The encyclopaedia of cereal diseases

Contents

Diseases listed alphabetically (common names)

AHDB is grateful to those who contributed to this and earlier versions of this publication.

Introduction

This encyclopaedia will help you understand the major and minor diseases of cereals, with a focus on the organisms that cause them.

The diseases are ordered alphabetically by their common names. The causal pathogens (scientific names) are indexed alphabetically near the end of the encyclopaedia, along with a glossary of technical terms.

Content is structured in a similar way for each disease. The common name features at the top of each page, followed by the pathogen(s) responsible. A blue box indicates the crop host(s) affected.

Where fungal pathogens have both a teleomorph (sexual stage) and an anamorph (asexual stage), the teleomorph is listed first, followed by the anamorph in brackets.

Symptoms are illustrated and described, together with an outline of the pathogen's life cycle and an indication of the importance of the disease.

This encyclopaedia is not a guide to disease control, but it can help lay the foundations for integrated pest management (IPM).

For all AHDB-related resources, visit our cereal disease management home page: **ahdb.org.uk/cereal-dmg**

Naming of fungal diseases

Agreed by international convention, scientific names of pathogenic fungi can change. For example, *Septoria tritici* was reclassified as *Mycosphaerella graminicola*, then *Zymoseptoria tritici*. Sometimes, however, the original scientific names are widely used to describe the diseases they cause. These common names are not italicised (e.g. septoria tritici blotch).

Ascochyta leaf scorch (spot)

Pathogen

Didymella exitialis (*Ascochyta* spp.)

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The pathogen infects wheat, barley, oats, rye, triticale and many grass species.

Symptoms

Disease symptoms are on lower leaves early in the season and on upper leaves later on. The lesions are usually elliptical and, although chlorotic at first, soon become a buff-to-brown colour, often splitting longitudinally. Initially, lesions have a dark-brown margin with a papery white centre. The fungus often invades damaged leaf tissue, such as that caused by liquid urea or nitrogen. Symptoms become less distinct with time, appearing very similar to those caused by septoria nodorum. However, pycnidia are generally black, whereas pycnidia associated with septoria nodorum are typically light in colour. The distinctive lesion shape distinguishes ascochyta infections from septoria tritici blotch.

Life cycle

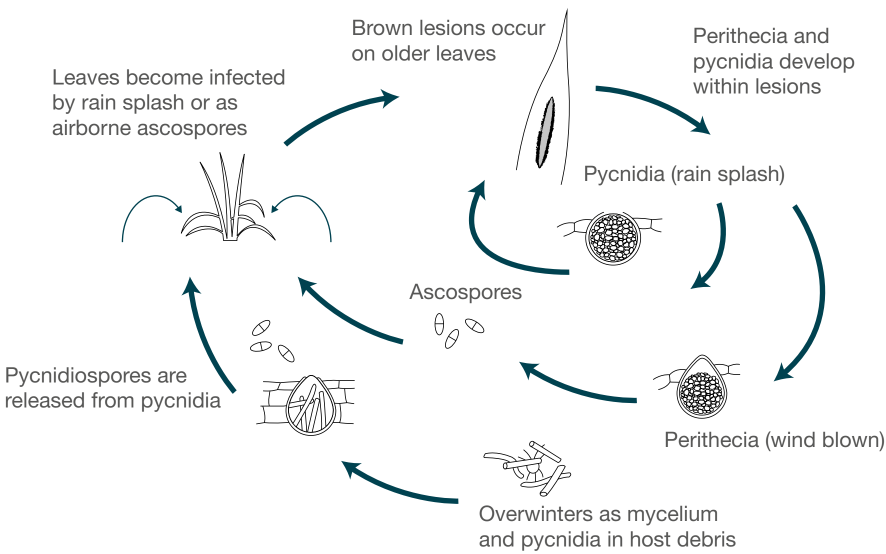
Pycnidia and mycelium within leaf tissue are thought to survive on crop debris, much like the septoria pathogens.

Typical ascochyta lesions showing dark margins and black pycnidia

Importance

The disease is sporadic and rarely severe. Although it is of relatively minor importance, it probably contributes to leaf death in the same way as the septoria diseases.

Symptoms are often seen later in the season, towards the end of grain filling, when they are unlikely to cause any yield loss. The teleomorph stage of the fungus is common in Europe. In the UK, airborne ascospores of the fungus are typically found in late summer and have been implicated in late summer asthma.



Ascochyta leaf scorch (spot) life cycle

Barley yellow dwarf virus (BYDV)

Virus

Barley yellow dwarf virus (BYDV)

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The virus infects all cereals and grasses. Usually, the disease affects barley and oats more severely than wheat.

Symptoms

Infections cause leaf yellowing and stunting. Initially, symptoms are confined to individual plants scattered throughout the crop. Eventually, distinct circular patches develop. Sometimes, these patches can merge to form extensive areas of infected crop. Red tipping of upper leaves can also occur. Very early infections can result in plant death.

Life cycle

The virus, which exists as several strains, is transmitted by various species of cereal aphid. The bird cherry–oat aphid (*Rhopalosiphum padi*) is the principal vector in the South. In the Midlands and the North, the grain aphid (*Sitobion avenae*) is usually more important.

Wheat plants infected with *BYDV* can show yellowing and red tipping of upper leaves

A *BYDV*-infected patch in wheat

In the autumn, *BYDV* can be introduced into cereal crops in two ways:

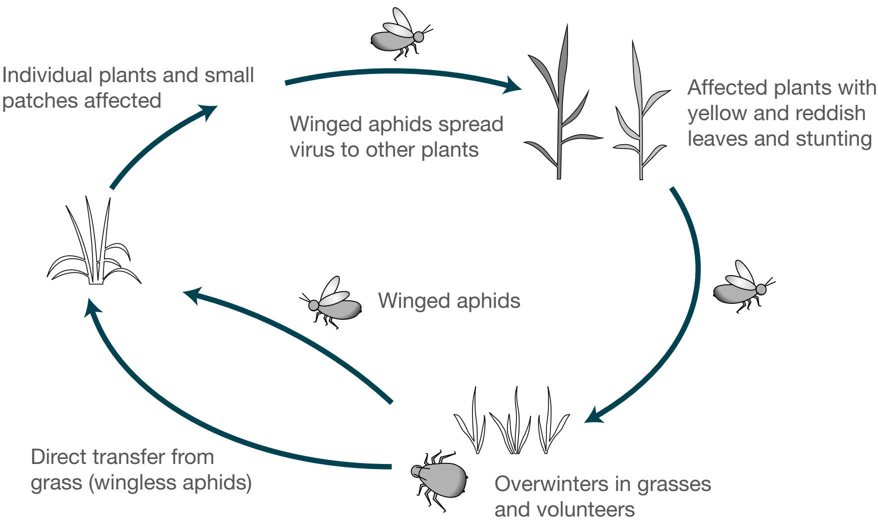
1. Indirect transfer by winged aphids, from grass or volunteer cereals elsewhere. This is the most common source of *BYDV* infection.
2. Direct transfer by wingless aphids, from grass or on volunteer cereals that survive cultivation. This is known as the 'green bridge' effect.

BYDV is transmitted in a persistent, non-propagative manner. This means that the virus does not pass directly to the aphids' offspring and must be acquired through feeding on infected host plants. The time between acquisition and the aphid being able to transmit the infection is 12–48 hours.

Importance

BYDV is the most economically important virus in UK cereals. Initially, only a small proportion of aphids are likely to carry *BYDV*. However, because of the way in which virus spreads from plants to aphids, even initial small populations of infected aphids can lead to significant economic damage.

The scale of yield loss depends on aphid activity, *BYDV* presence and strain, growth stage at infection and environmental conditions. In the case of severe infections, *BYDV* can cause losses of up to 60% in winter wheat and 50% in winter barley. However, the occurrence of these levels of infection is rare.



***BYDV* life cycle**

Black-point

Pathogen

Alternaria spp. and *Cladosporium* spp.

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The pathogens can infect all cereal species, although wheat and barley are most commonly affected.

Symptoms

Symptoms are only visible after harvest. Affected grain shows a darkening of the outer coat, particularly at the embryo end of the grain.

Darkening of grain at the germ end

Life cycle

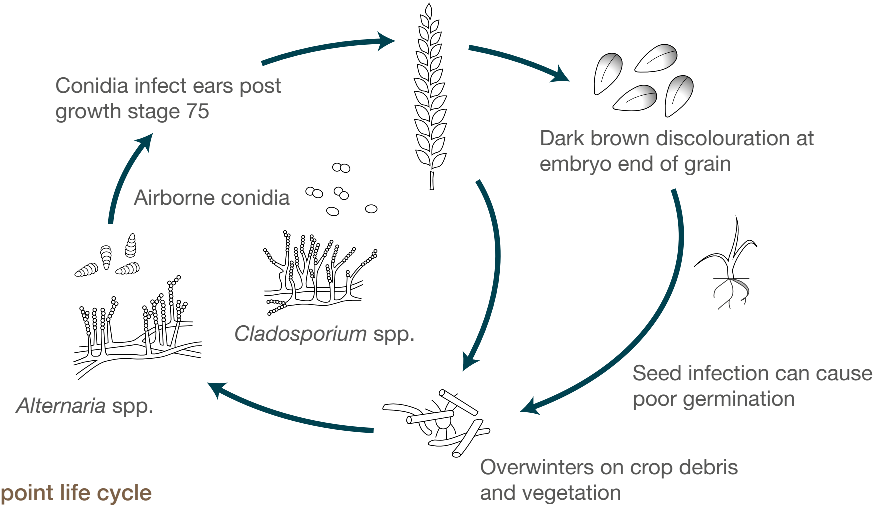
The disease is associated with several airborne fungi, including *Alternaria* spp. and *Cladosporium* spp. However, evidence linking these fungi with the disease is limited and mostly circumstantial.

High humidity or frequent rainfall from the milky-ripe to soft-dough stage and lodging can often trigger infection by these fungi.

Importance

Although the disease has no significant effect on yield, it can seriously affect milling quality. Grain discolouration can lead to poor flour, poor bran colour and rejection.

The disease is potentially more severe on larger grains, and disease incidence is greater in grains with a higher specific weight. Larger grains produce a more open floret, which potentially allows fungal spores greater access to the germ end of the grain.



Black point life cycle

Brown (leaf) rust

Pathogen

Puccinia triticina (formerly known as *P. recondita* f. sp. *tritici*), *P. hordei* and *P. recondita*

Crops affected

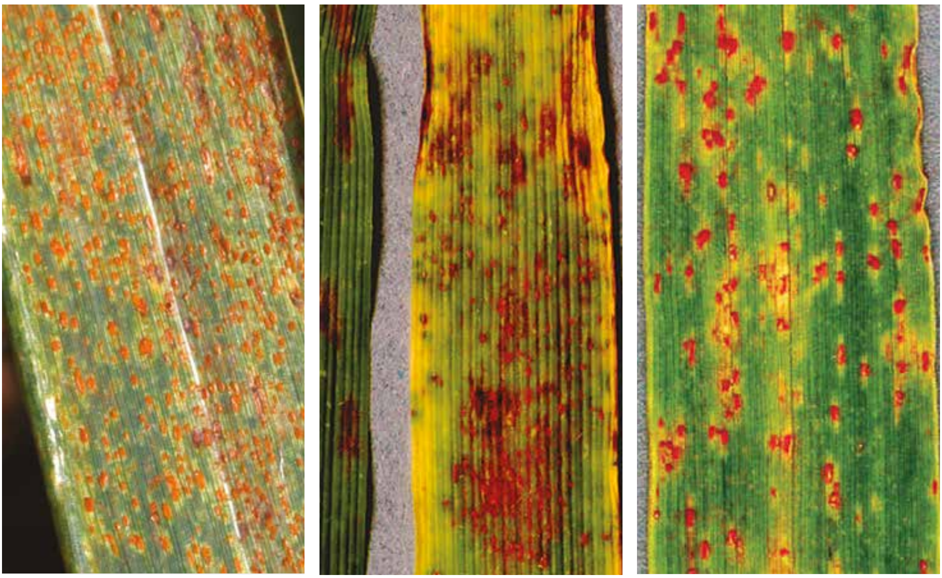
Wheat	Barley	Oats	Rye	Triticale

Hosts

Wheat (*Puccinia triticina*), barley (*P. hordei*), and rye and triticale (*P. recondita*). The host-specific pathogens do not cross-infect with other cereals.

Symptoms

Orange/brown coloured pustules (about 0.5–1.0 mm in diameter) often develop in the autumn on early sown crops. In early infections, pustules are frequently confused with yellow rust. There is greater differentiation of colour later in the season. Additionally, brown rust pustules tend to be scattered at random, compared with the striped symptoms of yellow rust. Often seen on the leaves, symptoms can also occur on the stem, leaf sheaths and ears, when infection is severe. When leaves begin to senesce, a 'green island' develops around individual pustules. Dark teliospores may be produced towards the end of the season.



Brown rust symptoms on wheat (left), barley (middle) and rye (right) leaves

Orange/brown coloured pustules and dark teliospores on rye

Life cycle

The fungus can only grow and survive on live leaf tissue. It overwinters mainly on volunteers and early drilled crops. It spreads by airborne spores. Dark teliospores may develop on diseased plant tissue, indicating a second developmental stage of the fungus.

The disease is active at 7–25°C (a wider temperature range than for yellow rust), with 15–22°C optimal for sporulation and spore germination. Surface moisture on leaves (i.e. 100% relative humidity) is essential for spore germination. Consequently, UK wheat brown rust epidemics normally occur during mid-to-late summer. At this time, windy days disperse spores, and cool nights with dew, favour the build-up of the disease. Symptoms can occur 5–6 days after infection at optimum temperatures. Cold weather slows disease development but does not kill the pathogen (unless the leaf dies). Barley tends to suffer from brown rust infection earlier in the spring than wheat. In both crops, rapid spread can occur in warm weather later in the season. Alternative host species exists for *P. triticina* but their role is not significant in the UK.

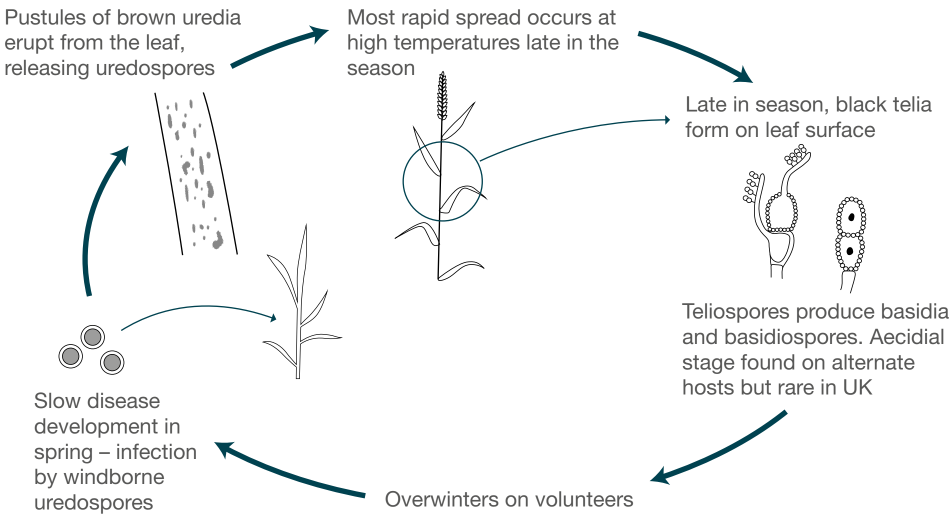
Importance

There is large seasonal and geographic variation in brown rust severity. Cold winters may reduce its spread. Climate change is leading to milder winters and higher than normal spring temperatures. Consequently, brown rust levels are now higher earlier in the spring and found in additional locations (e.g. further north).

Brown rust in wheat is common in southern and eastern parts of the UK, which have relatively high summer temperatures. Brown rust tends to develop later in the summer than yellow rust and results in a significant loss of green leaf area and, hence, yield and specific weight.

Brown rust in barley can be widespread, if conditions are conducive and there is dense cropping of barley. Brown rust epidemics on barley tend to start earlier in the spring than for wheat.

Brown rust is usually more of an issue in winter barley than in spring barley, especially in early sown crops when the winter is mild. A severe attack of brown rust early in the season affects final yield, through reduced green leaf area and tiller retention.



Brown (leaf) rust life cycle

Bunt (stinking smut)

Pathogen

Tilletia tritici

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The pathogen specifically infects wheat.

Symptoms

Bunt symptoms show after ear emergence. Flag leaves show yellow streaks, and plants can become stunted, with squat, dark grey-green ears and slightly gaping glumes. Extreme stunting (between one-quarter and one-half of their normal height) is a symptom of dwarf bunt, caused by *Tilletia controversa*. In infected ears, grain is replaced by seed-like 'bunt balls', each containing millions of greasy, black, foul-smelling spores. In severe cases, the whole field may smell of rotting fish. In wet conditions, a black ink-like substance may cover the ears. This occurs when released spores run out of the protective glumes onto the ear and stem.

Life cycle

The disease cycle of *T. tritici* closely matches that of *T. controversa*. The spores on the seed surface germinate along with the seed. Each spore produces a short fungal thread, terminating in a cluster of elongated cells. These produce secondary spores that infect the

Wheat flag leaf showing typical yellow streak symptoms

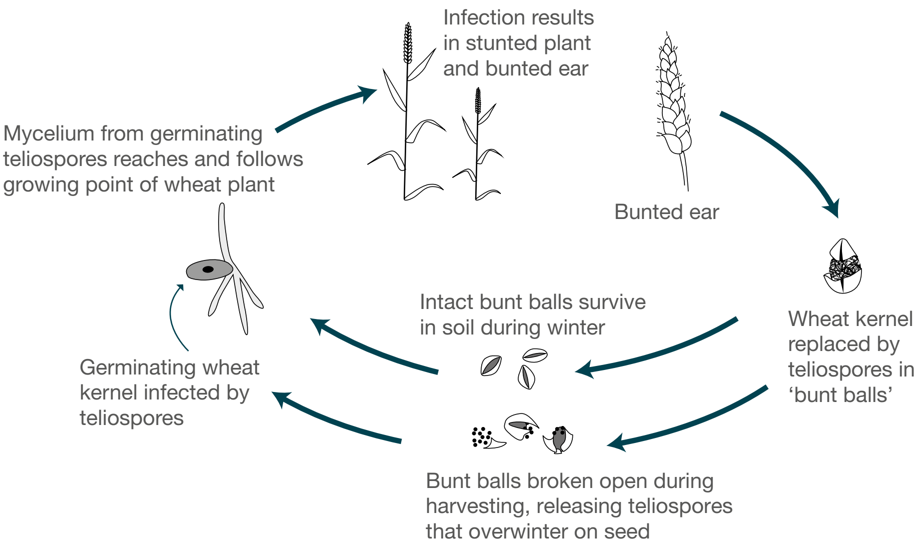
Bunt balls (left) and healthy grain (right) coleoptiles of the young seedlings before the emergence of the first true leaves. Conversely, *T. controversa* infects plants much later in development. The mycelium grows internally within the shoot, eventually infecting the developing ear. Affected plants develop apparently normally until the ear emerges, when bunt balls replace grain sites.

In damp soil, spores usually germinate and then, in the absence of the host plant, die. However, in dry seasons, they may survive in the soil (especially if protected within the glumes of shed ears) from the harvesting of one crop to the sowing of the next. Wind-blown spores, particularly from late-harvested crops, can contaminate neighbouring fields. Soilborne spores can invade seedlings very early in germination.

Importance

As each bunt ball contains millions of spores, the capacity for contamination of healthy grain in the same field is enormous. Thus, if seed is continually saved and resown without treatment, the disease can build up very rapidly. Dry spores can survive for several years. Harvesting or handling equipment contaminated by spores can introduce the pathogen into seed lots harvested in following seasons.

The disease is rare in the UK, as the vast majority of seed receives a fungicidal seed treatment. However, the disease can lead to unsaleable grain, because of discolouring and smell. Cases usually arise from sowing untreated farm-saved seed, although soilborne infections also occur.



Bunt or stinking smut life cycle

Cephalosporium leaf stripe

Pathogen

Hymenula cerealis (*Cephalosporium gramineum*)

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The pathogen infects wheat, barley, oats, rye and triticale.

Symptoms

Affected plants are usually randomly scattered throughout the crop. Affected tillers have a single, distinct, bright yellow stripe on each leaf, which extends onto the leaf sheath. All leaves on a tiller usually show symptoms, but not necessarily all tillers on a plant. The vascular tissue close to the nodes is frequently discoloured. Tillers can ripen prematurely and produce white heads.

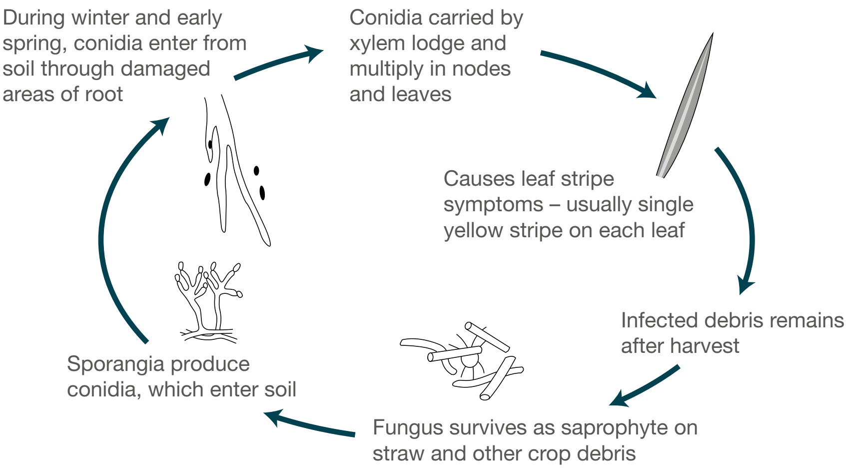
Life cycle

The causal fungus is soilborne and enters physically damaged plant roots. In the UK, this disease used to be common in wheat following grass, where high levels of root-damaging wireworm (*Agriotes* spp.) were found. Soilborne conidia normally enter damaged roots in the winter months and the fungus grows in the xylem vessels, blocking the vascular tissue, particularly at the nodes. The fungus survives in crop debris returned to the soil after harvest.

Importance

The disease is common at very low levels in the UK and does not cause economic losses.

Leaf stripe symptoms



Cephalosporium leaf stripe life cycle

Cereal mosaic viruses

Viruses

Barley yellow mosaic virus (*BaYMV*), *Barley mild mosaic virus* (*BaMMV*), *Oat mosaic virus* (*OMV*), *Oat golden stripe virus* (*OGSV*), *Soilborne cereal mosaic virus* (*SBCMV*)* and *Soilborne wheat mosaic virus* (*SBWMV*).

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

These viruses only affect winter-sown cereals. Each virus has a specific cereal host, as indicated by the virus name (*Note: *SBCMV* only affects wheat). These viruses do not cross-infect to other cereals.

Symptoms

A typical symptom is pale yellow streaks in the leaves, which are most pronounced during the early spring – particularly following a prolonged cold spell. The yellow streaks may become brown or purple at the leaf tip with dark brown flecking. Affected plants can be stunted. Mosaic disease symptoms often occur in distinct patches. Movement of the soil during cultivations spreads disease within a field and to other areas.

Life cycle

These viruses are closely related and all belong to the genus *Furovirus* or *Bymovirus*. They are all single-stranded ribonucleic acid (RNA) rod or filamentous viruses. The soilborne parasitic vector *Polymyxa graminis* infects crop roots and transmits these viruses.

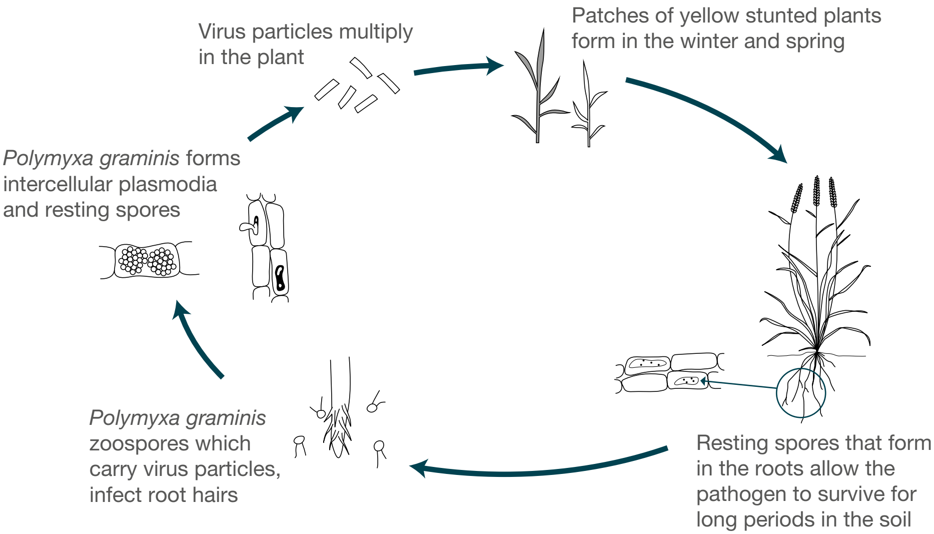
The virus survives within the spores of the vector and can persist in the soil, even in the absence of cereal crops, for many (more than 25) years.

Yellow streaks and dark brown flecking symptoms (*BaYMV*)

Importance

Yield losses of 50% have been recorded in affected patches of susceptible varieties. *BaYMV* and *BaMMV* are very common in the UK. *SBWMV* and *SBCMV* are present in the UK, but not common. *OMV* is common. *OSGV* is usually found in association with *OMV*. As patches are quite visible, it is easy to overestimate affected areas. However, overall yield can be reduced substantially as patches spread in successive crops.

Close-up of yellow streak symptoms on oats



Mosaic life cycle

Covered smut

Pathogen

Ustilago hordei and *U. segetum* (*U. kolleri*)

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The pathogen species are crop-specific. Barley (*U. hordei*) and oats (*U. segetum*) are mainly affected.

Symptoms

There are no symptoms of the disease before ear emergence. At ear emergence, the ears seem normal, but grains are covered in a thin membrane. If this is broken, it can be seen that the grains have been replaced by masses of black spores, held in place by an easily ruptured transparent membrane. As spores are released, the symptoms become similar to those of loose smut.

Life cycle

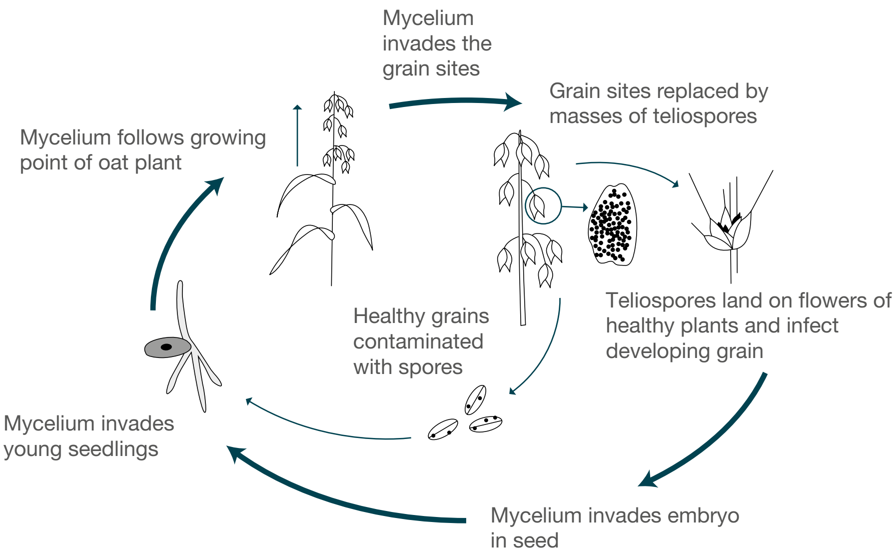
After ear emergence, some spores may be released and carried by wind to neighbouring plants (as in loose smut). However, many are retained within their membranous envelope until the crop is harvested. During the threshing process, spores are released and contaminate the surrounding seeds. Spores remain dormant on the outside of the seed. When seeds are sown, the spores germinate and infect the developing seedling. The fungus develops with the growing point of the plant until it colonises the developing ear.

Covered smut spores can also land on soil and infect seedlings but this soilborne phase is short-lived. Seed is a more important source of infection.

Covered smut affected barley ears (healthy ear on right)

Importance

The disease is very rare in the UK. It is usually only found in crops grown repeatedly from home-saved, untreated seed. There is normally a total loss of grain from affected plants.



Covered smut life cycle

Crown rust

Pathogen

Puccinia coronata

Crops affected

Wheat	Barley	**Oats**	Rye	Triticale

Hosts

The pathogen only infects oats and no other cereal crops. It can infect several grass species, particularly ryegrass, but these forms do not cross-infect oats.

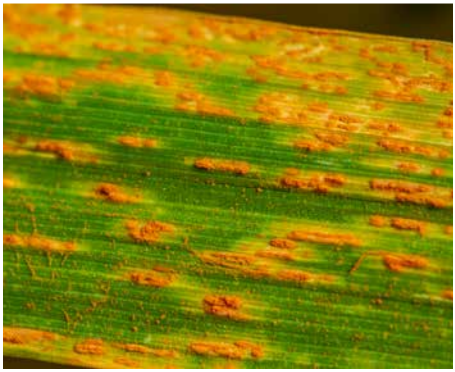
Symptoms

The first symptoms are very similar to those of brown rust of wheat and barley. Orange/brown pustules appear scattered over the leaf surface. Leaf sheaths and – later – the oat panicle can also become infected. High temperatures (20–25°C) favour disease development, so epidemics usually occur in June–July. Late in the season, black pustules appear within the existing crown rust lesions.

Life cycle

Orange airborne spores (uredospores) are produced on leaves. These can spread to others plants across long distances. Black pustules (containing teliospores) are produced later in the season. These remain dormant on crop debris until the spring, when they germinate to produce basidiospores.

The basidiospores of this fungus infect the alternate hosts buckthorn (*Rhamnus catharticus*) and alder buckthorn (*Frangula alnus*).
A third spore type, the aeciospore, is produced on these hosts, which can then reinfect oats.

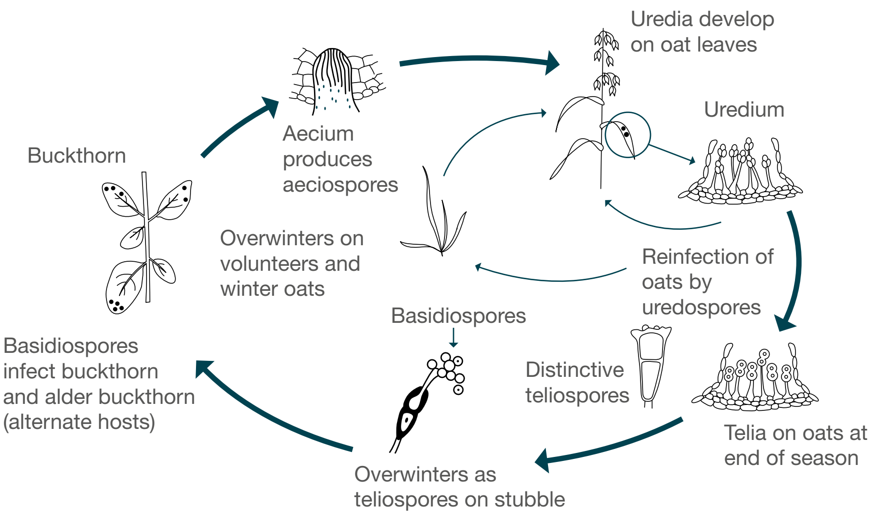


Orange/brown pustules on a leaf surface

Buckthorn leaf showing aecidial stage

Importance

The disease is the major disease of oats. It is favoured by warm and humid weather and mild winters. Severe attacks have been more common in recent years. Such epidemics can reduce yield by 10–20%.



Crown rust life cycle

Dwarf bunt

Pathogen

Tilletia controversa

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The pathogen affects winter-sown crops of wheat, barley, rye and triticale.

Symptoms

The symptoms of dwarf bunt are similar to those caused by bunt, except that in dwarf bunt affected plants are more severely stunted to between one-quarter and one-half of their normal height. Infected ears tend to have a more ragged appearance than with bunt.

Infected ears with slightly 'ragged' appearance

Affected leaves may also occasionally display yellow and flecked leaves. Microscopic examination of teliospore morphology is the primary means of distinguishing *Tilletia* spp. However, *Tilletia* spp. have many varied characteristics, so spore morphology alone is not sufficient for their identification.

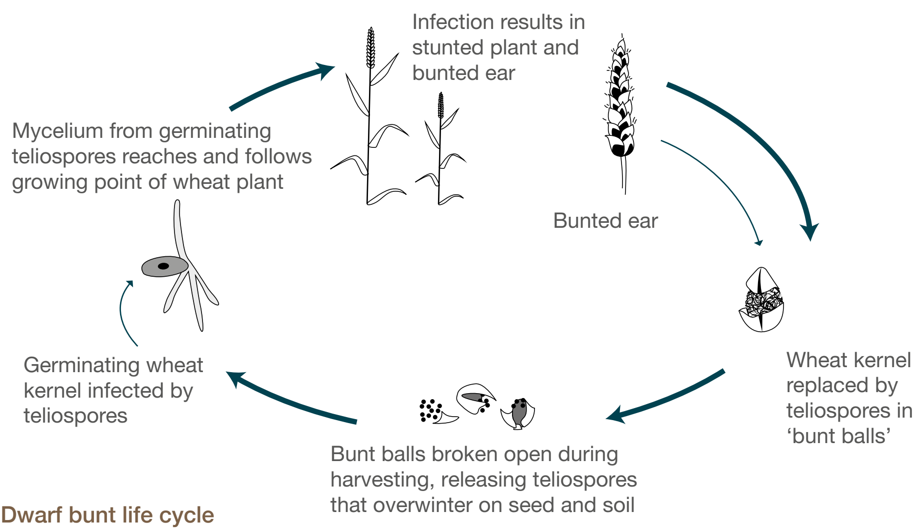
Life cycle

The disease cycle of *T. controversa* closely matches that of *T. tritici*. Infected plants appear unaffected until ear emergence. When the ears emerge, the seeds can be seen to have been replaced by 'bunt balls'. These break open during harvest, contaminating healthy grain (and soil). When contaminated grain is sown in the following season, the spores on the outside of the grain germinate, eventually reaching the growing point of the plant. It is at this stage that infection with *T. controversa* differs from that with *T. tritici*. With bunt, the fungus normally infects the plant via the coleoptile as the seedling is emerging. However, with *T. controversa*, there is a long incubation period and a requirement for cool temperatures before the spores will germinate. As a result, the fungus frequently infects plants much later in development. Dwarf bunt can survive in the soil for many years.

Free spores reportedly remain viable in soil for at least 3 years, while bunt balls can survive for up to 10 years.

Importance

This disease is not yet known in the UK but is of interest because of evidence of the long-term survival of bunt in soil. As dwarf bunt can also survive for long periods in the soil, the possibility of hybrids between *T. controversa* and *T. tritici* has been widely debated. Dwarf bunt occurs in Canada, North and South America, and many parts of Europe and Asia. The disease could be damaging, although seed treatments commonly used in the UK would prevent seedborne infection.



Dwarf bunt life cycle

Ergot

Pathogen

Claviceps purpurea

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

There are several strains of the fungus: some infect grasses and cereals, whereas others are restricted to specific hosts. The pathogen infects all cereal crops. In order of decreasing susceptibility: rye, triticale, wheat, barley and oats (infection of oats is rare). It also affects a wide range of grasses, particularly black-grass.

Symptoms

The causal fungus only attacks the ear at flowering, replacing the grain in a few spikelets by a hard, purple/black sclerotium, known as an 'ergot'. Ergots are formed of a mass of fungal tissue and have a grey/white interior (which distinguishes it from rodent droppings).

Ergots can be large – up to 2 cm in length – and are obvious in both the standing crop and in contaminated grain samples. The first sign of infection is often droplets of honeydew during anthesis. This honeydew can lead to the development of saprophytic moulds.

Life cycle

Ergot is not a true seedborne disease, as it is carried neither on nor in seed. However, it can be spread by ergots in contaminated lots of seed.

Black-grass (left) heads and wheat ears (right) infected with ergot

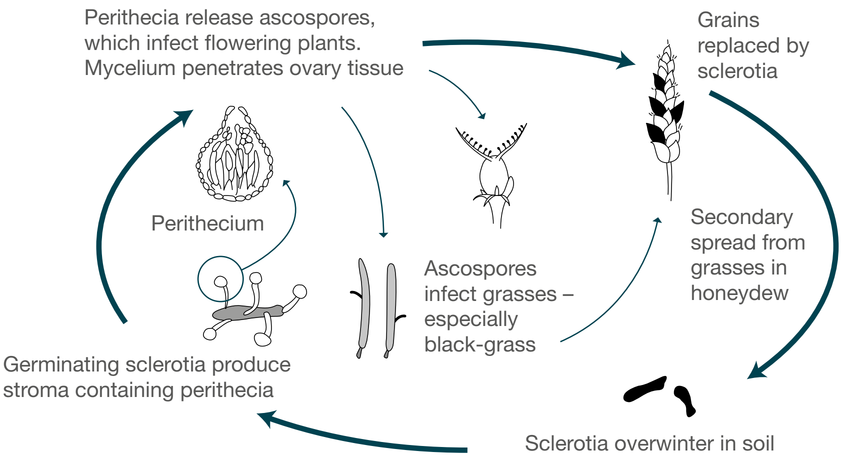
Ergots are either harvested with the grain or fall to the ground. Generally, ergots only remain viable on the soil surface for one year in the absence of host crops, but they may survive longer in stored grain. In the following spring, they germinate and produce mushroom-shaped spore-bearing structures (stroma). The spores are spread by the wind to nearby open flowers of grasses and cereals. The spores germinate in the flower, infecting the ovaries. This infection leads to the production of secondary spores (conidia) encased in a sweet-smelling, sticky secretion – commonly referred to as honeydew. This attracts insects that carry the spores to other flowers, where further infection can occur. Rain splash and physical contact can also spread the spores. The fungus then grows in place of the grain to form the visible ergot, completing the life cycle.

Importance

The disease has very little direct effect on yield, but the ergots contain large amounts of toxic alkaloids (mycotoxins). Contaminated grain, fed to stock or used to make flour, can pose a risk to animal and human health. Such grain may be rejected, require cleaning or demand a reduced price. Standards for the number of ergot pieces exist for certified seed.

The disease is favoured by cool, wet conditions during flowering, which facilitate spore production and prolong the flowering period. Late tillering crops, crops with secondary tillers and more open-flowered crops are more susceptible.

Improvements in agricultural practices and milling techniques (grading, sieving and sorting) have eliminated the severe epidemic outbreaks of ergotism in the UK.



Ergot life cycle

Eyespot

Pathogen

Oculimacula yallundae (*Helgardia herpotrichoides*), *O. acuformis* (*H. acuformis*)

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

Oculimacula yallundae (W-type) is a more severe pathogen on wheat and barley than it is on rye. *O. acuformis* (R-type) infects wheat, barley, rye and triticale.

Symptoms

Although severe and early attacks of eyespot can kill seedlings outright, symptoms typically first become visible in early spring, appearing as a brown smudge at the stem base. They have a diffuse margin and appear on one side of the outer leaf sheath. Symptoms can be confused with sharp eyespot and fusarium foot rot. However, as eyespot is much more important than these diseases, correct identification is important.

As the season progresses, symptoms become more distinct with an eye-shaped lesion with a dark, diffuse margin, usually below the first node. A central black 'pupil' may be visible: this is a mass of compacted hyphae and is difficult to remove by rubbing. Eyespot lesions then penetrate through the leaf layers. This is different from fusarium foot rot and sharp eyespot lesions, which tend to be confined to the outer leaf sheath during stem extension. As leaf sheaths die off during spring growth, eyespot symptoms may disappear but can reappear later. Look at stem bases from the milky ripe stage to see if eyespot lesions are present.

Severe eyespot infections can weaken stems around the lesion and cause lodging – stems can fall in all directions, as opposed to lodging caused by wind.

Severe eyespot lesions on wheat

Alternatively, white heads may form, where nutrient and water flow is restricted to the rest of the plant. Eventually, white heads may be colonised by sooty moulds and turn black. The hollow of infected straw is sometimes filled with a grey fungal growth in the region of the lesion.

Life cycle

Eyespot inoculum overwinters on infected stubble and volunteers. In the UK, the fungus has a sexual and an asexual phase. The sexual phase produces ascospores on stubble after harvest. Dispersed by wind across long distances, these spores infect emerging or young plants throughout the autumn and winter. The asexual phase produces conidia on stubble and trash over the winter. These spores are rain-splashed short distances onto cereal stem bases. The presence of an airborne stage means that surrounding crops can infect first wheat crops in the absence of infected trash. Therefore, the influence of previous cropping is not as large as it was thought to be.

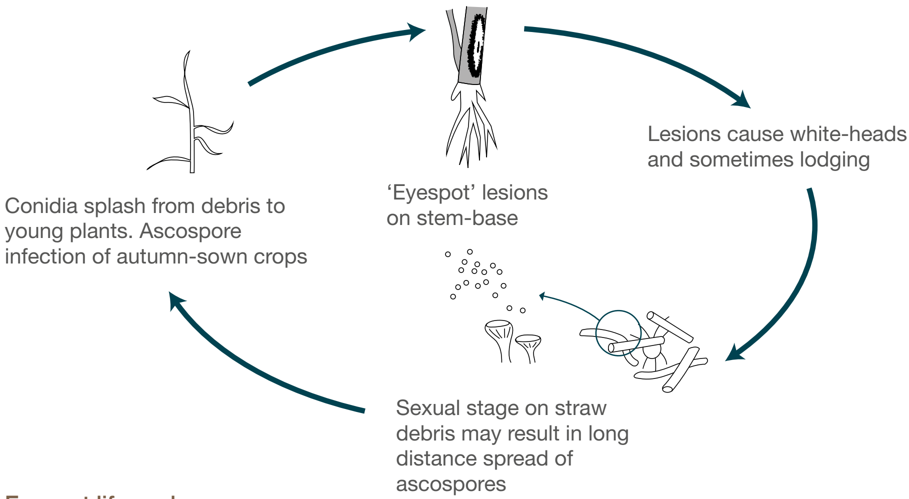
The disease can survive on stubble and trash for three years, especially if buried. Therefore, a one- or two-year break from cereals does not always reduce eyespot risk. Grass weeds also act as sources of inoculum.

Infection occurs at temperatures above 5°C, with a daytime optimum temperature of 15°C and a nighttime optimum temperature of 10°C. High temperatures inhibit infection. Prolonged humid conditions are conducive to infection. Following infection, the development of symptoms normally takes about 12 weeks, depending on environmental conditions. Dry weather can cause infected outer leaf sheaths to shrivel and die, which may prevent infection from progressing.

Importance

Eyespot is a common disease in intensive cereal rotations. The disease most seriously affects autumn-sown crops, especially when inoculum builds up across the rotation. Spring cereals can also suffer from infection. The disease affects wheat more than barley. Although oats are much less susceptible, when infected, they can transfer inoculum between crops.

The disease tends to damage yield only when the lesion penetrates the leaf sheath. This restricts water and nutrient flow to the ear, reduces grain number and size, and causes white heads. Associated lodging can also delay harvest, increase grain moisture, reduce grain quality and encourage other diseases. Moderate or severe eyespot infections can cause yield loss in the order of 10–30%, even in the absence of lodging.



Eyespot life cycle

Flag smut

Pathogen

Urocystis agropyri

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The pathogen infects wheat and many grass species; the strain(s) that affect wheat are specific to that crop.

Symptoms

Affected plants are severely stunted. Excessive tillering is common and often the ears fail to emerge, remaining within the boot. Plants show long, dark grey to black streaks on the leaf blades and leaf sheaths. The streaks eventually erupt, giving the leaves a ragged appearance and exposing the black teliospores. These teliospores are then dispersed, making plants look as though they are covered in soot.

Life cycle

The teliospores released from the leaves can either be blown onto grain of healthy plants, contaminating the grain, or they can drop to the soil where they are very persistent, surviving up to four years.

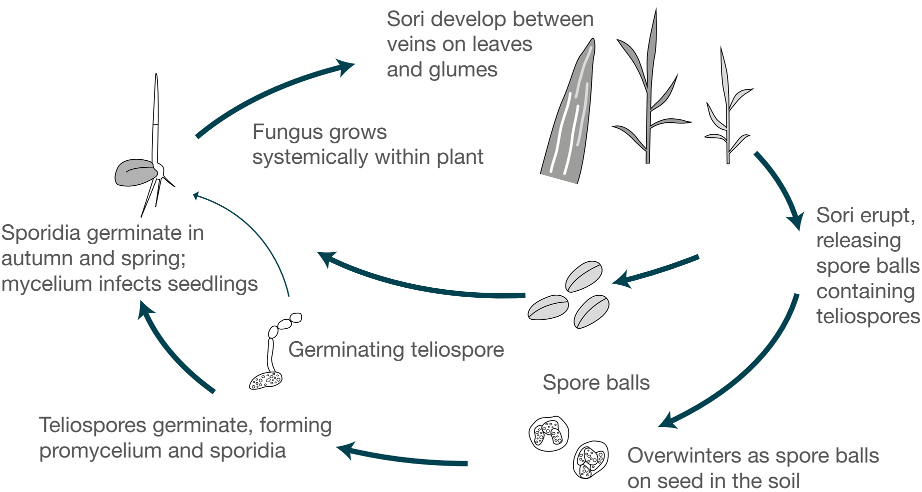
Streak symptoms on a wheat leaf

Black teliospores on a wheat leaf

When contaminated grain is sown, or if healthy grain is sown into contaminated soil, the teliospores germinate, producing a secondary spore type: the sporidia. These spores penetrate and infect the coleoptiles of germinating wheat seedlings, growing inside the plant and eventually producing the typical striping of the upper leaves late in the season. The fungus gives rise to a new generation of teliospores, which can survive in soil for several years. Therefore, even if a break from cereals occurs, subsequent wheat crops can become infected.

Importance

The disease is considered a problem on autumn- (but not spring-) sown wheat in countries with arid summers and mild winters. It occurs in some European countries and in Australia, Canada and the USA. However, it was not known in the UK until 1998, when an outbreak was confirmed in Essex. The disease is not particularly damaging, unless present at high levels, but it can have serious consequences for exporting grain or wheat products. Many countries have quarantine restrictions prohibiting the import of wheat products from countries in which the disease is established. The disease is favoured by minimal cultivation practices, which leave plant debris on the soil surface. One- to two-year breaks from wheat can reduce inoculum levels and deep ploughing can help to remove inoculum from the emerging seedlings.



Flag smut life cycle

Foot rot

Pathogen

Cochliobolus sativus (*Drechslera sorokiniana*)

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The disease affects all cereals.

Symptoms

The fungus causes disease symptoms similar to those caused by *Fusarium* spp. Seedborne infection can result in seedling death, although infected plants usually grow to maturity. Affected plants show brown spotting on the lower leaves and, if severely affected, can show stem-base rotting and poorly filled ears. This severe symptom is rare in the UK.

Life cycle

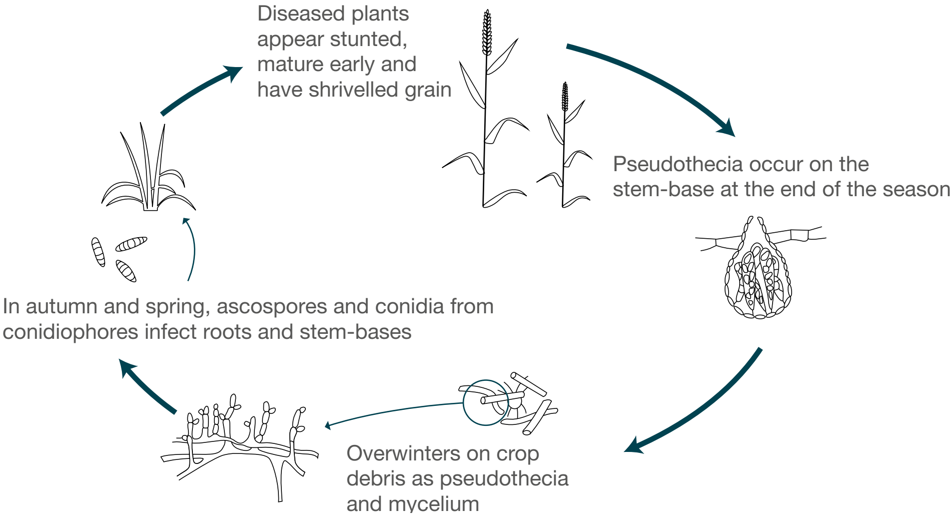
The fungus behaves like *Fusarium* spp. It is both soilborne and seedborne, and can survive on crop debris and grass weeds. It infects seedlings as they emerge,

Foot rot browning at the base of young barley plants occasionally producing a seedling blight. More commonly, it infects roots of seedlings, allowing the plant to survive. Leaf spotting and stem-base infections produce splash-borne spores, which can be carried to emerging ears, resulting in seed infection.

Importance

This is traditionally a disease of hotter climates than that of the UK, but seedling losses and leaf spotting can occasionally occur. The disease is more often recorded on spring barley than winter barley, and some varieties are more susceptible than others. Infections tend to be higher in organic compared with conventional systems.

Foot rot discolouration of wheat sub-crown internode



Foot rot life cycle

Fusarium and microdochium

Other common names

Seedling blight, foot/crown rot, ear (head) blight

Pathogen

Fusarium avenaceum, F. culmorum, F. graminearum, F. poae, F. langsethiae, Microdochium nivale and *M. majus*

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

Wheat, barley, oats, rye, triticale and grasses.

Symptoms

Many species of fusarium affect cereals. These fungi form a disease complex on seeds, seedlings and adult plants. The seedborne pathogens *Microdochium nivale* and *M. majus* (formerly known collectively as *Fusarium nivale*) are also included in this group. *M. nivale* also causes snow mould.

Fusarium seedling blight

M. nivale is the primary pathogen in the group that causes seedling blight. Seedling blight causes pre- and post-emergence damping off. This can result in seedling death and poor establishment. Surviving seedlings may develop a brown lesion around soil level. This can develop into foot and root rot. Symptomless infections can also occur.

Fusarium foot rot/crown rot

Foot rot becomes obvious from late stem extension onwards. It results in dark-brown staining of the lower nodes.

Dark-brown fusarium staining on the lower nodes

A brown and rotten stem base is a symptom of fusarium infection

Long dark streaks may also appear at the stem base. On older plants, fusarium infection can produce a true foot rot, where the stem base becomes brown and rotten, resulting in lodging and white heads. This symptom is less common in the UK but can develop in very dry seasons.

Fusarium ear (head) blight

Fusarium species cause a range of symptoms on the ear. Bleached ears often show above the point of infection around the milky ripe stage (growth stage 75). Later infections may result in infection of the grain without obvious bleaching of the ears. The presence of orange/pink fusarium spores may also be visible on infected spikelets. As the crop ripens, symptoms become less visible. At harvest, fusarium ear blight can result in shriveled grains with a chalky white or pink appearance, although this is not always the case. There is little correlation between fusarium-damaged grains and mycotoxin occurrence. Therefore, the presence of ear blight symptoms is not a good indicator of mycotoxin risk.

Fusarium infection resulting in bleached ears

Ear blight symptoms caused by *Fusarium poae*

Fusarium infection resulting in shriveled, pink grains

Life cycle

Primary infection by fusarium is from infected seed, soil, crop debris and volunteers or host weed species. The main source of ear blight infection is from spores – from seedling blight or foot rot lesions – splashed up the plant or spread by leaf contact. For some fusarium species, spores are also wind-spread, although this is not an important infection source. Ear blight infection occurs during flowering. It infects the grain and completes the life cycle.

Environmental conditions affect disease development, and fusarium species have different temperature requirements. For example, *M. nivale* seedling blight is most severe under cool, wet soil conditions, whereas *F. graminearum* seedling blight is most severe under warmer, drier soil conditions. Warm, wet, humid conditions during flowering favour infection by fusarium species, causing ear blights and seedborne infection. Further rainfall and humid conditions allow secondary infection to occur and further fungal growth.

Importance

Most cereal crops develop fusarium symptoms each year. *F. culmorum* and *F. graminearum* are the most commonly found species in the UK that cause ear blights. Although infection by fusarium species can cause poor establishment and lower yields, the most important issue is the production of mycotoxins in the grain by some species. However, the presence of ear blight is not a good indicator of likely mycotoxin risk. Mycotoxins are present at lower levels in barley and oats compared with wheat. The overall risk of DON exceeding legal limits in wheat is low, and in barley and oats is very low.

Wheat

F. graminearum and *M. nivale* cause the most significant seedling losses in UK wheat. However, crops usually compensate from the loss of a few plants through tillering. *F. graminearum* is more common in a maize-producing area, whereas *M. nivale* is more generally distributed. Severe foot rotting in wheat is rare in the UK, because badly infected seed is not used, seed treatments are effective, and losses are generally very small.

High levels of ear blight can occur, especially when conditions are conducive (e.g. wet) during flowering, but yield losses are rarely serious. Seed saved from these crops can suffer from poor establishment, unless the seed is treated with a product effective on fusarium.

The mycotoxins DON and ZON are frequently detected in wheat but average concentrations are usually below the legal limits. Limits are most frequently exceeded in wet harvest years.

Barley

Seedling blight in barley due to fusarium species is rare, but may occur where there are high infection levels and seed is sown into cold seedbeds. Losses are generally not as high as those seen for wheat.

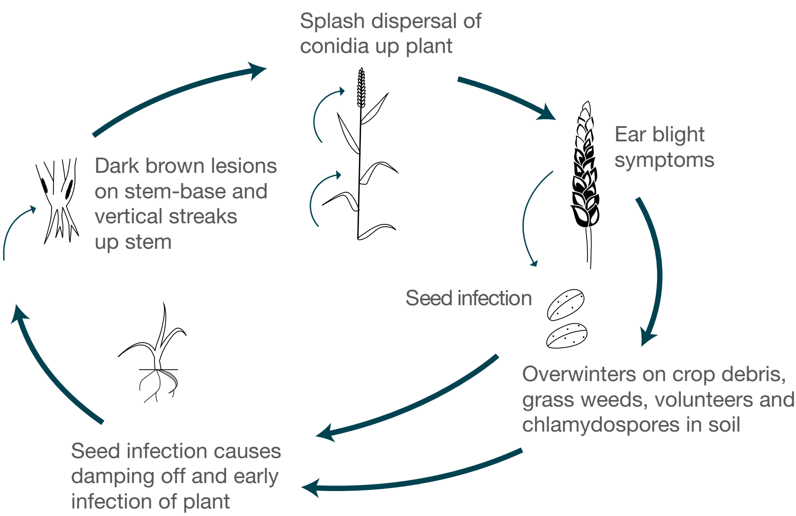
Ear blight and mycotoxin risk is also lower in barley than in wheat, but should be considered if barley is commonly grown in rotation with maize with minimum tillage. Developed for wheat, the AHDB fusarium mycotoxin risk assessment tool is also useful for assessing risk in barley.

DON, ZON, HT-2 and T-2 levels in barley have been routinely low, with legal limits rarely exceeded.

Oats

Oats are more resistant to fusarium infection than wheat and barley, and it is difficult to see the symptoms in this crop. Symptoms can include bleaching of spikelets and premature plant death.

F. langsethiae is the predominant species that infects oats and produces the mycotoxins HT-2 and T-2. There is good evidence that at least 90% of mycotoxins are removed during dehulling. Previous Food Standards Agency surveys of fusarium mycotoxins in retail oat products have identified that exposure to these toxins from oat products in the UK diet is low.



Fusarium and microdochium life cycle

Halo spot

Pathogen

Selenophoma donacis

Crops affected

Wheat	**Barley**	Oats	Rye	Triticale

Hosts

The disease only affects barley.

Symptoms

Halo spot is mainly found in western, coastal areas of the UK, where outbreaks occur in wet summers after flag leaf emergence. The disease appears as small leaf spots (1–3 mm long), often square or rectangular in shape, pale brown in the centre, with dark purple/brown, well-defined margins. Pycnidia occur in lines along the veins within the central area of a lesion. Spots generally occur towards the tips and along the edges of leaves. They also affect the leaf sheath and ear (especially the awns). This disease often occurs with rhynchosporium, but can be distinguished from the latter by the smaller size of the spots and the presence of pycnidia within the lesions. Halo spot also tends to occur most often on the upper leaves, while rhynchosporium is more common on older foliage.

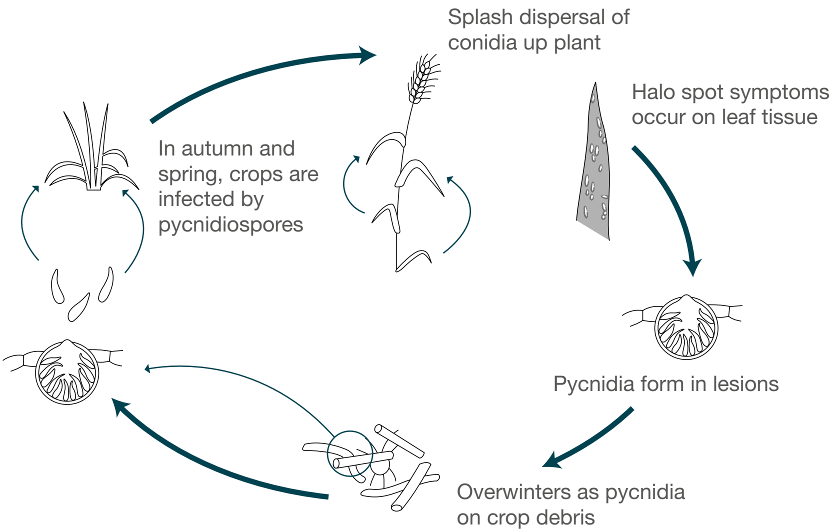
Halo spot symptoms on a barley leaf

Life cycle

The disease originates from infected seed, stubble and volunteer barley plants. Symptoms on lower leaves, which arise from seed infection or from stubble contact or splash, are indistinct, but rain splash helps to spread them up the plant – usually in warm conditions later in the season. The disease rarely becomes important until after flag leaf emergence, when it can develop rapidly in wet weather.

Importance

The disease occurs sporadically, usually in wet seasons. Traditionally, the disease mainly occurs in the south-west of England, where rainfall is high, but it is rare elsewhere in the UK. Generally, it does not cause significant yield loss.



Halo spot life cycle

Leaf spot

Pathogen

Pyrenophora avenae (*Drechslera avenae*)

Crops affected

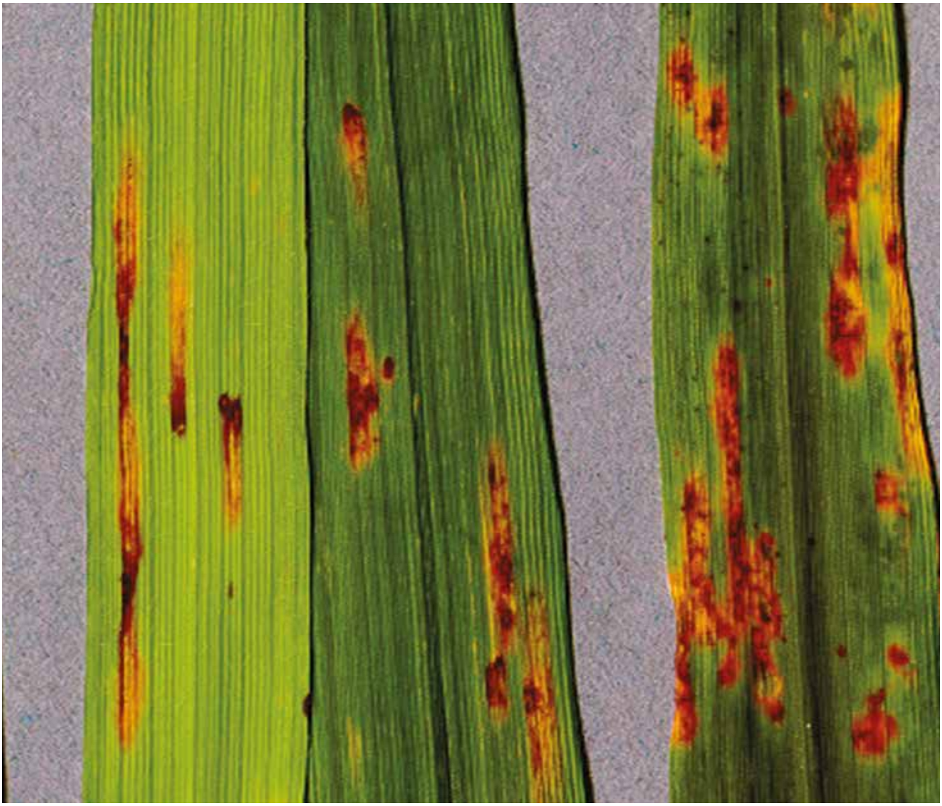
Wheat	Barley	**Oats**	Rye	Triticale

Hosts

The pathogen is specific to oats.

Symptoms

The primary phase of the disease (from seedborne infection) appears as short brown stripes with purple edges on the emerging leaves. These stripes appear on the first three or four leaves of emerging seedlings. The secondary phase of the disease (splash-borne spores) appears as red-brown spots with purple margins on leaves.



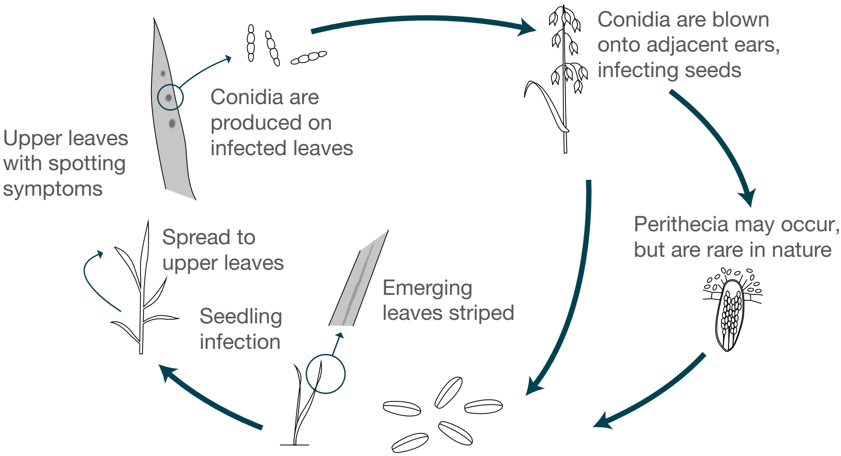
Symptoms on emerging leaves showing short brown stripes with purple edges

Life cycle

Infected grain can cause seedling death during or soon after emergence. Infected debris is not thought to be a significant part of the disease cycle. Spores from the early leaf stripes on surviving seedlings splash up the plant. Upper leaves develop spotting symptoms. Eventually, spores splash up onto the ear, where the grain becomes infected.

Importance

Although the disease is not uncommon, severe outbreaks are rare and are probably associated with sowing repeatedly home-saved, untreated seed.



Leaf spot life cycle

Leaf stripe

Pathogen

Pyrenophora graminea (*Drechslera graminea*)

Crops affected

Wheat	**Barley**	Oats	Rye	Triticale

Hosts

The disease is specific to barley.

Symptoms

The disease is seedborne and causes long brown stripes on the leaves. The stripes are often pale green at first, becoming yellow and finally dark brown. Usually, all of the leaves of affected plants show these symptoms and some leaves split along the stripes, giving the leaf a shredded appearance.

Symptoms are usually most prominent at ear emergence. The disease is generally most severe on crops grown from untreated seed.

Leaf stripe can affect barley in three ways. Firstly, it can kill seedlings as they emerge. This is unusual, but can occur if soil conditions are poor. Secondly, it can reduce the efficiency of the plant by reducing green leaf area. Thirdly, it can cause complete blindness of the ear, resulting in no harvestable grain from affected tillers.

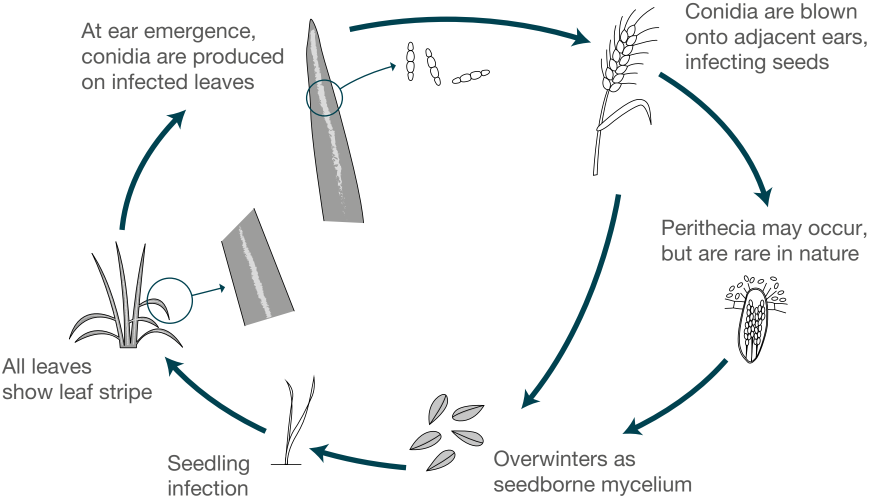
Leaf stripe symptoms on barley

Life cycle

The disease is seedborne, with the fungus present on the seed surface and in the seed coat. As the coleoptile emerges, the fungus invades the tissue and penetrates through to the emerging first leaf. The fungus grows through successive leaf sheaths, producing the characteristic symptoms on each leaf. Growth continues until the fungus infects the ear, which often remains in the leaf sheath. The fungus produces spores on the leaf stripes, which are blown onto adjacent ears and infect seeds (from anthesis through to soft dough). This infection is not associated with new symptoms.

Importance

This is potentially the most serious seedborne disease of barley. If seed from affected crops is resown without first being treated with an effective fungicidal seed treatment, the pathogen can multiply rapidly, causing significant yield losses. If seed is repeatedly saved and resown, complete crop loss is possible within a few generations.



Leaf stripe life cycle

Loose smut

Pathogen

Ustilago tritici (wheat), *U. nuda* (barley) and *U. avenae* (oats)

Crops affected

Wheat	**Barley**	**Oats**	Rye	Triticale

Hosts

Different species or variants of *Ustilago* infect specific crops.

Symptoms

Usually, a mass of black fungal spores replaces grain, affecting all or part of the ears. Spore release occurs as the ear emerges. This leaves only the bare remains of the ear rachis. Because the blackened ears are obvious, the disease appears to be severe, even at low incidence levels.

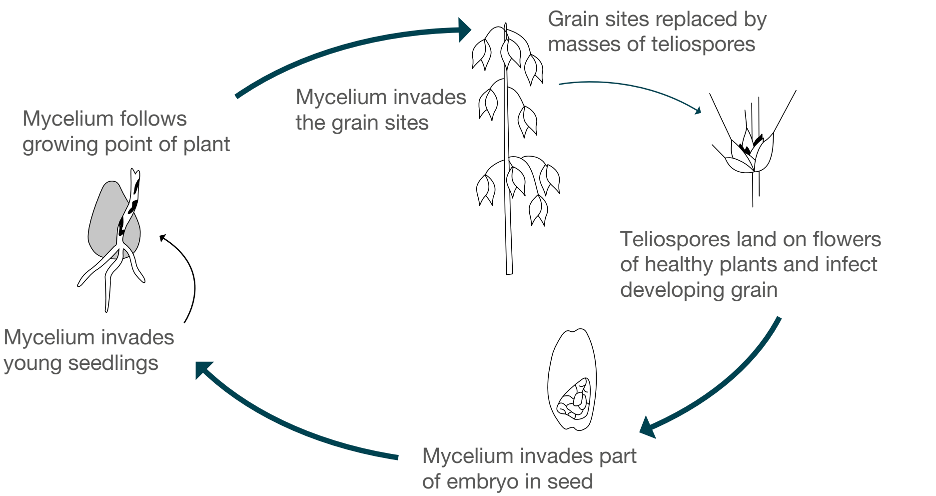
Life cycle

Wind spreads spores released from infected ears, to open flowers. Weather affects how long florets remain open and, hence, the time that the plant is susceptible to infection. Consequently, the infection levels vary considerably from season to season. Once spores germinate, the fungus grows in the developing grain site. The fungus lies dormant within the embryo of the seed. When the infected seed germinates, the fungus grows within the developing shoot, eventually reaching the ear primordia. The fungus develops within the young ear, eventually replacing spikelets with masses of fungal spores.

Close-up of infected wheat ears

Importance

Most important in UK barley, the disease is rare in wheat. The UK Seed Certification Scheme helps ensure that loose smut remains at low levels in UK seed stocks. Fungicidal seed treatments also control it well. Infected crops suffer yield loss. Although an infection of 0.1% (1 in 1,000 ears affected) looks severe, it only results in a yield loss of 0.1%. However, smutted ears can rapidly spread infection to surrounding crops. The grain of these crops becomes infected which, when replanted, do not show symptoms until the following spring.



Loose smut life cycle

Net blotch

Pathogen

Pyrenophora teres f. *teres* (*Drechslera teres*) (net form) and *P. teres* f. *maculata* (spot form)

Crops affected

Wheat	**Barley**	Oats	Rye	Triticale

Hosts

Many grass species are affected by net blotch, but there are specific forms that only infect barley and are specific to that crop.

Symptoms

Net blotch infects barley via infected seed or infected trash. Symptoms at the early growth stages can vary, depending on the source of the infection.

Seed infection causes brown stripes to spread from the base of leaves in seedlings and tillering plants, which can look similar to leaf stripe infection. Later in the season, the symptoms of leaf stripe and net blotch become more distinct, with the symptoms of net blotch becoming more typical of that disease.

The most common cause of infection is splash-borne spores, from infected trash or neighbouring plants.

Typical symptoms of net blotch

Net blotch symptoms in adult plants sometimes form long elongated stripes

Symptoms start as individual spots that can be easily mistaken for ramularia leaf spot. These elongate and turn into brown stripes or blotches with a random netting of darker lines along and across the leaf. Symptoms can be extensive in winter but affected leaves die back, and new leaves in spring can be symptom-free.

The 'spot form' of net blotch is less common. A chlorotic halo surrounds the oval brown lesions. Unlike the net form, these spots do not elongate, but grow to be 3–6 mm in diameter. This symptom can also be mistaken for ramularia leaf spot. However, spot form lesions are not limited by the leaf veins. Net blotch also occurs throughout the season, whereas ramularia leaf spot symptoms typically appear after flowering.

Leaves frequently have yellowing associated with all of these types of lesion, particularly when the symptoms are severe. Late attacks can also affect the glumes and awns, producing dark brown flecking and striping.

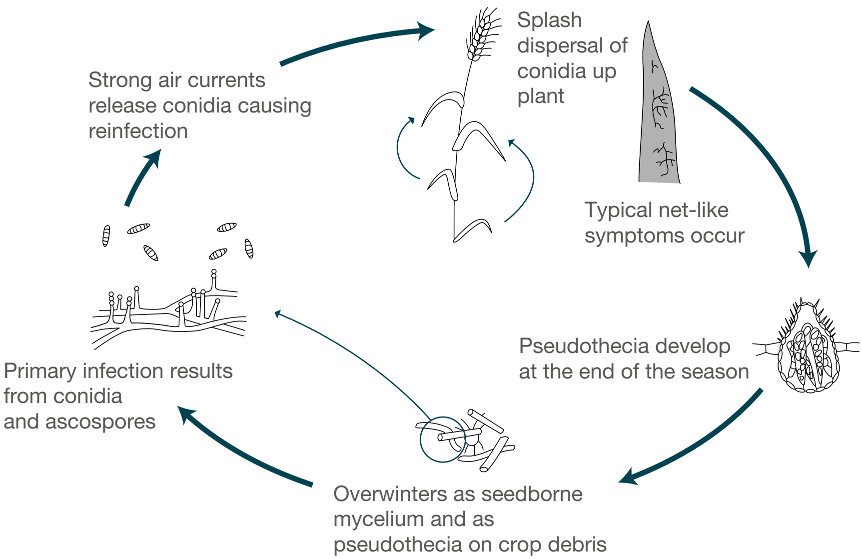
Life cycle

The disease is seedborne and trash-borne. Historically, infected seed was important in spreading the disease. However, the trash-borne phase is now the main inoculum source. Infected stubble and debris, along with volunteer barley, allow the pathogen to overwinter and produce spores. Straw residues into which a crop is drilled are the most important source of the disease, but straw in adjacent fields can also provide a source of wind-blown infection.
Asexually produced conidia, which arise from mycelium, initiate and spread most of the disease.
Sexually produced ascospores, which arise from pseudothecia, are wind-blown and water-splashed.
Following primary infection, further spores are produced. Strong air currents release the spores from the leaf, which are splashed over short distances in the canopy. Infection occurs during periods of prolonged high humidity and temperatures of 10–25°C. Higher temperatures and dry weather inhibit infection.
The disease cycle can complete in 14 days in optimal conditions.

Importance

Net blotch is a very important disease of barley, especially winter barley. It is prevalent across the UK, with no variation in the risk between regions. It can cause yield losses of 10–40%, where it is not well controlled. It also reduces the quality of grain, increasing screenings and the risk of crop rejection for malting.

The disease can be particularly damaging when symptoms continue to develop through the winter and into the early spring, producing an early epidemic as the crop develops. The most serious symptoms usually occur on upper leaves during warm humid weather in the summer, on unprotected susceptible varieties.



Net blotch life cycle

Omphalina patch

Pathogen

Omphalina pyxidata

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The disease affects wheat, barley and grasses.

Symptoms

As early as December, affected patches can be visible as sharply delineated but irregular areas of stunted growth. Foliage colour is not normally affected. Roots and the soil adjacent to affected plants show characteristic white hyphal masses (like small pieces of cotton wool about 1 mm across). Fruiting bodies (basidiocarps), like tiny mushrooms (about 2 cm high with a 1 cm diameter convex cap), sometimes appear within affected patches between January and March.

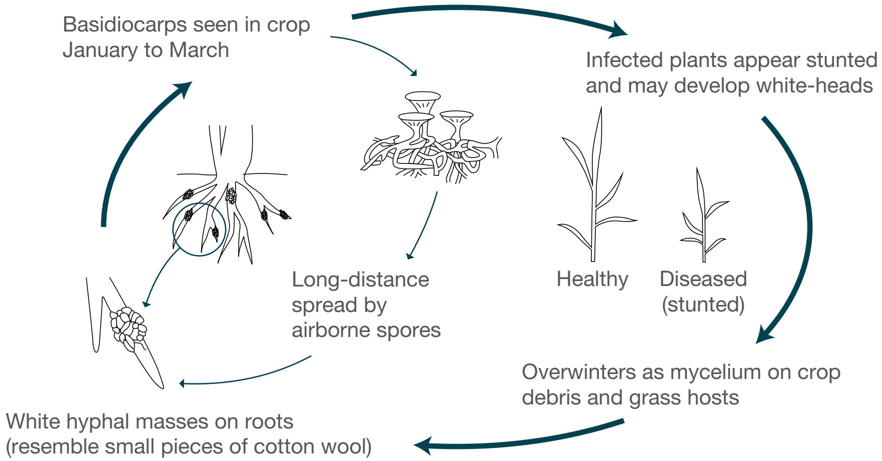
Fruiting bodies (basidiocarps) in affected soil

Life cycle

Little is known about the disease cycle. It is a soilborne fungus that survives between susceptible hosts as sclerotia or as mycelium on root debris. It infects crops soon after emergence, colonises roots, produces sclerotia and airborne basidiospores. These spores may play a part in long distance spread of the disease.

Importance

Although the fungus is now recognised as a pathogen of UK cereals, it is believed to be sporadic in nature. It only affects a small number of crops each year – mainly winter barley and crops on light land. Limited trials on winter barley suggest infection can reduce fertile tiller numbers by 40% and yields by 25–50%.



Omphalina patch life cycle

Powdery mildew

Pathogen

Blumeria graminis f. sp. *tritici* (wheat and triticale), f. sp. *hordei* (barley), f. sp. *avenae* (oats) and f. sp. *secalis* (rye)

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

Mildew can infect all cereals. However, there are several forms of the disease that are specific to individual crops and do not cross-infect.

Symptoms

Powdery mildew symptoms develop on leaves, stems and ears. Infection most commonly occurs on leaves, with symptoms occurring from autumn onwards. Typically, white, fluffy pustules appear. These produce masses of spores with a powdery appearance. Eventually, black spore cases (cleistothecia) develop in the mildew pustules, usually towards the end of the season.

Early symptoms (left) and mature pustules with black spore cases (right)

In wheat, leaf yellowing is associated with infection. On yellowing leaves, pustules retain a distinctive ‘green island’. In barley, infection often causes the leaf to turn brown. A hypersensitive response can occur when the plant tries to defend itself against powdery mildew infection, for example, in resistant varieties. This leads to small dark brown flecks on the leaf, with no visible pustules.

Life cycle

In the UK, powdery mildew survives the winter, and the period between harvest and planting of the new crop, as mycelium in living host plants, such as volunteers. It is possible for the fungus to survive in crop debris in the absence of a green bridge through black fungal bodies (cleistothecia), though this stage is not as important. However, this sexual stage can allow the pathogen population to evolve and lead to new races that can overcome varietal resistance or become resistant to fungicides. These cleistothecia release wind-dispersed ascospores in humid weather.

The fungal mycelium on living plant tissue produce wind-dispersed conidia that infect living host plants. Conidia germinate over a wide temperature range (5–30°C), although 15°C is optimal, and temperatures over 25°C can inhibit development.

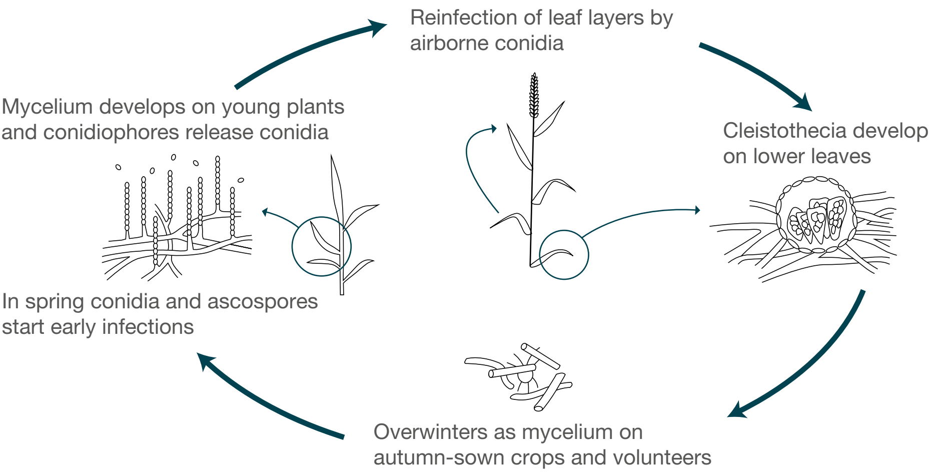
High humidity (>80%) is required for the conidia to germinate, with >95% relative humidity optimal. However, free water, for example, from rain, inhibits germination. The latent period of powdery mildew is just 7 days, under optimal conditions.

The disease continues to spread throughout winter, especially if it is mild. However, frosts and cold conditions reduce disease levels.

Importance

The visual appearance of powdery mildew usually outweighs its damage potential, especially during the autumn and winter. In very susceptible varieties, yield losses can be high (up to 20%) and early control can be very important. However, the disease generally causes much smaller yield losses (rarely exceeding 10%) and late attacks (after flowering) on the flag leaf and ear rarely cause significant losses.

Crops under stress, late-sown crops, and crops that are growing rapidly in the spring are often particularly prone to attack. Early attacks can reduce tiller number and excessive nitrogen fertiliser can encourage the disease. Mildew can be particularly severe in dense crops.



Powdery mildew life cycle

Ramularia leaf spot

Pathogen

Ramularia collo-cygni

Crops affected

Wheat	**Barley**	Oats	Rye	Triticale

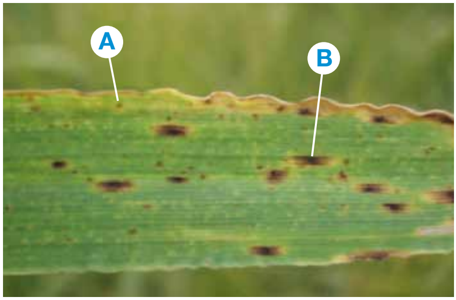
Hosts

Although primarily a disease of barley, the fungus is able to infect wheat and oats, but the incidence and importance of this is unknown.

Symptoms

Ramularia leaf spot shows no visible symptoms at the seedling stage, so identification (within seed and seedlings) requires molecular diagnostics. Symptoms usually appear on the upper leaves after flowering, but symptoms can show earlier in stressed crops or on senescing leaves.

Initial damage is a fine pepper spot (A), which darkens to a square spot, bounded by leaf veins and surrounded by a chlorotic halo (B).



Mature ramularia lesions can be distinguished from other foliar symptoms by applying the '5Rs':

1. Ringed with yellow margin of chlorosis
2. Rectangular shape
3. Restricted by the leaf veins
4. Reddish-brown colouration
5. Right through the leaf

Later in the season, rows of white spores can be seen with a hand lens on the undersides of affected leaves. As leaves senesce, these structures can be seen with the naked eye.

Ramularia is often mistaken for other diseases, such as the spot form of net blotch, tan spot or physiological spotting. Net blotch and tan spot lesions are not rectangular or restricted by leaf veins. Physiological leaf spots, caused by oxidative stress, tend to be caused by superficial browning on upper leaf surfaces, while the undersides remain unaffected. These cause less yield loss but can trigger the production of ramularia leaf spots.

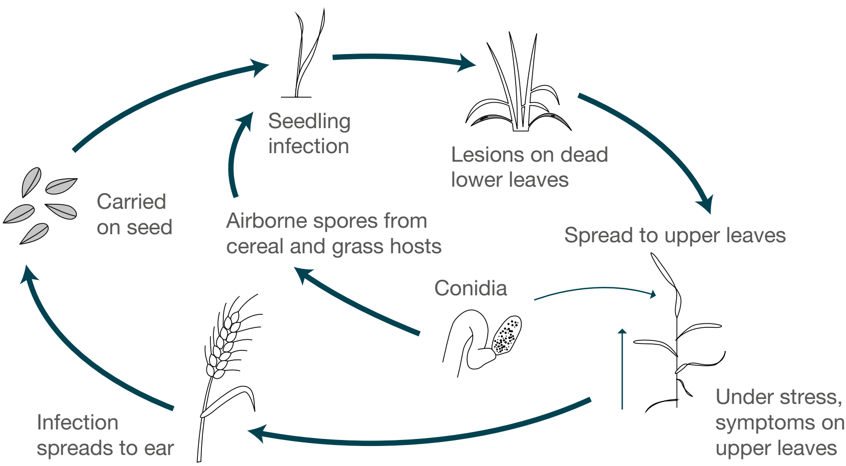
Life cycle

The fungus grows from infected seed and moves symptomless and systemically within new plant growth.

Airborne spores produced on trash and crop debris can also infect plants. The relative importance of the seedborne and airborne phases of infection, and the interactions between ramularia leaf spot and the host plant are complex and not fully understood.

Importance

Ramularia leaf spot can cause extensive damage to the upper leaves in barley, causing losses in yield and grain quality. Trials suggest yield loss can be up to 0.5 t/ha in heavily infested crops. Symptoms have been reported with increasing frequency across the UK. However, ramularia is probably still underreported, due to unfamiliarity with the symptoms. Though previously associated with spring crops, evidence of ramularia in winter crops has increased in recent years.



Ramularia leaf spot life cycle

Rhizoctonia stunt

Pathogen

Thanatephorus cucumeris (*Rhizoctonia solani*)

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The disease affects all the major cereal crops and probably most grasses.

Symptoms

The disease is usually apparent as patches of thin, stunted plants, which often show yellowing or purpling, with die-back of seedlings in the autumn. Patches may also become visible in early spring as areas of stunted purpled plants. The root systems of plants within these patches are usually poor and branched. Brown, rotten tissue may be seen as constrictions at intervals along the length of the root – often giving the root the appearance of a string of sausages. Affected plants remain thin and stunted, with maturity often delayed.

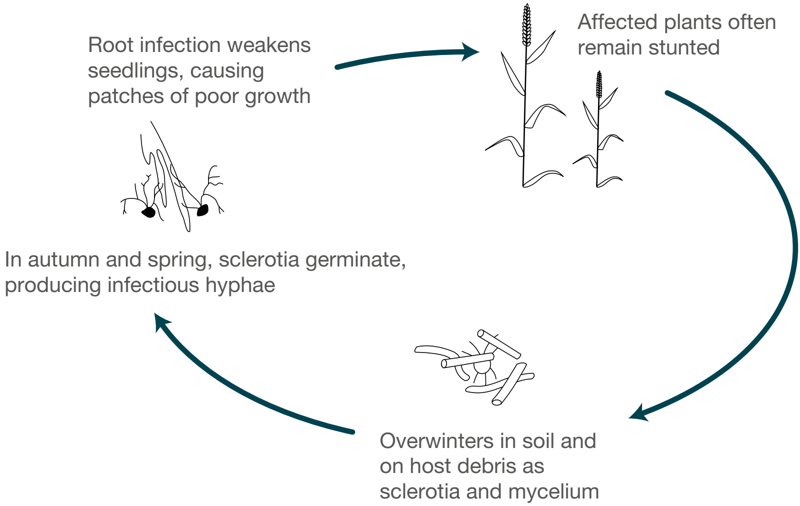
Life cycle

This disease is soilborne. The fungus is common and survives between susceptible crops as mycelium on dead tissues and other hosts.

Importance

The disease occurs erratically, but is usually confined to sandy loam or loamy sands, in areas such as the Brecklands of Norfolk or Suffolk. It is more severe where crops have been established by direct drilling or minimum cultivation. Individual crops may suffer considerable losses. However, in general, barley is the most susceptible and wheat is not seriously affected.

Roots of a stunted plant



Rhizoctonia stunt life cycle

Rhynchosporium (leaf scald)

Pathogen

Rhynchosporium commune

Crops affected

Wheat	**Barley**	Oats	**Rye**	**Triticale**

Hosts

The disease affects barley, rye, triticale and a number of grasses, particularly ryegrasses. There are specialised forms of the pathogen, which are generally restricted in their host range.

Symptoms

Initial symptoms often appear in random patches soon after sowing winter barley. Symptoms due to the seedborne phase of the disease do not appear until January/February, as the disease initially develops inside the leaves and roots without symptoms showing.

Typical early symptoms are oval or irregular, pale green-grey, water-soaked lesions. Infection often occurs in the leaf axil. Symptoms often first appear at the base of the leaf, close to the stem. Symptoms then spread to the rest of the leaf, leaf sheaths, ears and grain, particularly in wet conditions. As the lesions age, they acquire a dark brown margin (the centre remains pale green or turns pale brown). Lesions often coalesce and form large areas, around which leaf yellowing is common. These can cause chlorosis and eventual death of the rest of the leaf.

In winter barley, symptom expression can be high during tillering in early spring. In spring barley, it is rare to see symptoms until after tillering, except in early sown crops. In both crops, symptoms can build up rapidly after emergence of the flag leaf, under favourable conditions.

Rhynchosporium can be confused with other abiotic spotting symptoms, but symptoms are always present on the lower leaves, if they are present on the upper leaves.

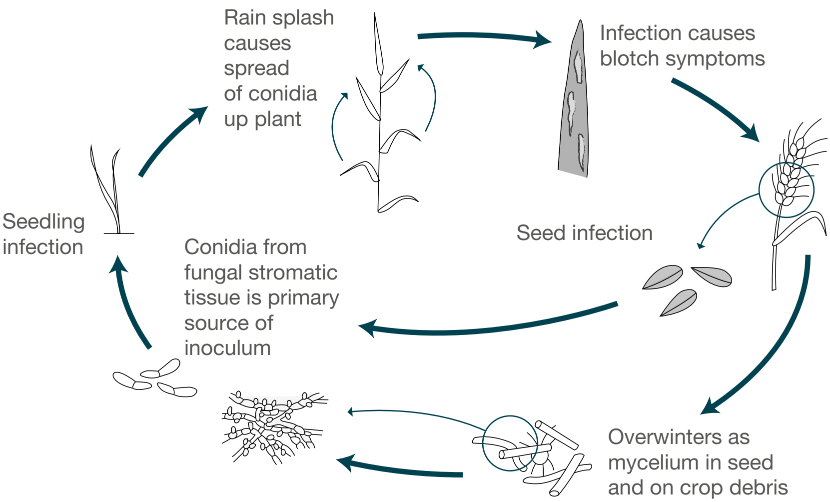
Scald-like lesions have dark brown margins and pale centres

Life cycle

The seedborne phase is not fully understood. Rhynchosporium does not survive well in soil, but survives for up to a year in crop debris. Rain-splashed spores, from infected trash, stubble and volunteers, infect seedlings. Rain splash continues to spread the disease up the canopy, infecting later-emerging leaves, ears and grains. Long-distance spread of airborne spores can also occur. This route of infection can be important in spring barley planted next to infected winter barley crops. The disease is polycyclic. This means it is capable of causing several infection cycles during the growing season. Cool, moist conditions favour the disease. The disease cycle can repeat every 14 days. The ideal temperature range is 18–20°C but temperatures over 20°C slow disease development. There is also potentially a sexual stage of this disease.

Importance

Rhynchosporium is the most damaging disease of UK barley. It can be very severe, particularly in the South West, West and North of the UK, where conditions are generally wet. In winter barley, yield losses can exceed 1.5 t/ha and grain quality can be reduced. The most serious effect on yield, in both winter and spring barley, results from attacks that develop between first node detectable and boot-swollen growth stages (growth stages 31–45). Visible levels of disease of 1–2% at growth stages 31–32 cause economic loss, if left untreated.



Rhynchosporium (leaf scald) life cycle

Septoria nodorum

Other common names

Septoria seedling blight, leaf blotch and glume blotch

Pathogen

Parastagonospora nodorum

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The pathogen mainly infects wheat, but occasionally barley and rye.

Symptoms

Septoria seedling blight

P. nodorum can be seedborne and infect seedlings in cool, wet soils. The most common effect is poor plant establishment. It can also result in water-soaked, dark green areas on the coleoptile, which later become necrotic. Twisted, distorted and stunted seedlings may also occur. As symptoms are similar to those of microdochium seedling blight, laboratory analysis is often required to distinguish the causal organism.

Leaf blotch

On mature leaves, the first symptoms of *P. nodorum* infection are small necrotic lesions. Later, these develop into brown oval lesions, surrounded by a chlorotic halo. These lesions frequently coalesce to produce large areas of dead, dry and sometimes split tissue. Under high disease pressure, leaf symptoms can include small purplish-brown spots.

The indistinct pale brown pycnidia of *P. nodorum* may only be visible with a hand lens when lesions are held up to the light. They are often sunken within the lesions. Note: Septoria tritici blotch (caused by *Zymoseptoria tritici*) is associated with black pycnidia.

Leaf blotch lesions on wheat leaves

Glume blotch

P. nodorum can also infect the ears, particularly of wheat, causing glume blotch. Dark brown patch-like burn marks develop on the glumes, which later become purple/brown. Glume blotch symptoms are easiest to see on green ears.

Life cycle

P. nodorum survives as dormant mycelium, and as pycnidia and pseudothecia on seed, stubble, crop debris, wild grasses, autumn-sown crops and volunteers. Infection of newly emerged crops occurs from these sources or from windborne ascospores released from infected stubble. Infection can also be seedborne. It is likely that the seedborne phase is responsible for septoria seedling blight.

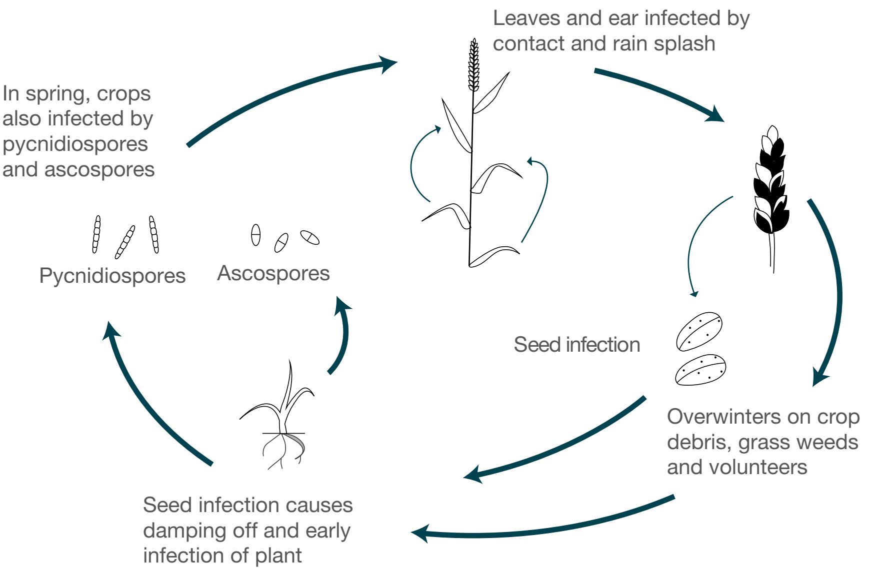
As temperatures rise and humidity increases, pycnidiospores are produced from the pycnidia. These are splash-dispersed up the plant and from plant to plant. Temperatures of 20–27°C, together with long periods (6–16 hours) of high humidity, are optimal for spore production and germination. A period of rain is essential for spore dispersal. The disease cycle can be completed in 10–14 days during such conditions.

Spores produced from pseudothecia and pycnidia, which develop on the flag leaf and ear at the end of the season, can initiate infection in very early autumn-sown crops and volunteers, but infections on debris are more likely to initiate infection on new crops. Glume blotch infection of the ear can lead to infection of the seed.

Glume blotch symptoms on a wheat ear

Importance

Once the most serious pathogens on UK cereals, *P. nodorum* now rarely causes significant losses, except in wet seasons in the south-west of England. The leaf and glume phase of the disease is more important than the seedling blight phase. Losses caused by septoria seedling blight are generally not significant and are usually less severe than microdochium seedling blight. The risk in barley is much lower than in wheat. Yield losses up to 50% have been reported in trials, although average annual losses in the UK probably do not exceed 3%.



Septoria nodorum life cycle

Septoria tritici blotch

Pathogen

Zymoseptoria tritici (teleomorph *Mycosphaerella graminicola*) – formerly known as *Septoria tritici*

Crops affected

Wheat	Barley	Oats	**Rye**	**Triticale**

Hosts

The pathogen infects mainly wheat, but occasionally also infects rye, triticale and some grass species.

Symptoms

Septoria tritici blotch often results in elongated, oval lesions that are restricted by leaf veins, giving a rectangular appearance. Water-soaked patches often form, surrounded by leaf yellowing or death. Lesions may coalesce to form large areas of necrotic brown tissue. Mature lesions contain characteristic, small (but visible) black fruiting bodies (pycnidia). However, pycnidia are not always visible in immature lesions.

In most years, symptoms develop very early. On young autumn-sown wheat, symptoms may be evident by early December on the lowest leaves. During leaf production phases in the winter and early spring, it is common for new leaves to appear green and healthy, and for lower leaves to die back with typical symptoms. Stressed crops can show greater levels of infection.

Life cycle

The pathogen is not seedborne. It survives the winter as dormant mycelium, pycnidia, and pseudothecia on crop debris, autumn sown crops and volunteers. Ascospores, released from previous

Coalesced lesions giving large areas of necrotic brown tissue

Mature, brown, necrotic lesions on young wheat plant showing black fruiting bodies (pycnidia) wheat stubbles, initiate epidemics in the winter and early spring.

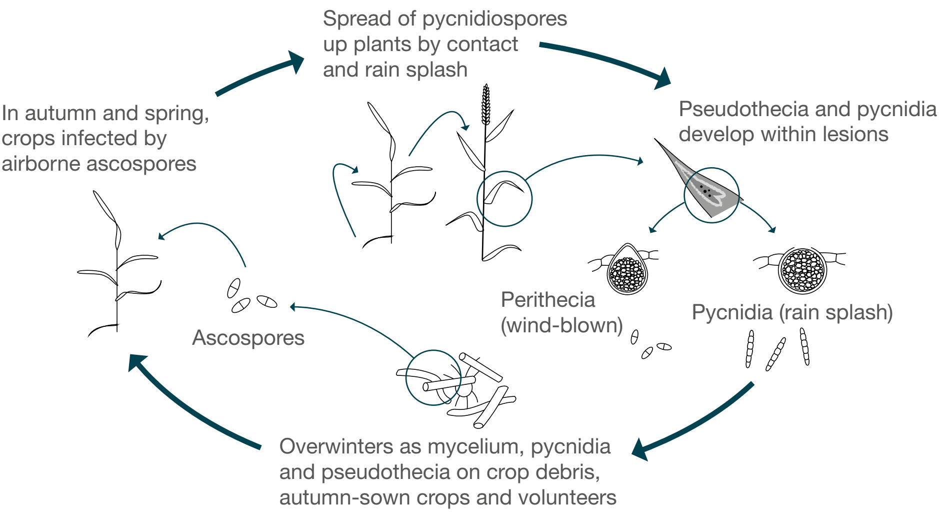
Pseudothecia release windborne, sexually produced, ascospores. Pycnidia release, asexually produced, pycnidiospores. Pycnidiospores are rain-splashed from infected lower leaves. Pycnidiospores are usually responsible for the spread of the epidemic throughout the spring and summer. Physical spread of these pycnidiospores can also occur without rainfall, particularly when leaves 3 and 4 overlap the upper leaves as they emerge.

Once a spore has landed on a new leaf, it can take 12 hours for the spore to germinate. Infection of the new leaf usually takes place within 24 hours of the spore landing, provided conditions are damp.

Symptoms appear after a 14–28-day latent period. The optimum temperature for *Z. tritici* is 15–20°C. Latent period reduces as temperatures get closer to this range.

Importance

Septoria tritici blotch is the most important and damaging foliar disease on winter wheat in the UK. The pathogen reduces green leaf area for photosynthesis. It causes significant yield loss every year. It also affects grain quality. Losses of 50% may occur in severely affected crops. Unusually dry weather throughout May and June may reduce losses, but heavy dews can still allow infection. Higher rainfall areas, in the South and West, are most at risk.



Septoria tritici blotch life cycle

Sharp eyespot

Pathogen

Ceratobasidium cereale (*Rhizoctonia cerealis*)

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The disease affects wheat, barley, oats, rye and triticale.

Symptoms

Symptoms occur as sharply defined lesions on the outer leaf sheaths. Young lesions have a clear, dark margin and, frequently, the epidermis within the lesion is shredded. Multiple lesions can be found up the stem, up to 30 cm away from the stem base. Later in the season, lesions on the stem have a pale cream centre with a dark brown, sharply defined edge. Sharp eyespot lesions are often superficial, distinguishing it from eyespot where lesions may penetrate one or two leaf sheaths. Severe sharp eyespot can cause white heads or lodging.

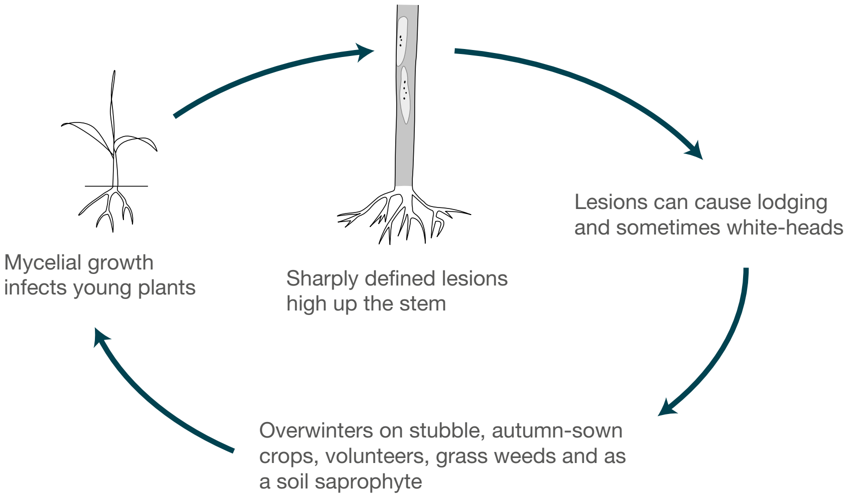
Distinct sharp eyespot lesions with sharply defined edges

Life cycle

The fungus overwinters primarily as mycelium on infected stubble, with volunteers and some grass weeds also acting as sources of inoculum. The fungus can produce sclerotia, which may act as overwintering structures. Infection may occur at any time during the growing season, but the disease favours temperatures of around 9°C, early sowing and acidic, dry, sandy soils.

Importance

Although common in the UK, average annual yield losses are probably less than 0.5%. However, losses may be significant in individual crops, particularly if the disease is present with take-all. Early infection, encouraged by cool autumn or spring temperatures, is associated with more severe disease. Severe sharp eyespot may reduce yield by up to 25%, but this is unusual.



Sharp eyespot life cycle

Snow mould (pink snow mould)

Pathogen

Monographella nivalis (*Microdochium nivale*)

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

Snow mould is mainly a disease of winter barley, although other winter cereals are also occasionally affected.

Symptoms

Symptoms typically appear after snow melts in the spring. Infected plants often have an extensive covering of white mycelium, which spreads on overlapping leaves and causes a matting of leaf tissue.

Later, as spores are produced on the mycelial mats, the affected patches assume a pink colouration. The fungus often infects the oldest leaves directly from the soil but can go on to affect the whole plant, resulting in patches of dead plants. Despite this, in good growing conditions surviving plants can recover.

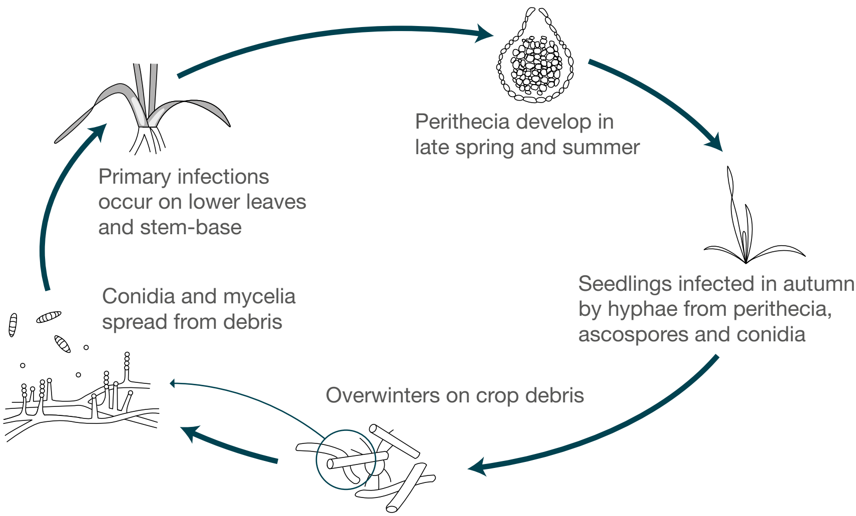
Patch of young seedlings damaged by snow mould

Life cycle

Primary infections occur on the stem base or lower leaves, when snow cover makes leaves touch the soil surface. Infection can occur from hyphae growing from perithecia or from plant debris in the soil. Affected plants or dead plant material carrying perithecia or mycelial growth are returned to the soil after harvest. Infected seed may also contribute to initial infection of seedlings in the autumn. Spring-sown crops are rarely affected.

Importance

Snow mould is commonly recorded, but damage is rarely severe, except in isolated cases. The disease tends to be more damaging in parts of Scotland, where snow cover is more common and prolonged. Where large areas of the crop die, redrilling with spring barley may be necessary.



Snow mould life cycle

Snow rot (grey or speckled snow mould)

Pathogen

Typhula incarnata

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The pathogen particularly infects winter barley, but can also affect winter wheat. Spring-sown crops are rarely affected.

Symptoms

The fungus infects the oldest leaves first. Plants affected by snow rot usually have abundant red-brown resting structures (sclerotia), which are 2–3 mm in diameter, embedded in the lower leaf sheaths and on dead leaf tissue. Eventually, the whole plant can turn yellow, start to wilt and, sometimes, die.

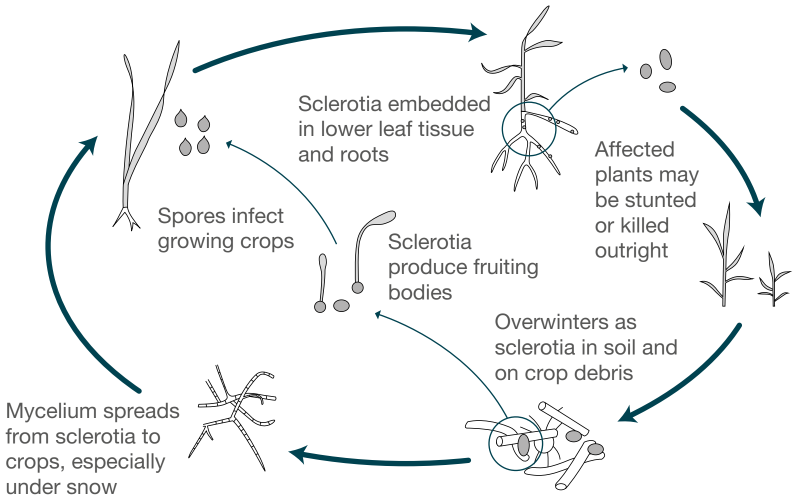
Life cycle

Winter-sown crops become infected during the winter months, often under snow cover. Affected plants produce many sclerotia, which can survive between crops during the winter. The sclerotia germinate and produce spores and/or mycelia, which infect emerging crops.

Importance

Snow rot is commonly recorded but damage is rarely severe. It is of higher risk in continuous winter barley stressed with manganese deficiency. The disease is generally more damaging in parts of Scotland, where

Resting structures (sclerotia) of snow rot on lower leaf sheaths snow cover is more common and prolonged. Although plants can die, good growing conditions in the spring often allow crop recovery. Surviving tillers compensate for dead shoots, so yield loss is usually small. Where large areas of crop die, redrilling with spring barley may be necessary.



Snow rot life cycle

Sooty moulds

Pathogen

Various species, including *Alternaria* spp. and *Cladosporium* spp.

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The pathogens that cause sooty moulds are not host-specific. They can affect all cereals.

Symptoms

The usual symptom of sooty moulds is a darkening of the ears before harvest. This is commonly seen when weather conditions are wet, but severe symptoms are often associated with root or stem-base diseases, which cause premature ripening of the crop. White heads often become severely affected by sooty moulds. Delays in harvesting in wet weather can lead to severe blackening of ears and discolouration of the grain.

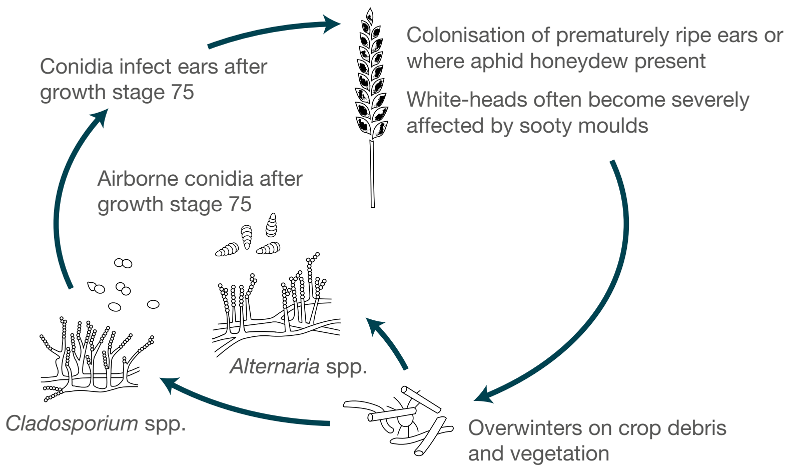
Wheat ears severely affected by sooty moulds

Life cycle

The fungi that can cause sooty moulds are very common in the atmosphere. They can survive adverse conditions as spores or mycelium on many types of material. They do not require living host material to survive, as they derive nutrients from dead or decaying tissues (i.e. saprophytic). They most commonly colonise ears after growth stage 75, especially ears that are prematurely ripe or affected by aphid honeydew.

Importance

Discolouration of ears and grain rarely has any effect on grain yield, but does affect marketability – particularly in milling wheat.



Sooty moulds life cycle

Stem (black) rust

Pathogen

Puccinia graminis f .sp. *tritici*

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The pathogen is specific to wheat.

Symptoms

Despite its name, the characteristic symptoms are orange/brown sporulating pustules, which occur in stripes on leaves and stems. Later in the season, black elongated pustules containing the teliospores develop, mainly on the stems.

Life cycle

The fungus develops teliospores on the wheat plant, which produce a secondary spore, the basidiospore. This spore infects a completely different host – the barberry (*Berberis* spp.). A further spore stage, the aeciospore, is produced on the barberry, which can spread and reinfect the cereal host. This infection gives rise to the uredospore stage, which produces the typical symptoms on wheat.

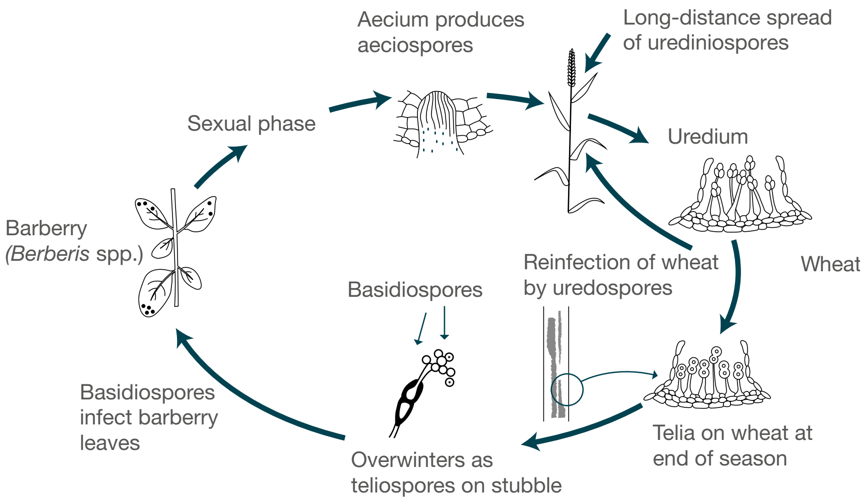
Orange/brown pustules on a wheat leaf (left) and wheat stems (right)

Stem rust on barberry leaves

In Britain, airborne spores generally originate from South West Europe and North Africa, so initial infection occurs when air movements are appropriate. Subsequent spread can also occur within season within the UK. The optimum temperature is in excess of 20°C, so suitable air movements must be associated with high temperatures. Temperatures below 15°C inhibit development of the disease, so it rarely occurs under UK conditions.

Importance

In the UK, severe outbreaks of the disease are extremely rare and yield losses very small. Movement of the disease from barberry hedgerows can result in the infection of a small number of wheat plants in close proximity (e.g. field edges) very late in the season.



Stem (black) rust life cycle

Stripe smut

Pathogen

Urocystis occulta

Crops affected

Wheat	Barley	Oats	**Rye**	Triticale

Hosts

The pathogen specifically infects rye.

Symptoms

This disease differs from the other types of smut that affect UK cereals because symptoms can be seen not only on the ears, but also on the stems and leaves. The disease affects only rye, producing long, dark blisters in stripes that run parallel to the veins. These eventually rupture to expose the spores.

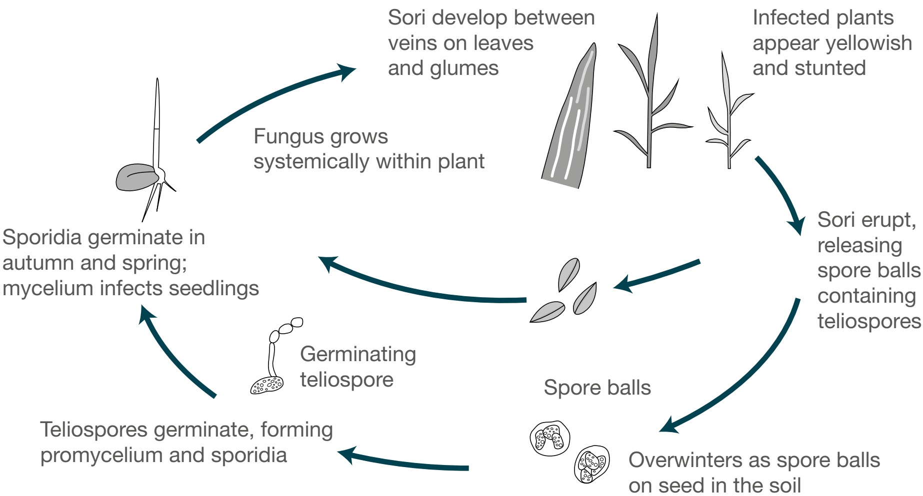
Life cycle

The pathogen that causes this disease is both soilborne and seedborne. Soilborne inoculum is more important with this disease than with the other smuts that affect UK-grown cereals. Developing grains in the ears are contaminated by wind-blown spores, but the spores remain on the seed surface.
As with bunt, seeds are infected during germination.

Importance

The disease is sporadic in occurrence and rarely causes significant loss.

Typical early symptoms of stripe smut



Stripe smut life cycle

Take-all

Pathogen

Gaeumannomyces tritici and *G. avenae*

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

G. tritici attacks wheat, barley, rye and may attack some grass species, particularly couch grass. Oats are immune. *G. avenae* attacks oats, wheat, barley, rye and many grass species. This strain is rare.

Symptoms

Take-all infects the roots of plants. Sometimes infection is at a low level, without obvious symptoms. Moderate or severe infections cause roots to become blackened, rotten, with a 'rat-tail' appearance. In severe outbreaks, the base of plants may also blacken. The reduction in root activity restricts water and nutrient uptake. This slows canopy growth and causes yellowing and stunting in severe cases. Patches of stunted plants and white heads (bleached ears) form, which are usually first seen during grain filling. Generally, white heads contain small and shrivelled grains or, occasionally, no grain at all.

Typical 'rat-tail' appearance of roots affected by take-all

Life cycle

The take-all fungus is soilborne. In the autumn, primary infection occurs from inoculum in the soil, and from mycelium on infected roots and cereal debris. Infection can occur on volunteer cereals, autumn-sown crops and some grass weeds. The disease survives the winter primarily as mycelium on infected roots or stubble debris.

Secondary infection, where the disease spreads directly from root to root, usually occurs in the spring and summer. The disease then spreads from infected seedling roots to developing crown roots (where the roots and stem meet). As the disease progresses, root area is lost, affecting the ability of the plant to absorb water and nutrients from the soil. In severe cases, plants ripen prematurely, resulting in white heads and poor grain filling.

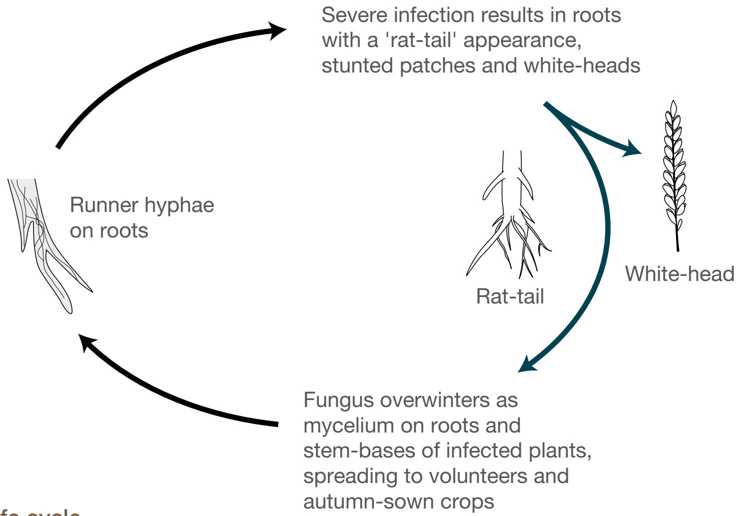
More secondary infection occurs when soils are warm and moist. Take-all development is encouraged by a warm winter followed by a wet spring/early summer. The pathogen is active in the soil when temperatures are above 10–12˚C.

Importance

The fungus is ubiquitous in UK arable land and reduces grain yield and quality. It may affect half of UK wheat, with average yield losses of 5–20%. More than half of the crop can be lost when disease is severe. It is most problematic in Eastern England, where cereal-dominated rotations are common and conditions are drier during grain filling. The disease is also moderately important in winter barley. Spring-sown cereals are not as badly affected.

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'.

Disease risk differs even within a soil series. The pathogen causes most damage on light soils (sand, sandy loams and loams), where the fungus spreads more easily and the loss of active roots has a relatively large effect on water and nutrient uptake. Soil condition is also influential. For example, poorly drained soils can encourage the disease. The weather also has a large influence on the impact of take-all, especially when conditions favour disease build-up over several seasons.



Take-all life cycle

Tan spot

Pathogen

Pyrenophora tritici-repentis (*Drechslera tritici-repentis*)

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The pathogen primarily infects wheat, but can also infect barley, rye and some grasses.

Symptoms

The seedborne phase infects seedlings, resulting in small tan-to-light-brown flecks on young leaves. These often have a chlorotic halo with a dark spot at the centre, which expands into elliptical/oval lesions. However, symptoms are generally seen later on leaves and sheaths in the middle and upper canopy. Under wet conditions, lesions produce dark spores. Under ideal conditions, lesions coalesce to produce large areas of dead tissue. Necrosis tends to progress from the leaf tips.

Symptoms are very similar to septoria nodorum. Correct diagnosis relies on spore identification.

Tan spot infected grains can have a reddish appearance, similar to fusarium infection, and the glumes can turn brown.

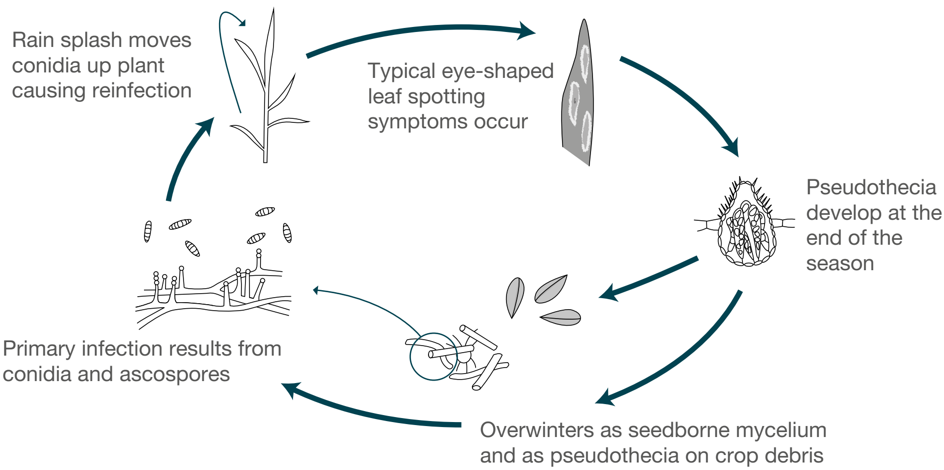
Spreading tan spot lesion with a chlorotic halo and dark spot at the centre

Life cycle

The pathogen survives mainly as dormant mycelium on stubble and crop debris. Pseudothecia form on the stubble that produce ascospores. The spores spread large distances by the wind, usually during the spring. Mycelium in infected seed can also be a source. Under warm, wet conditions, lesions produce dark asexual conidia that are rain-splashed up the plant. In severe infections, and when conditions during flowering are conducive to the disease, it can infect the ear, cause discoloration of the glumes and the grain, and infect seed. The disease develops over a wide range of temperatures but has quite a high optimum (20–28°C). It is also favoured by long periods (18 hours or more) of dew or rain. Leaf lesions appear in 7–14 days.

Importance

Tan spot is very common in Sweden, Denmark, Germany and France. Occasionally recorded in disease surveys, it rarely causes serious yield and specific weight losses in the UK.



Tan spot life cycle

Yellow rust

Pathogen

Puccinia striiformis

Crops affected

Wheat	Barley	Oats	Rye	Triticale

Hosts

The pathogen affects wheat, barley and triticale. There are distinct crop-specific forms of the fungus:

- *P. striiformis* f. sp. *tritici* mainly affects wheat, but can also affect barley
- *P. striiformis* f. sp. *hordei* can only affect barley

Symptoms

The characteristic symptom of yellow rust is parallel rows of yellow/orange coloured pustules on the leaves of adult plants. Epidemics of yellow rust often start on individual plants, usually in the autumn. Symptoms develop slowly over winter. Symptoms are often missed, until small patches (foci) of infected plants appear in early spring. These patches usually spread in the direction of prevailing wind.

Early on, the pustules are difficult to distinguish from brown rust. However, yellow rust lesions tend to spread as a band up and down young leaves, often with a yellow band on the leaf moving ahead of the sporulating lesion. Pustules are also often scattered randomly on young leaves. As leaves age, pustules form more obvious stripes. Hot, dry conditions or fungicide use can check disease and make pustules difficult to detect.

Infected leaves can rapidly become chlorotic and then necrotic in May/June, if weather conditions are conducive. In severe attacks, yellow rust infection of the ears can occur, resulting in the formation of masses of spores between the grain and the glumes.

Typical striped symptoms of yellow rust

At the end of the season, secondary black spores (teliospores or telia) are sometimes produced among the stripes of pustules.

Yellow rust pustules on a wheat glume

Life cycle

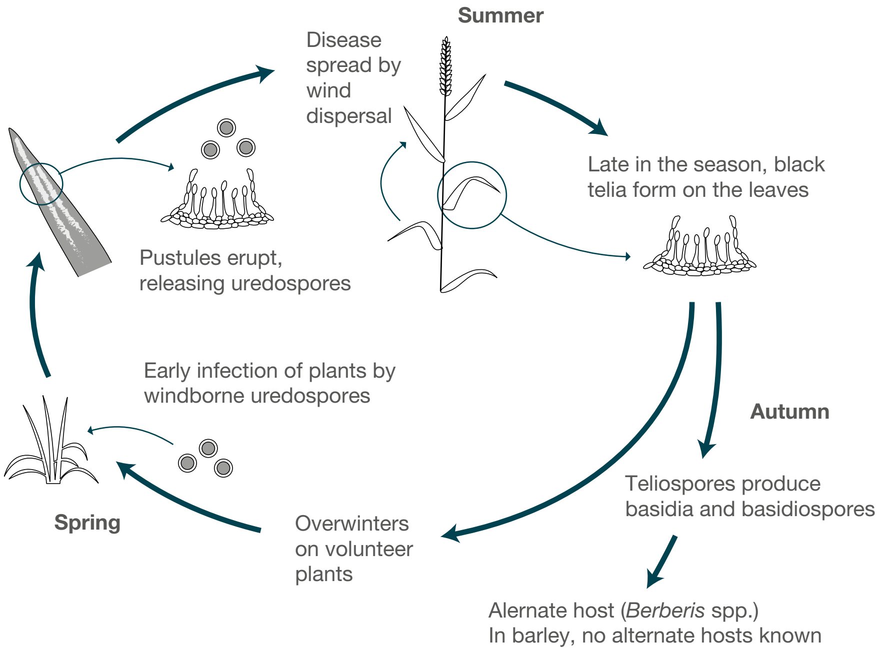
Yellow rust requires living green plant material to survive. In the winter, the fungus survives as dormant mycelium or active sporulating pustules on volunteers and autumn-sown crops. Although low temperatures kill pustules, mycelium within plant tissue can survive temperatures of -5°C. Cooler winter temperatures may also kill infected lower leaves and, therefore, the fungus.

The epidemic takes off as temperatures warm in April/May. Temperatures of 10–15°C and a relative humidity of 100% are optimal for spore germination, penetration and production of new spores. These are spread by wind – sometimes across very large distances – or leaf-to-leaf contact. Cool, damp weather in the spring, with overnight dew or rain, provides optimum conditions for disease development. Temperatures over 20°C slow the fungus, although there are strains tolerant to high temperatures. A prolonged spell of warm, dry weather often checks an epidemic. This is due to the direct effect on the fungus and increasing host resistance at higher temperatures. The complete cycle, from infection to the production of new spores, takes as little as 10 days during ideal conditions. As a result, leaf tips may show symptoms before leaves fully emerge. The disease cycle may repeat many times in one season.

At the end of the season, secondary black spores (teliospores or telia) may be produced as part of the sexual stage. In wheat, the basidiospores produced from these teliospores have an alternative host (*Berberis* spp.). This means sexual recombination can take place, forming new races. However, this sexual pathway is not known in the UK. In barley, there is no known alternate host, meaning sexual recombination cannot take place.

Importance

The main economic loss from yellow rust is in wheat. The disease does occur in barley but it is rare, due to effective varietal resistance.
The disease is most important in the East, although infection can occur all across the UK. Areas that have cool, damp summers and mild winters are prone to yellow rust infections, for example, coastal regions or regions around rivers or estuaries. Yield losses of 40–50% often occur in untreated susceptible wheat varieties. However, well-timed fungicide sprays are usually effective, especially when combined with effective varietal resistance. As a result, annual losses are often small. Yellow rust can also affect grain quality.



Yellow rust life cycle

Glossary

Alternate host	A second host (of a different plant species) that is required by some pathogens to complete their life cycle
Anamorph	The imperfect or asexual stage of a fungus
Apothecium	A cup- or saucer-like ascocarp
Asexual	Without sex organs or sex spores (vegetative)
Ascocarp	A fruiting body that bears asci
Ascospores	Sexually produced spores contained within an ascus
Ascus (pl. asci)	A sac-like cell that contains the products of the sexual stage (teleomorph) as ascospores (usually eight)
Basidiocarp	A fruiting body that bears basidia
Basidiospores	Sexually produced spores borne on the outside of a basidium
Basidium	A cell or organ from which the sexually produced basidiospores (generally four) are formed
Biotroph	An organism entirely dependent upon another living organism (the host) as a source of nutrients
Break crop	A crop (e.g. oilseed rape) grown in rotation with other crops (e.g. wheat) to improve the growing conditions of the following crop
Chlamydospore	An asexual spore arising from a hyphal segment; a resting stage
Chlorosis	The yellowing of normally green plant tissue
Cleistothecia (chasmothecia)	The closed spherical ascocarp of the powdery mildews
Coleoptile	Protective sheath surrounding the emerging shoot of a cereal
Conidia	Asexual fungal spores formed from the end of a conidiophore

Conidiophore	A specialised hypha on which one or more conidia are produced
Cotyledon	Part of the embryo that forms the primary leaf
Crown roots	Roots that emerge from the base of the stem of the plant rather than the seed
Damping off	Disease of plant seedlings caused by seedborne or soilborne fungi
Dicotyledon	A flowering plant that has an embryo with two cotyledons (seed leaves)
Die-back	Necrosis of a shoot, beginning at the apex and spreading towards the older tissue; stem death may occur
Direct drilling	Drilling seed into ground with minimal cultivation
Ear blight	Infection of cereal ears resulting in bleaching of parts of the ear or discolouration of the glumes and grains
Endosperm	Nutritive tissue in a seed
Epidemic	The widespread incidence of an infectious disease in a population
Epidermis	The outermost layer of cells of an organ, usually only one cell thick
Ergot	The fruiting structure (sclerotium) of *Claviceps* spp.
Flag leaf	The final leaf to emerge in a cereal plant
Focus (pl. foci)	A concentrated area of diseased plants, usually around a primary source of infection, or coinciding with an area particularly favourable to disease
Forma specialis (f. sp.)	A group within a pathogen species that can only infect particular hosts
Glume	The outermost and lowermost bract of a grass (including cereals) spikelet (inflorescence)

Honeydew	A general term to describe a sticky secretion produced by some organisms, such as aphids or the pathogen *Claviceps purpurea*. Honeydew of the latter, which causes ergot, contains conidia.
Host	A living organism that harbours another (e.g. a pathogen)
Host-specific	Pertaining to a particular host; usually species-specific
Hypha	One of the filaments of a mycelium
Immune	Cannot be infected by a given pathogen
Inoculum	Microorganisms or virus particles that act as a source of infection
Inflorescence	The group or arrangement in which flowers are borne on a plant
Internode	Part of a plant stem between two successive nodes
Leaf sheath	The lower part of the leaf that more or less completely surrounds the stem
Lesion	A localised area of diseased tissue
Lodging	When a standing crop leans or bends; for example, because of adverse weather or soil conditions
Minimal cultivation	A reduced form of cultivation
Morphology	The form and structure of an organism
Mosaic	A pattern of disease symptoms on a plant, apparent as green/yellow or dark/light areas; usually referring to virus infections
Mycotoxin	A toxin produced by a fungus
Mycelium	The mass of hyphae forming the body of a fungus
Necrotroph	A microorganism that feeds only on dead organic tissue

Node	The level of a stem from which one or more leaves arise
Pathogen	An organism that causes disease
Perithecium	A flask-shaped ascocarp, containing asci
Primary inoculum	Spores or fragments of mycelium capable of initiating disease
Pseudothecia	Perithecium-like structures, each with a single cavity containing ascospores
Pustule	A spore mass that develops below the epidermis and breaks through at maturity
Pycnidium	Flask-shaped fruiting body, with an apical pore lined internally with pycnidiospores
Pycnidiospores	Spores from within a pycnidium
Rachis	The main axis of the inflorescence, or spike, of cereals to which the spikelets are attached
Resistance	The inherent capacity of a host plant to prevent or reduce the development of a disease
Saprophyte	An organism that derives its nutrients from dead or decaying tissue of another organism
Sclerotia	Compact masses of fungal hyphae (e.g. ergots), capable of remaining dormant for long periods and giving rise to fruiting bodies or mycelium
Seminal roots	Roots that develop directly from the seed
Senescence	The dying process of a plant or plant part
Sporangiophore	A hypha or fruiting structure bearing spores
Sporangium	A container or case of asexual spores. In some cases, it functions as a single spore
Spore	A reproductive unit in fungi
Sporulation	The period of active spore production

Species	Organisms in which the members have similar characteristics to each other and can breed with each other. Plural abbreviated as spp.
Susceptible	A host plant unable to prevent or reduce the development of a disease
Telium	Structure containing teliospores
Teliospores	Sexual spores produced within a telium
Teleomorph	In fungi, the sexual, or so-called 'perfect', stage or phase of growth
Tolerance	The ability of a plant host to sustain the effects of a disease without dying or suffering serious injury or crop loss
Uredium	The fruiting structure of a rust fungus in which uredospores are produced
Uredospore	The asexual spore of the rust fungus
Vector	An organism capable of transmitting inoculum
Virulence	The ability of a pathogen to produce disease
White heads (bleached ears)	Prematurely ripened ears of cereals, often caused by pathogen damage of the roots or stem base

Index

Disease-causing organisms listed alphabetically (scientific names).
For diseases listed alphabetically by common names, see the Contents section.

Further information

Wheat and barley disease management guide

This guide provides an overview of the most important diseases of wheat and barley. It outlines the key options for integrated pest management (IPM), with a focus on the main risk factors and key management steps. Disease management programmes that balance non-chemical and chemical options, in the context of fungicide resistance, are also summarised.

ahdb.org.uk/cereal-dmg

Recommended Lists

The AHDB Recommended Lists (RL) provide information on yield and quality, agronomic features and market options to assist with variety selection. Varietal resistance should be the foundation of any disease management strategy. The RL presents resistance ratings for several key diseases on a simple scale: 1 (least resistant) to 9 (most resistant).

ahdb.org.uk/rl

Wheat and barley growth guides

The AHDB growth guides for wheat and barley provide comprehensive information on how these crops develop. The guides allow crop progress, structure and final performance to be measured and compared to a series of UK benchmarks. Each guide also includes an illustrated cereal growth stages (GS) key to guide management (e.g. fungicide spray timings).

ahdb.org.uk/wheatgg

ahdb.org.uk/barleygg

Fungicide performance

AHDB's fungicide performance work provides high-quality, independent information on the efficacy of new and established fungicides against key diseases in wheat, barley and oilseed rape. Published annually, use the results to build fungicide programmes – based on mixtures of active ingredients and products – appropriate to the local disease threat profile and in keeping with best practice anti-resistance guidelines.

ahdb.org.uk/fungicide-performance

Fungicide programmes

The availability of cereal fungicides changes frequently because authorisation or efficacy can be lost and new chemistry can come to the market. The AHDB Fungicide programmes for wheat and barley web page provides the latest information, including implications for fungicide resistance management.

ahdb.org.uk/fungicide-programmes

Access all resources referred to within this guide via **ahdb.org.uk/cereal-dmg**

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