Mycosphaerella graminicola* and has now been reclassified as *Zymoseptoria tritici*). 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.

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.

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

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

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.

Most recent name	Previous name	Commonly called
Zymoseptoria tritici	*Mycosphaerella graminicola*	Septoria tritici
Stagonospora nodorum or *Phaeosphaeria nodorum*	*Septoria nodorum*	Septoria nodorum
Blumeria graminis	*Erysiphe graminis*	Powdery mildew
Puccinia triticina	*Puccinia recondita*	Brown rust

Contents

Seed sampling and testing

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

Sampling

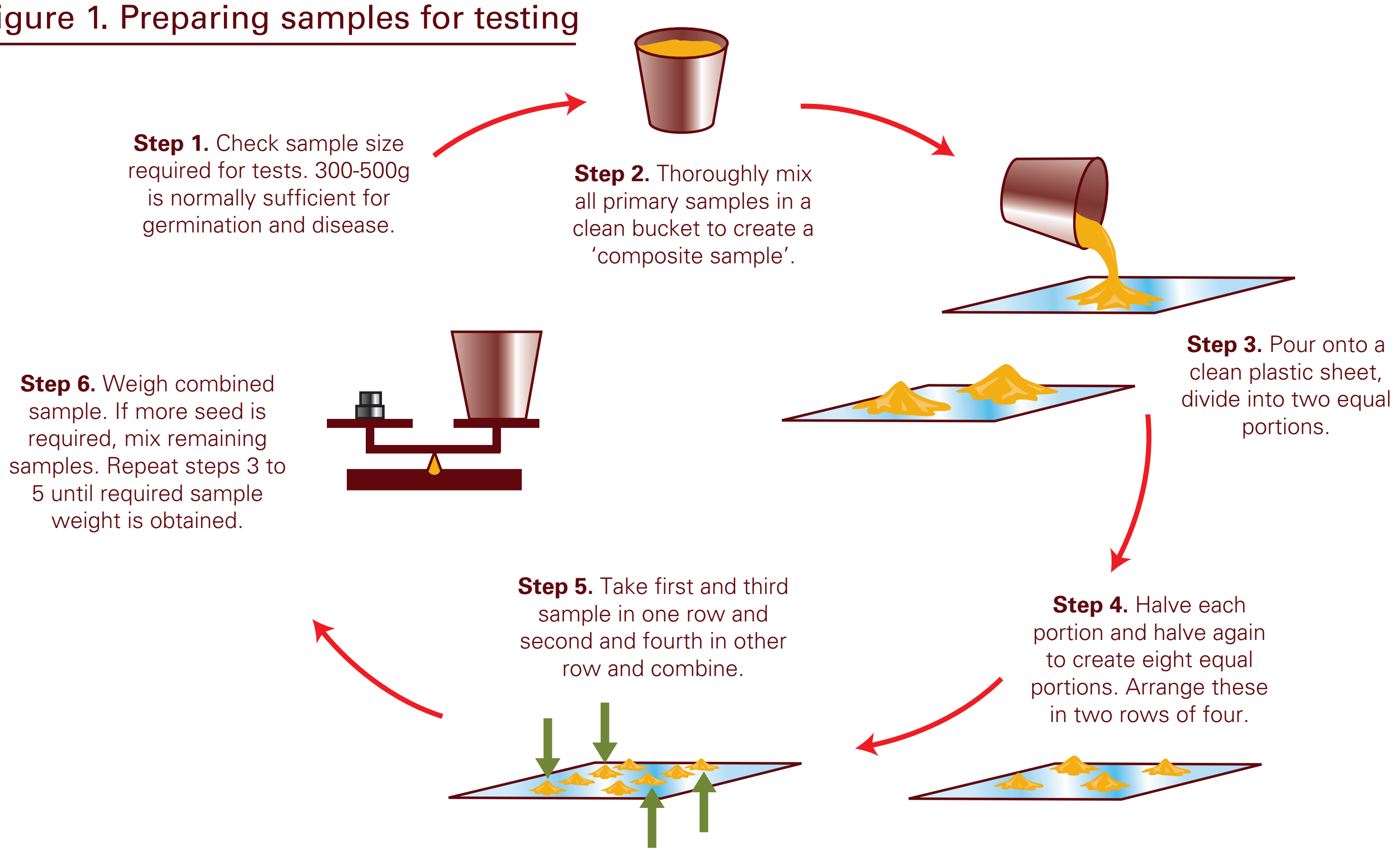
- Sample grain before cleaning or drying, ideally with a single or multi-chamber stick sampler
- Wash equipment with water and detergent, before and between lots
- Keep grain intended for sowing separate from larger grain bulks
- Only use seed from one field to reduce variability within a seed lot
-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

Primary samples required for given lot sizes

Lot size (tonnes)	Primary samples required
<5*	10
5	10
10	20
20–30	40

* 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.

Figure 1. Preparing samples for testing



Cleanliness and hygiene

Bunt spores can contaminate equipment and storage areas and diseased seed lots can contaminate healthy lots. Wash all sampling equipment prior to starting sampling and between lots using water, detergent and a brush. Dry equipment or allow it to dry before use.

Equipment

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

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

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

Germination testing

Low germination, due to disease, sprouting, drying, mechanical or chemical damage, is a major cause of poor quality in UK seed. Where time is limited, the tetrazolium (TZ) test is recommended. 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 and fusarium seedling blight if a problem is suspected.

Regulatory standards and advisory thresholds

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

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

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.

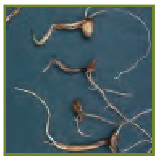
Life cycle

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

Microdochium seedling blight



– *Microdochium nivale* and *M. 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

High infection of microdochium seedling blight (left)

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

Seedling blight, foot rot and leaf spot

– Cochliobolus sativus

Symptoms

Early symptoms include brown roots and coleoptiles. Infected plants with brown spotting on lower leaves usually grow to maturity. Severe infections cause stem-base rotting and poorly filled ears.

Importance

Cochliobolus sativus is traditionally a disease of hotter climates. Symptoms only occasionally occur in the UK.

Life cycle

The soil and seed-borne fungus survives on crop debris and grass weeds. It sometimes causes seedling blight. More usually it infects roots but the plant survives. Splash-borne spores infect seed in ears.

Risk factors

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

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 humans 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.

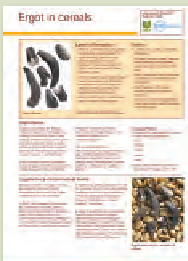
Control

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

- Grass weeds, particularly black-grass
- Cool, wet conditions during flowering
- Prolonged flowering periods
- Late tillering

For more information, see Information Sheet 33.
cereals.ahdb.org.uk/publications


Ergot in cereals

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 incidence appears 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.

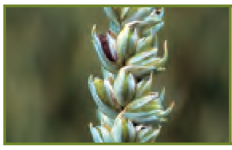
Risk factors

- Cool, moist conditions during flowering
- Infected neighbouring crops
- Seed repeatedly sown without treatment

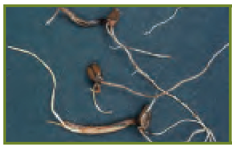
Seed treatment

- **Certified seed** → Considering sowing untreated?
- **Farm-saved seed** → Germination test
  - 85% plus → Considering sowing untreated?
  - 78–84% → Is heat damage present?
    - NO → Treat seed with an appropriate product
    - YES → Do not use for seed
  - Under 78% → **Do not use for seed**

Considering sowing untreated?
- NO → Treat seed with an appropriate product
- YES → Test seed for bunt and microdochium seedling blight. Test for septoria seedling blight if septoria nodorum is present in the growing crop



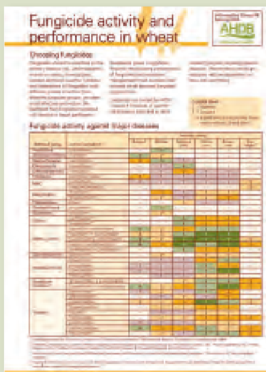
Does bunt exceed one spore/seed?
- YES → Treat seed with an appropriate product
- NO → Do combined seedling diseases exceed 10%?



Do combined seedling diseases exceed 10%?
- YES → Treat seed with an appropriate product
- NO → **Very low risk of seed-borne disease, consider sowing seed untreated**

Treat seed with an appropriate product

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



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.

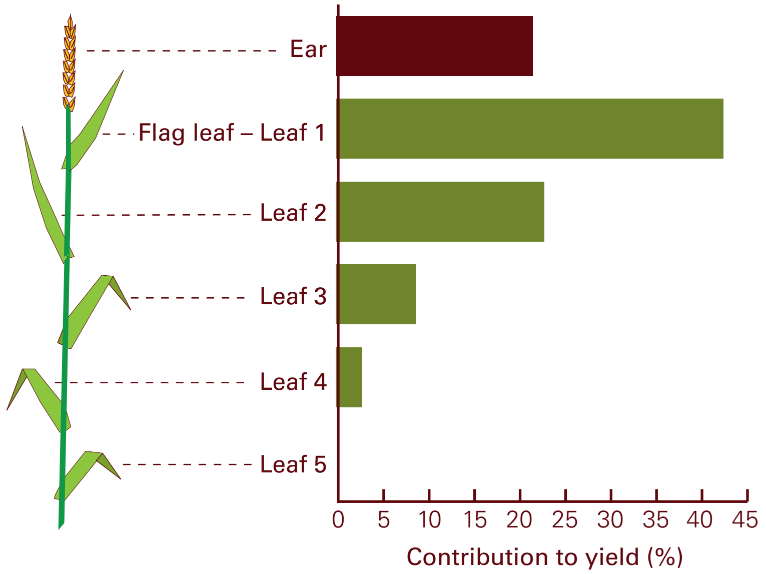
Applying sprays during this critical phase – at T1 (GS32) and T2 (GS39) – limits disease progress and protects emerging upper leaves, so maximising photosynthesis later.

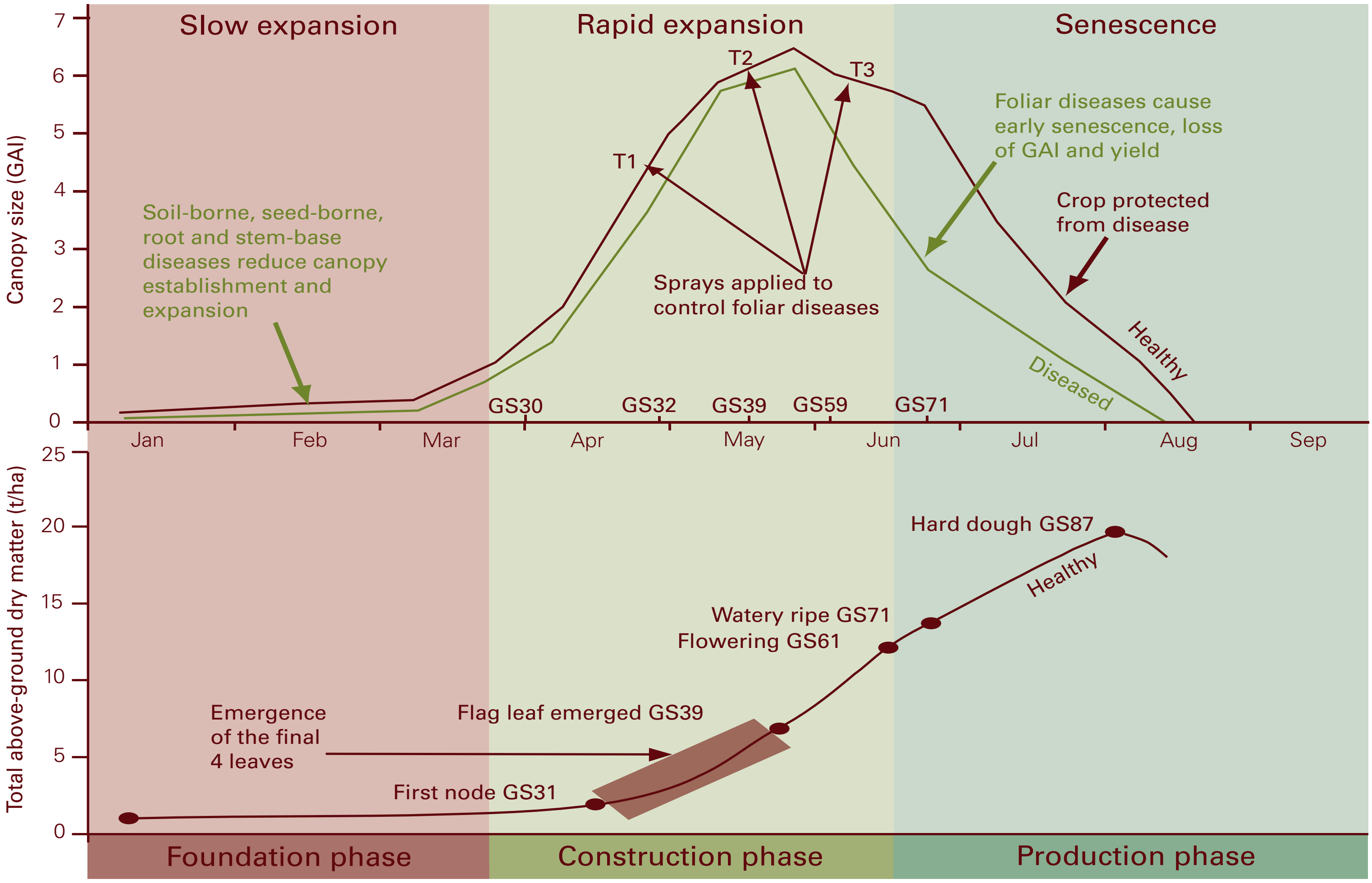
Production phase

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.

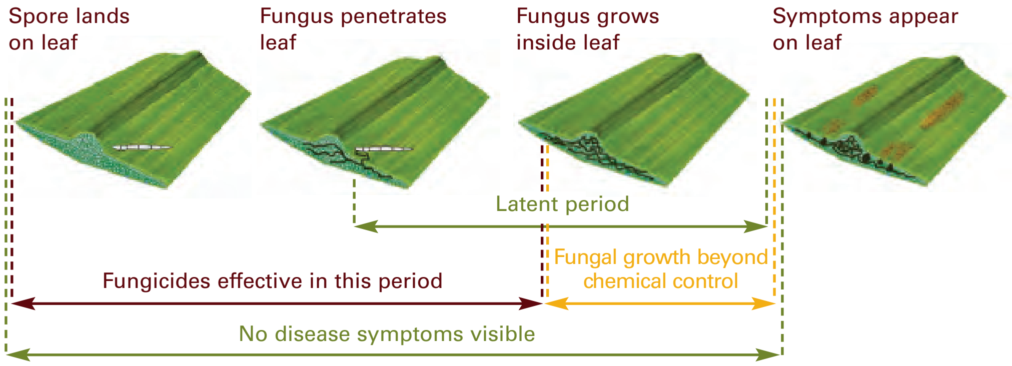
Infection from within crops

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.

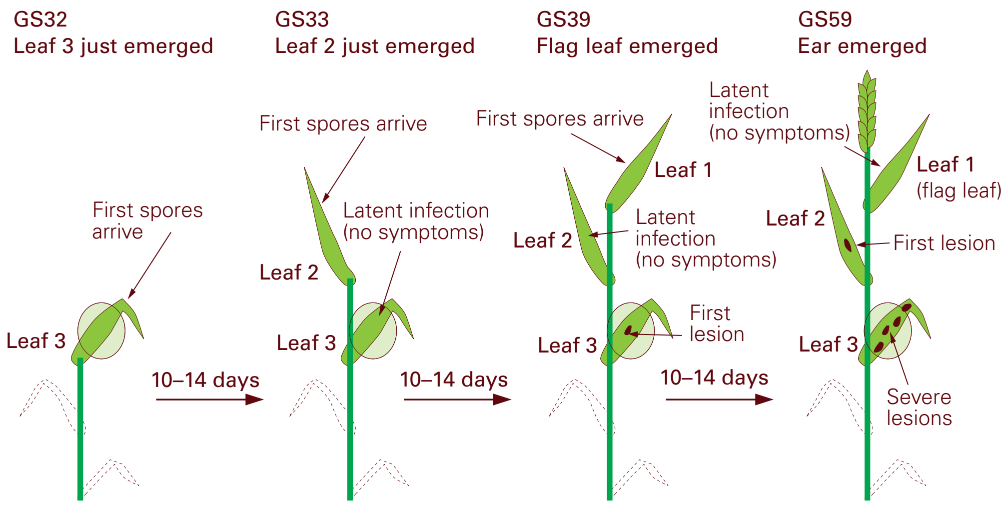
Importance of spray timing and latent period



Latent periods can be as short as 4–5 days for mildew and brown rust. Strategies to manage these diseases depend largely on protecting leaves as they emerge.

Latent periods, fungicide activity and spray timing

Example based on septoria tritici



Leaf 4 and below already showing symptoms. Disease on these leaves cannot now be controlled.

Leaf 3 can be protected.

Leaf 3 infected but disease still in latent period and controllable.

Leaf 2 just infected.

Leaf 3 may now be showing symptoms – disease not now controllable on this leaf layer.

Leaf 2 infected but still in latent period, so disease controllable by flag leaf sprays.

Symptoms now visible on leaves 2 and 3, not controllable by ear sprays. Ear sprays top up protectant activity on the flag leaf.

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. Leaf emergence is, therefore, 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 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

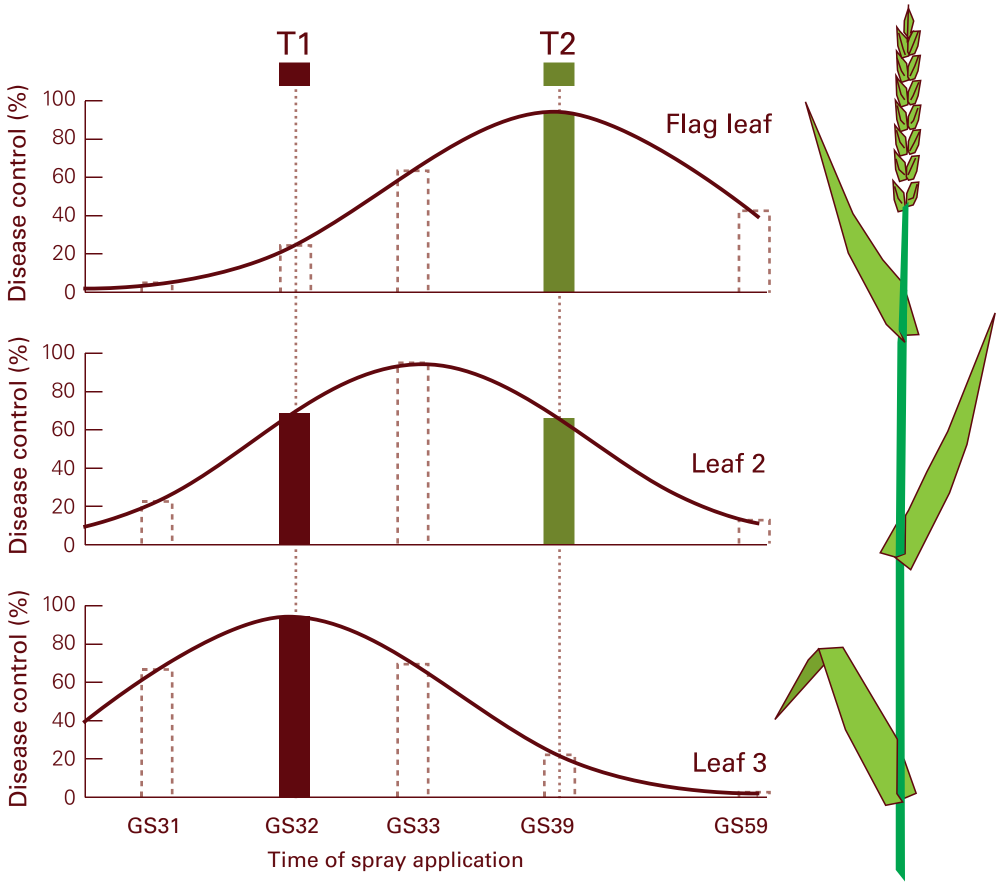
T3 timing – Ear spray

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.



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

These graphs 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, eg rusts or powdery mildew, are active.

Septoria tritici

Zymoseptoria tritici

sometimes known as leaf blotch

Symptoms

In autumn and winter, brown oval leaf spots (lesions) which contain the diagnostic small black fruiting bodies (pycnidia) occur on older leaves. 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.

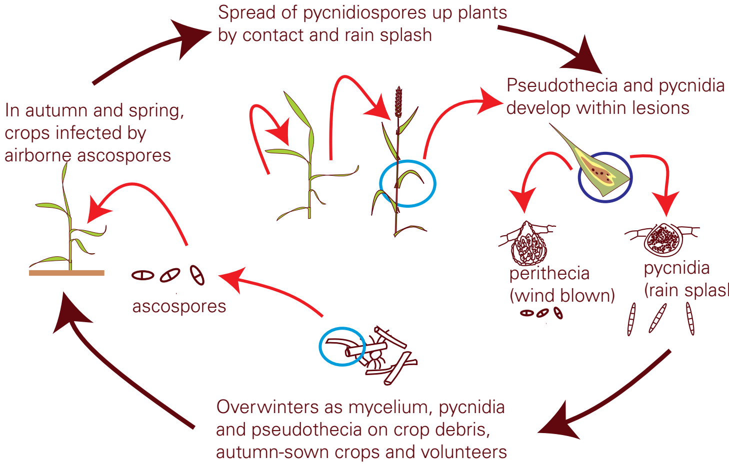
The national survey, reported by CropMonitor, showed that septoria tritici levels in 2015 were the highest of all the foliar diseases but lower than recorded in 2014, with 61% of crops affected. This is the lowest incidence of septoria tritici recorded since 2011. Crops had an average of 0.3% mean area of the flag leaf and 1.3% of the area of leaf 2 affected. This is markedly lower than the long-term means (2001–2010) of 1.0% and 3.7%, respectively.

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.

Heavy rainfall encourages rapid spore movement from lower to upper leaves during stem extension. Optimum temperatures are 15–20°C.

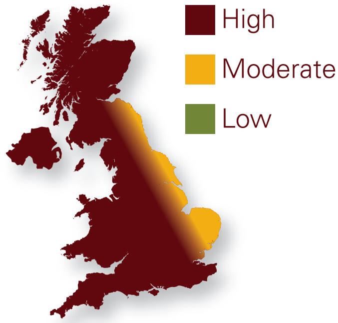
Symptoms appear after a latent period (14–28 days after infection); this period reduces as temperatures rise.



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

Information on varietal resistance is presented in the AHDB Recommended Lists for cereals and oilseeds on a 1–9 scale. A higher number represents better resistance. All varieties need to be monitored regularly for disease, as new races can occur that could potentially overcome the resistance.

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 (penthiopyrad, bixafen, isopyrazam, fluxapyroxad or boscalid) and/or chlorothalonil.

Resistance to strobilurin products is widespread and they will not provide adequate control.

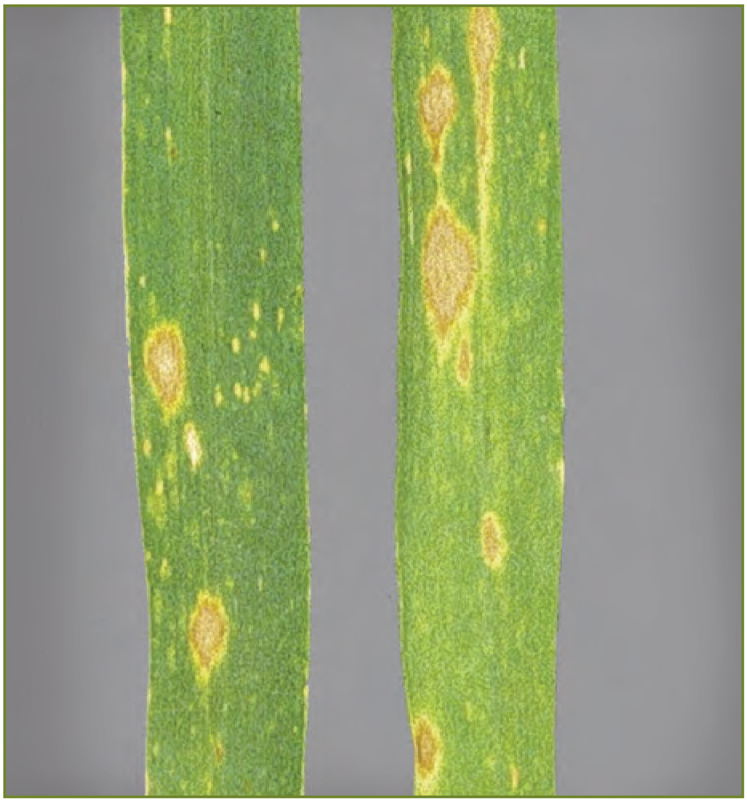
Some systemic seed treatments (eg fluquinconazole) may give limited early control.

For more information, see Topic Sheet 113.
cereals.ahdb.org.uk/publications

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

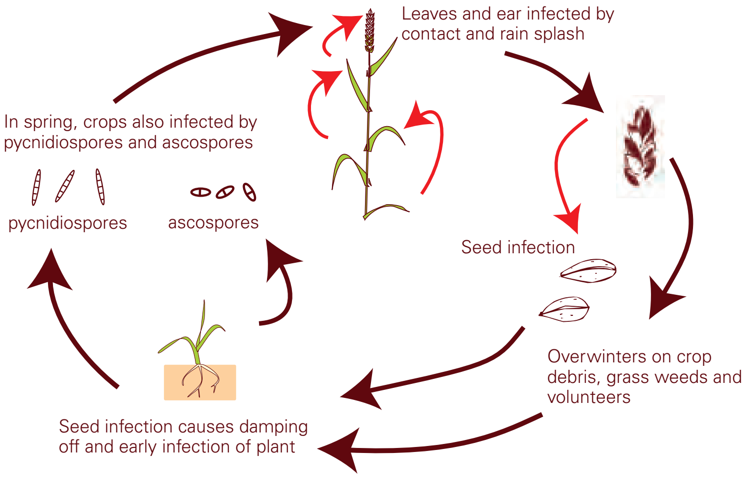
In 2015, septoria nodorum was recorded for the first time since 2009 in the national survey, reported by CropMonitor. When severe attacks occur, it is usually in association with high rainfall at ear emergence (eg in the south west). Here, yield losses in untreated crops may exceed 50%.

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.

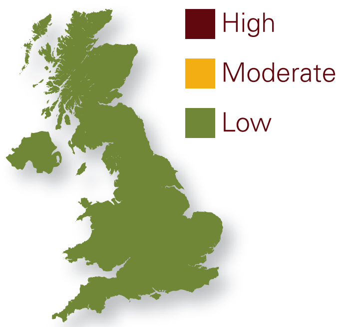
Secondary spread occurs when pycnidiospores, produced within leaf spots, are dispersed by rain splash.

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

Information on varietal resistance is presented in the AHDB Recommended Lists for cereals and oilseeds on a 1–9 scale. A higher number represents better resistance. All varieties need to be monitored regularly for disease, as new races of pathogens can occur that could potentially overcome the resistance.

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.

Yellow 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 and 2011. Annual surveys are done by UKCPVS to identify any new races at the earliest possible opportunity.

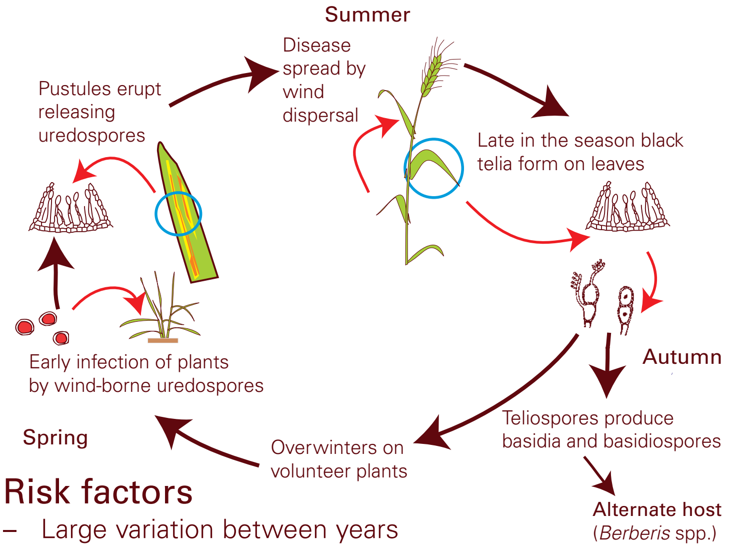
Severe epidemics can occur where large areas of susceptible varieties are grown. In untreated susceptible varieties, yellow rust can reduce yields by over 50%. However, well-timed fungicide sprays are usually very effective so annual losses are small. Outbreaks often occur in coastal areas from Essex 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.

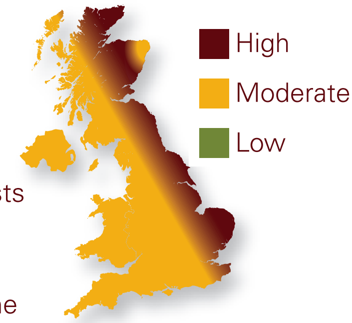
In early spring, distinct foci may occur; secondary spread is through airborne spores as well as leaf-to-leaf contact. Cool (10–15°C), damp weather, with overnight dew or rain, provides optimum conditions for disease development.

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 that overcome the major gene resistance of some new varieties continue to develop



Control

Varieties

Varieties with resistance ratings of 7 and 8 on the AHDB Recommended Lists for cereals and oilseeds give effective control and may be less prone to a sudden reduction in resistance than those with a rating of 9. All varieties need to be monitored regularly, as new races can occur which could potentially overcome the resistance. Varieties can be allocated to 'diversification groups' to limit the spread of disease. Sometimes this is not possible – with the incursion of the diverse Warrior race in 2011, this grouping has become more difficult as the varieties all react in slightly different ways. Susceptible varieties should be grown alongside more resistant varieties to limit the spread of the disease.

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.

For yellow rust population information, see **cereals.ahdb.org.uk/ukcpvs**

UKCPVS

Foliar diseases – Brown rust

Brown rust

Puccinia triticina

Symptoms

Most commonly seen as tiny orange-brown pustules scattered over leaves. During autumn and winter, a 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.

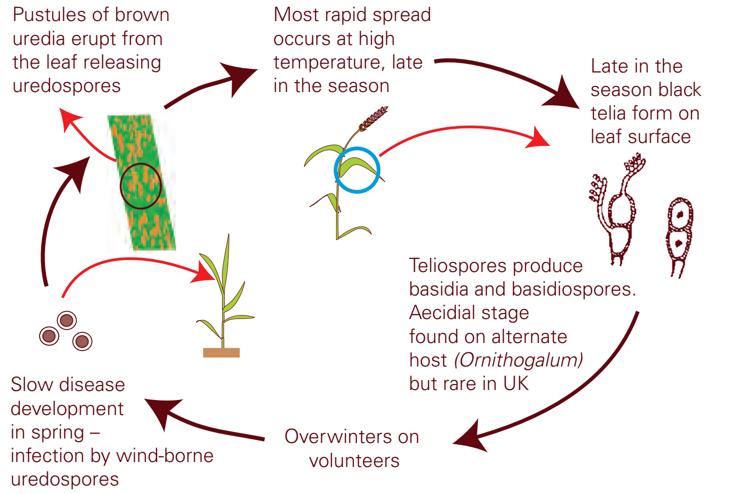
Brown rust was recorded in 2% of crops in the 2015 national survey, reported by CropMonitor. This is lower than in 2014 when the disease was recorded in 7% of crops. In 2007, a season where above average temperatures led to unusually early epidemics and when brown rust was prevalent, the estimated cost of yield loss was £11.2 million.

Life cycle

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

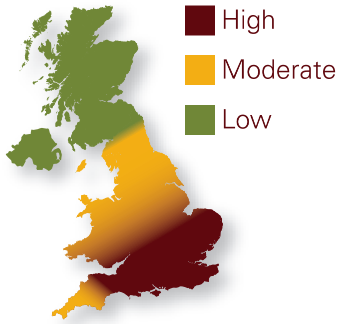
Optimum conditions are days with high temperatures (15–22°C) followed by overnight dews. Surface moisture on leaves is essential for spore germination.

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
- High humidity is necessary for epidemic progress
- Early sowing
- New races that overcome the major gene resistance of some new varieties continue to develop



Control

Varieties

Information on varietal resistance is presented in the AHDB Recommended Lists for cereals and oilseeds on a 1–9 scale. A higher number represents better resistance. All varieties need to be monitored regularly for disease, as new races of pathogens can occur that could potentially overcome the 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.

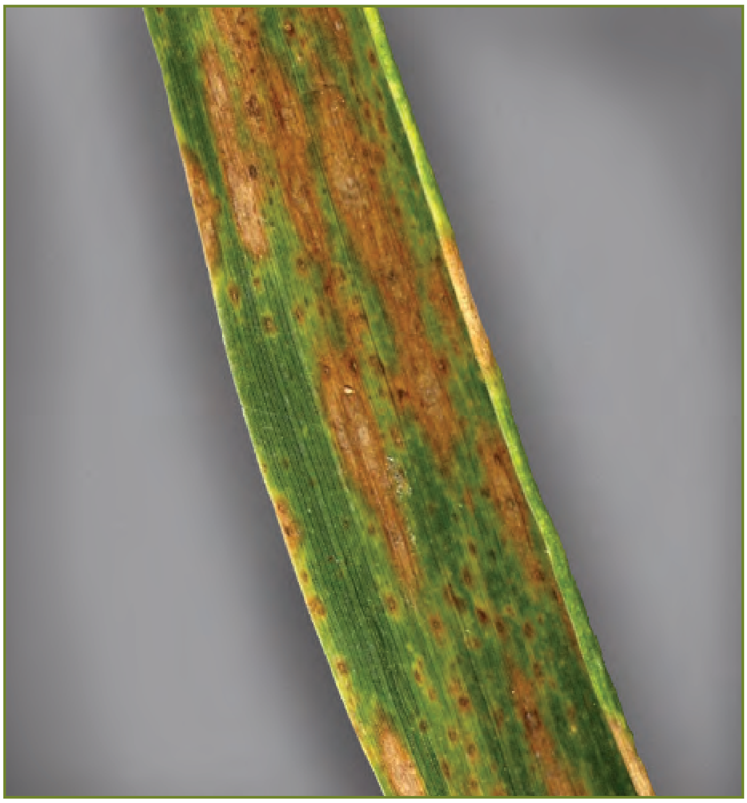
Fungicides

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.

For the wheat brown rust diversification scheme and more information, see Topic Sheet 120.
cereals.ahdb.org.uk/ukcpvs

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.

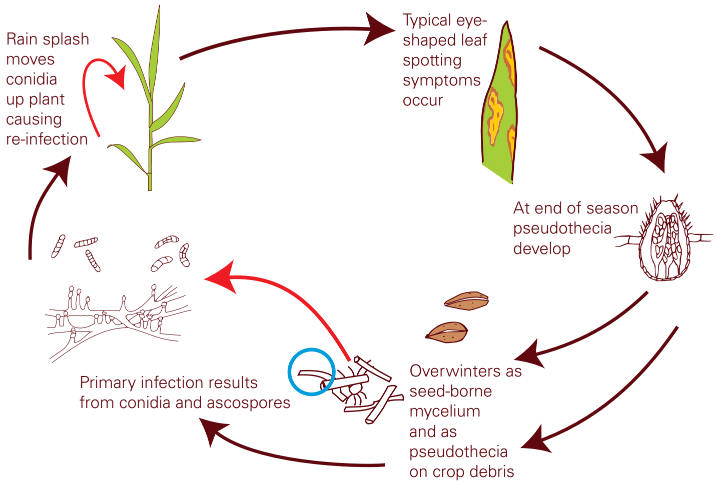
Importance

Tan spot is still a minor UK disease but has become more common. The 2015 national survey, reported through CropMonitor, showed tan spot to be the second most commonly occurring disease (after septoria tritici), affecting 18% of crops. Some severe cases have occurred in recent years and it is a major problem in Sweden, Denmark, Germany and France.

Life cycle

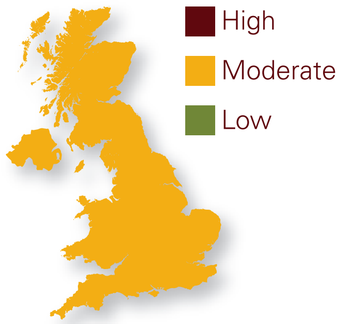
Like septoria nodorum, tan spot is trash-borne and favoured by minimum tillage. Ascospores produced on stubble, probably in spring, introduce the disease into crops. Leaf lesions appear in 7–14 days and produce splash-dispersed asexual spores.

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 on the AHDB Recommended Lists for cereals and oilseeds.

Cultural

Ploughing or cultivation to bury infected crop residues.

Fungicides

Fungicidal control is difficult due to the short latent period but older azoles used in the spring to protect crops from rust (eg tebuconazole, cyproconazole and propiconazole) will help to protect crops from early infection.

Strobilurin resistance in tan spot has been confirmed elsewhere in Europe and is likely to be present in the UK.

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, pinhead-sized, black fruiting bodies (cleistothecia) that produce sexual spores (ascospores) may be found on the white colonies.

Importance

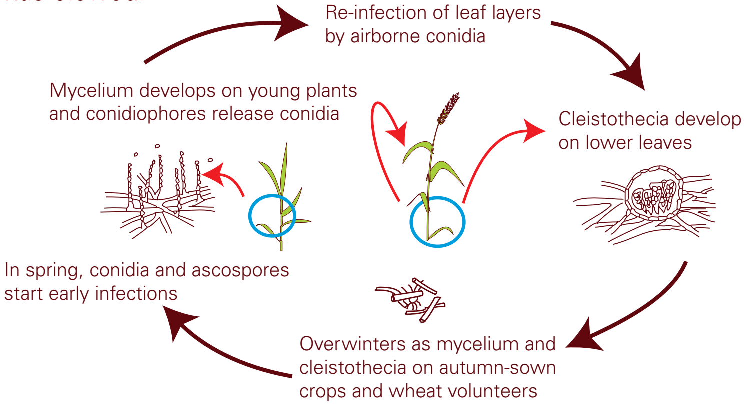
Mildew can develop over a wide range of conditions but is sporadic, often affecting crops under stress. Although very visible, it generally reduces yield much less than other foliar diseases. Damaging attacks can occur anywhere in the UK but yield losses rarely exceed 10%.

The 2015 national survey, reported by CropMonitor, showed that 17% of crops were affected; this is similar to 2014 when 13% of crops were affected.

Life cycle

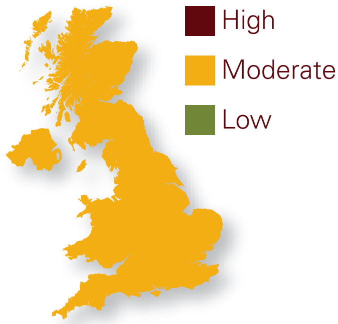
Airborne conidia, produced on crops or volunteers, enable mildew to spread widely. Warm (15–22°C), breezy conditions with short periods of high humidity favour infection. New pustules are produced in 5–14 days.

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

Information on varietal resistance is presented in the AHDB Recommended Lists for cereals and oilseeds on a 1–9 scale. A higher number represents better resistance. All varieties need to be monitored regularly for disease, as new races of pathogens can occur that could potentially overcome the resistance.

Cultural

Avoid excessive nitrogen fertilisation.

Fungicides

Fungicides with specific activity against mildew are required where powdery mildew is a particular threat, although other fungicides, including azole/SDHI mixtures, have useful activity against powdery mildew. 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 and morpholines).

For further information, see cereals.ahdb.org.uk/ukcpvs UKCPVS

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 yields generally 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 but severe attacks can also occur in acidic 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 yields for second wheats on the AHDB Recommended List give some guidance to choosing the most suitable varieties for second and subsequent sowings. Yield responses reflect take-all tolerance and eyespot resistance. Information on winter wheat varieties known to perform well as second wheats is available in the AHDB Recommended List.

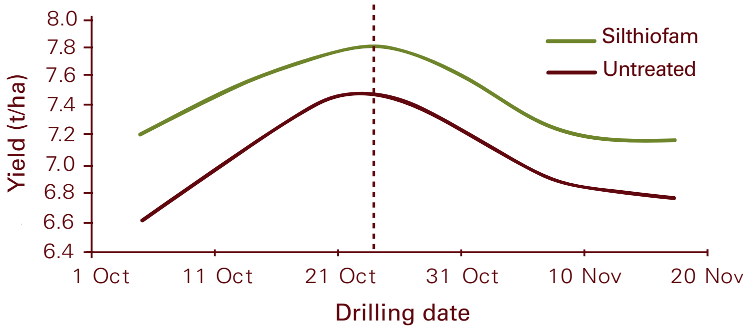
Fungicides

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

Optimum sowing date for second wheats with or without treatment



AHDB-funded trials, ADAS Rosemaund

For further information

See *Take-all in winter wheat – management guidelines, AHDB (2006).*
cereals.ahdb.org.uk/publications

Stem-base diseases – Eyespot

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%.

The 2015 national survey, reported by CropMonitor, showed that 7% of stems had damaging eyespot (moderate or severe symptoms).

Risk factors

Traditionally, eyespot assessment in wheat crops was carried out in the spring (GS30–31) to judge the need for chemical control. A new risk assessment method includes an early, pre-sowing, assessment of agronomic risks. This enables individual fields at greater disease risk to be identified, allowing an integrated management approach through cultural control measures, such as the use of eyespot-resistant varieties and delayed sowing.

For fields judged to be at low or moderate risk in the autumn, the decision to treat against eyespot in the spring is made using the second part of the new risk assessment, which takes account of the incidence of stem base lesions as the crop approaches stem extension.

Control

Varieties

Information on varietal resistance is presented in the AHDB Recommended Lists for cereals and oilseeds on a 1–9 scale. A higher number represents better resistance. All varieties need to be monitored regularly for disease, as new races of pathogens can occur that could potentially overcome the resistance.

Fungicides

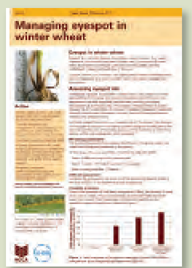
Good control is difficult to achieve and may be affected by the type of eyespot present. Many treatments only reduce severity.

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.

For the eyespot risk assessment and more information, see Topic Sheet 111.


Managing eyespot in winter wheat

cereals.ahdb.org.uk/publications

Ear diseases

Diseases can affect grain quality by reducing grain filling, leading to low specific weights and shrivelled grain. Infections of *Fusarium* species may result in mycotoxins. Sooty moulds and similar diseases may affect grain appearance, causing rejection for milling. In 2013, ear blight symptoms, although slightly higher than those seen in recent years, were at markedly lower levels than in 2012, with 55% of samples and 10% of ears affected (CropMonitor national survey data).

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 infects ears in severe cases.

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 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 on pages 6 and 7.

Control of ear diseases

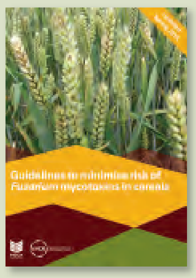
Sprays applied after ear emergence:

- 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.

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

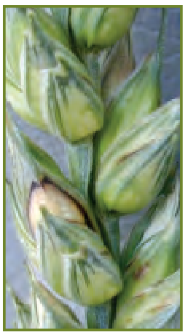


Septoria nodorum

Yellow rust

Mildew

Sooty moulds



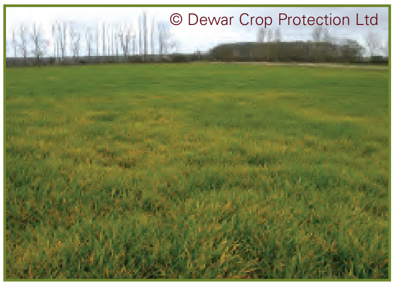
Fusarium poae

Fusarium culmorum

Fusarium graminearum

Fusarium avenaceum

Barley yellow dwarf virus (BYDV)



Symptoms

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. Loss from a severe infection can make the crop unprofitable. Substantial yield loss is rare in spring-sown crops.

Life cycle

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

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

Risk factors

- Early crop emergence
- Mild winters
- 'Green bridge' transmission, ie from weeds and volunteers

Control

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

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

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

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

Chemical

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

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

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

Resistance

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

Soil-borne mosaic viruses

Soil-borne cereal mosaic virus (SBCMV)
Soil-borne wheat mosaic virus (SBWMV)

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

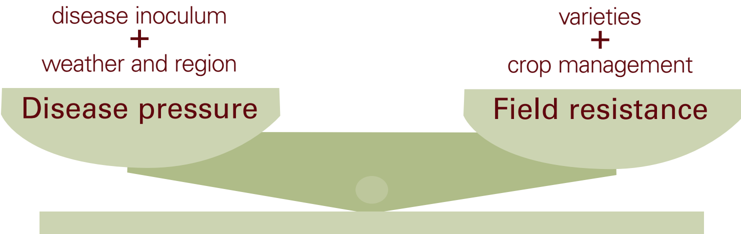
Once land is infected by SBCMV or SBWMV, the only practicable means of control is to grow resistant varieties. Cleaning cultivation equipment between fields will reduce the risk of the virus spreading.

Assessing disease risk

Disease pressure must be balanced against field resistance

Crop protection decisions need to be taken as upper leaves emerge, well before symptoms develop on yield-forming leaves.

To estimate the chance of disease development, the likelihood of infection – 'disease pressure' – has to be balanced against the ability of the crop to resist or avoid infection – 'field resistance'.



Disease inoculum

Disease lesions on lower leaves are the most common source of infection of upper leaves emerging during stem extension. Crops should be inspected regularly. If even a small amount of disease is visible 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

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.

	Septoria tritici	Septoria nodorum	Brown rust	Yellow rust	Powdery mildew (in spring)
Early sown	↑↑	↑			↓*
High N/ dense crop	↑		↑↑	↑↑	↑↑
Min-till, after wheat	↑	↑	↑	↑	↑

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

*mildew tends to proliferate in spring on late-sown crops

Varieties

AHDB Recommended List trials assess disease susceptibility and yield across the UK, helping growers select varieties with resistance to diseases prevalent in specific regions. Robust fungicide programmes are used in these trials to maximise varietal potential. Comparing treated and untreated yields provides an 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.

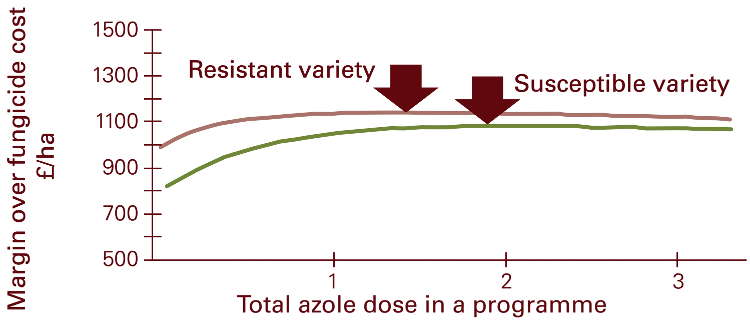
The susceptibility of varieties to each disease is partly reflected in the yield response to fungicides. Other factors may affect varietal yield response:

- 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

Disease resistance

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

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



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

Types of resistance

Race non-specific resistance is effective against all fungal races and is not subject to sudden failure. The resistance ratings on the AHDB Recommended Lists provide a guide to the relative resistance of this type, which 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 (resistance ratings of 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. New races of brown rust and yellow rust were detected in 2011 – all varieties should be monitored closely, particularly in regions with a high risk of infection.

Resistance management

Resistance

Resistance can arise rapidly so that control is lost in a single step or develop gradually. In this case, the pathogen population becomes progressively less sensitive and field performance may initially only be affected under very high disease pressure and with susceptible varieties.

Septoria tritici

Sensitivity to azoles has declined slowly since the mid-90s but protectant activity of epoxiconazole and prothioconazole remains good at full label doses. Azole resistance is due to various mutations and their frequency has changed quite rapidly in recent years. Resistance is widespread to both MBC fungicides and strobilurin fungicides.

Yellow and brown rust

Although shifts in sensitivity to azoles were reported in the 1990s, field performance has been maintained. No resistance has been found to morpholine or strobilurin fungicides in wheat.

Powdery mildew

With rapid growth and many disease cycles each season, there is an inherently high resistance risk. High levels of resistance to strobilurins in mildew mean these fungicides are ineffective. After an initial shift, the sensitivity to morpholines and azoles has stabilised and they still provide partial control. Quinoxyfen-resistant isolates are now widespread in the UK. Low levels of isolates resistant to metrafenone have been 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 azoles and boscalid achieve good control.

Succinate Dehydrogenase Inhibitors (SDHIs)

A number of new SDHIs have been approved for use on wheat: bixafen, isopyrazam, fluxapyroxad and penthiopyrad. SDHIs inhibit a different enzyme in the mitochondria of fungi to azoles. These new generation SDHIs have excellent efficacy on septoria tritici and a broad spectrum of foliar disease control. They are at medium/high risk of fungicide resistance and mutations in the target site associated with reduced sensitivity have been recorded in septoria in the field. In order to retain efficacy they should always be used in mixtures (see below).

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.

Azole and SDHI 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 or another multi-site fungicide 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 azole or SDHI/azole 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 (**http://www.pesticides.gov.uk/guidance/industries/pesticides/advisory-groups/Resistance-Action-Groups/frag**)

FRAG - UK

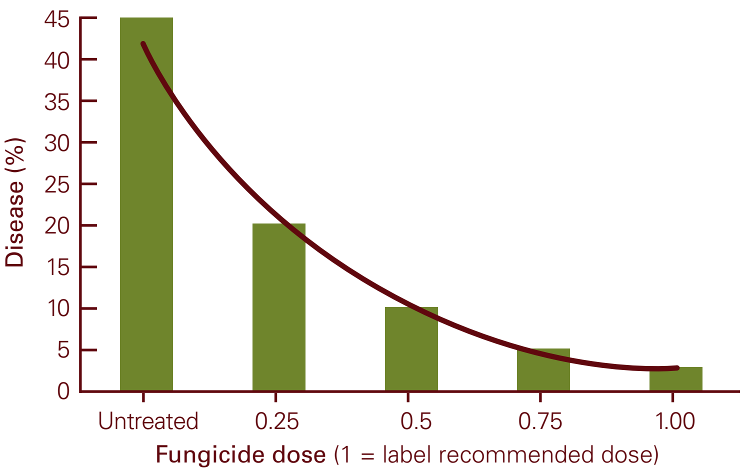
Determining appropriate dose

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

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

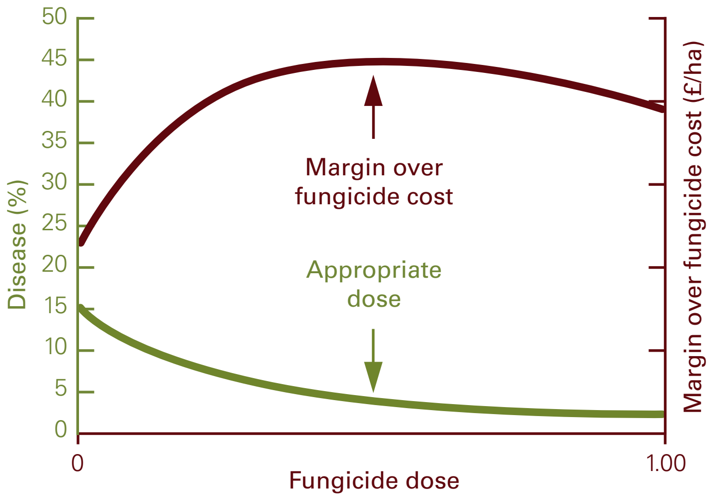
Disease severity in untreated crops depends on local disease pressure and varietal resistance. In treated crops, severity also depends on fungicide dose applied.

The dose-response curve



Fungicide dose and margin

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



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

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

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

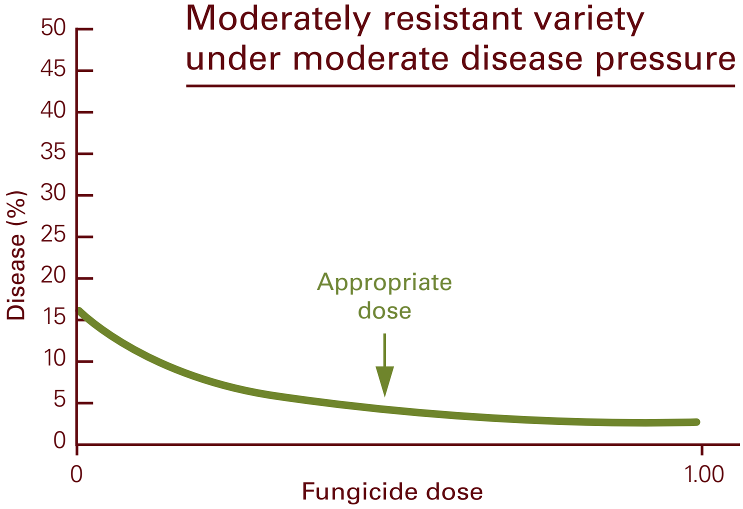
How disease and variety affect appropriate dose

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

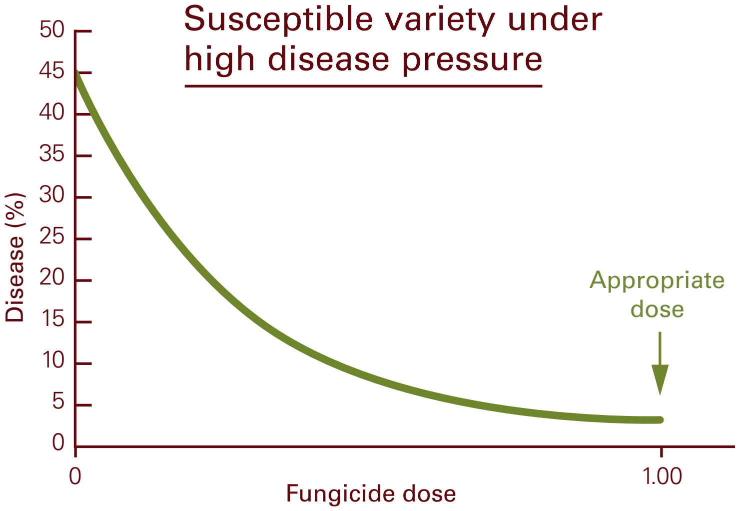
However, crop tolerance to disease (ie yield loss from a given level of disease) and fungicide effectiveness also modify the appropriate dose.

To help select an appropriate dose, see **cereals.ahdb.org.uk/disease**

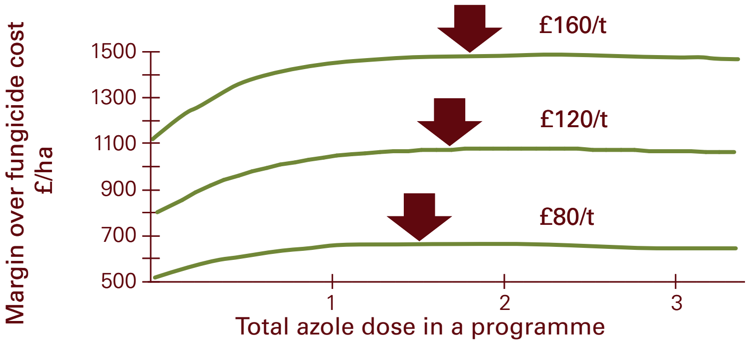
Moderately resistant variety under moderate disease pressure



Susceptible variety under high disease pressure



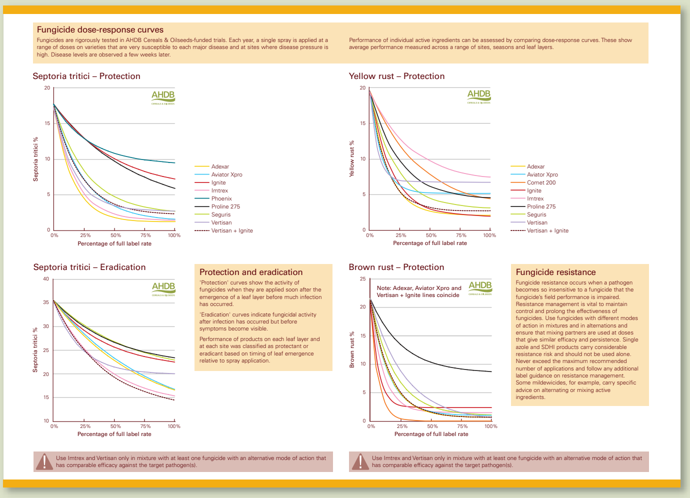
Fungicide dose and wheat price



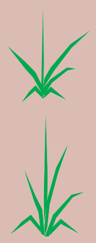
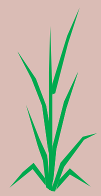
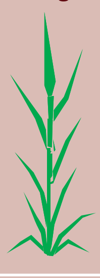
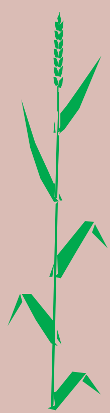
The optimum fungicide dose changes little with wheat price. As the graph above illustrates, if wheat price increases from £80 to £160/tonne then the optimum azole dose increases by 20%.

Actual dose required varies less with grain price than with disease pressure and variety resistance. Under moderate disease pressure the optimum dose of azole for a disease-susceptible variety is more than that required for the more disease-resistant one.

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



Decision guide – T0, T1, T2 and T3

Spray timing	Rationale	Product choice (adjust dose to suit risk)
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. 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 – azole, morpholine, strobilurin Mildew – cyflufenamid, cyprodinil, morpholine, metrafenone, proquinazid, quinoxyfen, Eyespot – boscalid + epoxiconazole, cyprodinil, metrafenone, prochloraz, prothioconazole Septoria tritici – chlorothalonil
T1 Leaf 3 emerged 	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 AHDB 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 an azole/multi-site mixture, possibly with the addition of SDHIs. Septoria tritici – chlorothalonil, mancozeb, folpet, azole, SDHI Rusts – morpholine, spiroxamine, strobilurin, azole, SDHI Mildew – cyflufenamid, cyprodinil, morpholine, metrafenone, proquinazid, quinoxyfen, SDHI Eyespot – boscalid + epoxiconazole, cyprodinil, metrafenone, prochloraz, prothioconazole
T2 Flag leaf emerged 	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 AHDB 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.	Use azole/SDHI mixture to ensure good control of septoria tritici and prolong green leaf area of the top two leaves. Add multi-site on septoria tritici susceptible varieties in protectant situations. Septoria tritici – chlorothalonil, mancozeb, folpet, azole, SDHI Rusts – morpholine, strobilurin, azole, SDHI Mildew – cyflufenamid, fenpropidin, metrafenone, morpholines, proquinazid, quinoxyfen, spiroxamine, SDHI
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 azole 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 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 an azole-based product or mixture with specific activity against ear diseases. This also provides broad-spectrum control on upper leaves. Consider adding a strobilurin where grain filling is likely to be prolonged or where brown rust is a risk. A minimum of three-quarters dose of azole 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

Further information

AHDB Cereals & Oilseeds information

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

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

Guides

AHDB Recommended Lists for cereals and oilseeds (annual)

G66 Wheat growth guide (2015)

G62 Encyclopaedia of pests and natural enemies in field crops (2014)

G34 Guidelines to minimise the risk of fusarium mycotoxins in cereals (2014)

P05 Nozzle selection chart (2010)

G49 Cereal growth stages – a guide for crop treatments (2009)

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

G31 Take-all in winter wheat – management guidelines (2006)

G64 Barley disease management guide (2016)

Information Sheets

IS42 Controlling aphids and virus diseases in cereals and oilseed rape (2015)

IS40 Risk assessment for fusarium mycotoxins in wheat (2015)

IS36 Yellow rust in wheat (2015)

IS33 Ergot in cereals (2014)

TS120 Wheat brown rust management (2012)

TS113 Septoria tritici in winter wheat (2012)

TS111 Managing eyespot in winter wheat (2012)

Current AHDB Cereals & Oilseeds-funded projects

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

3751 United Kingdom Cereal Pathogen Virulence Survey (UKCPVS)

3777 Exploring the genetic and mechanistic basis of resistance to take-all disease in wheat

3779 Monitoring of Mycotoxins and other contaminants in UK cereals used in malting, milling & animal feed

3800 Consequences of intensification or integration of fungicide use for resistance management and sustainable disease control

3801 Assessing the resistance risks associated with systemic fungicide seed treatments

3803 Maximising the potential for *Pch1* eyespot resistance and increased grain protein content in commercial wheat

214-0006 Fungicide performance in wheat, barley and oilseed rape

Project Reports

PR550 Fungicide performance on winter wheat (2016)

PR549 Integrated strategy to prevent mycotoxin risk: Inspyr (2015)

PR542 Cephalosporium leaf stripe - an emerging threat to wheat crops in short rotations (2015)

SR32 The identification, prevalence and impacts of viral disease of UK winter wheat (2015)

SR31 Identification and characterisation of resistance to the take-all fungus in wheat (2015)

PR541 Assessing the impact of the restrictions on the use of neonicotinoid seed treatments (2015)

PR539 Impact of climate change on disease in susceptible arable crop systems: CLIMDIS (2015)

SR23 Study of *Fusarium langsethiae* infection in UK cereals (2013)

SR22 Identification and characterisation of eyespot resistance in wheat (2013)

RR77 Implications of the restriction on the neonicotinoids: imidacloprid, clothianidin and thiamethoxam on crop protection in oilseeds and cereals in the UK (2013)

PR502 Desk study to evaluate contributory causes of the current 'yield plateau' in wheat and oilseed rape (2012)

PR492 Improved resistance to septoria in superior varieties (IMPRESSIV) (2012)

PR491 Forecasting eyespot development and yield losses in winter wheat (2012)

PR456 Towards a sustainable whole-farm approach to the control of ergot (2009)

Other information

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

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

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

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

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

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