

THE ENCYCLOPAEDIA OF CEREAL DISEASES



 **BASF**
The Chemical Company

How to use this Encyclopaedia

We have aimed to structure this publication to provide easy reference to the diseases of UK cereals and the causal organisms. The diseases are ordered alphabetically by common name, from Ascochyta leaf scorch to yellow rust. Quick access to a particular disease or pathogen can also be gained through the Contents, which lists diseases both by common name (including variants) and pathogen(s). In the case of fungal pathogens both the teleomorph (sexual stage) and anamorph (asexual stage) are listed, when appropriate.

For each disease, the pages are structured in a similar way. A banner provides, at a glance, the common name(s), the pathogen(s) responsible and the hosts affected. Where fungal pathogens have both a teleomorph and an anamorph, the teleomorph is listed first, with the anamorph in brackets. There then follows a more detailed description of the disease under the following headings; Hosts, Symptoms, Life cycle, Importance. This is complemented by photographs as appropriate. A simple Glossary of technical terms can be found at the end of the Encyclopaedia.



Introduction

The need to deliver consistent, high yields of high quality grain makes control of cereal diseases an important component of successful crop management. Recognition of the disease, and an understanding of the pathogen(s) responsible, is the first step in successful disease control. The Encyclopaedia was produced to help the grower, adviser and others involved in cereal production recognise diseases and learn something about them.

Symptoms of both common and less frequently found diseases are illustrated and described, together with an outline of the disease cycle of the pathogen and an indication of the importance of the disease. The Encyclopaedia is not intended to be a guide to disease control. Such information is readily available elsewhere, for example the principles of wheat disease management can be found in the HGCA Wheat Disease Management Guide and current information on fungicide performance is published annually on the HGCA website.

The production of this Encyclopaedia was very much a team effort, bringing together Bill Clark of Broom's Barn Research Centre (formerly of ADAS), who wrote the text, with Rosie Bryson and Lindy Tonguç of BASF and Clare Kelly and myself from HGCA, who edited and formatted it. The publication was funded by BASF and HGCA. We hope you find it interesting and informative.

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Common name:

Ascochyta Leaf Scorch (Spot)

Pathogen:

Didymella exitialis (*Ascochyta* spp.)

WHEAT ✓

BARLEY ✓

OATS ✓

RYE ✓

TRITICALE ✓

Hosts

The disease affects wheat, barley, oats, rye, triticale and many grass species.



Typical Ascochyta lesion showing dark margin and black pycnidia

Symptoms

Disease symptoms are found 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 buff to brown in 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 and become very similar to those caused by *S. nodorum*. Pycnidia within the lesions are generally black, distinguishing the disease from *S. nodorum* which tends to have light coloured pycnidia.

Life cycle

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

Importance

The disease is of relatively minor importance although in individual crops it is likely to add to leaf death



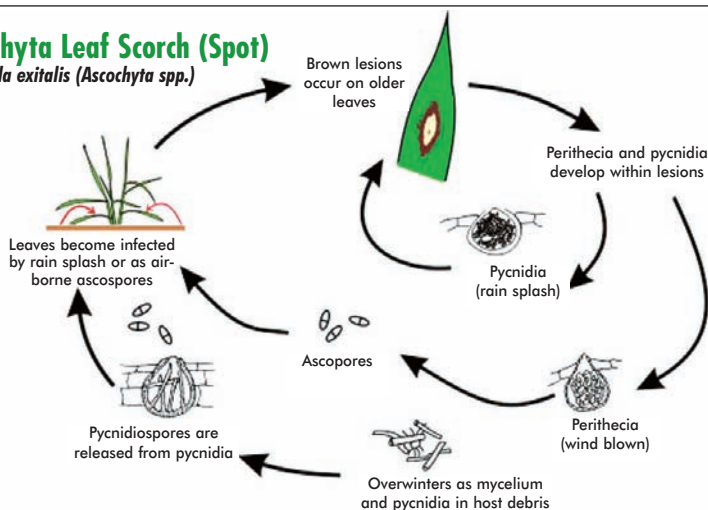
Typical Ascochyta symptoms on wheat leaves

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 (*Didymella exitialis*) is common in

Europe and the air-borne ascospores of the fungus are commonly found in late summer in the UK, where they have been implicated in late summer asthma.

Ascochyta Leaf Scorch (Spot)

Didymella exitialis (*Ascochyta* spp.)



Common name:

Black Point

Pathogen:

Alternaria spp. and *Cladosporium spp.*

WHEAT ✓

BARLEY ✓

OATS ✓

RYE ✓

TRITICALE ✓

Hosts

The disease can affect all cereal species although wheat and barley are most commonly affected. The same fungi can cause discolouration of oats.

Symptoms

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

Life cycle

The disease is associated with a number of airborne fungi including

Alternaria spp. and *Cladosporium spp.* although the evidence for these fungi actually causing the disease is still limited and is mainly circumstantial. High humidity or frequent rainfall from the milky ripe to soft dough stage and lodging can often trigger infection by these fungi.

Importance

The disease has no significant effect on yield but can have serious implications for the quality of milling wheat, barley and oats for processing. The discolouration of the grain can lead to poor flour and bran colour, and rejection on the basis of discoloured grains. Durum wheat seems to be particularly susceptible.

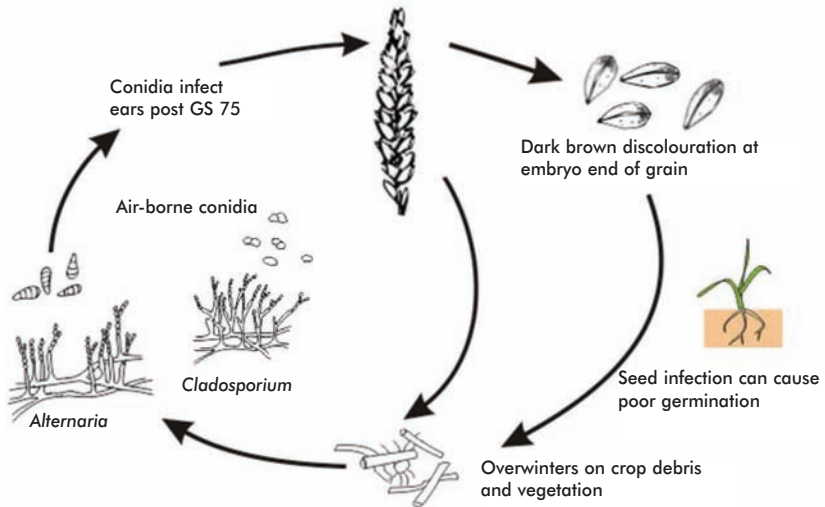
The disease is commonly reported to be more severe on larger grains, so high specific weight grain can have a higher incidence. This is thought to be due to the larger grains producing a more open floret, allowing fungal spores greater access to the germ end of the grain.



Darkening of grain at the germ end

Black Point

Alternaria spp. and
Cladosporium spp.



Common name:

Black (Stem) Rust

Pathogen:

Puccinia graminis f.sp. *tritici*WHEAT ☒BARLEY ☐OATS ☐RYE ☐TRITICALE ☐**Hosts**

Puccinia graminis f.sp. *tritici* is specific to wheat.

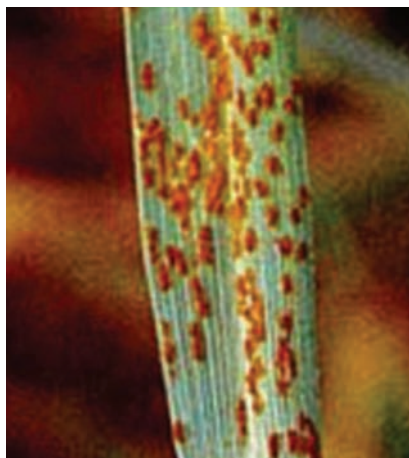
Symptoms

Despite its name, the characteristic symptoms are brown sporulating pustules which occur in stripes on leaves and stems. Later in the season, black elongate 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 normal symptoms on wheat. Out-breaks in Britain are caused by air-borne spores originating in South West Europe and North Africa so infection generally occurs



Orange/brown pustules on a wheat leaf

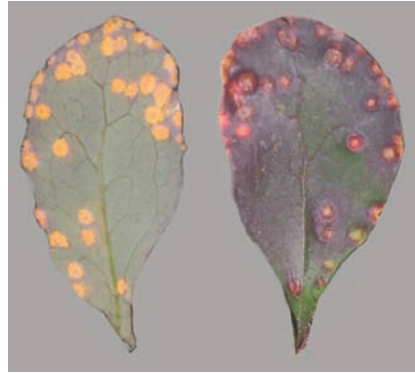


Orange/brown pustules on wheat stems

when appropriate air movements occur. 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

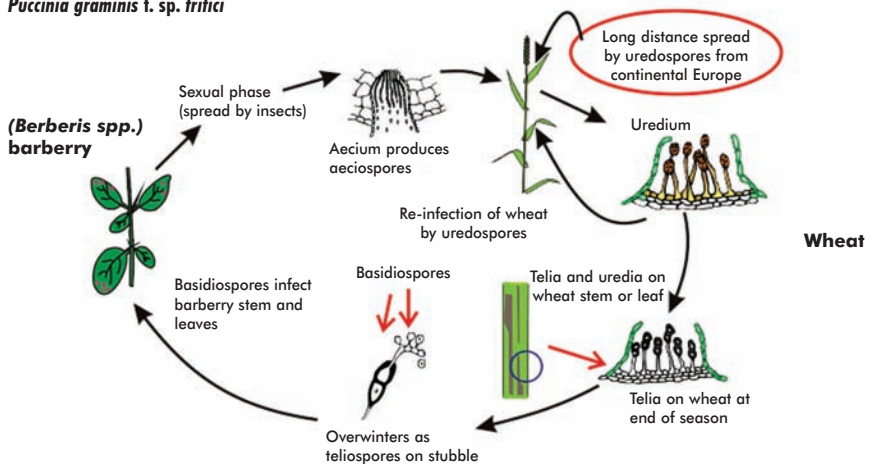
The disease is very rare in the UK but may occur late in the season. Losses due to the disease in the UK are presently very small.



Black stem rust on barberry leaves

Black (Stem) Rust

Puccinia graminis f. sp. *tritici*



Common name:

Brown (Leaf) Rust

Pathogen:

Puccinia triticina (formerly known as *Puccinia recondita* f. sp. *tritici*) - Wheat*Puccinia hordei* - Barley*Puccinia recondita* - Rye, Triticale

WHEAT ✓

BARLEY ✓

OATS

RYE ✓

TRITICALE ✓

Hosts

Puccinia triticina is specific to wheat, other *Puccinia spp.* and pathotypes can affect barley, rye and triticale but do not cross-infect.

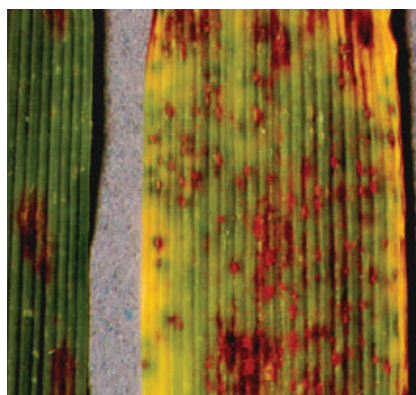
Symptoms

Symptoms of brown rust infection are often seen in the autumn on early-sown crops as individual orange to brown pustules. With early autumn infection individual pustules can be confused with yellow rust, being orange to brown in colour and about 0.5-1.0 mm in diameter. Later in the season, diag-

nosis is much easier as the brown pustules tend to be scattered at random compared with the more striped symptoms of yellow rust (*Puccinia striiformis*). Although symptoms are most common on leaves, in severe attacks pustules can also occur on the stem and glumes. Brown rust infection of the glumes can result in a reduction in specific weight. When leaves begin to senesce, a 'green island' develops around individual pustules. Towards the end of the season dark teliospores are sometimes produced.



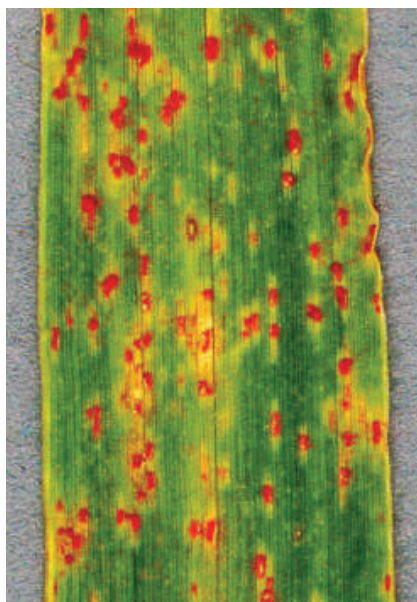
Brown rust pustules on wheat



Brown rust pustules on barley



Brown rust pustules on wheat



Brown rust pustules on rye

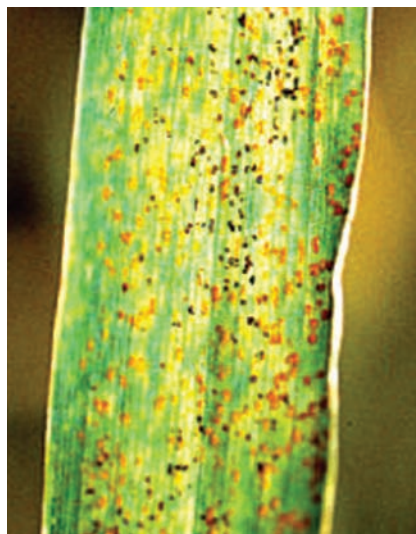
Life cycle

The fungus over-winters primarily on volunteers and early-drilled crops. The alternate hosts for *P. triticea* include species of *Thalictrum*, *Isopyrum* and *Clematis*, although their role in the life cycle in the UK is not thought to be significant.

Until recently the disease was rarely important in the spring as temperatures between 15°C and 22°C, accompanied by 100% relative humidity, are needed for sporulation and spore germination. Consequently, brown rust epidemics have normally occurred during mid to late summer in the UK with dry windy days which disperse spores, and cool nights with dew, favouring the build-up of the disease. However, with mild winters, brown rust can often be found at high levels in the spring. With climate change mild winters and warm springs are likely to become more common which could lead to brown rust becoming a much more common problem earlier in the season.

Importance

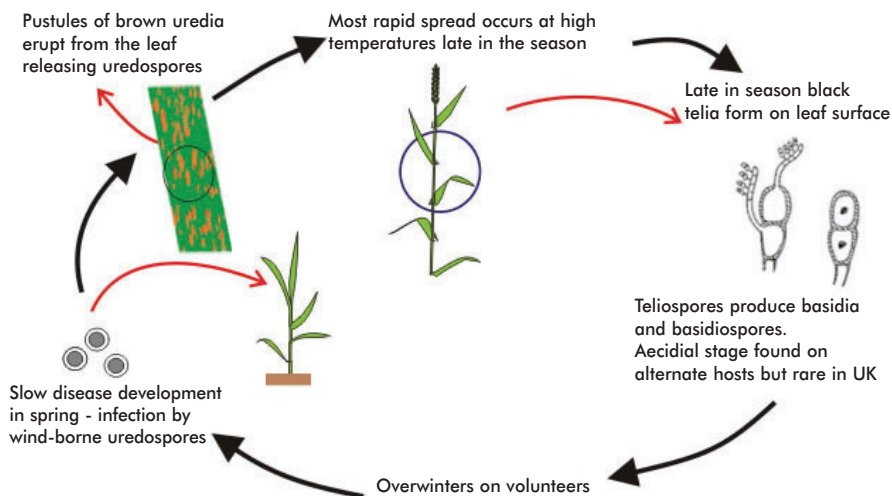
Until recently brown rust was not considered to be a major problem despite early-sown crops generally carrying high levels of brown rust through the winter. However, the occurrence of new virulent strains overcoming varietal resistance in a few key wheat varieties has moved brown rust up the league table of importance. Severe attacks result in a significant loss of green leaf area and hence yield, infection of the ears will also result in loss of grain quality. It is too soon to predict epidemic levels of brown rust in future seasons but it is now a disease that cannot be ignored.



Brown rust pustules and teliospores on rye

Brown (Leaf) Rust

Puccinia tritici



Common name:

Bunt or Stinking Smut

Pathogen:

*Tilletia tritici*WHEAT ☒BARLEY ☐OATS ☐RYE ☐TRITICALE ☐**Hosts**

The disease is specific to wheat.

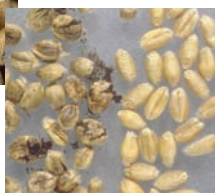


Wheat flag leaf showing typical yellow streak symptoms



Contaminated wheat grain

Bunt balls (left) and healthy grain (right)

**Symptoms**

No symptoms can be observed prior to ear emergence. The flag leaves of infected plants show yellow streaks and plants can be stunted, with 'squat', dark grey-green ears and slightly gaping glumes. In infected ears the 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 weather the ears may appear to be covered in a black ink-like substance as the spores ooze out of the protective glumes onto the ear and stem.

Life cycle

The spores on the seed surface germinate along with the seed. Each produces a short fungal thread terminating in a cluster of elongated cells. These then produce secondary spores which infect the coleoptiles of the young seedlings before the emergence of the first true leaves. The mycelium grows internally within the shoot, infecting the developing ear. Infected plants develop apparently normally until the ear emerges and the grain sites

can be seen to have been replaced by bunt balls.

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 they are 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 which may present bare soil ready for planting the next crop.

Importance

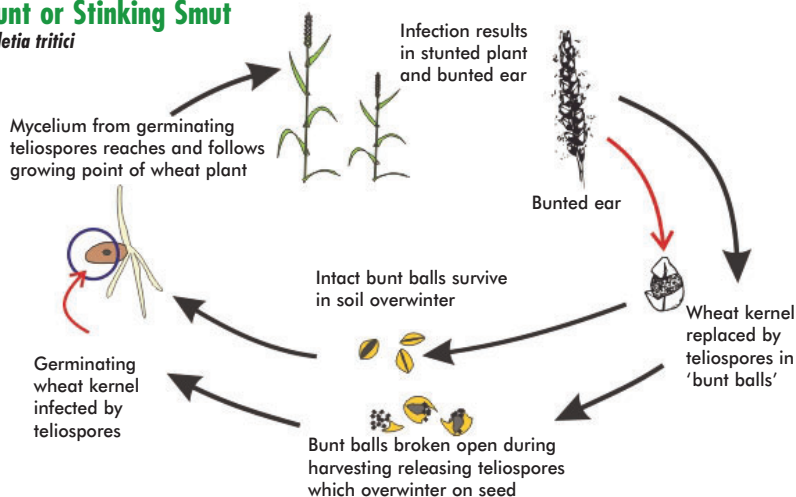
As each bunt ball contains millions of spores, the capacity for contamination of healthy grain in the same field is enormous. Thus, if seed is continually saved and re-sown

without treatment the disease can build up very rapidly. Dry spores can survive for several years. Harvesting or handling equipment contaminated by spores from an infected crop can introduce the pathogen into seed lots harvested in the following season.

The disease is rare in the UK as the vast majority of seed is treated with a fungicidal seed treatment. However, the disease is potentially very damaging and can lead to complete crop loss due to the grain being unsaleable because of discolouration and smell. Cases usually arise from sowing untreated farm-saved seed although soil-borne infections also occur.

Bunt or Stinking Smut

Tilletia tritici



Common name:

BYDV – Barley Yellow Dwarf

Pathogen:

Barley yellow dwarf virus

WHEAT ✓

BARLEY ✓

OATS ✓

RYE ✓

TRITICALE ✓

Hosts

The disease affects all cereals and grasses. Barley and oats are usually more severely affected than wheat.

Symptoms

The initial symptoms of BYDV infection are normally seen as individual plants with bright yellow upper leaves scattered through the crop. Later, as infection spreads, larger areas of the crop become



Wheat plants showing yellowing and red tipping of upper leaves

infected, appearing as patches of bright yellow and severely stunted plants. BYDV is most damaging to plants infected at early growth stages; plants can be killed by very early infections. The effects of BYDV may be exacerbated by other stress factors such as adverse weather conditions, soil acidity and other pests and diseases.

Life cycle

BYDV became much more important and widespread with the increase in early-drilling of winter cereals. The virus exists as several strains and is transmitted by various species of cereal aphid. The bird-cherry aphid (*Rhopalosiphum padi*) is the principal vector in the south of England. In the north of England and in the Midlands the grain aphid (*Sitobion avenae*) is usually more important.

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

- 1) Direct transfer by wingless aphids living on grass or on volunteer cereals which survive cultivation and move through the soil colonising the following

cereal crop. This is much more common in coastal areas of the south west where cereals may follow grass and winters can be mild.

- 2) Indirect transfer by winged aphids migrating into newly emerged crops from grass or volunteer cereals elsewhere. BYDV introduced by winged aphids flying into crops is generally much more common and important than BYDV resulting from direct transfer.

Importance

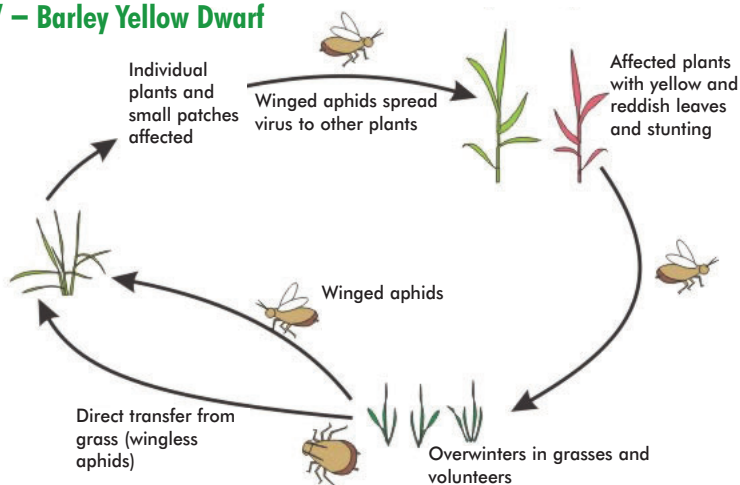
With the now common practice of sowing winter barley very early, BYDV has increased in importance in many areas of the UK. The frequency of very mild winters has also meant that, for many farms,

BYDV is now a regular problem. Early infections can kill patches of plants potentially resulting in large yield losses.



BYDV infected patch in a wheat field

BYDV – Barley Yellow Dwarf



Common name:

Cephalosporium Leaf Stripe

Pathogen:

Hymenella cerealis (*Cephalosporium gramineum*)

WHEAT ✓

BARLEY ✓

OATS ✓

RYE ✓

TRITICALE ✓

Hosts

The disease affects 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 fungus causing the disease is soil-borne and enters the roots of plants via physical damage. In the UK this disease used to be common in wheat following grass where high levels of wireworm (*Agriotes spp.*) were found - causing root damage. Soil-borne conidia normally enter roots through damage in the winter months and the fungus grows in the xylem vessels, blocking vascular tissues, 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.



Close-up of leaf stripe symptoms



Cephalosporium leaf stripe on wheat

Cephalosporium Leaf Stripe

Hymenella cerealis (*Cephalosporium gramineum*)

During winter and early spring, conidia enter roots from soil through damaged areas

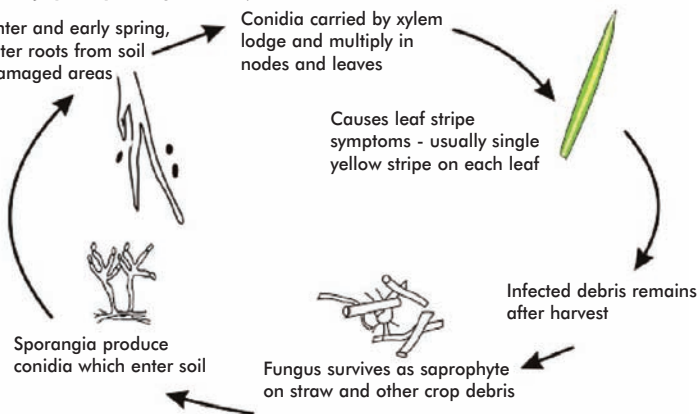
Conidia carried by xylem lodge and multiply in nodes and leaves

Causes leaf stripe symptoms - usually single yellow stripe on each leaf

Infected debris remains after harvest

Fungus survives as saprophyte on straw and other crop debris

Sporangia produce conidia which enter soil



Common name:

Covered Smut

Pathogen:

Ustilago hordei – Barley

Ustilago segetum (*Ustilago kollerii*) – Oats

WHEAT

BARLEY ✓

OATS ✓

RYE

TRITICALE

Hosts

The species of the pathogen are crop specific, mainly occurring on barley and oats.

Symptoms

There are no symptoms of the disease before ear emergence. At ear emergence the ears seem to be normal except that the grains appear to be covered in a thin membrane. If this is broken open it can be seen that the grains have been replaced by masses of black spores held in

place by the transparent membrane. The membrane is relatively easily ruptured and as spores are released the symptoms become similar to those of loose smut.

Life cycle

After ear emergence some spores may be released on to the rest of the crop and carried by the wind to neighbouring plants (as in loose smut, caused by *U. avenae* and *U. nuda*). However, many are retained within their membranous envelope until the crop is harvested when, during the threshing process, they are released to contaminate the surrounding seeds. In either case, the spores remain dormant on the outside of the seed until it is sown when they germinate and infect the developing seedling. The fungus then develops with the growing point of the plant until it once again colonises the developing ear.



Covered smut affected barley ears (healthy one on right)

Importance

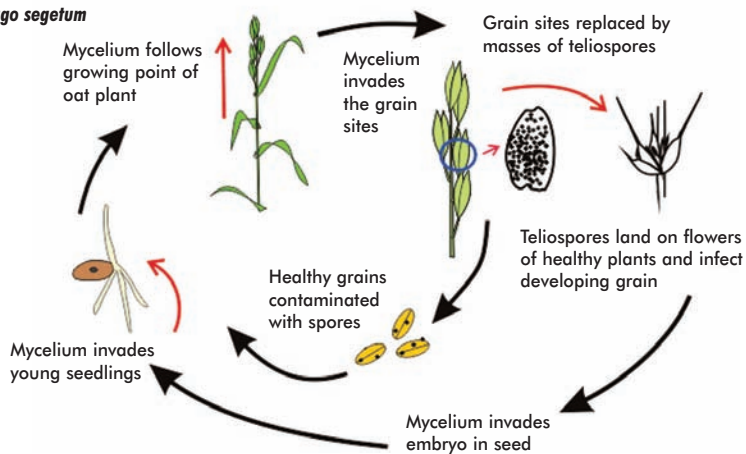
The disease is very rare in the UK and is usually only found in crops grown repeatedly from home-saved, untreated seed.



Covered smut on oats

Covered Smut

Ustilago segetum



Common name:

Crown Rust

Pathogen:

Puccinia coronata

WHEAT

BARLEY

OATS 

RYE

TRITICALE

Hosts

The crown rust fungus affects only oats: it does not attack other cereals. It can infect a number of grasses, particularly ryegrass but the forms on grass do not cross infect to oats.



Crown rust pustules

Symptoms

The first symptoms of crown rust are very similar to 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. The disease is favoured by high temperatures (20-25°C) so epidemics usually occur in June-July. Late in the season black pustules appear within the existing crown rust lesions.

Life cycle

The orange spores (uredospores) produced on leaves are air-borne and spread the disease long distances to other plants and adjacent crops. Later in the season black pustules containing teliospores are produced. These remain dormant on crop debris until the spring when they germinate to produce basidiospores. The basidiospores of this fungus infect the alternate hosts, the buckthorn (*Rhamnus catharticus*) and alder buckthorn (*Frangula alnus*) on which are produced a third spore type, the aeciospores, which can then infect oats once again.

Uredospores produced in the oat crop also infect volunteer oat plants and then emerging winter oats.

Importance

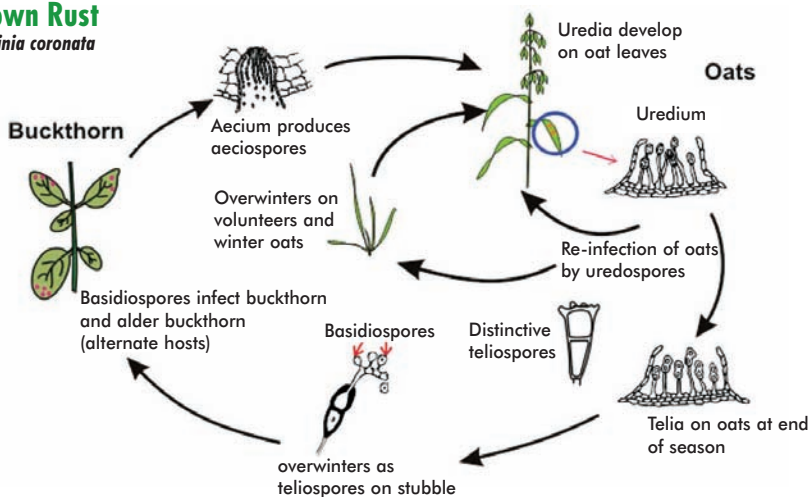
The disease is favoured by warm and humid weather and mild winters. Severe attacks have been more common in recent years. Such epidemics can reduce yield by 10-20%.



Buckthorn leaf showing aecial stage

Crown Rust

Puccinia coronata



Common name:

Dwarf Bunt

Pathogen:

Tilletia controversa

WHEAT ✓

BARLEY ✓

OATS

RYE ✓

TRITICALE ✓

Hosts

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



Infected ears with slightly "ragged" appearance

Symptoms

This disease is not yet known in the UK but is of interest because of evidence of the long-term survival of bunt (*T. tritici*) 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.

Microscopic examination of teliospore morphology is the primary means of distinguishing species of *Tilletia*. However, there is a wide range of teliospore characteristics in *Tilletia spp.* so spore morphology alone is not a suitable method of identification. The symptoms of dwarf bunt are very similar to bunt except that affected plants are stunted to between half and quarter of their normal height. Infected ears tend to have a more ragged appearance than with bunt. Yellowing and flecking of leaves of affected plants is also occasionally found.

Life cycle

The disease cycle of *T. controversa* matches that of *T. tritici* very closely. Infected plants appear unaffected until ear emergence. When the ears emerge the seeds are seen to have been replaced by “bunt balls” which break open during harvest, contaminating healthy grain. When contaminated grain is sown 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 *T. controversa* differs from *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.

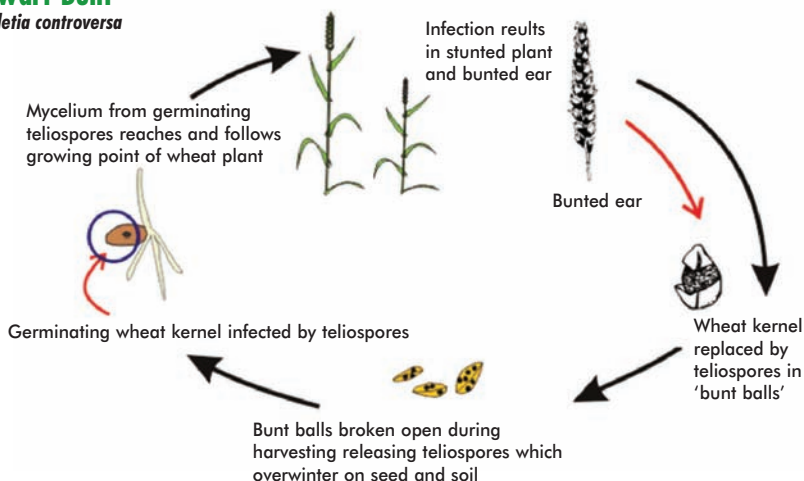
At harvest, “bunt balls” contaminate the soil as well as healthy seed but with dwarf bunt this is very significant as the fungus can survive in soil for many years. Free spores are reported to remain viable in soil for at least three years and “bunt balls” can survive for up to 10 years.

Importance

Presently, the disease is not known in the UK. However, like bunt, the disease could be very damaging although seed treatments commonly used in the UK would prevent seed-borne infection.

Dwarf Bunt

Tilletia controversa



Common name:

Ergot

Pathogen:

Claviceps purpurea

WHEAT ✓

BARLEY ✓

OATS ✓

RYE ✓

TRITICALE ✓

Hosts

The disease affects all cereal crops and a wide range of grasses, particularly black-grass (*Alopecurus myosuroides*).

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. Such ergots can be very large, up to 2cm in length, and are very obvious in the standing crop and in contaminated grain samples.



Black-grass heads infected with ergot

Life cycle

Ergot is not truly a seed-borne disease as it is not carried on or in seed. However, it can be spread by ergots in contaminated seed. It is also one of only two diseases which are included in the UK Seed Certification Scheme for Cereals (the other being loose smut).

At or near to harvest, ergots fall to the ground where they remain until the following summer, when they germinate to produce club-shaped spore-bearing structures (stroma). These ascospores 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 sticky secretion commonly referred to as honeydew. This attracts insects which carry the spores to other flowers where further infection can occur.

There are a number of strains of the fungus, some of which can infect grasses and cereals, others which are restricted to certain hosts. Wheat and other cereals are less

severely affected than rye although occasionally more open-flowered wheat varieties can be badly affected. The disease is favoured by cool, wet conditions during flowering which facilitate spore production and prolong the flowering period - making infection more likely.

Importance

The disease has very little direct effect on yield but the ergots contain large amounts of toxic alkaloids. Consequently, if grain contaminated with ergots is fed to stock or used to make flour then there are real risks to animal and human health. As a result, contaminated grain may be rejected.



Ergots in a sample of treated seed



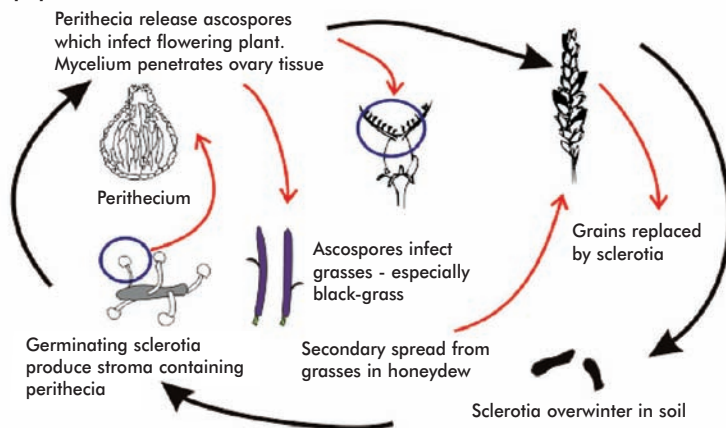
Club-shaped, spore bearing structures (stroma) from germinated ergots



Ergots in infected wheat ears

Ergot

Claviceps purpurea



Common name: **Eyespot**

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

WHEAT ✓

BARLEY ✓

OATS ✓

RYE ✓

TRITICALE ✓



White-head symptom in wheat crop

Hosts

O. yallundae (W-type) is more pathogenic on wheat and barley than on rye, *O. acuformis* (R-type) is pathogenic on wheat, barley, rye and triticale.

Symptoms

Early symptoms can be confused with sharp eyespot and *Fusarium spp.* Frequently, all that is visible is a brown smudge on the leaf sheath at the stem-base. In early-sown crops eyespot lesions may penetrate one or two leaf sheaths, making identification more conclusive. Lesions caused by *Fusarium spp.* and sharp eyespot are generally confined to the outer leaf sheath. Later in the season eyespot symptoms become more distinct and appear as an eye-shaped lesion with a dark margin, usually below the first node. Later still, the margin of the eyespot lesion is often dark and diffuse with a central black 'pupil' occasionally visible. In severe attacks of eyespot, white-heads ("bleached" ears) are commonly seen scattered through the crop, later in the season these may become colonised by sooty moulds.



Close-up of eyespot lesions at the stem base

Eyespot tends to be more severe if plants are also suffering from take-all.

Life cycle

The fungus over-winters on infected stubble, volunteers and grass weeds acting as sources of inoculum. It can survive on stubble for up to three years, so a break from cereals will not necessarily reduce eyespot risk in following crops. Spores are produced throughout autumn and winter, posing a threat to early-sown crops. Infection occurs at temperatures above 5°C and during wet periods. Spores are rain splashed short distances from infected stubble. The development of symptoms following infection takes 6-8 weeks, depending upon environmental conditions. Eyespot can be a serious problem in continuous cereals, where inoculum may build up from year to year.

The sexual stage of both eyespot fungi may play an important part in the pathogen life cycle. This stage of the fungus is produced on stubble at the end of the season and after harvest, ascospores may travel long distances and infect emerging or young plants.



Close-up of eyespot lesion on winter wheat

Importance

Eyespot is often underestimated in importance because few farmers ever look at the stem bases of crops at the milky ripe stage or later - when severe eyespot can often be seen. Moderate or severe eyespot infections can cause yield loss in the order of 10-30%, even in the absence of lodging. Where eyespot is severe, lodging can occur - causing problems in harvesting and frequently a reduction in Hagberg Falling Number.



Severe eyespot lesions on wheat

Eyespot

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



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

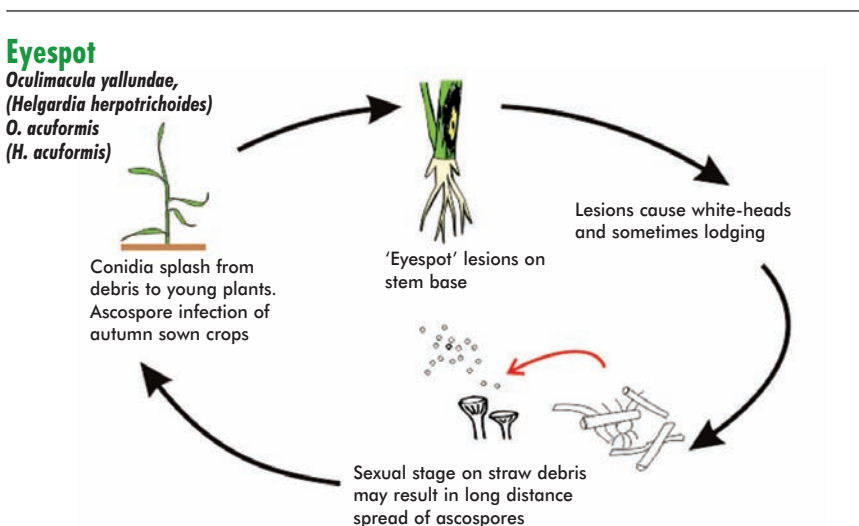


'Eyespot' lesions on stem base

Lesions cause white-heads and sometimes lodging



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



Common name: **Flag Smut**

Pathogen: *Urocystis agropyri*

WHEAT ☒

BARLEY ☐

OATS ☐

RYE ☐

TRITICALE ☐

Hosts

The disease affects 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 which are then dispersed, giving the plants the appearance of being 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. 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 infect the germinating wheat seedlings coleoptile. The fungus, having penetrated the seedling, then grows inside the plant, eventually producing the typical striping on the upper leaves late in the season, giving rise to a new generation of teliospores. The teliospores can survive in soil for several years, so even where a break from cereals occurs, subsequent wheat crops may become infected.

Importance

Flag smut of wheat 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 with regard to exporting grain or wheat products. Many countries have quarantine restrictions which prohibit the import of wheat products from countries where the disease is established.



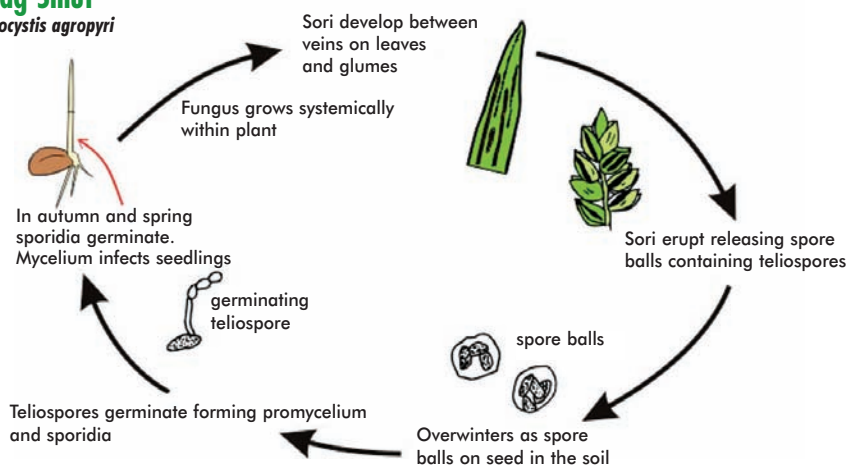
Streak symptoms of flag smut on a wheat leaf



Black teliospores on a wheat leaf

Flag Smut

Urocystis agropyri



Common name:

Foot Rot

Pathogen:

Cochliobolus sativus (*Drechslera sorokiniana*)

WHEAT ✓

BARLEY ✓

OATS ✓

RYE ✓

TRITICALE ✓

Hosts

The disease affects all cereals.

Symptoms

The fungus causes disease symptoms similar to *Fusarium* spp. Seed-borne 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 very rare in the UK.

Life cycle

The fungus behaves very much like *Fusarium* spp. in its survival and life history. It is both soil and seed-borne. It infects seedlings as they emerge, occasionally producing a seedling blight. More usually 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

Foot rot due to *C. sativus* is traditionally a disease of hotter climates than that of the UK.



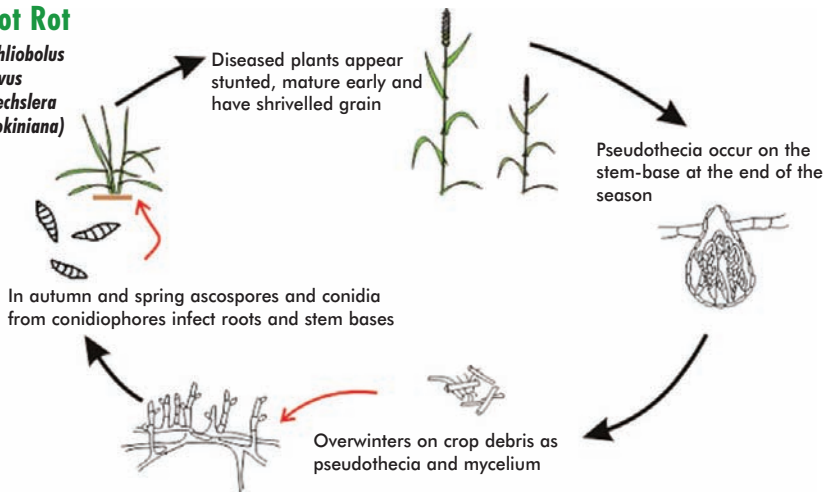
Foot rot discolouration of wheat sub crown internode



Foot rot browning at the base of young barley plants

Foot Rot

Cochliobolus sativus
(*Drechslera sorokiniana*)



Common name:

Fusarium**(Foot Rot, Seedling Blight, Ear (Head) Blight)**

Pathogen:

Fusarium spp. and *Microdochium nivale*

WHEAT ✓

BARLEY ✓

OATS ✓

RYE ✓

TRITICALE ✓



Fusarium on the stem-base



Fusarium staining on the lower nodes

Hosts

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

Symptoms

There are many species of *Fusarium* that affect cereals. These fungi form a complex of diseases on seeds, seedlings and adult plants. The seed-borne pathogen *Microdochium nivale* (formerly known as *Fusarium nivale*) is also usually included in this group of fungi.

M. nivale is the primary pathogen in the group which causes seedling blight resulting in seedling death and thinning of the plant stand. Other species cause a range of symptoms including brown lesions on stem bases, often restricted to the outer leaf sheath. *Fusarium* lesions often begin in the leaf sheath at the stem base where crown roots split the leaf sheath when emerging. This infection can then spread up the leaf sheath causing long dark brown streaks at the stem base. The most commonly seen symptom in the UK is the dark



Ear blight infection resulting in bleached ears



Pink grains caused by Fusarium

brown staining of the lower nodes. 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, although it can be found in very dry seasons.

Many of the *Fusarium* species cause a range of symptoms - often termed ear blights. *F. culmorum* and *F. graminearum* are the two most commonly found species in the UK. Other species include *F. avenaceum*, *F. poae* and *F. langsethiae*. Infection frequently results in the whole or part of the ear becoming bleached. This symptom is seen when ears become infect-

ed during the early flowering stages. Later infections may result in infection of the grain but without obvious bleaching of the ears. The ear blight phase of the disease can cause yield loss but is most important as it can result in mycotoxin production in the grain. Mycotoxins are substances toxic to animals and humans. Levels in grain, flour and flour products for human and animal consumption are limited under EU legislation. See HGCA 'Guidelines to minimise risk of fusarium mycotoxins in cereals' for more details.



Ear blight symptoms on wheat (*Fusarium poae*)

Life cycle

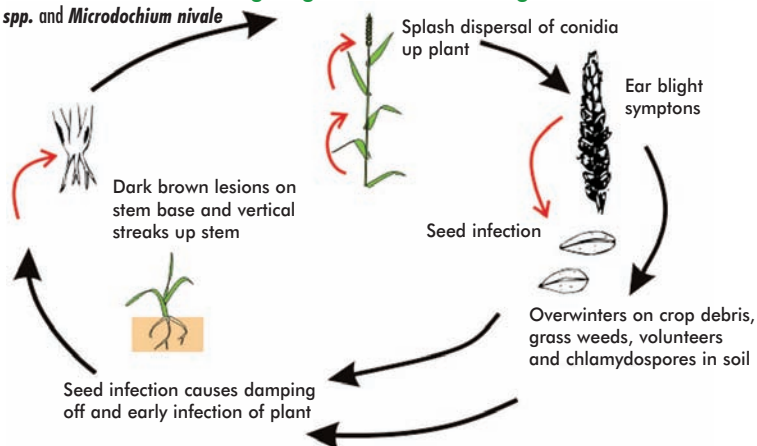
The most important source of *Fusarium* on wheat crops is the seed but the fungus can also survive on debris in the soil. In seasons where weather conditions are wet during flowering and grain formation, spores are splashed from lower in the canopy causing ear blights and seed-borne infection. In such seasons seed-borne infection can pose a serious threat to crop establishment unless seed is treated to control *Fusarium*. All of the cereal *Fusarium* species are common in soil. Most have competitive saprophytic abilities which allow them to colonise debris and stubble in soil. Volunteers may also act as a source of inoculum.

Importance

Symptoms of *Fusarium* infection are common in wheat crops in the UK and most cereal crops will have some symptoms of one or other of these diseases. When weather conditions are wet during flowering, high levels of ear blight can occur but their incidence is frequently over-estimated and losses are only rarely serious. Severe foot rotting is very rare in the UK and losses are generally very small. The seed-borne phase of the disease is potentially very damaging. Seed treatment plays a major role in preventing seedling losses in wheat. Seedling blight is rare in barley.

Fusarium (Foot Rot, Seedling Blight, Ear (Head) Blight)

Fusarium spp. and *Microdochium nivale*



Common name:

Halo Spot

Pathogen:

Selenophoma donacis

WHEAT

BARLEY ✓

OATS

RYE

TRITICALE

Hosts

The disease only affects barley.

Symptoms

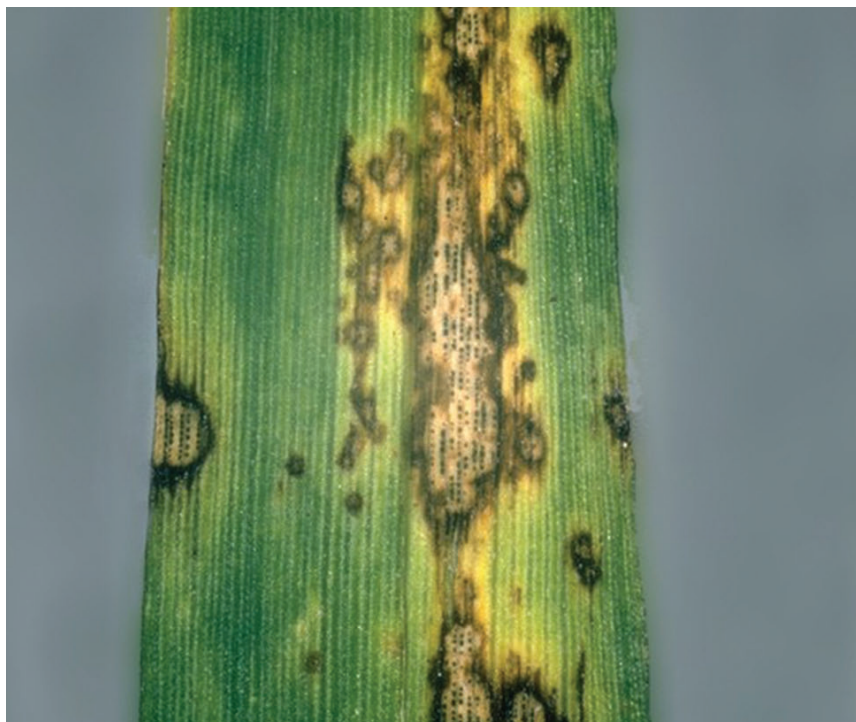
Halo spot is found mainly in western coastal areas where outbreaks occur in wet summers after flag leaf emergence. The disease appears as small leaf spots (1-3mm long) often square or rectangular in shape, pale brown in the centre with dark purple/brown well defined margins. Pycnidia occur in lines along 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. Also, halo spot tends to occur most frequently on the upper leaves whilst *Rhynchosporium* is often more common on the older foliage.

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 spread up the plant in rain-splash, 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

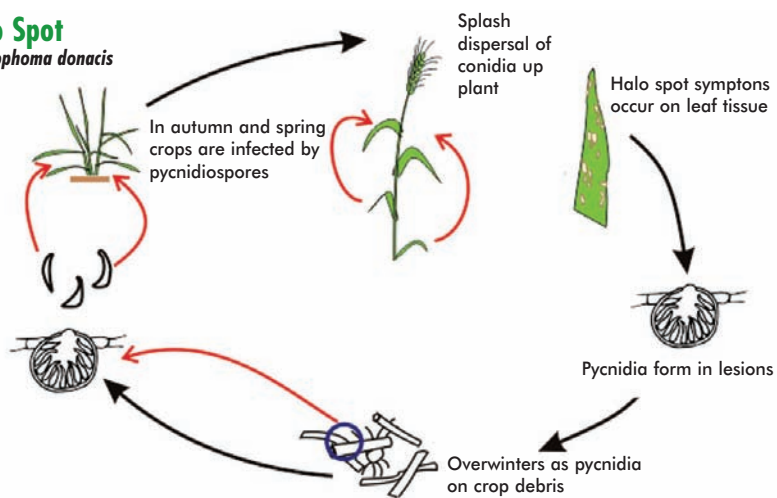
The disease occurs sporadically, usually in wet seasons. Traditionally the disease occurs mainly in the south west of England where rainfall is high but is rare elsewhere in the UK - it generally does not cause significant yield loss.



Halo spot symptoms on a barley leaf

Halo Spot

Selenophoma donacis



Common name:

Leaf and Glume Blotch

Pathogen:

*Phaeosphaeria nodorum**(Stagonospora nodorum formerly Septoria nodorum)*

WHEAT ✓

BARLEY ✓

OATS

RYE ✓

TRITICALE

Hosts

Mainly wheat, but occasionally barley and rye.



Glume blotch symptoms on a wheat ear

Symptoms

S. nodorum can be seed-borne and infect seedlings, resulting in water-soaked, dark green areas on the coleoptile, later becoming necrotic. Twisted, distorted and stunted seedlings may also occur. On mature leaf tissue the first symptoms of 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. Pycnidia form within infected tissue, but these are a pale pinkish brown colour and difficult to see in the field, even with a hand lens. They are best seen by viewing the lesions in transmitted light with a hand lens. *S. nodorum* can also infect the ears, particularly of wheat, causing glume blotch. Dark brown patches like burn-marks develop on the glumes, which later become purple-brown. Glume blotch symptoms are easiest to see on green ears.

Although more usually associated with necrotic blotching of leaves and glumes, *S. nodorum* can cause post-emergence seedling blight in cool wet soils.

Life cycle

S. nodorum survives as dormant mycelium, and as pycnidia and pseudothecia on seed, stubble, debris, autumn-sown crops and volunteers. In the absence of crop debris, initial infections in the autumn or spring may result from wind-borne ascospores released from pseudothecia long distances away. As temperatures rise and humidity increases pycnidiospores are produced from the pycnidia. These are splash-dispersed up the infected plant and from plant to plant. Temperatures of 20-27°C, together with 100% relative humidity, are optimal for spore production and germination and 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 early autumn-sown crops and volunteers and may also remain dormant for the winter. Glume blotch infection of the ear can lead to infection of the seed.

Like the *Fusarium spp.*, *S. nodorum* can survive between crops either on seed or on plant debris. While trash-borne inoculum is usually more important in initiating the later phases of the disease (leaf and glume blotch), fungus carried on the seed is more likely to be responsible for septoria seedling blight.

Importance

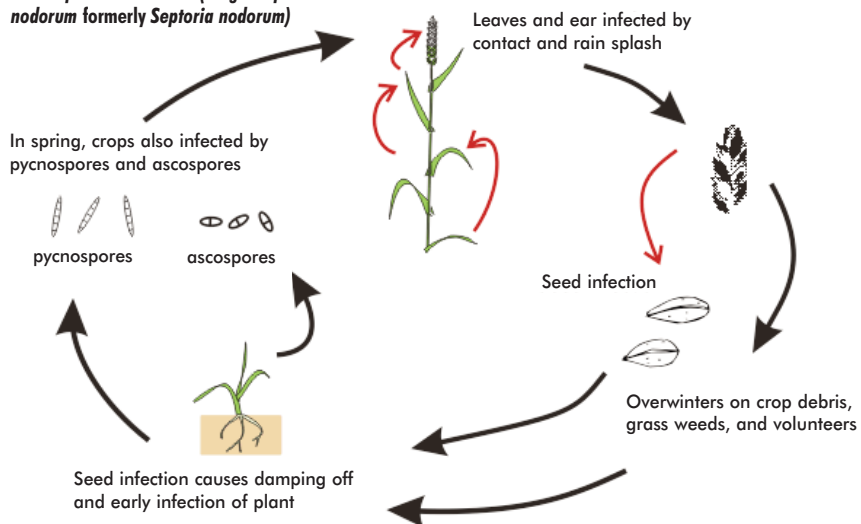
S. nodorum was once the most serious pathogen on cereals in the UK, although it now rarely causes significant losses except in wet seasons in the south west of England. Yield losses up to 50% have been reported in trials although average annual losses in the UK probably do not exceed 3%. Losses caused by septoria seedling blight are generally not significant.



Glume blotch lesions on wheat leaves

Leaf and Glume Blotch

Phaeosphaeria nodorum (*Stagonospora nodorum* formerly *Septoria nodorum*)



Common name:

Leaf Spot

Pathogen:

Pyrenophora avenae (*Drechslera avenae*)

WHEAT

BARLEY

OATS ☒

RYE

TRITICALE

Hosts

The disease is specific to oats.

Symptoms

The primary phase of the disease (from seed-borne 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.

Life cycle

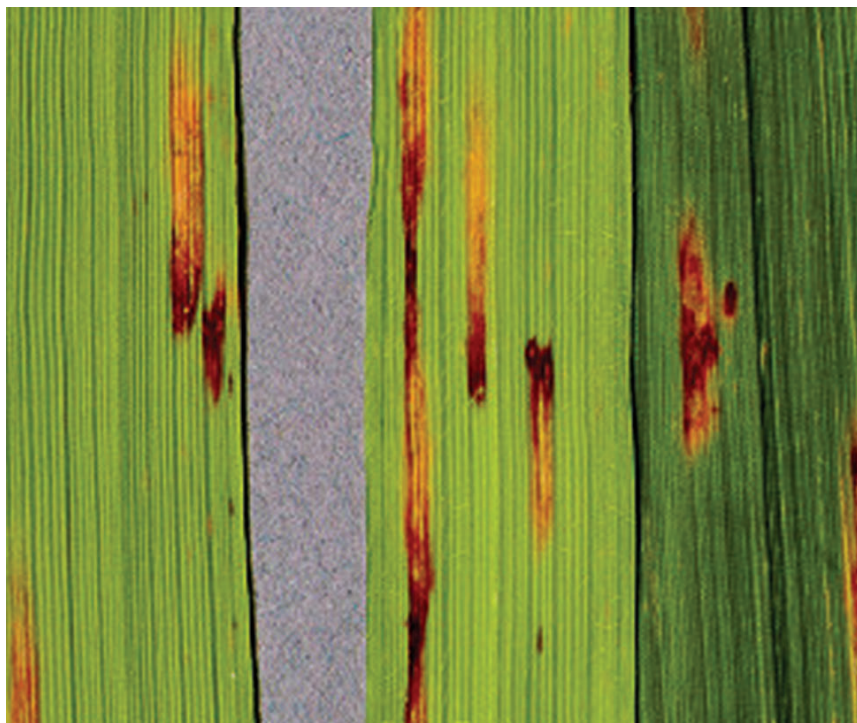
The primary phase of the disease arises from seed-borne infection. Spores from the early leaf stripes then splash up the plant, producing the secondary leaf spot phase of the disease. Eventually spores splash up onto the ear where the grain becomes infected. Infected grain can cause seedling death during or soon after emergence. Surviving seedlings give rise to the primary phase of the disease. Infected debris is not thought to be a significant part of the disease cycle.

Importance

The disease is no longer a serious pathogen of oats. Although it is not uncommon, severe outbreaks are very rare and probably associated with repeated home-saving of untreated seed.



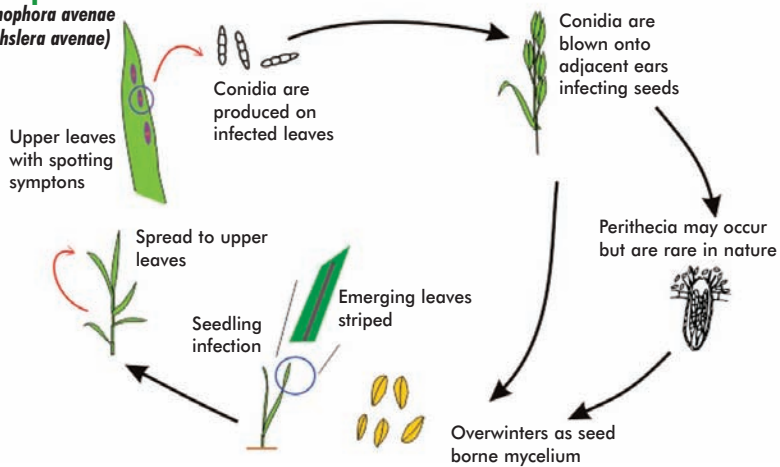
Leaf spot symptoms on oat leaves



Close-up of symptoms showing short brown stripes with purple edges

Leaf Spot

Pyrenophora avenae
(*Drechslera avenae*)



Common name:

Leaf Stripe

Pathogen:

Pyrenophora graminea (*Drechslera graminea*)

WHEAT

BARLEY ✓

OATS

RYE

TRITICALE

Hosts

The disease is specific to barley.

Symptoms

The disease is seed-borne and causes long brown stripes on the leaves. The stripes are often pale green at first, becoming yellow and then 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 which have been grown from untreated seed.

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

Life cycle

The fungus is present on the seed surface and as mycelium 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 until it infects the ear which often remains in the leaf sheath. Although the fungus produces spores on the stripes these are not thought to be very important in the UK as a means of spreading the disease.

Importance

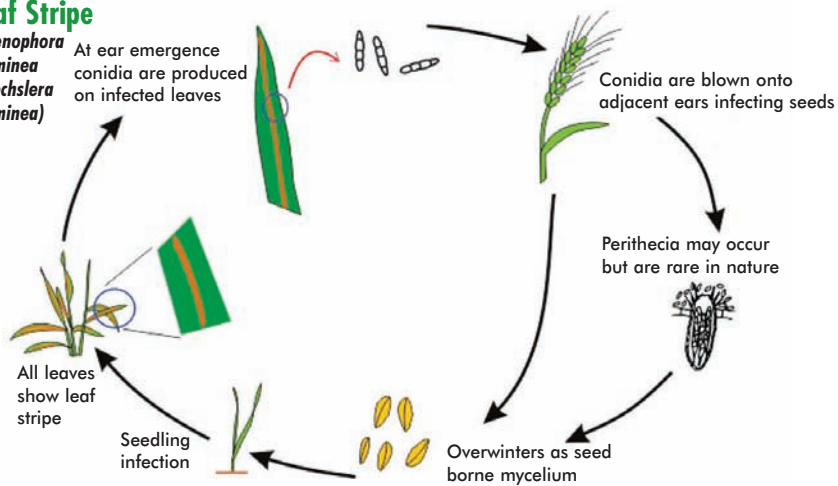
This is potentially the most serious seed-borne disease of barley. If seed from affected crops is re-sown without an effective fungicidal seed treatment being applied, the disease can multiply very significantly and produce large yield losses. If seed is saved and re-sown repeatedly, complete crop loss is possible within a few generations of seed multiplication.



Leaf stripe symptoms on barley

Leaf Stripe

*Pyrenophora
graminea*
(*Drechslera
graminea*)



Common name:

Loose Smut

Pathogen:

Ustilago nuda f.sp. *tritici* (*U. tritici*) - Wheat

Ustilago nuda f.sp. *hordei* - Barley

Ustilago avenae - Oats

WHEAT



BARLEY



OATS



RYE

TRITICALE

Hosts

There are distinct forms of the pathogen which are crop specific.



Close-up of infected wheat ears

Symptoms

Loose smut is easily recognised at ear emergence as individual grains are completely replaced by a mass of black fungal spores. Partly affected ears are sometimes seen. The spores are released as soon as the ear emerges, leaving only the bare remains of the ear rachis. Because the blackened ears are so obvious in the crop at ear emergence the disease appears to be very severe, even at very low incidence.

Life cycle

Spores are released from infected ears and are carried by the wind to the open flowers of surrounding healthy plants. There they germinate and the fungus grows into the developing grain site. Weather conditions during flowering affect the length of time that the florets remain open and hence the time that the plant is susceptible to infection. Thus, the likely level of infection varies considerably from season to season. The fungus lies dormant within the embryo of the



Loose smut infected wheat ears

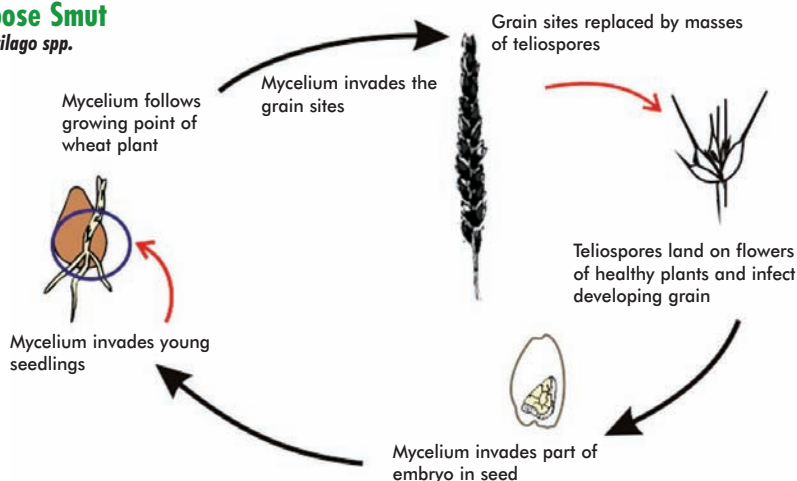
seed until the seeds are sown and germinate. When the infected seed germinates the fungus grows within the developing shoot, eventually reaching the ear primordia. The fungus develops within the young ear, eventually replacing spikelets with masses of fungal spores which are released once again as the ear emerges.

Importance

The UK Seed Certification Scheme is undoubtedly successful in ensuring that loose smut remains at very low levels in UK seed stocks and is of low importance. Seed crops grown under the scheme are inspected for loose smut and because the disease is so easily seen at low levels it can be detected by visual examination.

Loose Smut

Ustilago spp.



Common name:

Mosaics

Pathogen:

See below

WHEAT

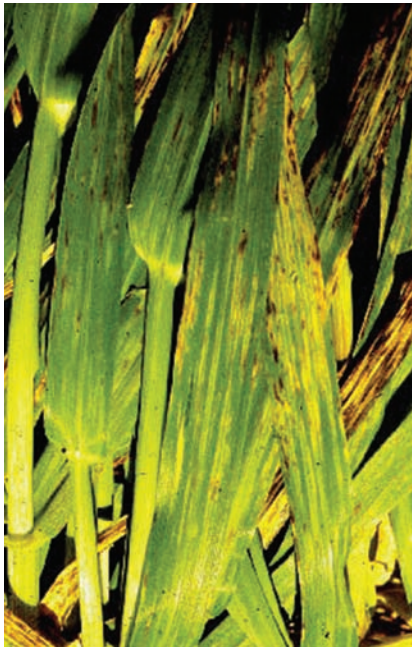
BARLEY

OATS

RYE

TRITICALE

Mosaic Viruses

*Barley yellow mosaic virus (BaYMV)**Barley mild mosaic virus (BaMMV)**Oat mosaic virus (OMV)**Oat golden stripe virus (OGSV)**Soil-borne cereal mosaic virus (SBCMV)**Soil-borne wheat mosaic virus (SBWMV)*

Typical yellow streaks and brown flecking of barley yellow mosaic

Each of these mosaic diseases is caused by a virus, transmitted by the soil-borne vector *Polymyxa graminis*. The viruses causing these diseases are closely related single stranded RNA (ribonucleic acid) rod or filamentous viruses belonging to the genus *Furovirus* or *Bymovirus*.

Hosts

The diseases affect only winter-sown crops. All cereals are affected by their own form of the virus which does not cross-infect to other cereals.

Symptoms

Affected plants can be very stunted and pale in colour. Typical symptoms are pale yellow streaks in the leaves which are most pronounced

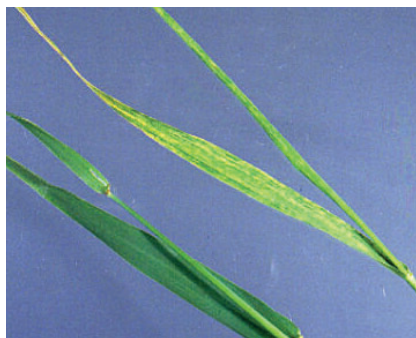
during the early spring, particularly following a prolonged cold spell. The yellow streaks may become brown or purple at the leaf tip and dark brown flecking may replace the yellow streaking.

Life cycle

The disease often occurs in distinct patches which increase in size from one year to the next. The virus is carried in the soil by the root-infecting organism *Polymyxa graminis*. Movement of the soil during cultivations will spread the disease within the field and to other areas. The virus survives within the spores of the vector so that once it is present in soil it persists even in the absence of cereal crops for many (more than 25) years.

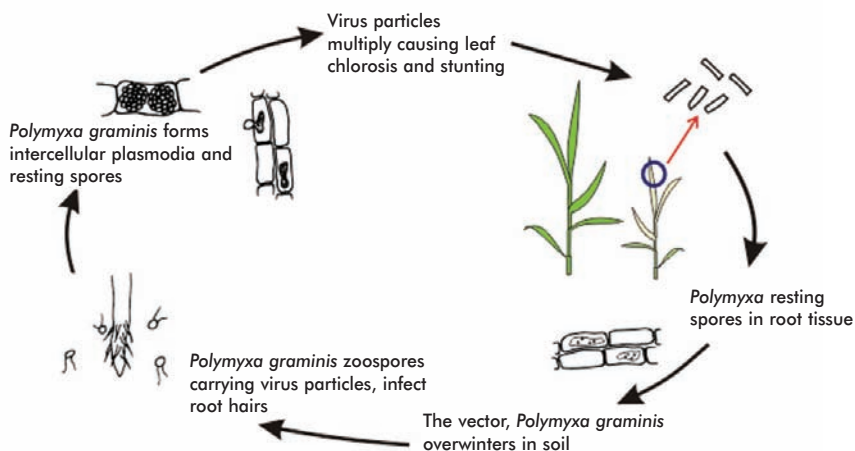
Importance

Yield losses of 50% have been recorded in the patches on susceptible varieties. BaYMV and BaMMV are very common in the UK. SBWMV and SBCMV are present in the UK but are not yet commonly found. OMV is commonly found OGSV is usually found in association with OMV.



Close-up of yellow streak symptoms on oats

Mosaics



Common name:

Net Blotch

Pathogen:

Pyrenophora teres f. *teres* (*Drechslera teres*)*Pyrenophora teres* f. *maculata* (spot form)

WHEAT

BARLEY ✓

OATS

RYE

TRITICALE

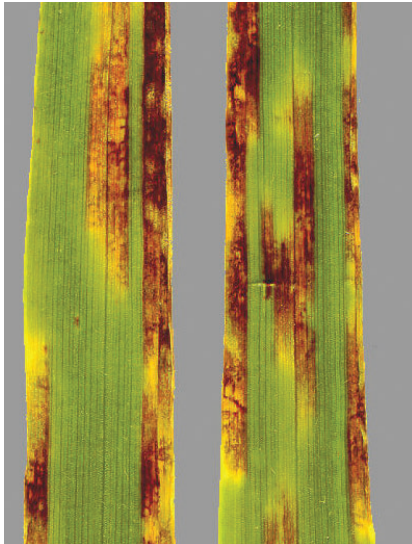
Hosts

The disease affects a wide range of grasses but the forms on barley are specific to that crop and do not affect other cereals or grasses.

Symptoms

Infection of young seedlings with net blotch can look very similar to leaf stripe infection - the first leaf often has a single brown stripe extending the whole length of the

leaf. However, later leaves do not usually show striped symptoms. Leaves infected by splash-borne spores typically show short brown stripes or blotches with a network of darker lines at random on the leaves. The disease tends to produce 'stripe' symptoms or 'netting' symptoms which are distinctly different in appearance. There is also another, less common symptom which is termed 'spot blotch' where lesions are more oval in appearance. Leaves frequently have yellowing associated with all of these types of lesion, particularly when the symptoms are severe. The glumes and awns can also be affected, producing dark brown flecking and striping.



Close-up of typical symptoms of net blotch

Life cycle

Seed-borne mycelium infects the coleoptile and the first leaf becomes infected as it emerges. Spores produced on this first leaf serve to spread the disease to other leaves and to surrounding plants. Seed-borne inoculum is usually much less important than infected stubble and debris which allows the



Net blotch symptoms on barley

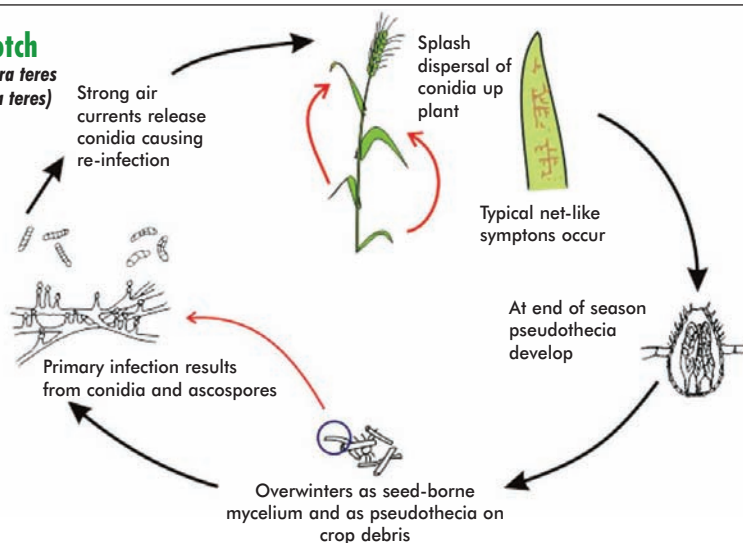
pathogen to over-winter. Trash and crop debris provides much higher levels of inoculum which is splash borne up the plant. Although there are suggestions of long distance spread of ascospores from overwintering pseudothecia the role of these is not thought to be as important as trash-borne inoculum.

Importance

Because the seed-borne phase is relatively unimportant compared with trash-borne inoculum the seed-borne phase does not often threaten yield. Net blotch is now a very important disease of barley and can cause large losses where the disease is not well controlled. 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.

Net Blotch

Pyrenophora teres
(*Drechslera teres*)



Common name:

Omphalina Patch

Pathogen:

Omphalina pyxidata

WHEAT ✓

BARLEY ✓

OATS

RYE

TRITICALE



Fruiting bodies in an infected patch of barley

Hosts

The disease affects wheat, barley and grasses.

Symptoms

The disease is normally first seen as stunted areas of poor growth. Affected crops are frequently found on light land. Affected patches can be visible as early as December as sharply delineated but irregular areas of stunted growth although the crop remains a normal green colour. Roots and the soil adjacent to affected plants show characteristic white hyphal masses (like small pieces of cotton wool about 1mm across). Fruiting bodies (basidiocarps) like tiny mushrooms can sometimes be found within affected patches between January and March. They are approximately 2 cm high with a 1 cm diameter convex cap.

Life cycle

Little is known about the disease cycle although this is a soil-borne fungus which survives between susceptible hosts as sclerotia or as mycelium on root debris. It infects crops soon after emergence,



Close-up of the fruiting bodies (basidiocarps)

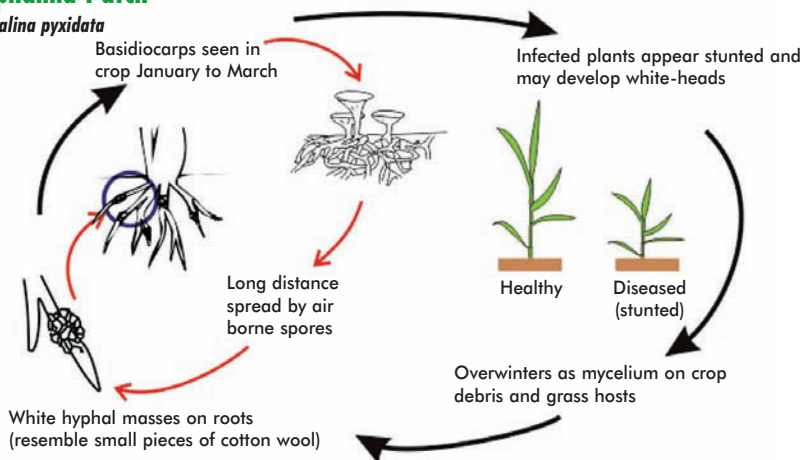
colonises roots, produces sclerotia and then produces air-borne basidiospores. These spores may play a part in long distance spread of the disease. The role of the basidiospores is unclear.

Importance

Until recently, the fungus had not been recognised as a pathogen of cereals in the UK. It is now believed to be sporadic in nature, affecting a small number of crops each year, mainly winter barley. Winter wheat is less frequently affected than barley and losses each year will be very small in comparison with other diseases. Limited trials on winter barley suggest infection can reduce fertile tiller number by 40% and yields by 25-50%.

Omphalina Patch

Omphalina pyxidata



Common name:

Powdery Mildew

Pathogen:

Blumeria graminis f. sp. *tritici* - Wheat, Triticale

Blumeria graminis f. sp. *hordei* - Barley

Blumeria graminis f. sp. *avenae* - Oats

Blumeria graminis f. sp. *secalis* - Rye

WHEAT ✓

BARLEY ✓

OATS ✓

RYE ✓

TRITICALE ✓



Mature mildew pustules with cleistothecia on wheat

Hosts

All cereals can be affected by mildew although there are several forms of the disease which are specific to individual crops and do not cross-infect.

Symptoms

Symptoms of powdery mildew can be found on leaves, stems and ears, but leaves are most commonly infected. Typically, white pustules appear which produce a mass of spores with a powdery appearance. As the mildew pustules become older, they darken to a grey or brown colour. Eventually, black spore cases (cleistothecia) can be found embedded in the mildew pustules - usually towards the end of the season.

Life cycle

Mildew overwinters primarily as mycelium on volunteers and autumn-sown crops. The cleistothecia produced during late summer are resistant to low temperatures and



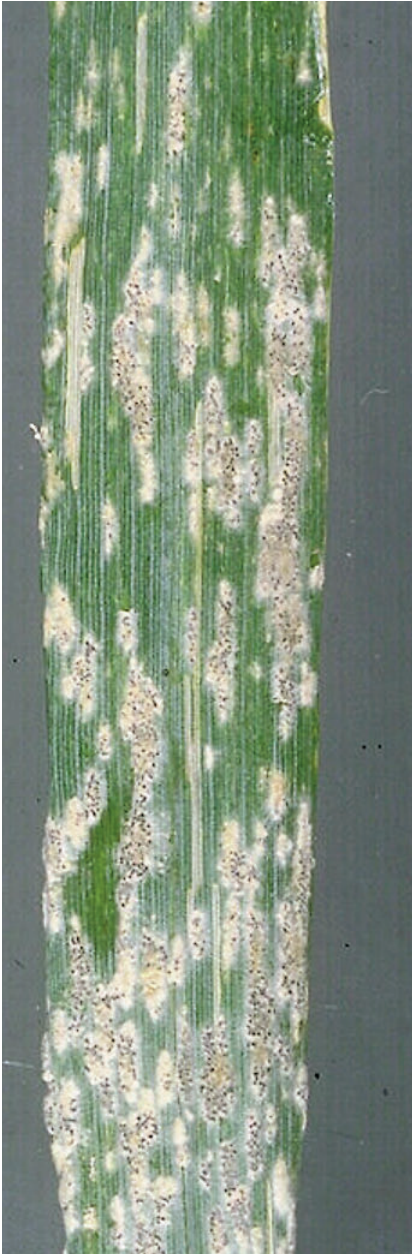
Typical white pustules on barley



Early powdery mildew symptoms on wheat

drying which allows the fungus to survive in the absence of a host. In humid weather, cleistothecia release the sexually produced ascospores which can initiate autumn infections. However, in the UK, green plant material is nearly always available and cleistothecia are thought to be of secondary importance to mycelium. As temperatures

rise in the spring, dormant mycelium starts to grow and spores are quickly produced. These germinate over a wide range of temperatures, from 5°C to 30°C, although 15°C is optimal with relative humidity above 95%. Free water inhibits spore germination. Under dry conditions, fresh spores can be formed in about seven days. At the end of



Powdery mildew with cleistothecia on wheat

the season, volunteers and early autumn-sown crops may become infected, providing inoculum for the following crop.

Importance

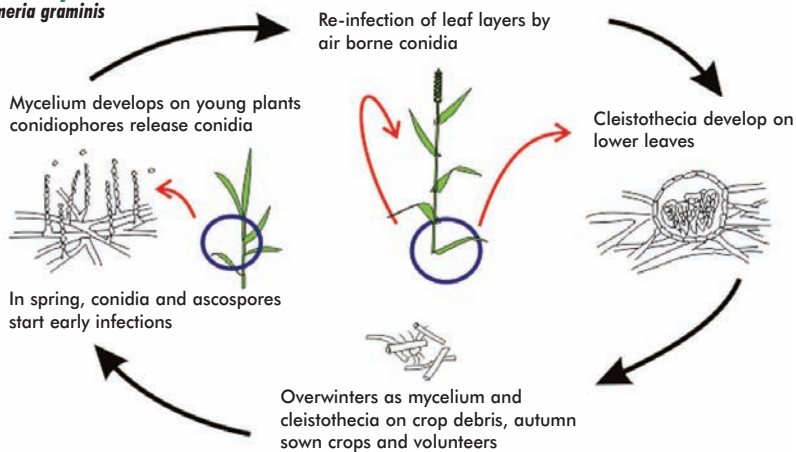
Late-sown winter wheat crops are often particularly prone to attack, especially when growing rapidly in the spring. High levels of nitrogen fertiliser encourage the disease and mildew can be particularly severe in dense crops. The visual appearance of the disease usually outweighs its damage potential especially during the autumn and winter. In 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 and late attacks (after flowering) on the flag-leaf and ear rarely cause significant losses.



Young barley plant infected with powdery mildew

Powdery Mildew

Blumeria graminis



Common name:

Ramularia Leaf Spot

Pathogen:

Ramularia collo-cygni

WHEAT

BARLEY ✓

OATS

RYE

TRITICALE



Small, brown rectangular lesions of Ramularia leaf spot

Hosts

The disease affects only winter and spring barley.

Symptoms

Typical symptoms of Ramularia comprise small brown rectangular lesions, often surrounded by a yellow halo. They resemble the spot-form of net blotch. Following high levels of infection, the leaves may senesce rapidly. Lesions are often obvious on dead leaves as black spots. The spores of the fungus are visible on the surface of dead leaves. Ramularia is frequently found in association with other leaf spots such as abiotic sun scorch, physiological leaf spot and spotting caused by damage to the leaf wax following the application of some fungicides.

Life cycle

Ramularia can be detected on the seed and within symptomless leaves. The disease can also be dispersed via air-borne spores. Symptoms can develop on dead lower leaves but symptoms are rarely seen on healthy green leaves until after flowering. There may be a stress or physiolog-

ical trigger for symptoms to develop. The toxin rubellin D is also thought to be produced by the fungus when the barley host is stressed. Under certain light conditions, this toxin causes oxidative stress, leading to plant cell damage and causing typical leaf symptoms.

Importance

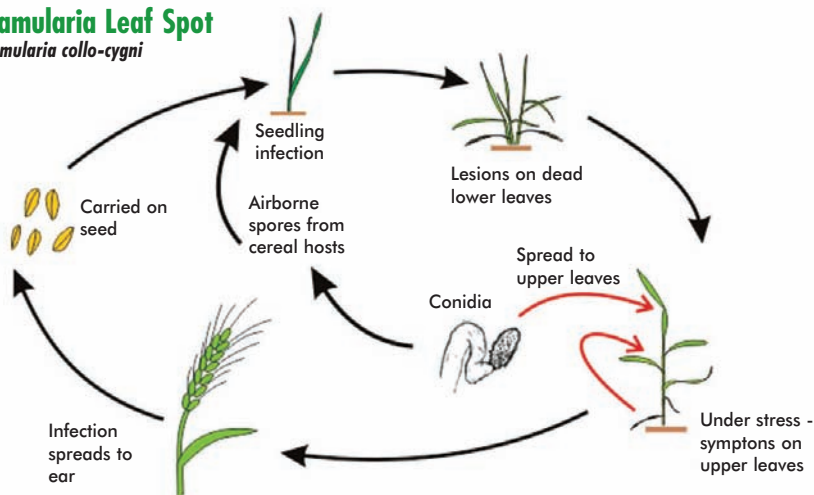
Ramularia leaf spot can cause extensive damage to the upper leaves in spring and winter barley once crops have finished flowering. This can cause extensive losses in yield and quality. Yield losses in spring barley can be up to 0.6 tonnes per hectare.



Close-up of Ramularia leaf spot lesions

Ramularia Leaf Spot

Ramularia collo-cygni



Common name:

Rhizoctonia Stunt

Pathogen:

Thanatephorus cucumeris (Rhizoctonia solani)

WHEAT ✓

BARLEY ✓

OATS ✓

RYE ✓

TRITICALE ✓

Hosts

The disease is known to affect all the major cereal crops and probably most grasses. Barley is much more susceptible to the disease than other cereals.

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. Points of brown rotten tissue may be seen at intervals along the length of the root where they appear as constrictions, often giving the root the appearance of a string of sausages. Affected plants remain thin and stunted throughout the season and their maturity is often delayed. Affected crops are usually confined to sandy loam or loamy sands, in areas such as the Brecklands of Norfolk or Suffolk.

Life cycle

The disease is soil-borne. The fungus is very common in soils and can survive between susceptible crops as mycelium on dead tissues and other hosts.

Importance

The disease is erratic in occurrence and frequently more severe where crops have been established by direct drilling or minimum cultivation. Individual crops may suffer significant losses but in general wheat is not seriously affected. Losses in barley can be much more significant.



Roots of a stunted plant

Rhizoctonia Stunt

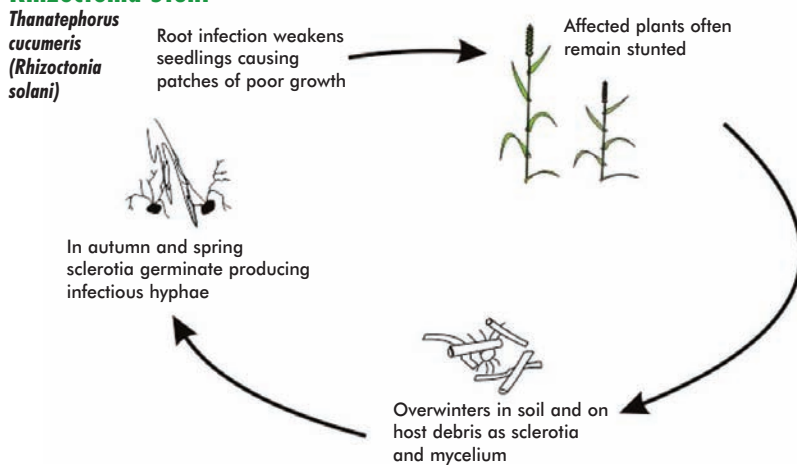
*Thanatephorus
cucumeris*
(*Rhizoctonia
solani*)

Root infection weakens
seedlings causing
patches of poor growth

Affected plants often
remain stunted

In autumn and spring
sclerotia germinate producing
infectious hyphae

Overwinters in soil and on
host debris as sclerotia
and mycelium



Common name:

Rhynchosporium (Leaf Scald)

Pathogen:

Rhynchosporium secalis

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

The fungus causes scald-like lesions on leaves, leaf sheaths and ears. Early symptoms are generally oval lesions which are pale green. As the lesions age they acquire a dark brown margin, the centre of the lesion remaining pale green or pale brown. Lesions often coalesce forming large areas around which leaf yellowing is very common. Infection often occurs in the leaf axil which can cause chlorosis and eventual death of the rest of the leaf.

Life cycle

The fungus is seed-borne but the importance of this phase of the disease is not fully understood. The most important source of the disease is probably crop debris from previous crops and volunteers which become infected from the stubble from previous crops.



Scald-like lesions showing dark brown margins and pale centres

Autumn sown crops can become infected very soon after sowing. The disease spreads mainly by rain-splash although long-distance spread by air-borne spores is also possible.

Importance

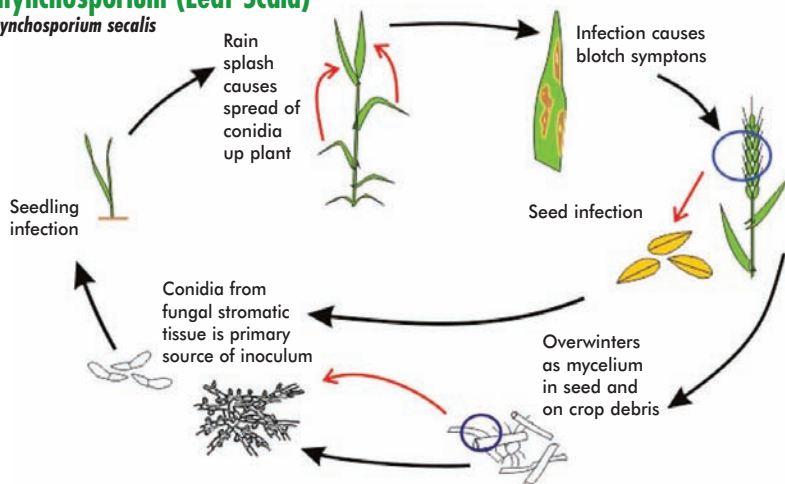
The disease can be very severe, particularly in the south west and west of the UK where conditions are generally mild and wet. The most serious effect on yield in both winter and spring barley results from attacks that develop between first node detectable and boot-swollen growth stages.



Rhynchosporium symptoms

Rhynchosporium (Leaf Scald)

Rhynchosporium secalis



Common name:

Septoria Leaf Blotch

Pathogen:

Mycosphaerella graminicola (*Septoria tritici*)

WHEAT ✓

BARLEY

OATS

RYE ✓

TRITICALE ✓

Hosts

Mainly wheat, but also occasionally on rye, triticale and some grass species.

Symptoms

Symptoms of Septoria can be seen very early in the growing season in most years. On young autumn-sown wheat, water-soaked patches which quickly turn brown and necrotic may be evident by early December and throughout the winter on the

lowest leaves. These contain the visible black pycnidia which are the most characteristic feature of *M. graminicola*. Pycnidia are particularly common on dead over-wintering leaves of winter wheat. Lesions on the mature plant are brown and are sometimes restricted by veins giving a rectangular appearance. The black pycnidia become more visible in the lesions as the symptoms develop. Lesions may coalesce leading to large areas of necrotic brown tissue.



Brown, necrotic lesions on young wheat plant showing black pycnidia



Coalesced lesions giving large areas of necrotic brown tissue

Life cycle

The disease cycle of *M. graminicola* is similar to that of *S. nodorum*, although *M. graminicola* can go through its life cycle at slightly lower temperatures with 15–20°C as the optimum and requires longer periods of high humidity to initiate infection. The lower leaves of win-

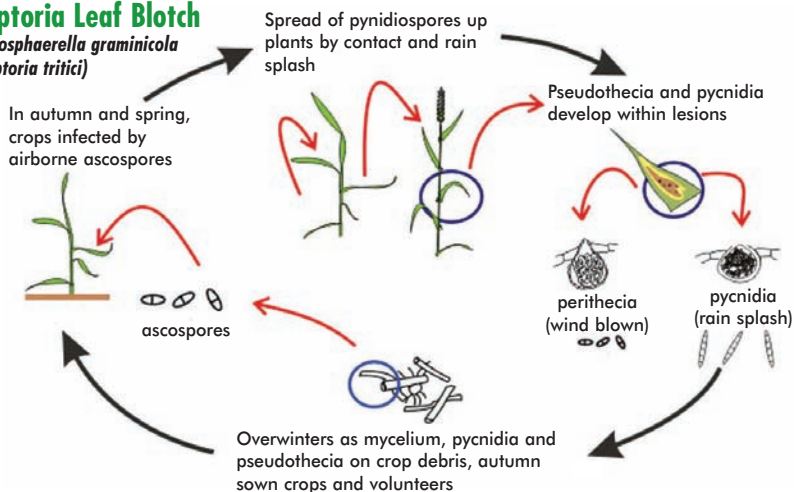
ter-sown crops are normally infected by long distance spread of airborne ascospores throughout the winter and early spring. In the spring the lower leaves of the most susceptible varieties are infected and have actively sporulating lesions. Most disease spread to upper leaves occurs by rain-splash from the lower-leaves during heavy rainfall. Physical spread can occur without heavy rainfall, particularly when leaves 3 and 4 overlap the upper leaves as they emerge.

Importance

This is the most important foliar disease on winter wheat in the UK. Losses of 50% have been reported in severely affected crops. This is largely because of the predominance of varieties which are susceptible to the disease.

Septoria Leaf Blotch

Mycosphaerella graminicola
(*Septoria tritici*)



Common name:

Sharp Eyespot

Pathogen:

Ceratobasidium cereale (*Rhizoctonia cerealis*)

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 sharply defined dark margin and frequently have shredding of the epidermis

within the lesion. Multiple lesions up the stem can be found up to 30cm 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, but severe sharp eyespot is not uncommon and can cause white-heads or lodging.



Distinct sharp eyespot lesions with sharply defined edge

Life cycle

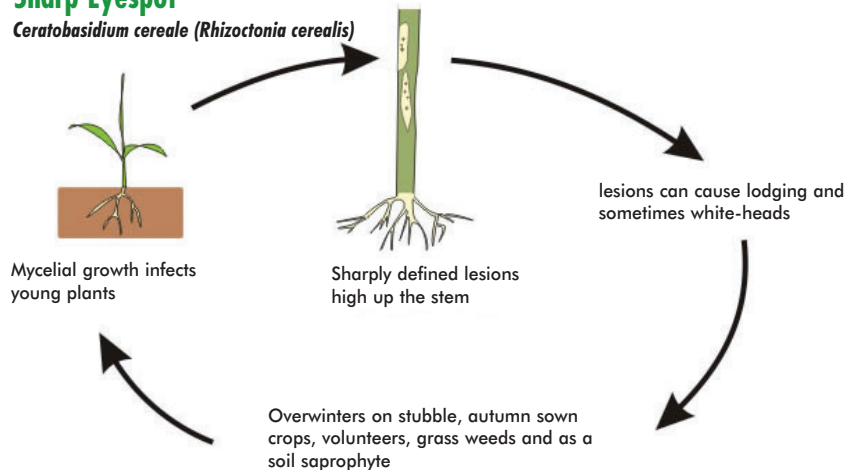
The fungus over-winters primarily as mycelium on infected stubble with volunteers and some grass weeds also acting as sources of inoculum. The fungus can produce sclerotia which may act as over-wintering structures. Infection may occur at any time during the growing season, but the disease is favoured by temperatures of around 9°C. Acid, dry and sandy soils and early sowing favour the disease. Cool autumn or spring temperatures may result in early infection by the fungus which can lead to severe disease.

Importance

Sharp eyespot is common in the UK although, nationally, it does not usually cause significant yield loss. However, individual crops may suffer significant losses, particularly if the disease is present with take-all. Severe sharp eyespot has been shown to reduce yield by up to 25% but this is very unusual. Annual losses in the UK on average are probably less than 0.5%.

Sharp Eyespot

Ceratobasidium cereale (*Rhizoctonia cerealis*)



Common name:

Snow Mould (Pink Snow Mould)

Pathogen:

Monographella nivalis (*Microdochium nivale*)

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 are typically seen after snow melts in the spring. Infected plants often have an extensive covering of white mycelium which spreads on overlapping leaves, causing 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 eventually the whole plant can be affected. Plants die-off in patches, but good growing conditions in the spring can allow crop recovery where plants have survived infection. In years with prolonged snow cover, the disease can be severe. Large areas of the crop may be killed and re-drilling with spring barley may then be necessary.

Life cycle

Winter-sown crops become infected during the winter months, often under snow cover. The lower leaves of plants touching the soil surface become infected by hyphae growing from perithecia or directly 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

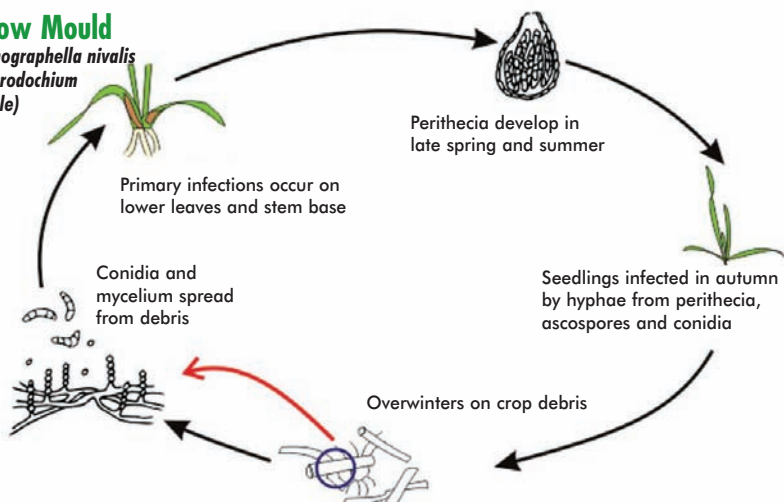
Snow mould is commonly recorded but, except in isolated cases, damage is rarely severe. The disease is generally more damaging in parts of Scotland where snow cover is more common.



Damaged patch of young seedlings due to snow mould

Snow Mould

Monographella nivalis
(*Microdochium nivale*)



Common name:

**Snow Rot
(Grey or Speckled Snow Mould)**

Pathogen:

Typhula incarnata

WHEAT ✓

BARLEY ✓

OATS

RYE

TRITICALE

Hosts

Snow rot affects only winter cereals, especially winter barley, although infections have been noted in winter wheat.

Symptoms

The fungus infects the oldest leaves first but eventually the whole plant can be affected causing yellowing and wilting. Affected plants usually have abundant red-brown resting structures (sclerotia) 2-3 mm in diameter embedded in the lower leaf sheaths and on dead leaf tissue. Plants can be killed, but often good growing conditions in the spring allow crop recovery. Surviving tillers compensate for dead shoots so that yield loss is usually small. In years with prolonged snow cover, the disease can be more severe. Large areas of the crop may be killed and re-drilling with spring barley may then be necessary.

Life cycle

Affected plants produce large numbers of sclerotia which can survive between crops over-winter. The sclerotia germinate and produce spores and/or mycelium which infect emerging crops. Winter-sown crops become infected during the winter months, often under snow cover. Spring-sown crops are rarely affected.

Importance

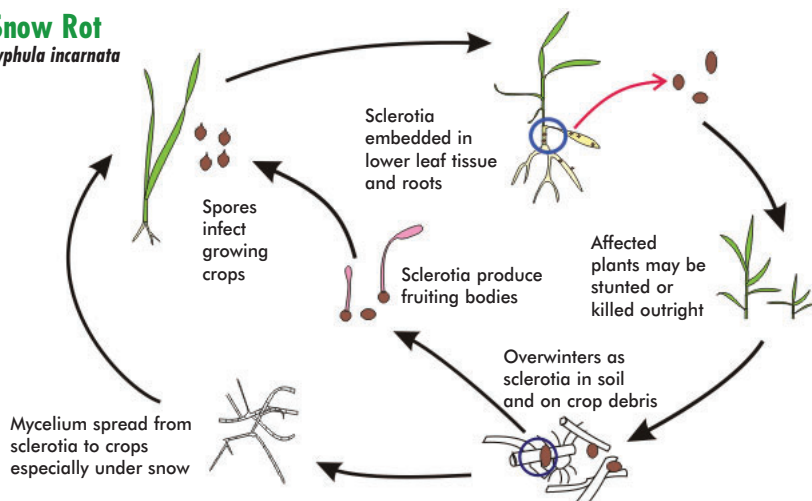
Snow rot is commonly recorded but, except in isolated cases, damage is rarely severe. The disease is generally more damaging in parts of Scotland where snow cover is more common.



Resting structures (sclerotia) of snow rot on lower leaf sheaths

Snow Rot

Typhula incarnata



Common name:

Sooty Moulds

Pathogen:

Alternaria spp. and Cladosporium spp.

WHEAT ✓

BARLEY ✓

OATS ✓

RYE ✓

TRITICALE ✓

Hosts

These fungi are saprophytes, are not host specific and so can affect all cereals.



Comparison of ears without and with sooty moulds



Wheat ears severely affected by sooty moulds

Symptoms

The usual symptoms of sooty moulds are 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. Delays in harvesting in wet weather can lead to severe blackening of ears which can lead to discolouration of the grain.

Life cycle

The fungi that can cause sooty moulds are very common in the atmosphere and can survive adverse conditions as spores or as mycelium on a wide range of materials. They do not require living host material to survive.

Importance

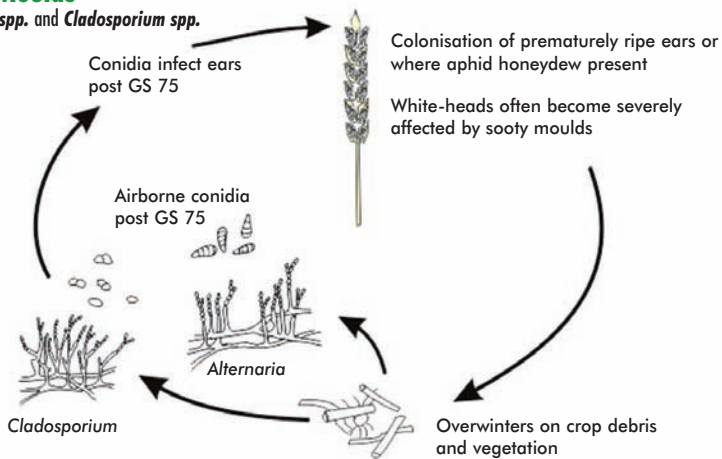
The discolouration of ears and grain rarely have any effect on grain yield but the mixing of spores with the grain at harvest can lead to discolouration which will affect marketability, particularly if the grain is planned for milling for flour production.



Comparison of untreated and treated plots showing the difference in sooty mould infection

Sooty Moulds

Alternaria spp. and *Cladosporium* spp.



Common name:

Stripe Smut

Pathogen:

Urocystis occulta

WHEAT

BARLEY

OATS

RYE

TRITICALE



Typical early symptoms of stripe smut

Hosts

The disease is specific to rye.

Symptoms

This disease differs from the other smuts of UK cereals in that it affects not only the ears but also the stems and leaves. It is specific to rye, producing long dark blisters in stripes parallel to the veins which eventually rupture to expose the spores.

Life cycle

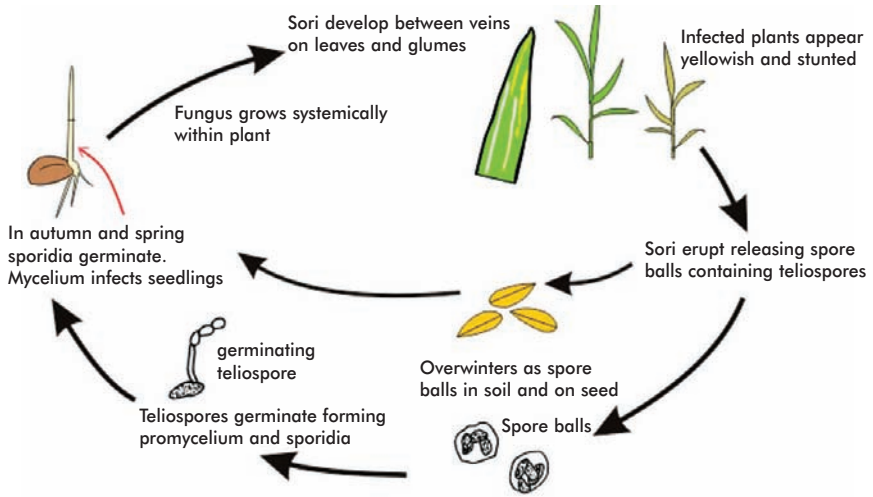
The disease is both soil-borne and seed-borne. The developing grains in ears are contaminated by wind-blown spores but the spores remain on the seed surface. Infection of the seed occurs at germination as with bunt. Soil-borne inoculum is more important with this disease than with the smuts affecting other cereals in the UK.

Importance

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

Stripe Smut

Urocystis occulta



Common name:

Take-all

Pathogen:

Gaeumannomyces graminis var. *tritici**Gaeumannomyces graminis* var. *avenae*

WHEAT ✓

BARLEY ✓

OATS ✓

RYE ✓

TRITICALE ✓

Hosts

Gaeumannomyces graminis var. *tritici* attacks wheat, barley, rye and may attack some grass species, particularly couch grass (*Elytrigia repens*). Oats are immune. *Gaeumannomyces graminis* var. *avenae* attacks oats, wheat, barley, rye and many grass species.

Symptoms

The take-all fungus attacks the roots of plants as it is soil-borne. If diseased plants are pulled up, the roots can be seen to be blackened and rotten and have a “rat-tail” appearance. In severe outbreaks the base of infected plants may also show blackening. Above ground symptoms are seen as patches of stunted plants and white-heads (“bleached” ears) in mature plants. White-heads generally contain small grains or, occasionally, no grain at all.

Life cycle

The take-all fungus survives the winter as mycelium primarily on roots or stubble debris but also volunteer cereals, early autumn-sown crops and some grass weeds. Primary infection occurs in autumn

from inoculum in the soil. Secondary (root-to-root) infection occurs mostly in spring and summer. The disease spreads from infected seedling roots to developing crown roots. As the disease progresses, the root area lost increases and the ability of the plant to absorb water and nutrients declines. When root rotting is severe plants are unable to absorb water and nutrients. As a result the plants ripen prematurely, resulting in white-heads and often poor grain filling.

Importance

Take-all is one of the most important diseases of wheat in the UK, partly because it is not easily controlled chemically or by varietal resistance and relies mainly on rotational strategies for control. Even on chalky boulder clay soil, losses of 10-20% are common in second and third wheat crops. On less well-bodied soils, yield losses can be much higher or indeed it may be impossible to grow second or subsequent wheat. Grain from plants showing white-heads are usually small and shrivelled.



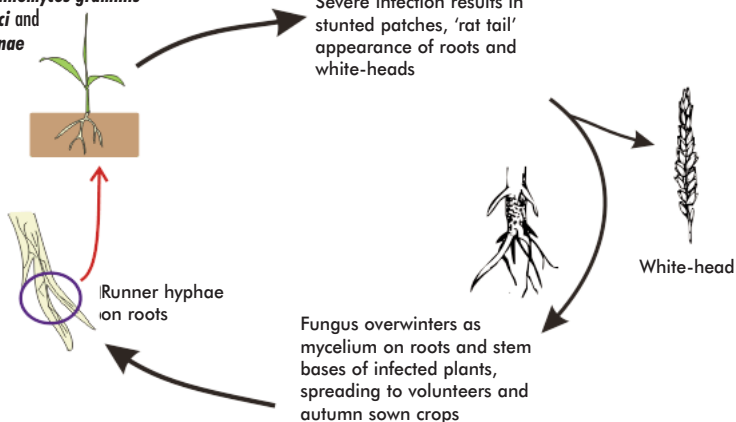
Typical "rat-tail" appearance of roots due to take-all

Take-all causes most damage on light soils, particularly if they are alkaline in nature. Severe attacks can also occur in acid patches. Poor drainage and nutrient status also encourage the disease. Take-all is particularly encouraged by early sowing and light, puffy seedbeds.

The disease is usually most severe in second, third or fourth successive cereal crops, but generally declines in importance in continuous cereals (take-all decline).

Take-all

Gaeumannomyces graminis
var. *tritici* and
var. *avenae*



Common name:

Tan Spot (DTR)

Pathogen:

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

WHEAT ✓

BARLEY ✓

OATS

RYE ✓

TRITICALE

Hosts

The disease affects wheat but can also attack barley, rye and some grasses.



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

Symptoms

P. tritici-repentis can be seed-borne and infect seedlings, resulting in small tan to light brown flecks on young leaves. However, symptoms are generally seen later in the season on the middle and upper canopy. Early symptoms appear as small tan to light brown flecks, with a chlorotic halo, often with a dark spot at the centre. Later these develop into light brown oval lesions with slightly darker margins with a light coloured spot at the centre. Under wet conditions the lesions produce spores which can make lesions darker in colour. Under ideal conditions these lesions coalesce to produce large areas of dead tissue.

Life cycle

P. tritici-repentis survives mainly as dormant mycelium on stubble and crop debris. This produces pseudothecia on stubble which in turn produce ascospores for long distance spread. Under warm, wet conditions, leaf spots produce dark conidia which are spread up the plant. The disease can infect the ear and cause discolouration of the

glumes and the grain. Symptoms on the head are indistinct but can cause brownish glumes. Infected grains can have a reddish appearance, similar to *Fusarium spp.* infection. The disease develops over a wide range of temperatures but has quite a high optimum (20–28°C) and is favoured by long periods (18 hours or more) of dew or rain.

Importance

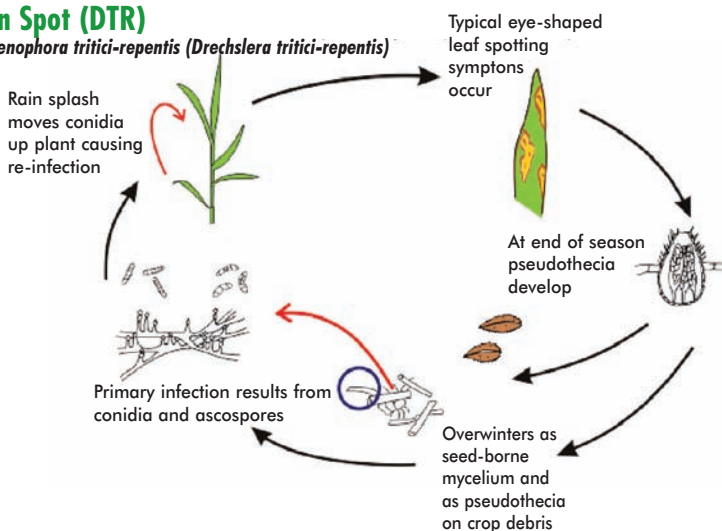
Tan spot is very common in Scandinavia and parts of France but is still rare in the UK. Although it is occasionally recorded in disease surveys it rarely causes serious losses. However, in a few isolated cases the disease has caused serious losses on individual crops grown under minimum tillage systems.



Tan spot symptoms

Tan Spot (DTR)

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



Common name:

Yellow (Stripe) Rust

Pathogen:

Puccinia striiformis

WHEAT ✓

BARLEY ✓

OATS

RYE

TRITICALE ✓

Hosts

There are distinct forms of the fungus that are specific to different cereal crops, i.e. *P. striiformis* f.sp. *tritici* attacks wheat whereas *P. striiformis* f.sp. *hordei* can only attack barley. Within the forms of *P. striiformis* there are a number of different races that can only attack certain varieties.



Typical striped symptoms of yellow rust

Symptoms

Yellow rust symptoms appear as parallel rows of yellowish orange coloured pustules on the leaves of adult plants. Epidemics often start on individual plants, usually in the autumn. Symptoms develop slowly over winter and are often missed until the early spring when small patches or foci of infected plants can be seen in fields. Early on, the yellow to orange coloured yellow rust pustules are difficult to distinguish from brown rust. However, yellow rust lesions tend to spread as a yellow band on young leaves moving ahead of the sporulating lesion. On older leaves pustules occur in obvious stripes hence it sometimes being referred to as stripe rust. Severe infections quickly give rise to chlorosis, and later necrosis, of leaves resulting in desiccation in May/June if the weather conditions are warm and dry. In severe attacks yellow rust infection of the ears can occur with the formation of masses of spores between the grain and the glumes. At the end of the season, secondary black spores (teliospores) are sometimes produced amongst the stripes of pustules.

Life cycle

P. striiformis requires living green plant material in order to survive, over-wintering as dormant mycelium or active sporulating lesions on volunteers or early autumn-sown crops. Within plant tissue the fungus can survive at very low temperatures and will usually survive the winter in infected plants. In the spring, particularly in cool moist weather, the fungus starts to grow and produces active sporulating lesions. Temperatures of 10-15°C and a relative humidity of 100% are optimal for spore germination, penetration and production of new, wind-dispersed spores. The fungus is generally inhibited by temperatures over 20°C although strains tolerant of high temperatures do exist. The complete cycle from infection to the production of new spores can take as little as seven days with ideal conditions and may be repeated many times in one season. During late summer, the dark teliospores may be produced. These can germinate to produce basidiospores, however, no alternate host has been found. Although the teliospores seem to have no function in the disease cycle they may contribute to the development of new races through sexual recombination.

Importance

The disease is generally sporadic in the UK occurring more often in the



Yellow rust pustules on a wheat glume

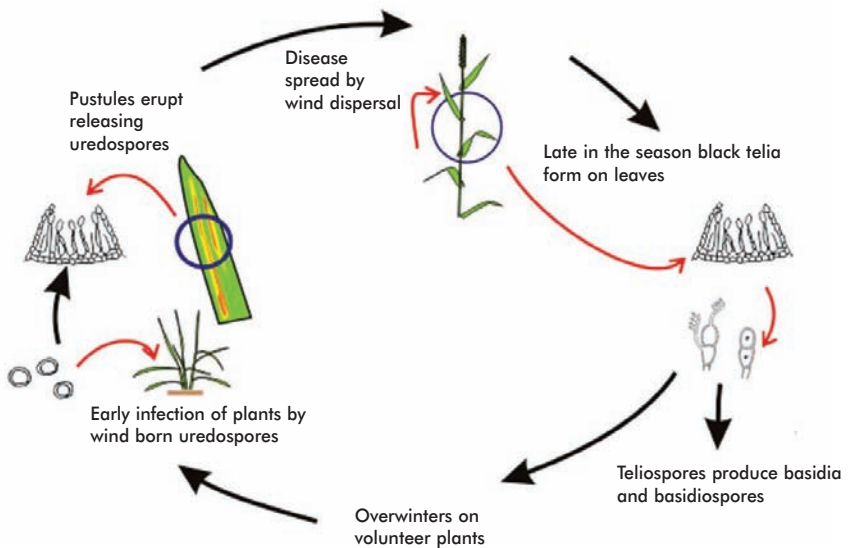
east of the country and in coastal areas which may have cool summer weather accompanied by regular mists. Severe epidemics are usually associated with susceptible varieties, mild winters and cool moist summers. The development of new races of *P. striiformis* can result in varietal resistance being overcome within a short period of time. Yield losses of 40-50% have often been recorded in susceptible varieties.



Yellow rust focus

Yellow (Stripe) Rust

Puccinia striiformis



Glossary

A

Alternate host - a second host (of a different plant species) required by some pathogens in order 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 which bears asci

Ascospores - sexually produced spores contained within an ascus

Ascus (pl. asci) - a sac-like cell which contains the products of the sexual stage (teleomorph) as ascospores (generally 8)

B

Basidiocarp - a fruiting body which 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 4) 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

C

Chlamydospore - an asexual spore arising from a hyphal segment, a resting stage

Chlorosis - the yellowing of normally green plant tissue

Cleistothecia - 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 - the roots which emerge from the base of the stem of the plant rather than the seed

D

Damping - off - disease of plant seedlings caused by seed- or soil-borne fungi

Dicotyledon - a flowering plant whose embryo has two cotyledons (seed leaves)

Dieback - necrosis of a shoot beginning at the apex and spreading towards the older tissue, stem death may occur

Direct drilling - the drilling of seed into ground which has received minimal cultivation

E

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 - a widespread increase in the incidence of an infectious disease

Epidermis - the outermost layer of cells of an organ, usually only one cell thick

Ergot - the fruiting structure (sclerotium) of *Claviceps spp.*

F

Flag leaf - the final leaf to emerge in a cereal plant

Focus - a site of local concentration of diseased plants, usually about a primary source of infection or coinciding with an area originally favourable to disease establishment

Forma specialis (f. sp) - a group within a pathogen species that can only infect particular hosts

G

Glume - an outer and lowermost bract of a grass (including cereals) spikelet (inflorescence)

H

Honeydew (fungal) - a sticky secretion containing conidia produced during the lifecycle of *Claviceps purpurea* (Ergot)

Host - a living organism harbouring a pathogen

Host specific - pertaining to a particular host, generally species specific

Hypha - one of the filaments of a mycelium

I - K

Immune - cannot be infected by a given pathogen

Inoculum - micro-organisms or virus particles which 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

L

Leaf sheath - the lower part of the leaf which surrounds the stem more or less completely

Lesion - a localised area of diseased tissue

Lodging - when a standing crop is caused to lean or bend due to adverse weather or soil conditions

M

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

N-O

Necrotroph - micro-organism feeding only on dead organic tissue

Node - the level of a stem at which one or more leaves arise

P-Q

Pathogen - an organism which causes disease

Perithecium - an ascocarp shaped like a flask containing asci

Primary inoculum - spores or fragments of mycelium capable of initiating disease

Pseudothecia - a perithecium-like structure with a single cavity containing ascospores

Pustule - a spore mass developing below the epidermis and then breaking through at maturity

Pycnidium - flask shaped fruiting body with an apical pore lined internally with pycnidiospores

Pycnidiospores - spores from within a pycnidium

R

Rachis - the main axis of the inflorescence, or spike, of wheat and other cereals, to which the spikelets are attached

Resistance - the inherent capacity of a host plant to prevent or reduce the development of a disease

S

Saprophyte - an organism deriving its nutrients from dead or decaying tissue of another organism

Sclerotia - compact mass of fungal hyphae e.g. ergot, capable of being dormant for long periods, and giving rise to fruiting bodies or mycelium

Seminal roots - the roots developing 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

Susceptible - non-immune i.e. capable of becoming infected by a pathogen

T

Telium - structure containing teliospores

Teliospores - sexual spores produced within a telium

Teleomorph - the sexual or so-called perfect growth stage or phase in fungi

Tolerance - the ability of a plant host to sustain the effects of a disease without dying or suffering serious injury or crop loss

U

Uredium - the fruiting structure of a rust fungi in which uredospores are produced

Uredospore - the asexual spore of the rust fungus

V

Vector - an organism capable of transmitting inoculum

Virulence - the ability of a pathogen to produce disease

W-Z

White-head - prematurely ripened ears of cereals often caused by pathogens attacking the roots or stem base

Reference Material and Further Reading

HGCA:

- HGCA Recommended Lists 2008/09 (Updated annually)
- Wheat Disease Management Guide - update 2008 (Updated annually)
- Take-all in winter wheat - management guidelines (Autumn 2006)
- Guidelines to minimise risk of fusarium mycotoxins in cereals (Summer 2007)
- Wheat seed health & seed-borne diseases - a guide (Summer 2004)
- Topic Sheet 97 Ramularia leaf spot in barley (Summer 2007)
- Topic Sheet 95 Foliar disease control in wheat (Spring 2007)
- Topic Sheet 80 Determining eyespot risk in winter wheat (Autumn 2004)
- Topic Sheet 73 Testing winter wheat for seed-borne disease (Summer 2003)
- Topic Sheet 72 Sampling wheat seed for seed-borne disease (Summer 2003)
- Topic Sheet 61 Soil-borne mosaic viruses of winter barley: an update (Summer 2002)
- Topic Sheet 57 Necrotic spots in barley: causes and control (Spring 2002)
- Topic Sheet 56 Managing ergot in cereal crops (Spring 2002)
- Topic Sheet 43 Soil-borne wheat mosaic virus (Spring 2001)
- Topic Sheet 42 Rhynchosporium control programmes (Winter 2000/201)

Others:

- SAC Technical Note 'Barley Disease Control' (TN611, March 2008)
- Food Standards Agency 'Code of Good Agricultural Practice for the reduction of mycotoxins in UK cereals' (FSA/1170/0507)

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