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GRDC GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CEREAL RYE

SECTION 9

DISEASES

ERGOT | TAKE-ALL | RUSTS | YELLOW SPOT | CROWN ROT AND FUSARIUM HEAD BLIGHT | COMMON ROOT ROT | SMUTS | RHIZOCTONIA ROOT ROT | CEREAL FUNGICIDES | DISEASE FOLLOWING EXTREME WEATHER EVENTS

Diseases

Key messages

- Rye has good tolerance to cereal-root diseases.
- The most important disease of rye is ergot (*Claviceps purpurea*). Feeding stock with ergot-infested grain can result in serious stock losses: grain with three ergots per 1,000 kernels can be toxic.
- Stem and leaf rusts are seen on cereal rye in most years, but they are only occasionally a serious problem.
- All commercial cereal rye varieties have resistance to the current pathotypes of stripe rust. However, the outcrossing nature of the species means that under high disease pressure, 15–20% of the crop may show evidence of the disease. Other diseases are usually insignificant. Be wary that varietal resistance can change with the outbreak of new strains.
- Cereal rye has tolerance to take-all, making it a useful break crop following grassy pastures.
- Bevy is a host for the root disease take-all and this should be carefully monitored.

For disease to occur, the pathogen must have virulence to the particular variety, inoculum must be available and easily transported, and there must be favourable conditions for infection and disease development.

General disease-management strategies

- Use resistant or partially resistant varieties.
- Use disease-free seed.
- Use fungicidal seed treatments to kill fungi carried on the seed coat or in the seed.
- Have a planned in-crop fungicide regime.
- Conduct in-crop disease audits to determine the severity of disease. This can be used as a tool to determine what crop is grown in what paddock the following year.
- Conduct in-fallow disease audits to determine the severity of disease, e.g. yellow leaf spot and crown rot. This can also be used as a tool to determine what crop is grown in what paddock the following year.
- Send plant or stubble samples for analysis to determine the pathogen or strain you are dealing with, or the severity of the disease.
- Keep the farm free of weeds, which may carry over some diseases to the next season or crop. This includes cereals over summer that may act as a green bridge.
- Rotate crops.

MORE INFORMATION

GRDC's Cereal root and crown diseases: the back pocket guide.

9.1 Ergot

The most important disease of rye is ergot (*Claviceps purpurea*). Ergot, a purplish-black fungal disease that makes grains unsafe for consumption, is a prevalent problem in cereal rye crops.

Ergot produces black growths called sclerotia (Photo 1), which are visible in the heads of the rye (Photo 2). The fungi infect young, usually unfertilised ovaries, replacing the seeds with the sclerotia, which are dark mycelial masses. Usually, ergot infestations affect the borders of rye fields first, so it is important to take note of the presence of ergot and harvest infested sections of the field separately, especially if you are saving rye seed for next year's crop.

Photo 1: *Ergot bodies (sclerotia) taken from rye grain head.*

Photo: University of Hawaii

Good crop-rotation practices will minimise the chances of damage from disease, but rye crops should always be tested before human consumption. [1]

Ergot occurs throughout the world and affects many grass species, including cultivated cereals. Although it is relatively rare in Australian grains, it is considered to be a constant threat as it contains toxic chemicals (alkaloids) that are very harmful to both animals and humans. For this reason, ergot in grain could prove damaging to our trade. [2]

Ergot produces alkaloids similar to the psychotomimetic drug LSD. [3] Two types of sweet scabious intoxication have been reported: gangrenous ergotism, from consuming a small amount over a long period; and convulsive ergotism. Both affect people and animals.

Grain with three ergots per 1,000 kernels can be toxic. [4]

When using grain with known low levels of ergot from a silo, it is important to continue to monitor the concentration of ergot because it is often in highest concentration in the bottom 10% of silo content. [5]

MORE INFORMATION

MR Lee (2009) The history of ergot of rye (Claviceps purpurea) I: From antiquity to 1900. Journal of the Royal College of Physicians Edinburgh. 39, 179–184.

9.1.1 Varietal resistance

Cereal rye and many grass species (including ryegrass) are particularly susceptible to ergot because they are open-flowered species.

9.1.2 Damage caused by disease

Ergot bodies contain alkaloid chemicals that can cause lameness, gangrene of the extremities, and nervous convulsions (staggers) that can lead to death in both humans and animals. As these toxins accumulate in the body, symptoms may begin to occur only after long periods of low-level ingestion. Crops affected by ergot generally do

1 UVM Extension Crops and Soils Team (2011) Cereal rye, http://northerngraingrowers.org/wp-content/uploads/RYE.pdf

2 AWB Grower Services. Ergot: wheat quality fact sheet. AWB, https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT_factsheet.pdf

3 Ergot of rye. 1: Introduction and history. Faculty of Botany. University of Hawaii, http://www.botany.hawaii.edu/faculty/wong/BOT135/LECT12.HTM

4 HerbiGuide. Rye. HerbiGuide, http://www.herbiguide.com.au/Descriptions/hg_Rye.htm

5 DAFWA (2015) Look out for ergots when selecting stock feed. DAFWA, https://www.agric.wa.gov.au/news/media-releases/look-out-ergots-when-selecting-stock-feed

not result in significant yield losses, but economic losses can be quite severe when grain tendered by growers is rejected at receival. [6]

Gangrenous ergotism of humans and cattle

In humans and in other animals, gangrenous ergotism results in a blockage of circulation to the extremities, tingling in the fingers, vomiting, diarrhoea, gangrene of the toes and fingers, and ulceration of the mouth. Limbs may fall off. This is a dry form of gangrene.

In cattle, there is lameness, especially in the hindquarters, and gangrene of the feet, ears and tail. Pregnant cows may abort. There is a characteristic band where the gangrenous tissue ends.

Convulsive ergotism

Convulsive ergotism has symptoms similar to those of gangrenous ergotism. The appearance of physical symptoms is followed in humans by painful spasms of the limbs, epilepsy-like convulsions, and delirium. Cattle become excitable and run with a swaying, uncoordinated gait. [7]

9.1.3 Symptoms

Characteristically ergot pieces have a purple–black surface with a white to grey interior (Photo 2). They are usually horn-like in shape, and replace one or more grains in the heads of cereals and grasses. These ergot bodies can be up to four times larger than normal grain.

What to look for in the crop

- Hard dry purple–black fungal bodies (ergots) that replace the grain in the seed head.
- Yellow droplets of sugary slime in infected heads during flowering. [8]

Photo 2: *Ergot bodies in rye grain head.*

Photo: Cary Wolinsky, National Geographic Creative

What to look for in stock

Producers are encouraged to keep an eye on animals that may be eating ergot-infected grain, especially in hot or sunny weather (see Photo 3). Signs of ergot poisoning include animals seeking shade, being reluctant to move, and panting and distress following any exercise. Animals may also drool, have an increased respiratory rate and reduced feed intake. [9]

6 AWB Grower Services. Ergot: wheat quality fact sheet. AWB, https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT_factsheet.pdf

7 HerbiGuide. Rye. HerbiGuide, http://www.herbiguide.com.au/Descriptions/hg_Rye.htm

8 DAFWA (2015) Diagnosing ergot. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-ergot

9 DAFWA (2015) Look out for ergots when selecting stock feed. DAFWA, https://www.agric.wa.gov.au/news/media-releases/look-out-ergots-when-selecting-stock-feed

Photo 3: *Producers need to be aware that even a small amount of ergot in grain can cause serious illness to their stock.*

Photo: Michael Raine

9.1.4 Conditions favouring development

- Ergots survive in the soil for up to one year, and can then produce spores that infect plants during flowering.
- Infection is more likely when there is cool wet weather at flowering.
- It can be spread by rain splash or by insects attracted to the sugary droplets.
- High levels of grass-weed contamination can increase ergot infection in cereals, and ergots produced in grasses can contaminate grain samples.

The development of ergot is favoured by moist soil surfaces during spring and early summer. In addition, wet conditions during the flowering of cereals and grasses increase the period of infection.

The disease cycle of ergot consists of two stages. The cycle begins in spring when the ergot bodies germinate in wet soils after winter, and develop fruiting bodies that contain spores (ascospores). The spores can be spread to neighbouring susceptible plants by wind and rain. To infect plants, the spores must land on the florets; within five days the second stage commences. This is referred to as the 'honeydew' stage. During this stage the infected florets exude a sugary slime that contains spores (conidia). These spores can infect other florets via insect vectors, rain splash and/or wind. This period of infection lasts for as long as the susceptible plants are in flower. The ovary in the floret becomes infected, then enlarges and is replaced by the purple–black ergot body, which can survive in soil for up to one year.

Crops are generally perceived to be at greatest risk when grass-weed populations are high. Infected grasses usually produce slender ergots, and in some cases can be fully responsible for the contamination of grain samples. [10]

Ongoing periods of spring and summer rain can increase the occurrence of ergots in ryegrass; therefore ergots are more likely to develop in crops in years of above-average rain when ryegrass is flowering. Ergots produced in grasses outside the crop can contaminate grain samples. [11]

9.1.5 Managing ergot

- Give contaminated paddocks a one-year break without cereals or grasses.

10 AWB Grower Services. Ergot: wheat quality fact sheet. AWB, https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT_factsheet.pdf

11 DAFWA (2015) Look out for ergots when selecting stock feed. DAFWA, https://www.agric.wa.gov.au/news/media-releases/look-out-ergots-when-selecting-stock-feed

- Manage grass-weed contamination in crops.
- Use clean seed.

Grain-cleaning equipment can be used to remove most ergot bodies in contaminated grain (Photo 4). However, the grower will need to determine whether this is economically viable.

Photo 4: *Ergot-contaminated seed.*

Photo: DAFWA

Tactics to reduce the risk of ergot infection

Key points:

- Use ergot-free seed if possible.
- Rotate with crops such as flax, canola and legumes, that are resistant to ergot.
- As the source of ergot infection is often the grass in headlands or ditches, mowing this grass before it flowers or sets seed will greatly reduce or eliminate the chances of ergot infection.
- Ergots germinate at or near the soil surface. To prevent them from germinating, work the field to a depth greater than 5 cm to bury the ergot bodies.
- Plant crop seed at a uniform depth and as shallow as possible for adequate moisture to obtain a uniform early emergence.
- Separate the seed collected from the first few combine rounds to prevent contamination of the entire lot as most of the ergot infested grain will likely be concentrated in this region. [12]

12 Alberta Agriculture and Forestry (2016) Fall rye production. Agdex 117/20-1. Alberta Agriculture and Forestry, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1269/$file/117_20-1.pdf

To avoid the development of ergot in subsequent cereal crops, effective farm management practices are required. One option available to growers is the use of crop rotations to stay away from cereals for at least one year to reduce the number of viable ergot pieces in the soil to negligible levels.

Another tactic is to use only clean seed during planting. [13] This is necessary, as there is currently no effective treatment seed dressing against ergot. For growers using conventional tillage, ergot pieces need to be buried to a minimum depth of 4 cm. This prevents the fruiting bodies from reaching the soil surface and releasing spores. As this may have an effect on the usual sowing operations, guidance should be sought.

Finally, to eliminate the development of host reservoirs, growers may be able to mow or spray grass pastures to prevent flowering. [14]

Control of grasses within cereal crops will help prevent cross-infection. This is best achieved by preventing seedset in the previous season, by clear fallowing, hard grazing or hay cutting, together with the use of selective herbicides. [15]

There are no ergot-resistant rye varieties. The only practical control is to sow clean, year-old seed on land that hasn't grown rye for at least a year. Mowing roadside and headland grass before they set seed will reduce or eliminate this major source of ergot re-infestation. [16]

Marketing options

IN FOCUS

Alkaloids in Australian rye ergot sclerotia: implications for food and stockfeed regulations.

Rye ergot (*Claviceps purpurea*) occasionally causes toxicity (chiefly expressed as hyperthermia, in which the body becomes overheated) in Australian livestock, either because they have grazed on infected annual ryegrass (*Lolium rigidum*) and perennial ryegrass (*L. perenne*), or when the ergot sclerotia produced in ryegrasses contaminate grain crops used as stockfood. Researchers wanted to determine whether current regulations on the permissible limits of ergot in food and stockfeed were sufficient, as the limit had been set many years previously on the basis of very limited toxicological data. They took alkaloids from 30 samples of Australian rye ergot sclerotia from ryegrasses and grain screenings, and some samples from contaminated feed, and analysed how potent they were.

Bulk grain traders limit rye ergot sclerotia by length (laid end to end). The maximum limits set by Grain Trade Australia for 2009–10 for rye ergot sclerotia per half litre of grain were: wheat, 2 cm; barley, 0.5 cm; oats, 2 cm; triticale, nil; rye, nil. As well, rye ergot sclerotia are restricted to 0.02% weight per weight (w/w) in grain under Queensland Stockfood Regulations. The limit of 0.02% (200 mg ergot/kg) is roughly equivalent to 8 cm of rye ergot sclerotia per half litre of grain.

The researchers reviewed cases of livestock poisoning and limited experiments on the effects of ergot poisoning. They concluded that ruminants that are exposed to the sun are more sensitive to the effects of ergot than humans and other monogastric animals are. The material they reviewed showed severe hyperthermia in ruminants fed 1–2 mg ergot

13 DAFWA (2015) Diagnosing ergot. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-ergot

14 AWB Grower Services. Ergot: wheat quality fact sheet. AWB, https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT_factsheet.pdf

15 R Clarke (1999) Ergot of pasture grasses. Note AG0721. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/ergot-of-pasture-grasses

16 Alberta Agriculture and Forestry (2016) Fall rye production. Agdex 117/20-1. Alberta Agriculture and Forestry, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1269/$file/117_20-1.pdf

alkaloids/kg of feed. This suggested that the total alkaloid content of feed should be restricted to <0.5 mg/kg.

They argued that an extra safety margin was desirable to allow for the irregular distribution of ergot sclerotia in bulk grain, and variations in individual susceptibility to ergot, and recommended a limit of <0.1 mg/kg. This equates to ~0.004% rye ergot sclerotia (40 mg/kg) for sclerotia having an alkaloid content of around 2,500 mg/kg (<2 cm sclerotia per half litre of grain). However, other risk factors include the unknown role of the ergot pigments in exacerbating hyperthermia in sunlight-exposed stock.

All these variables combine to indicate that feed likely to contain any detectable rye ergot should be avoided in ruminant feedlot rations. Poultry and non-lactating mature (finisher) pigs are able to tolerate lightly contaminated grain. [17]

9.2 Take-all

Key points:

- Cereal rye has tolerance to take-all, making is a useful break crop following grassy pastures.
- Monitor rainfall patterns (when and how much), and adjust sowing times where possible.
- Control weeds during late summer and early autumn.
- Use ammonium-based nitrogenous fertilisers to improve crop nutrition and decrease the incidence of take-all.
- In severe take-all outbreaks, consider using grass-free cropping as a management strategy.

PODCAST

GRDC (2016) Crown rot and take-all warning. MP3 (audio) GRDC Radio (Northern Update).

Take-all (*Gaeumannomyces graminis*) is a soil-borne disease of cereal crops and is most severe on wheat crops in southern Australia. In New South Wales, the disease is caused by two variations of the *Gaeumannomyces graminis* fungus, *G. graminis* var. *tritici (Ggt)* and *G. graminis* var. *avenae (Gga),* and is most severe in the high-rainfall areas of the agricultural region (i.e. southern cropping regions and areas closer to the coast). Control of take-all is predominantly cultural, and relies on practices which minimise carry-over of the disease from one cereal crop to the next. [18]

9.2.1 Varietal resistance

Cereal rye's resistance and tolerance to take-all (which is also known as haydie) makes it a useful break crop for sowing before susceptible wheat, triticale or barley crops. It can also be sown in situations where take-all is expected, e.g. following grassy pasture on soils that are unsuitable for oats. [19]

Cereal rye: a host for take-all?

One study from New Zealand suggests that rye may increase take-all inoculum, even though it is regarded as resistant to the disease. [20] The Foundation for Arable Research reported that:

17 BJ Blaney, JB Molloy and IJ Brock (2009) Alkaloids in Australian rye ergot (Claviceps purpurea) sclerotia: implications for food and stockfeed regulations. Animal Production Science, 49 (11), 975–982, http://www.publish.csiro.au/an/AN09030

18 A Wherrett and B MacLeod (2016) Take-all disease: New South Wales. Fact sheet. Soilquality, http://www.soilquality.org.au/factsheets/take-all-disease-nsw

19 Wrightson Seeds (2010) Forage focus—Southern Green forage ryecorn. Wrightson Seeds, http://www.pggwrightsonseeds.com.au/assets/FTP-Uploads/Forage_Focus/Cereals/FF_Southern-Green-Forage-Ryecorn.pdf

20 Foundation for Arable Research (2009) High take-all inoculum levels can follow resistant cereals. Arable Update No. 194. FAR, https://www.far.org.nz/assets/files/uploads/C194Take-all.pdf

- Wheat and barley roots are both infected by take-all. Triticale, depending on the parentage of the cultivar, ranges from being almost as susceptible as wheat to as resistant as rye.
- The effects on wheat are usually more serious than for barley. A field trial confirmed that wheat is more susceptible to take-all than rye, triticale and barley. The triticale cultivar (cv.) Kortego was more resistant than barley (tested using cv. Quench), while rye had no visible infection by take-all. The results support the selection of rye, triticale and barley over wheat for growing in fields known to have *G. graminis* var. *tritici (Ggt*).
- Although barley, triticale and rye do not become heavily infected by take-all, levels of *Ggt* in the soil after these cereals can be high. The large root systems of these species may provide more material for infection and *Ggt* inoculum build-up.

Growers are keen to keep cropping rotations flexible. This research shows that the risk to take-all in wheat cannot be reduced by using barley, triticale and rye as break crops between wheat crops. [21]

The cereal rye variety Bevy, which was developed from a composite of nine predominantly semi-dwarf spring rye types, is a host for take-all, and should be monitored carefully. [22]

9.2.2 Symptoms

Initial indications of take-all in a crop are the appearance of indistinct patches of poor growth in the crop; these may be from a few metres across to significant areas of crop. Closer inspection of individual plants will indicate discolouration of the crown, roots and stem base. Blackening of the centre of the roots (stele) is symptomatic of an early take-all infection. Severely infected plants will have a blackened crown and stem base, and be easy to pull from the soil because they will no longer have an attached root system. Any remaining roots are brittle and break off with a 'square end'.

The appearance of whiteheads later in the season is another indicator of a take-all (although frost and micronutrient deficiencies can also cause whiteheads), with severe infections causing the crop to hay-off early. Infected plants will produce pinched grain, with severe infections yielding little harvestable seed in the head (hence 'take-all'); in some cases infected areas may not be worth harvesting. [23]

What to look for in the paddock

- Patches (up to several metres in diameter and with indistinct and irregular edges) of white-coloured tillers and heads containing shrivelled grain or no grain (Figure 5). [24]
- Affected plants can be individuals scattered among healthy plants, or entire populations of plants over a large area.

21 Foundation for Arable Research (2009) High take-all inoculum levels can follow resistant cereals. Arable Update No. 194. FAR, https://www.far.org.nz/assets/files/uploads/C194Take-all.pdf

22 Agriculture Victoria (2013) Growing cereal rye. Note AG0403. Updated. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-cereal-rye

23 A Wherrett and B MacLeod (2016) Take-all disease: New South Wales. Fact sheet. Soilquality, http://www.soilquality.org.au/factsheets/take-all-disease-nsw

24 DAFWA (2015) Diagnosing take-all in cereals. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-take-all-cereals

Photo 5: *Patches with irregular edges of white-coloured tillers and heads containing shrivelled grain or no grain.*

Photo: DAFWA

What to look for in the plant

- The first obvious signs of infection are seen after flowering, with the development of whiteheads.
- Roots of affected plants are blackened to the core (not just on the surface) and are brittle and break easily (Figure 6).
- Severely affected plants can also have blackened crowns and lower stems.

Photo 6: *Roots of affected plants are blackened and brittle (left). Severely affected plants can have blackened crowns and lower stems (right).*

Photos: DAFWA

9.2.3 Conditions favouring development

Gaeumannomyces graminis survives the Australian summer in the residue of the previous season's grass host (Figure 1). The arrival of cooler temperatures and rainfall in the autumn triggers the fungus into action. The fungus infects the roots of the emerging crop during this period. Higher rainfall in winter is likely to increase take-all disease pressure. For this reason, the southern regions of New South Wales are most likely to suffer yield loss in cereal crops due to take-all. While lower soil moisture will decrease the chance of a severe outbreak of take-all, plants that are already infected will find it difficult to cope due to water stress.

Soil at field capacity (i.e. is fully wet) encourages early-season infection of seedlings by both *G. graminis* var. *tritici* and *G. graminis* var. *avenae*. Greatest yield loss occurs on infected plants when moisture is limiting post-anthesis.

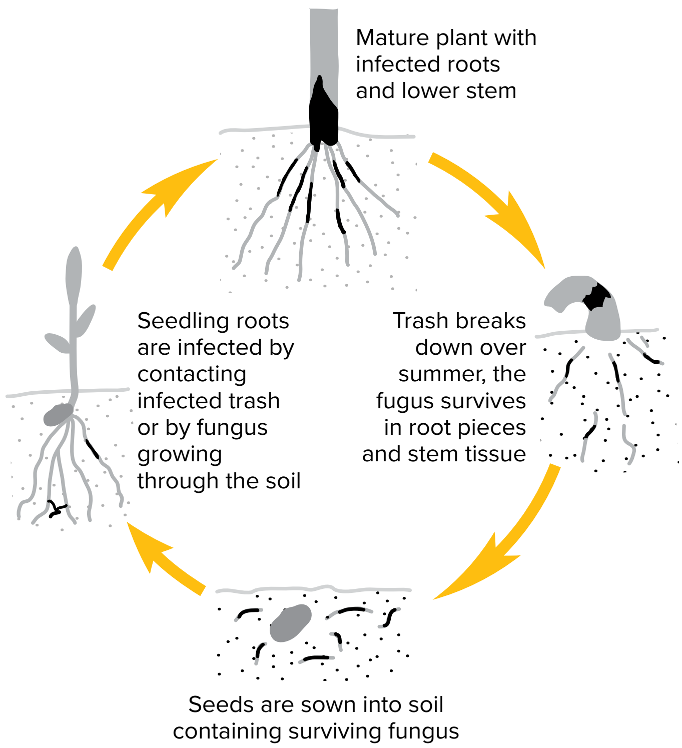


Figure 1: *Common life cycle of the take-all fungus in Western Australian cropping regions.*

Source: Soilquality

Hosts

All annual grasses can be infected by *G. graminis*, although some species are more susceptible than others. While wheat, barley and triticale are the most susceptible crops to take-all, barley grass is also an effective host to the disease. Oats are the only cereal crop to offer resistance, although evidence of *G. graminis* strains capable of causing yield loss has been reported in areas where continual oat cropping occurs. Brome grass, silver grass and ryegrass are all viable host species for take-all. All non-cereal crops (e.g. lupins, canola and clover) are non-hosts to take-all. [25]

25 A Wherrett and B MacLeod (2016) Take-all disease: New South Wales. Fact sheet. Soilquality, http://www.soilquality.org.au/factsheets/take-all-disease-nsw

9.2.4 Managing take-all

- By far the most effective method of reducing take-all is to remove grasses in the year before you plant the susceptible crop, and replace grasses with a grass-free pasture or break crop.
- Cereal rye's resistance and tolerance to take-all makes it a useful break crop for sowing before susceptible wheat, triticale or barley crops. [26] However, research from New Zealand suggests that cereal rye can be a host for take-all disease. [27]
- There are fungicides to be applied with seeding, fertiliser and in-furrow that are registered for take-all control.
- Acidifying fertilisers can slightly reduce disease severity; conversely, take-all severity may increase following liming.
- Control volunteer grasses and cereals.
- Delay sowing following the opening rains by implementing a short chemical fallow. [28]

The most effective management strategy for take-all is to deny the fungus the ability to survive in the paddock, through the elimination of hosts. This is most effectively done through the use of a non-cereal break crop (e.g. lupins, canola, field peas, faba beans, chickpeas, or sorghum) and by controlling grass weeds during autumn. Pastures containing low levels of grass species will also have reduced take-all carryover the following season. Where minimum tillage is practiced the time taken for residues to break down is increased, allowing the disease to stay viable for longer. The use of break crops and activities to hasten residue breakdown may be beneficial. While burning does decrease the amount of surface residue infected with the fungus, the fire is generally not hot enough to affect the infected material below ground.

Registered fungicides applied as either fertiliser or seed treatments are generally only economically viable where severe outbreaks have occurred. In many cases it is more practical to sow non-cereal crops or pasture to reduce take-all carryover.

Competition from other soil organisms decreases the survival of *G. graminis* in the soil. Summer rains or an early break in the season allows for such conditions to develop. The effect of this can be negated by poor weed control during this period, because:

- Cereal weeds become infected, thus enabling *G. graminis* to survive until crop establishment.
- Rapid drying of the topsoil due to weeds decreases the survival of competitive soil organisms, therefore slowing the decline of *G. graminis*.

Decline of take-all

Take-all decline is the apparent waning of the extent of the occurrence of take-all following many years of continuous cereal cropping, and has been shown to occur in South Australia. This has been attributed to the build-up of antagonistic microorganisms in the soil. Although this process may occur, it is not a viable way to deal with take-all, as the economic losses incurred during the build-up appear to be unacceptable. There have, however, been examples of a reduction in take-all incidence due to gradual acidification of soil; this decline is reversed when lime is applied to increase soil pH. [29]

26 Wrightson Seeds (2010) Forage Focus – Southern Green forage ryecorn. Wrightson Seeds, http://www.pggwrightsonseeds.com.au/assets/FTP-Uploads/Forage_Focus/Cereals/FF_Southern-Green-Forage-Ryecorn.pdf

27 Foundation for Arable Research (2009) High take-all inoculum levels can follow resistant cereals. Arable Update No. 194. FAR, https://www.far.org.nz/assets/files/uploads/C194Take-all.pdf

28 DAFWA (2015) Diagnosing take-all in cereals. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-take-all-cereals

29 A Wherrett and B MacLeod (2016) Take-all disease: New South Wales. Fact sheet. Soilquality, http://www.soilquality.org.au/factsheets/take-all-disease-nsw

9.3 Rusts

Stem and leaf rusts are seen on cereal rye in most years, but they are only occasionally a serious problem. [30] All commercial cereal rye varieties have resistance to the current pathotypes of stripe rust. However, the outcrossing nature of the species means that under high disease pressure, 15–20% of the crop may show evidence of the disease. Other diseases are usually insignificant. Be wary that varietal resistance can change with the outbreak of new strains.

In Queensland and New South Wales, there are three rust diseases of rye and wheat:

- stripe rust
- stem rust
- leaf rust.

They are caused by three closely related fungi all belonging to the genus *Puccinia*.

The rusts are so named because the powdery mass of spores which erupt through the plant's epidermis have the appearance of rusty metal. The spores can be spread over considerable distances by wind, and may also be spread via clothing and equipment.

The three rusts that affect rye have a number of features in common. They can only infect a limited number of specific host plants (mostly volunteer wheat, triticale and barley) and can only survive on green, growing plant tissue. Biotrophic (parasitic) pathogens including stem rust, stripe rust and leaf rust require a living plant host and cannot survive on soil, seed or dead tissue. They therefore need a green bridge of grassy weeds or overlapping crops to persist. These plants facilitate the survival of rust fungi through the summer. [31]

Rust diseases occur throughout the Northern grain region, frequently causing economic damage. In Queensland stripe rust has recently been the more prevalent rust disease. Stripe rust reached epidemic levels in eastern Australia during 2009, and resulted in widespread fungicidal spraying.

The most recent cereal rust report, of September 2016, reports that a sample of rye leaf rust was received from Borrika in South Australia in late July, 2016.

In the Northern region, samples of leaf rust were received from the Queensland districts of Millmerran in mid-August and Mirabooka late August. Identification of the pathotypes (variants that also cause disease) for these two samples were under way at the time of publication. Samples subsequently received from Warwick, Gatton and Emerald were also scheduled for pathotype identification. Samples of stripe rust had been received from Boree Creek in NSW, and from Gatton in Queensland, sampled off a susceptible wheat spreader. [32]

The three rusts are relatively easy to differentiate (Table 1). [33]

30 Agriculture Victoria (2013) Growing cereal rye. Note AG0403. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-cereal-rye

31 DAF Queensland (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

32 W Cuddy, R Park, and D Singh (2016) Cereal rust situation. Cereal Rust Report. 19 September 2016. University of Sydney. 14 (7), http://sydney.edu.au/agriculture/documents/pbi/cereal_rust_report_2016_14_7.pdf

33 DAF Queensland (2015) Integrated disease management of wheat rusts and yellow spot. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/wheat-rusts

9.3.1 Symptoms

Table 1: *Diagnosing leaf diseases in cereals.*

Disease	Spore colour	Symptoms	Plant part affected
Stripe rust	Yellow–orange	Small closely packed circular pustules during the vegetative stage, becoming stripes along leaves of older plants	Upper surface of leaf, leaf sheaths, awns and inside glumes
Leaf rust	Orange or brown	Random, circular to oval pustules	Upper surface of leaf and leaf sheaths
Stem rust	Reddish brown	Random, oblong pustules with torn margins	Both sides of leaf, leaf sheaths, stems and outside of head
Yellow spot	Small tan oval spots with a yellow margin	Spots up to 10 mm, varied shapes and may coalesce	Both sides of leaf, leaf sheaths, stems and outside of head

Source: DAF Qld

Stripe rust

Stripe rust (also known as yellow rust) is caused by the fungus *Puccinia striiformis*. It is easily distinguished from other wheat rusts by the yellow–orange spores, which produce small, closely packed pustules that develop into stripes along the length of the leaf veins. The spores occur on the upper surface of the leaves, the leaf sheaths, awns and inside of the glumes (Photo 7, Table 1).

Stripe rust requires cool and wet conditions to infect a crop. Free moisture on the leaves and an optimal temperature of 10–15°C are required. Pustules erupt within 10–14 days of infection.

If the weather is conducive to stripe rust, the disease can cause up to 25% yield loss on varieties scored as moderately susceptible, i.e. 5 (MR–MS) or lower. This is provided there is inoculum from a neglected green bridge or from an infected crop.

There are several fungicides recommended for the control of stripe rust. They can be incorporated with the fertiliser or applied as seed dressings to delay the onset of disease (Table 2). Later on, if 'money' leaves require protection, foliar fungicides (Table 3) can be applied.

In Queensland, stripe rust pathotypes 134 E16 A+ and 134 E16 A+ 17+ were prevalent during 2011. Grain growers should refer to the wheat varieties guide when selecting stripe rust-resistant varieties, as there is a threat from additional stripe rust pathotypes 134 E16 A+ J+ and 134 E16 A+ J+ T+, which have also been identified in Queensland.

VIDEOS

WATCH: GRDC (2010) Cereal rust. GCTV1, GRDC.

Photo 7: *Stripe rust in cereals.*

Photo: DAF Qld

Leaf rust

Leaf rust (also known as brown rust) is caused by the fungus *Puccinia triticinia* (previously called *Puccinia recondite* f. sp. *tritici*). The disease infects rye, wheat and triticale.

Leaf rust produces reddish-orange-coloured spores which occur in small, 1.5 mm, circular to oval-shaped pustules. These are found on the top surface of the leaves; this distinguishes leaf rust from stem rust, which is found on both surfaces of the leaf (Photo 8).

Queensland wheat varieties mostly have reasonable resistance (rating of MR-MS, or 5 or higher) and so leaf rust is currently not of major concern to Queensland cereal growers.

The spores require temperatures of 15–20°C and free moisture (dew, rain, or irrigation water) on the leaves to successfully infect wheat. The first signs of the disease, at sporulation, occur 10–14 days after infection. Removal of volunteer wheat plants, which form a green bridge for the fungus through the summer, can eliminate or delay the onset of leaf rust. [34]

One fungicide is available to treat leaf rust when seeding or fertilising (Table 2), and several are available as foliar fungicides in established crops (Table 3).

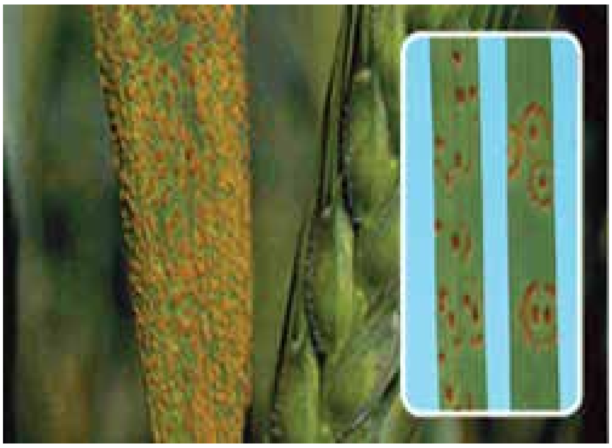


Photo 8: *Leaf rust in cereals.*

Photo: DAF Qld

Stem rust

Stem rust (or black rust) is caused by the fungus *Puccinia graminis* f. sp. *tritici*. In addition to rye, it also attacks wheat, barley and triticale.

Stem rust produces reddish-brown spore masses in oval, elongated or spindle-shaped pustules on the stems and leaves. Unlike leaf rust, pustules erupt through both sides of the leaves (Figure 10). When the pustules rupture they release masses of stem rust spores, which are disseminated by wind and other carriers.

Stem rust develops at higher temperatures than the other wheat rusts, within the range of 18–30°C. Spores require free moisture (dew, rain or irrigation water) and take up to six hours to infect the plant. The pustules can be seen 10–20 days after infection.

Queensland wheat varieties have reasonable resistance to stem rust (a rating 5 or higher). However, in the past, stem rust has caused significant economic damage, from 50–100% of yield. This has happened when conditions conducive for the disease occur when susceptible varieties were grown, or when a new stem rust pathotype has developed and overcome the wheat's resistance.

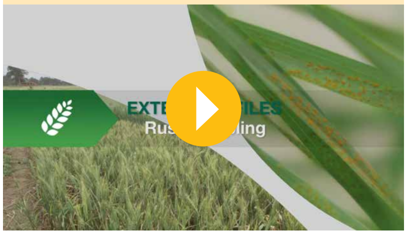
34 DAF Queensland (2015) Integrated disease management of wheat rusts and yellow spot. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/wheat-rusts

VIDEOS

WATCH: GRDC (2012) Green bridge control for less stem rust. GCTV5. GRDC.

VIDEOS

WATCH: GRDC (2015) GCTV: Extension files: rust sampling.



Inoculum must be present for the disease to develop. Practising crop hygiene by removing volunteer wheat, which forms a green bridge for the fungus through the summer, can eliminate or delay the onset of stem rust. [35]

There are no fungicides registered for use at seeding or with fertiliser for stem rust (Table 2), but several foliar fungicides are available (Table 3).

Figure 2: *Stem rust in cereals.*

Photo: DAF Qld

9.3.2 Managing rust

Rust diseases of wheat can be eliminated or significantly reduced by removing any green bridges. This should be done well before the new crop is sown, to allow time for any herbicide to work and for the fungus to stop producing spores.

Rust fungi continually change, producing new pathotypes. The pathotypes are detected when disease is found on a previously resistant variety. Therefore, even if a resistant variety has been sown, the crop should be monitored regularly for foliar diseases. This should start no later than growth stage 31, the second-node stage on the main stem, and continue to at least growth stage 39, the flag-leaf stage. This is because the flag leaf and the two leaves below it are the main factories that contribute to yield and quality. It is very important that these leaves are protected from diseases. [36]

Integrated disease management of rusts and yellow spot

- Destroy volunteer wheat plants by March, as they can provide a green bridge for rust carryover.
- Community efforts are required to eradicate volunteers from roadsides, railway lines, bridges, paddocks and around silos.
- Crop rotation is very important in the cases of yellow spot and *Fusarium* head blight.
- Growing resistant varieties is an economical and environmentally friendly way of reducing the incidence of disease.
- Seed or fertiliser treatment can control stripe rust up to four weeks after sowing, and suppress it thereafter.
- During the growing season active crop monitoring is very important for early detection of diseases.

35 DAF Queensland (2015) Integrated disease management of wheat rusts and yellow spot. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/wheat-rusts

36 DAF Queensland (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

- Correct disease identification is very important: consult agricultural department fact sheets, charts and websites, and consult experts.
- When deciding if a fungicide spray is needed, consider crop stage and potential yield loss.
- Select a recommended and cost-effective fungicide.
- For effective coverage, the use of the right spray equipment and nozzles is very important.
- Read the label and follow instructions on it, and wear protective gear to protect yourself and the environment.
- Avoid the repeated use of fungicides with the same active ingredient in the same season.
- Always check for withholding periods before grazing or harvesting a crop that has had fungicide applied.
- If you suspect a severe disease outbreak, especially on resistant varieties, contact DAF Queensland or DPI NSW.

Wherever possible, sow resistant cereal varieties that have been rated MR (moderately resistant, or 6) and above. All commercial varieties of rye have stripe rust resistance to the current pathotypes although out-crossing can occur.

There are a number of fungicides recommended for the control of foliar diseases of wheat (Table 2 and Table 3).

Table 2: *Fungicides recommended for seed and fertiliser treatment.*

Disease	Fungicide	
	Fluquinconazole (167 g/L)	Flutriafol (250 g/L)
Stripe rust (yellow rust)	Rate: 450 mL/100 kg seed	Rate: 200 or 400 mL/ha fertiliser
Leaf rust (brown rust)	Rate: 450 mL/100 kg seed	–
Stem rust (black rust)	–	–
Yellow spot (tan spot)	–	–
Withholding period after treatment	12 weeks for grazing and harvest	4 weeks for grazing and harvest

Source: DAF Qld

Table 3: *Rate of fungicide (product formulation) recommended as foliar sprays for the control of rust diseases and yellow spot of wheat.*

Disease	Foliar fungicide (rate of application)							
	Epoxi-conazole (125 g/L)	Flutriafol (250 g/L)	Propi-conazole (250 g/L)	Triadimefon (125 g/L)	Tebu-conazole (430 g/L)	Prothio-conazole (210 g/L) + Tebu-conazole (210 g/L)	Azoxy-strobin (200 g/L) + Cypro-conazole (80 g/L)	Propi-conazole (250 g/L) + Cypro-conazole (80 g/L)
Stripe rust (yellow rust)	250–500 mL/ha	250–500 mL/ha	250–500 mL/ha	500 or 1000 mL/ha	145 or 290 mL/ha	150–300 mL/ha + Hasten 1% v/v	400 or 800 mL/ha	250–500 mL/ha
Leaf rust (brown rust)	500 mL/ha	250–500 mL/ha	150–500 mL/ha	–	145 or 290 mL/ha	150–300 mL/ha + Hasten 1% v/v	400 or 800 mL/ha	150–500 mL/ha
Stem rust (black rust)	–	–	500 mL/ha	–	145 or 290 mL/ha	150–300 mL/ha + Hasten 1% v/v	–	500 mL/ha
Yellow spot (tan spot)	–	–	250–500 mL/ha	–	145 or 290 mL/ha	150–300 mL/ha	400 or 800 mL/ha	250–500 mL/ha
Withholding period after treatment	6 weeks for grazing and harvest	7 weeks for grazing and harvest	4 weeks for harvest, 7 days for grazing	4 weeks for grazing and harvest	5 weeks for harvest, 14 days for grazing	5 weeks for harvest, 14 days for grazing	6 weeks for harvest, 21 days for grazing	6 weeks for harvest, 21 days for grazing

Source: DAF Qld

MORE INFORMATION

[CSIRO (2016) Cereal rusts.]

[Rust Bust. (2015) How to manage rust.]

IN FOCUS

Breeding cereals for rust resistance in Australia

Rust diseases have caused significant losses to Australian cereal crops, and continue to pose a serious threat. Because Australian cereal crop yields are generally low, genetic resistance remains the most economical means of controlling rust. Resistant cultivars also contribute significantly to reducing rust survival over summer.

A policy of releasing only rust-resistant wheats in northern New South Wales and Queensland resulted in industry-wide protection from rust in the northern grains region for the 40 years up to the early 2000s. The Australian Cereal Rust Control Program conducts annual pathogenicity surveys for all cereal rust pathogens, undertakes genetic research to identify and characterise new sources of resistance, and provides a germplasm screening and enhancement service to all Australian cereal breeding groups. These three activities are interdependent, and are closely integrated, with particular emphasis on linking pathology and genetics to ensure breeding outcomes that continue to offer protection to domestic crops from rust.

In a paper published in 2008, a researcher discusses the rise of recent changes in the wheat-rust pathogens that have made the protection of crops more difficult. Changes include the development of virulence for the disease-resistance genes *Yr17*, *Lr24*, *Lr37* and *Sr38 (which had been incorporated into several wheat cultivars)*, and the evolution of a new pathotype of the wheat stripe-rust pathogen. They have provided

VIDEOS

WATCH: GRDC (2015) Adult plant resistance – revisited. GCTV18.

WATCH: GRDC (2012) Cereal rust – adult plant resistance. GCTV9.

GRDC (2015) Triple rust resistance. GCTV18.

WATCH: GRDC (2010) Yellow or tan spot. GCTV2.

significant challenges for wheat rust resistance breeding. Similar challenges exist in breeding barley and oats for rust resistance.

The author also discusses the opportunities that arise from the evolution of new pathotypes: new virulence can inform observant researchers how they might approach breeding for resistance in new ways. Examples are discussed to illustrate the ways in which rust isolates are providing information that can be used in breeding for rust resistance. In future, as more markers linked to durable sources of rust resistance become available, it is likely that the use of marker-assisted selection will become more common-place in rust resistance breeding. [37]

9.4 Yellow spot

Yellow spot (which is also known as yellow leaf spot and tan spot) is caused by the fungus *Pyrenophora tritici-repentis*. It survives in wheat and, occasionally, triticale stubble. In rare cases, the fungus may survive in barley stubble. Wet spores (ascospores) develop in fungal fruiting bodies on wheat stubble, spread during wet conditions, and infect growing cereal plants.

As the crop develops, masses of a second type of spore (conidia) are produced on old lesions and dead tissues. Conidia result in the rapid development of a yellow-spot epidemic in a crop, and in the spread of the disease to other crops and areas. Again, wet conditions are necessary for conidia spore production and infection. Strong winds are needed to spread the disease any great distance. [38]

9.4.1 Varietal resistance

Cereal rye is partially susceptible to yellow spot. [39]

9.4.2 Damage caused by disease

Grain yield can be substantially reduced and losses of more than 50% may occur in extreme situations. Pink grain that is reduced in value is also a frequent result of severe yellow-spot epidemics. In continuous cereal cropping and where some stubble is left on the soil surface, losses may be 10–15%, and up to 30% in wet seasons.

9.4.3 Symptoms

Yellow spot shows up as tan-brown flecks that turn into yellow-brown oval-shaped spots or lesions with yellow margins. They may expand to 10–12 mm in diameter. Large lesions coalesce, and have dark brown centres. Spot develops on both sides of leaves (Photo 9). Severe yellow spot may result in short, spindly plants with reduced tillering and root development. Where conditions are favourable, plants may be fully defoliated soon after flowering. [40]

37 RF Park (2008) Breeding cereals for rust resistance in Australia. Plant Pathology, 57 (4), 591–602, http://onlinelibrary.wiley.com/doi/10.1111/j.1365-3059.2008.01836.x/abstract

38 DAF Queensland (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

39 HerbiGuide. Yellow spot of wheat. HerbiGuide, http://www.herbiguide.com.au/Descriptions/hg_Yellow_Spot_of_Wheat.htm

40 DAF Queensland (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

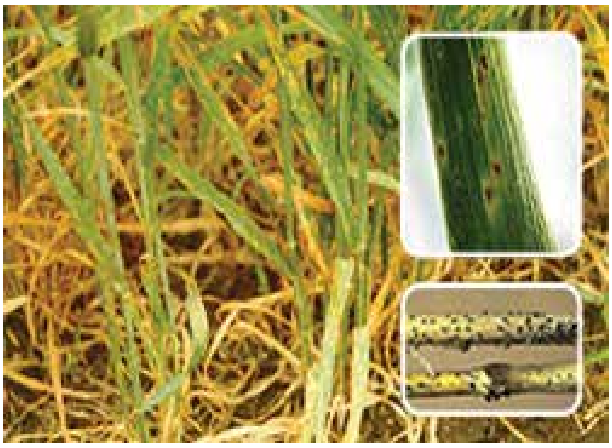


Photo 9: *Yellow spot in cereals.*

Photo: DAF Qld

9.4.4 Conditions favouring development

Yellow spot is likely to develop in wet years in fields where wheat residues remain on the soil surface. Temperatures from 20–30°C and free moisture (dew, rain, or irrigation water) favour disease development.

9.4.5 Managing yellow spot

The impact of the disease can be reduced by:

- planting partially resistant varieties
- rotating with resistant crops such as barley, oats or chickpeas
- incorporating stubble into the soil
- grazing or burning the stubble late in the fallow period.

Incorporation or burning stubble is not recommended unless infestation levels are very high. Correct identification of the yellow spot fungus in infected stubble should be carried out before the stubble is removed. Varieties partially resistant to yellow spot offer the only long-term solution and should be considered for planting where yellow spot could be a problem. [41]

If you do not want to be concerned by yellow spot (including at seedling stages) then:

- *Do not* sow wheat on wheat.
- If you are going to sow wheat on wheat consider a late (autumn) stubble burn and/or select a wheat variety with some level of resistance to yellow spot (noting also tolerance and resistance to other diseases).
- Primary management decisions for yellow spot need to be made before sowing or at sowing. Fungicides are a poor last resort for controlling yellow spot as they control but do not kill the lesions. Yellow spot is very different to stripe rust! [42]

In-crop fungicides and timing

Fungicides used against yellow spot in Australia include:

- propiconazole
- tebuconazole
- azoxystrobin with cyproconazole
- propiconazole with cyproconazole

MORE INFORMATION

Management of yellow spot in wheat: decide before you sow.

41 DAF Queensland (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

42 S Simpfendorfer (2013) Management of yellow spot in wheat: decide before you sow. GRDC Update Papers. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Management-of-yellow-spot-in-wheat-decide-before-you-sow

MORE INFORMATION

Management to reduce the risk of yellow leaf spot.

Timing for applying the chosen fungicide is crucial. The most effective time of application is at 90% flag-leaf emergence with disease levels of less than 10% on the flag leaf. Table 3 (section 9.3.2) gives rates of application for the different fungicides.

The higher rate of application has been shown to provide longer protection during periods of high disease pressure. Fungicide is more effective on susceptible varieties, and effectiveness reduces with increasing levels of resistance, at least in irrigated field trials. The economic viability of such applications during the extreme pressure of large-scale epidemics is another question, and the grower must consider all factors when deciding whether to apply fungicide. [43]

Search the APVMA's database of registered chemical products and permits for fungicide updates.

9.5 Crown rot and Fusarium head blight

- *Fusarium* species are responsible for causing two distinctly different diseases in winter cereal crops: crown rot and Fusarium head blight.
- Crown rot survives on infected stubble, from where it is passed onto the following crop.
- Use non-host crops (e.g. pulses, oilseeds and broad-leaf pasture species) in rotation sequences to reduce inoculum levels.
- Control grass-weed hosts to reduce opportunities for *Fusarium* spp. to survive fallow or non-host rotations.
- Sow varieties with partial resistance or improved tolerance where available.
- The approximate order of increasing yield loss from crown rot is cereal rye, oats, barley, bread wheat, triticale and durum wheat. [44]

The frequency of crown rot has increased in recent years due to the continuous cropping of wheat and other cereals. Some of the current options for managing the disease are to control grass hosts prior to cropping, rotate susceptible cereals with non-host break crops, burn infected stubble, and grow tolerant varieties.

There are two types of *Fusarium* disease that affect Northern region crops: Fusarium head blight (FHB) and crown rot (CR).

Fusarium head blight is usually caused by the fungus *Fusarium graminearum,* but the crown rot fungus *Fusarium pseudograminearum* may also cause FNB in wet years if rain splash distributes the fungus from nodes on the lower stem into the grain heads. Crown rot is generally caused by *Fusarium pseudograminearum.*

While all winter cereals host the crown-rot fungus, yield loss due to infection varies with cereal type. The approximate order of increasing yield loss is cereal rye, oats, barley, bread wheat, triticale and durum wheat. [45]

Crown rot is a major disease in the Northern grains region. Infection requires moist soil, and the past few years have caused problems for growers by increasing the disease's prevalence. [46]

Both CR and FHB become apparent after flowering; however FHB requires prolonged wet weather during flowering and grain fill to occur, and crown rot expresses as whiteheads following periods of moisture and/or heat stress. (Whiteheads are dead heads that contain shrivelled grain or none at all.) Crown rot is sometimes first seen in patches or in wheel tracks, but is often not obvious until after heading, when whiteheads become apparent. It is important to note that yield loss can occur even without the formation of whiteheads.

43 DAF Queensland (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

44 GRDC (2016) Crown rot in winter cereals—southern region. Tips and Tactics. GRDC, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2016/02/tt-crownrotwintercereals

45 GRDC (2016) Crown rot in winter cereals—southern region. Tips and Tactics. GRDC, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2016/02/tt-crownrotwintercereals

46 T Dixon (2013) Balancing crown rot and nematodes in wheat. Ground Cover. Issue 104, May–June 2013. GRDC, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-104-May-June-2013/Balancing-crown-rot-and-nematodes-in-wheat

Update on the latest research on crown rot

Key points:

- The impact of crown rot on yield and quality is a balance between inoculum levels and soil water.
- The balance is heavily tipped towards soil water, yet most management strategies focus on combating inoculum, sometimes to the detriment of considering soil water.
- Cultivation, even when shallow, distributes infected residue more evenly across paddocks and into the infection zones below ground for crown rot.
- Some of the newer wheat varieties appear to be promising in that they provide improved tolerance to crown rot.
- PreDicta B (see section 1.5.3, Managing crown rot) is a good technique for identifying the level of risk for crown rot (and other soil-borne pathogens) prior to sowing. However, this requires a dedicated sampling strategy and is *not* a simple add-on to a soil-nutrition test.

Crown rot is a significant disease of winter cereals in the northern region. Infection is characterised by a light honey-brown to dark brown discolouration of the base of infected tillers, although major yield loss, from the production of whiteheads, is related to moisture stress after flowering. It is critical that growers understand that there are three distinct and separate phases of crown rot: *survival, infection* and *expression.* Management strategies can affect each phase in distinctive ways.

Survival: the crown-rot fungus survives as mycelium (cottony growth) inside infected residues of winter cereals (wheat, barley, durum, triticale and oats) and grass weeds. The fungus will survive as inoculum inside the stubble for as long as the stubble remains intact. This varies greatly with soil and weather conditions, although decomposition generally is a *very slow* process.

Infection: given some level of soil moisture the crown-rot fungus grows out of stubble residues and infects new winter cereal plants through the coleoptile, sub-crown internode or crown tissue, which are all below the soil surface. The fungus can also infect plants above ground level *right at* the soil surface through the outer leaf sheathes. However, with all points of infection, direct contact with the previously infected residues is required and infections can occur throughout the whole season, if there is moisture. Hence, wet seasons favour increased infection by crown rot, especially when combined with the production of greater stubble loads, which significantly builds up inoculum levels.

Expression: Yield loss is related to moisture or temperature stress around flowering and through grain-fill. Stress is believed to trigger the fungus to proliferate in the base of infected tillers, which restricts water movement from the roots and through the stems, and results in whiteheads that contain either no grain or lightweight shrivelled grain. The expression of whiteheads in plants infected with crown rot (i.e. still have basal browning) is restricted in wet seasons and increases greatly with increasing moisture and temperature stress during grain-fill. Focus attention on crops around trees in a paddock or along tree lines. Even in good years (of little infection) whiteheads associated with crown-rot infection are likely to be seen around trees. This is due to the extra competition for water.

9.5.1 Varietal resistance or tolerance

While all winter cereals host the crown-rot fungus, yield loss due to infection varies with cereal type. The approximate order of increasing yield loss is cereal rye, oats, barley, bread wheat, triticale and durum wheat. [47] Variety choice is not a total solution to crown rot, because all cereal grains are susceptible to crown rot to varying degrees.

9.5.2 Damage caused by crown rot

The presence of crown rot within the plant stem limits water movement, which can result in the premature death of the tiller and the presence of white (dead) heads (Photo 10; see also Figure 14). Crown rot survives from one season to the next on infected stubble, from where it is passed onto the following crop. The impact of a bad crown-rot season can make or break a crop, with bread wheat yield losses of up to 55% being possible when there are high levels of inoculum; losses in durum may be up to 90%.

Photo 10: *Scattered whiteheads lead to large yield losses in cereal crops.*

Photo: DAFWA

9.5.3 Symptoms of crown rot

If the leaf bases are removed from the crowns of diseased plants, a honey-brown to dark-brown discolouration will be seen (Photo 11). In moist weather, a pink–purple fungal growth forms inside the lower leaf sheaths and on the lower nodes (Photo 13).

The infection of plants with crown rot occurs at the base of the plant and spreads up the stem during the growing season. The onset of crown rot is often not obvious until after heading, when whiteheads appear with the onset of water stress. Plants infected with crown rot display a number of symptoms, including:

- Brown tiller bases, often extending up 2–4 nodes (Photo 11). This is the most reliable indicator of crown rot, with browning often becoming more pronounced from mid to late grain filling through to harvest.
- Whitehead formation, particularly in seasons with a wet start and dry finish (Photos 10 and 12). These are usually scattered throughout the crop, and do not appear in distinct patches. These may first appear in wheel tracks where crop-available moisture is more limited.

47 GRDC (2016) Crown rot in winter cereals—southern region. Tips and Tactics. GRDC, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2016/02/tt-crownrotwintercereals

- A cottony fungal growth that may be found around the inside of tillers, and a pinkish fungal growth that may form on the lower nodes, especially during moist weather (Photo 13).
- Pinched grain at harvest. [48]

Photo 11: *Honey-brown discolouration of stem bases.*

Photo: DAFWA

Photo 12: *Scattered single tillers and whiteheads.*

Photo: DAFWA

48 Soilquality (2016) Crown rot: Queensland. Fact sheet. Soilquality, http://www.soilquality.org.au/factsheets/crown-rot-queensland

Photo 13: *Pink discolouration often forms around or in the crown or under leaf sheaths.*

Photo: DAFWA

9.5.4 Managing crown rot

- Rotate crops. This is the most important management option. A grass-free break from winter cereals is the best way to lower crown rot inoculum levels.
- Observe: check plants for browning at the base of infected tillers, as this is the most reliable indicator of crown rot. Don't rely solely on whiteheads as an indicator (see Figure 3).
- Test using a pre-sowing PreDicta B soil test to identify paddocks at risk of crown rot.
- Sow winter cereals into paddocks where the risk is lowest.
- Choosing more resistant crop varieties can help, but this still need to be combined with effective management.
- Keeping crown rot inoculum at low levels is the most effective way to reduce yield loss from this disease. [49]

49 GRDC (2016) Crown rot in winter cereals—northern region. Tips and Tactics. GRDC, https://grdc.com.au/Resources/Factsheets/2016/02/Crown-rot-in-winter-cereals

Figure 3: *The GRDC's 'Stop the crown rot' campaign.*

Source: GRDC

Crop rotation

> *The disease may be controlled through planting partially resistant varieties or crop rotation. If the disease is severe, rotation to a non-susceptible crop for at least two and preferably three years is recommended. A winter crop such as chickpeas, oats or any summer crop may be used as a disease-free rotation crop.* [50]

Agronomist's view

The most effective way to reduce crown-rot inoculum is to include non-susceptible crops in the rotation sequence. As the fungus can survive for two to three years in stubble and soil, growing a non-host crop for at least two seasons is recommended to reduce inoculum levels. This allows time for decomposition of winter-cereal residues that host the fungus. Stubble decomposition varies with the type of break crop grown, and is influenced by canopy density and rate of the canopy closure, as well as row spacing, the amount of soil water the break crop uses, and seasonal rainfall. Trials in the northern region have indicated that faba beans and canola are better break crops for crown rot than chickpeas.

Because crown rot survives from one season to the next on infected stubble, the use of break crops can give stubble a chance to decompose and thus reduce soil inoculum levels. The use of break crops with dense canopies, such as canola and sorghum, can be particularly effective, as these help to maintain a moist soil surface, which encourages the breakdown of cereal residues.

The number or break crops required to sufficiently reduce crown rot levels will vary, depending on rainfall in the break year. In dry years, when residue breakdown is slower, a two-year break crop may be required to reduce crown rot to acceptable levels. In wetter seasons a one-year break may be sufficient.

It should be noted that incorporating plant residues into the soil by cultivation during the break period can increase the rate of residue decay. However, cultivation also spreads infected residue, which may increase plant infection rates in following crops, thus counteracting any benefits from increased residue breakdown.

Baling, grazing and/or burning crop residues are not effective solutions for the removal of crown rot, either. Most of the inoculum is below ground and in the bottom 7 cm of the stem, so the fungus can still survive even if above ground material is removed.

Cereal crop and variety choice

All winter cereal crops host the crow-rot fungus. Yield losses vary between crops and the approximate order of increasing loss is oats, barley, triticale, bread wheat and durum.

Bread-wheat varieties appear to differ significantly in their level of yield loss to crown rot. Newer varieties in the Northern region appear to maintain greater yields compared to the widely grown EGA GREGORY⚲. NSW DPI trials at 23 sites across the Northern region in 2013–14 indicate that this can represent a yield benefit of around 0.5 t/ha in the presence of high levels of crown-rot infection.

All current durum varieties are very susceptible to crown rot and should be avoided in medium and high risk situations.

Variety choice alone is not a solution to crown rot, with even the best varieties still yielding up to 40% less when crown rot is bad and the season finishes dry and hot.

The Queensland Government has been working to develop winter cereals with resistance to crown rot. Growers need to be aware of the levels of crown rot in their

50 DAF Queensland (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

VIDEOS

WATCH: GRDC (2015) Crown rot tolerance in new cereal varieties.

paddocks, as even the most resistant crops can suffer yield loss when there are high levels of the disease. In this case, a break crop may be required. At intermediate levels, the grower can make a calculated risk of returns versus yield loss by growing only resistant varieties.

Cultivation

Growers cultivate their stubble for a number of reasons. However, cultivation may increase the likelihood of spreading crown rot, and have an impact on all three phases of the disease cycle. Like all farming practices, cultivation is a balancing act between benefits and costs, and all these need to be weighed up when deciding how to manage farming land to minimise crown rot.

Survival: stubble decomposition is a microbial process driven by temperature and moisture. Cultivating stubble in theory increases the rate of decomposition as it reduces the particle size of stubble, buries the particles in the soil where microbial activity is greater, and puts the stubble in greater contact with the soil environment, which maintains more optimal moisture and temperature conditions for breakdown. However, in practice, cultivation also dries out the soil in the cultivation layer, and this immediately limits the potential for decomposition of the incorporated stubble. Decomposition of cereal stubbles is a *very slow* process that requires adequate moisture for an extended period to occur completely: a summer fallow (even if extremely wet and stubble has been cultivated) is *not* long enough!

Infection: as most infection sites are below ground and the plant must make physical contact with infected residue to initiate infection, the cultivation of winter-cereal stubble that harbours the fungus in effect breaks the inoculum into smaller pieces and spreads them more evenly through the paddock. Consequently, as the next winter cereal crop germinates and develops, the crown-rot fungus is been given a much greater chance of coming into contact with the major infection sites below ground. In a no-till system the crown rot fungus becomes confined to the previous cereal rows and is more reliant on infection through the outer leaf sheathes at the soil surface. This is why inter-row sowing with GPS guidance has been shown to provide around a 50% reduction in the number of plants infected with crown rot when used in no-till cropping. Cultivation or harrowing negates the option of inter-row sowing as a crown-rot management strategy.

Expression: extensive research has shown that cultivation dries out the soil to the depth of the cultivation and reduces the rate of water infiltration due to the loss of soil structure (macropores, etc.). The lack of cereal-stubble cover can also increase soil evaporation. With poorer infiltration and higher evaporation, the efficiency of fallow is reduced for cultivated systems compared to a no-till stubble-retention system. Greater moisture availability has the potential to provide buffering against the expression of crown rot late in the season.

Stubble burning

Stubble burning is not a ‘quick fix’ for high-inoculum situations, because although it removes the above-ground portion of crown-rot inoculum, the fungus will still survive in infected crown tissue below ground. Removal of stubble through burning will increase evaporation from the soil surface and make the fallow less efficient. A cooler autumn burn is preferable to an earlier hotter burn, as it minimises the negative impacts on soil-moisture storage while still reducing inoculum levels.

Crop management

Stressed plants are the most susceptible to the effects of crown rot. Management practices that optimise soil water and ensure good crop nutrition can help reduce the impacts of crown rot. Effective strategies can include:

- Reducing moisture stress in plants through good fallow management and avoiding excessively high sowing rates.
- Matching nitrogen fertiliser inputs to available soil water to avoid excessive early crop growth.

- Ensuring good crop nutrition. Zinc nutrition can be particularly important as the expression of whiteheads can be more severe in zinc-deficient crops.

Reducing water loss

Inoculum level is important in limiting the potential loss of yield from crown rot, but the overriding factor that dictates the extent of yield loss is moisture or temperature stress during grain-fill. Any management strategy that limits the storage of soil water or creates constraints that reduce the ability of the roots to access soil water will increase the probability and/or severity of moisture stress during grain-fill, and exacerbate the impact of crown rot.

Managing grass weeds

Grass weeds should be controlled in fallow periods and in-crop, especially in break crops, as they host the crown rot fungus and can also significantly reduce soil moisture storage. In pasture situations grasses need to be cleaned out well in advance of a following cereal crop as they serve as a host for the crown rot fungus.

Row placement

In a no-till system, the crown-rot fungus becomes confined to the previous cereal rows and is more reliant on infection spreading through the outer leaf sheathes at the soil surface. This is why inter-row sowing with GPS guidance has been shown to provide around a 50% reduction in the number of plants infected with crown rot when used in no-till cropping. Research conducted by NSW DPI has also demonstrated that it is beneficial to use inter-row sowing in combination with crop rotation and the relative placement of break crop rows and winter cereal rows within the sequence in order to limit disease and maximise yield. [51] Sowing break crops between standing wheat rows which are kept intact, then sowing the following wheat crop directly over the row of the previous year's break crop, ensures four years between wheat being sown in the same row. This substantially reduces the incidence of crown rot in wheat crops. It also improves the establishment of break crops (especially canola), and chickpeas will benefit from reduced incidence of viruses in standing wheat stubble.

Soil type

Soil type in itself does not affect the survival or infection phases of crown rot. However, the inherent water-holding capacity of each soil type influences the expression of crown rot by the degree to which it provides buffering against moisture stress late in the season. Hence yield loss can be worse on red soils compared to black soils due to their generally lower water-holding capacities. Any other sub-soil constraint, e.g. sodicity, salinity or shallower soil depth, effectively reduces the level of water available to the plant, and this may increase the expression of crown rot.

Sowing time

Earlier sowing within the recommended window of a given variety for a region can bring the grain-fill period forward and reduce the probability of moisture and temperature stress during grain-fill. Earlier sowing can increase root length and depth, which provides the plant with greater access to deeper soil water later in the season. This buffers the plant against crown rot, and has been shown in NSW DPI research across seasons to reduce yield loss from this disease.

However, earlier sowing can place a crop at risk of frost damage during its most susceptible age. Sowing time in the northern region is a balancing act between the risk of frost and the risk of heat stress. However, when it comes to crown rot, increased disease expression with delayed sowing can have as big an impact on yield as frost. The big difference that was observed in NSW DPI trials is the additional detrimental impact of later sowing on grain size in the presence of crown rot.

51 GRDC Grains Research Update paper (July 2014) on Managing crown-rot through crop sequencing and row placement, Andrew Verrell, NSW DPI

VIDEOS

WATCH: GRDC (2014) Does variety choice matter with crown rot? Northern region.

MORE INFORMATION

Crown rot in winter cereals—Northern region.

Interaction with root-lesion nematodes

Root-lesion nematodes (RLNs) are also a widespread constraint to wheat production across the region. Two important species of RLN, *Pratylenchus thornei* (*Pt*) and *P. neglectus* (*Pn*), exist throughout the northern region. Surveys in the northern NSW have revealed that *Pt* is more widespread and generally at higher populations than *Pn*. RLNs feed inside the root systems of susceptible winter cereals, creating lesions and reducing lateral branching. This reduces the efficacy of the root system to extract soil water and nutrients, which subsequently can exacerbate the expression of crown rot. if both of these pathogens are present in a paddock, varieties with reduced tolerance of *Pt* can have significantly greater yield loss.

How do I know my level of risk for crown rot and RLN?

PreDicta B is a DNA-based soil test which detects levels of a number of cereal pathogens. It is commercially available to growers through the South Australian Research and Development Institute (SARDI). Because the crown-rot fungus is stubble-borne, normal soil samples are unreliable. This means that detection of the disease is highly sensitive to the sampling technique used. Follow the specific protocols for how to collect samples for crown-rot testing. [52]

Soil testing

To work out the best option for your situation, it is important to know if crown rot is present in the paddock, and how severe it is. Testing involves carrying out a visual assessment on stubble followed by a precise plating test. This is the only way of accurately testing for the disease. Results are provided to the grower and consultant within approximately four weeks of receiving the sample.

In addition to visual symptoms, the DNA-based soil test PreDicta B, which was developed specifically to identify soil-borne pathogens in Northern Australian cropping regions, can be used to assess the level of crown rot in the paddock. [53] (The B stands for broadacre.) Soil samples that include plant residues should be tested early in late summer to allow results to be returned before seeding. This test is particularly useful when sowing susceptible wheat varieties, and for assessing the risk after a non-cereal crop. [54] It is also useful for testing before sowing to oats which, although not susceptible to crown rot itself, does host it. Other diseases that can be tested for are:

- cereal cyst nematode (CCN)
- take-all (*Gaeumannomyces graminis* var. *tritici* (Ggt) and *G. graminis* var. *avenae* (Gga))
- rhizoctonia barepatch (*Rhizoctonia solani* AG8)
- root lesion nematode (*Pratylenchus neglectus* and *P. thornei*)
- stem nematode (*Ditylenchus dipsaci*)

Figure 4:

Photo: GRDC

PreDicta B samples are processed weekly from February to mid-May (prior to crops being sown) to assist with planning the cropping program. The test is not intended for in-crop diagnosis: that is best achieved by sending samples of affected plants

52 S Simpfendorfer (2015). Crown rot: an update on latest research. GRDC Update Paper. GRDC. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Crown-rot-an-update-on-latest-research

53 Access PreDicta B information and testing service at http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

54 Soilquality (2016) Crown rot: Queensland. Fact sheet. Soilquality, http://www.soilquality.org.au/factsheets/crown-rot-queensland

MORE INFORMATION

PIRSA, PreDicta B website

Crown Analytical Services

VIDEOS

WATCH: GRDC (2015) Crown rot: Improving PreDicta B.

WATCH: GRDC (2013) Over the Fence north: Drew Penberthy.

to your local plant pathology laboratory. It should be used in conjunction with other management options. [55]

Crown Analytical Services also has a test for crown rot that is based on five years of laboratory research. The company's website includes its testing protocols. [56]

9.5.5 Symptoms of Fusarium head blight

Fusarium head blight is an infection of the head of the plant rather than root or crown as with CR. In cereals, FHB appears as premature bleaching of spikelets within a head. Frequently only part of the head (usually the upper half) is affected (Photo 5). [57] Salmon pink to orange spore masses (sporodochia) at the bases of infected spikelets can also be apparent during prolonged warm, humid weather. Infected wheat grains have a chalky white appearance and are usually shrivelled and lightweight; they may sometimes have pink staining, too. In barley, infected spikelets have a brown or a water-soaked appearance, rather than bleaching. The grains have an orange or black encrustation on their surfaces, rather than being chalky.

Figure 5: *Heads are partly or fully bleached with FHB.*

Photo: DAFWA

55 D Lush (2014) PreDicta B sampling strategy. GRDC, https://grdc.com.au/Media-Centre/Media-News/South/2014/04/PreDicta-B-sampling-strategy

56 Crown Analytical Services (n.d.) Protocol. Crown Analytical Services, https://sites.google.com/site/crownanalyticalservices/home/testing-process

57 DAFWA (2015) Diagnosing fusarium head blight in cereals. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-fusarium-head-blight-cereals

9.5.6 Conditions favouring FHB development

Crown rot is a fungal disease that affects cereals. It survives from one season to the next in the stubble remains of infected plants. The disease is more common on heavy clay soils.

Infection is favoured by high soil moisture in the two months after planting. Drought stress during elongation and flowering will lead to the production of whiteheads (or deadheads) in the crop.

The effects of crown rot on yield tend to be most severe when there are good crop conditions in the first part of the season followed by a dry finish. This is because the moist conditions earlier enable the fungus to grow from infected stubble to an adjacent seedling, while the dry conditions during flowering and grain filling cause moisture stress, which allows for the rapid growth of the pathogen within the plant. A wet finish to the season can reduce the damage caused by crown rot, but will not prevent yield loss in all cases. [58]

Soil water is by far the biggest factor in the impact of crown rot on profitability. The effect of moisture on crown rot yield losses is huge.

Cultivation can also have a huge impact. Crown rot is a stubble-borne disease and for a plant to become infected it must come into contact with inoculum from previous winter cereal crops. So by cultivating soil, growers help to spread the crown rot inoculum to next year's crop. The best thing a grower can do with infected stubble is leave it alone. [59]

9.6 Common root rot

Common root rot (*Bipolaris sorokiniana*) is a soil-borne fungal disease which attacks wheat, barley and triticale. It survives from one season to the next through fungal spores, which remain in the cultivated layer of the soil. The disease increases in severity with continuous wheat or wheat-barley sequences. Common symptoms are:

- a dark-brown to black discolouration of the stem just below the soil surface
- black streaks on the base of stems
- slight root rotting

9.6.1 Damage caused by disease

Common root rot can cause yield losses of 10–15% in susceptible varieties.

9.6.2 Symptoms

What to look for in the paddock

- Affected plants tend to be scattered over a paddock, and they may be slightly stunted, have fewer tillers and produce smaller heads. [60]

What to look for in the plant

- Browning of roots and sub-crown internode (the piece of stem emerging from the seed to the crown).
- Blackening of sub-crown internode in extreme cases (Photo 14).

58 Soilquality (2016) Crown rot: Queensland. Fact sheet. Soilquality, http://www.soilquality.org.au/factsheets/crown-rot-queensland

59 T Dixon (2013) Balancing crown rot and nematodes in wheat. Ground Cover. Issue 104, May–June 2013. GRDC, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-104-May-June-2013/Balancing-crown-rot-and-nematodes-in-wheat

60 DAFWA (2015) Diagnosing common root rot of cereals. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-common-root-rot-cereals

Photo 14: *Blackening of sub-crown internode in extreme cases.*

Photo: DAFWA

9.6.3 Conditions favouring development

- Common root rot can occur from tillering onwards, and is most obvious after flowering.
- There are no distinct paddock symptoms, although the crop may lack vigour.
- Severe infections can lead to the stunting of plants.
- It appears more prevalent in paddocks that are deficient in nitrogen (N). When N is not limiting, yield loss occurs through a reduction in tillering due to poor N-use efficiency.
- Affected plants are usually scattered through the crop.
- This form of rot is widespread through the grain belt, and is often found in association with crown rot.
- The fungus that causes common root rot survives on the roots of grasses and as dormant spores in the soil. It can build up to damaging levels in continuous wheat rotations. [61]

Infection is favoured by high soil moisture for six to eight weeks after planting.

9.6.4 Managing common root rot

The disease may be controlled by planting partially resistant varieties or by crop rotation. Where the disease is severe, rotation to non-susceptible crops for at least two years is recommended. Summer crops such as sorghum, sunflower, or white French millet can be used for this purpose. [62]

61 K Moore, B Manning, S Simpfendorfer, and A Verrell. (n.d.) Root and crown diseases of wheat and barley in northern NSW. NSW DPI, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/159031/root-crown-rot-diseases.pdf

62 DAF Queensland (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

- Reduce levels of the fungus in your paddocks by rotating with crops such as field peas, faba beans, canola, mustard, mungbeans, sorghum and sunflower.
- Weak crops or pasture must be grass-free.
- Sow partly resistant wheat or barley varieties.
- If moisture permits, reduce sowing depth to limit the length of the sub-crown internode (SCI).
- Ensure adequate nutrition, especially of phosphorus, which reduces the severity of common root rot.
- Burning does not decrease the number of spores in the soil. [63]

9.7 Smuts

9.7.1 Bunt or stinking smut

Bunt, or stinking smut, is caused by the fungi *Tilletia laevis* and *Tilletia caries*. Bunt affects mature wheat ears in which a mass of black fungal spores replaces the interior of the grain and forms a bunt ball. Infected plants are shorter than healthy plants, and have darker green ears and gaping glumes (Photo 15). [64] Bunt is usually only noticed at harvest ,when bunt balls and fragments can be seen in the grain. Grain deliveries with traces of bunt balls are not accepted by AWB Limited.

Photo 15: *Common bunt in cereal head showing glumes containing bunt balls.*

Photo: DAFWA

If a bunt ball is crushed, a putrid fish-like odour is released.

Spores released during harvest contaminate sound grain. The spores germinate with the seed when planted and infect the young seedling. The fungus then grows inside the developing wheat plant, finally replacing each normal grain with a mass of spores.

Bunt has not been recorded in commercial wheat crops in Queensland for more than 30 years. This is probably because of the widespread use of fungicidal seed dressings.

63 K Moore, B Manning, S Simpfendorfer, and A Verrell. (n.d.) Root and crown diseases of wheat and barley in northern NSW. NSW DPI, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/159031/root-crown-rot-diseases.pdf

64 DAFWA (2016) Smut and bunt diseases of cereal: biology, identification and management. DAFWA, https://www.agric.wa.gov.au/autumn/smut-and-bunt-diseases-cereal-biology-identification-and-management?page=0.1

9.7.2 Managing bunt

- Seed that is sown to provide the following season's wheat seed should be treated with a fungicidal seed dressing.
- Seed obtained from plants grown from untreated seed should be treated with a fungicidal seed dressing before planting.
- All seed entering Queensland should be treated with a fungicidal seed dressing which will control bunt.
- Grain from a crop with bunt should not be used for seed.
- On farms where a crop has been affected by bunt, all wheat seed should be treated with fungicidal seed dressing for at least six years.

These recommendations could be adopted in one of two ways:

1. Treat all wheat seed with a fungicidal seed dressing every second year.
2. Treat a small quantity of seed of each variety with a fungicidal seed dressing every year, and use the grain from this as planting seed in the following year. [65]

9.7.3 Loose smut

Loose smut is a fungal disease that becomes evident at head emergence. A loose, powdery mass of fungal spores is formed in the head; these spores are readily blown away leaving a bare, ragged stalk (Photo 16).

Photo 16: *Barley heads affected with loose smut.*

Photo: DAFWA

If the spores settle on healthy flowers, they may germinate and infect the embryo of the developing seed. When the seed is planted, the smut grows inside the plant until flowering when the disease appears externally. Because loose smut is carried inside the seed, systemic seed dressings are needed to control it. These are more expensive than other fungicides and should be used only when a high incidence of loose smut is expected. [66]

65 DAF Queensland (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

66 DAF Queensland (2015) Wheat: diseases, physiological disorders and frost. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

9.7.4 Managing loose smut

The disease is controlled by pickling seed with a systemic fungicide which penetrates the developing seedling to kill the internal infection. Cereal seed-dressing fungicides differ in their efficacy for smut management, with trial research demonstrating that some seed dressings can reduce the incidence of loose smut in heavily infected seed to nearly zero. The correct application of seed dressings is critical to ensuring adequate control. In-furrow and foliar fungicide applications are not effective. [67]

9.8 Rhizoctonia root rot

- Rhizoctonia root rot is most evident as bare patches in a young crop. Close inspection of infected seedlings shows brown discolouration or rotting of the roots and evidence of 'spear tips'.
- Adequate nutrition during crop emergence gives the crop better chance of getting ahead of the disease.
- Fast growing roots will push past the infected topsoil before *Rhizoctonia* infects the root tip.
- Poor weed management prior to seeding allows *Rhizoctonia solani* to 'prime' itself for infection of the upcoming crop.
- In severe paddock infections cultivation following late summer – early autumn rains can help to reduce infection by the fungus.

Rhizoctonia root rot (*Rhizoctonia solani* Kuhn) is a fungal disease that affects a wide range of crops and has become more prevalent in light soils in recent years following the introduction of minimum-tillage practices. The previous practice of tillage prior to seeding encouraged the breakdown of the fungus in the soil prior to emergence. Minimum tillage decreases the rate of organic-matter breakdown, thereby providing a habitat for the *Rhizoctonia* sp. over summer. Bare patch and root rot of cereals, and damping off and hypocotyl rot of oilseeds and legumes are all caused by different strains of *R. solani*. [68]

9.8.1 Symptoms

The characteristic symptom of *Rhizoctonia* is clearly defined bare patches in the crop (figure 1). The reason these patches are clearly defined relates to the susceptibility of young seedlings, and the placement of the fungus within the soil profile. *Rhizoctonia solani* tends to reside in the upper layers of soil but not in the surface and only infects seedlings through the root tip soon after germination. Older plants have a more developed root epidermis that does not allow the penetration of hyphae into the root. For this reason, once the crop is fully established, plants have either perished due to seedling infection or reasonably healthy. Some yield loss may be associated with plants on the margins of the bare patch. Roots of a plant infected with *R. solani* will typically be shortened with a brown 'spear tip' where they have rotted. Plants within a patch remain stunted with stiff, rolled leaves and can be darker green than those outside the patch. [69]

What to look for in the paddock

- Severely stunted plants occur in patches with a distinct edge between diseased and healthy plants. [70]
- Patches vary in size from less than half a metre to several metres in diameter.
- Patches of uneven growth occur from mid-winter, when seminal roots have established (Photo 17).

67 DAFWA (2016) Smut and bunt diseases for cereal: biology, identification and management. DAFWA, https://www.agric.wa.gov.au/autumn/smut-and-bunt-diseases-cereal-biology-identification-and-management?page=0%2C0

68 Soilquality (2016) Rhizoctonia: New South Wales. Fact sheet. Soilquality, http://www.soilquality.org.au/factsheets/rhizoctonia-nsw

69 Soilquality (2016) Rhizoctonia: New South Wales. Fact sheet. Soilquality, http://www.soilquality.org.au/factsheets/rhizoctonia-nsw

70 DAFWA (2016) Diagnosing rhizoctonia root rot in cereals. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-rhizoctonia-root-rot-cereals

Photo 17: *Patches have a distinct edge, and vary in size from less than a metre to several metres in diameter.*

Photo: DAFWA

What to look for in the plant

- Affected plants are stunted with stiff, rolled leaves that are sometimes darker green than in healthy plants (Photo 18).
- The roots of affected plants are short with characteristic pinched ends called 'spear tips' (Photo 19).

Photo 18: *Affected plants are stunted with stiff, rolled leaves which are sometimes darker than those of healthy plants.*

Photo: DAFWA

VIDEOS

WATCH: DAFWA (2014) How to diagnose Rhizoctonia root rot. DAFWA

Photo 19: *Roots of affected plants are short with characteristic pinched ends or 'spear tips'.*

Photo: DAFWA

9.8.2 Conditions favouring development

Rhizoctonia solani survives best in organic matter just below the surface of an undisturbed soil. The fungus benefits from summer rainfall by infecting weeds and multiplying on them, and has a limited ability to survive on the residue of the previous season's crops. The break of season initiates the development of the fungus in soil, which primes itself to infect germinating seeds.

Infection by the pathogen is encouraged by factors that restrict root growth, such as low soil fertility and the prior use of sulfonylurea herbicides. If there is a delay between the season break and seeding, it is imperative that weeds are controlled to minimise proliferation of the fungus. Good nitrogen nutrition helps to minimise the effects of the disease: bare patches are smaller and less severe.

In general, *Rhizoctonia* root rot is most likely to be a severe problem where plants are stressed from factors other than the disease, e.g. low rainfall or poor nutrition.

Some soil conditions favour the development of *Rhizoctonia* root rot during and after seeding.

Soil nutrition

The disease is most common in soils of poor fertility. Crops with access to sufficient nutrients for growth have a better ability to get ahead of *Rhizoctonia* sp. infections.

Soil disturbance

Rhizoctonia root rot is sensitive to cultivation, with cultivation after rain and before sowing being the most effective means of reducing infection. By disturbing the soil, the grower prevents the fungus from priming itself to infect the emerging crop.

Soil moisture

When it is moisture stressed the crop becomes more susceptible to *R. solani* infection, and has a decreased ability to get ahead of the disease.

Weeds

Poor weed management following late summer and early autumn rain allows *Rhizoctonia solani* to infect grass weeds, thereby allowing the fungus to multiply and be able to take advantage of the crop.

Herbicides

Sulfonylurea herbicides can sometimes worsen *Rhizoctonia solani infections*, and this is attributed to minor herbicidal effects on the crop. [71]

9.8.3 Managing Rhizoctonia root rot

Where reduced tillage is practiced, bare patch caused by *Rhizoctonia* root rot is best controlled by killing weeds and maintaining adequate nutrition for the establishing crop. Spraying weeds with a fast-acting knockdown herbicide will minimise the development of the fungus in the ground prior to seeding, and good nutrition gives the crop a better chance of getting ahead of the disease.

The best tillage practices for this disease are deep cultivation and shallow sowing, with minimal time between the two. In no-till systems the use of modified sowing points that provide some soil disturbance 5–10 cm below the seed can be useful in controlling the disease.

In the past, tillage was the most effective method of reducing the impact of *Rhizoctonia solani*. The establishment of *the fungus* in the topsoil late in autumn was negated as cultivation broke the network of fungal hyphae. The fungus did not have time to recover before seedling establishment. In severely infected paddocks, cultivation may be an important management strategy.

Currently there are no resistant crop varieties, but there are products on the market for *Rhizoctonia* root rot control in NSW. Consult your local adviser for specific information.

In areas where the disease is known or suspected it is best practice to clean knife points once the seeding is complete, thereby eliminating movement of the fungus from one paddock to the next. In general, maintaining adequate nutrition (especially nitrogen) during crop establishment is the best way to reduce the chance of *R. solani* infection. [72]

9.9 Cereal fungicides

All of the diseases addressed so far are caused by different fungi. Fungal disease is a major disease threat to all Australian crops, and is treated using a number of complementary tactics.

- Fungicides are only one component of a good management strategy.
- Correct identification of the cause of plant symptoms is essential, as is an understanding of the growth and spread of any pathogen, as these will assist in decision-making.

71 Soilquality (2016) Rhizoctonia: New South Wales. Fact sheet. Soilquality, http://www.soilquality.org.au/factsheets/rhizoctonia-nsw

72 Soilquality (2016) Rhizoctonia: New South Wales. Fact sheet. Soilquality, http://www.soilquality.org.au/factsheets/rhizoctonia-nsw

- Cultivar resistance is the best protection against fungal diseases. Ideally, when agronomically suitable varieties are available, opt for moderately resistant (MR) to resistant (R) varieties in disease-prone environments.
- Disease control using fungicides is an economic decision.
- Understand the role of the season and have a plan in place before planting, and if growing susceptible varieties have on hand the right chemicals to support crop health and combat pests.
- For cereal rusts and mildew, remove the green bridge between crops to prevent rusts from over-seasoning.
- Monitor crops throughout the season.
- Spray if disease threatens key plant parts (flag to flag-2) of varieties that are moderately susceptible (MS) or susceptible (S).
- Fungicides do not increase yield; they protect yield potential and cannot retrieve lost yield if applied after infection is established.
- Fungicide resistance is a major emerging issue. Do not use tebuconazole-based products on barley if there is any chance of powdery mildew occurring, and select varieties that are resistant to powdery mildew (Table 4). [73]

Table 4: *Modes of action registered for the control of foliar diseases in Australian cereals.*

Group	Active Ingredient	Example Product Name	Foliar (F), seed (S) or in-furrow (IF)
3 - DMI	Triadimefon	Triad®	F and IF
	Propiconazole	Tilt®	F
	Propiconazole + cyproconazole	Tilt® Xtra	F
	Tebuconazole	Folicur®	F and S
	Flutriafol	Impact®	F and IF
	Tebuconazole + flutriafol	Impact® Topguard	F
	Tebuconazole + prothioconazole	Prosaro®	F
	Epoxiconazole	Opus®	F
	Triadimenol	Baytan®	S
	Fluquinconazole	Jockey®	S
3 + 11 (Strobilurins)	Azoxystrobin + cyproconazole	Amistar® Xtra	F
	Pyraclostrobin + epoxiconazole	Opera®	F

Source: GRDC

VIDEOS

WATCH: GRDC (2012) Banding Fungicide in Cereals. GCTV9. GRDC.

9.9.1 Fungicide stewardship

There have been a number of pathogens such as Septoria tritici blotch (STB) which have recently developed a level of fungicide resistance in Australia. Their occurrence highlights the important role all growers play in fungicide-resistance management.

To help minimise the development of resistance to fungicides and to minimise the occurrence of disease, there are three important steps growers need to implement.

1. Remove the source of infection.

73 GRDC (2013) Cereal fungicides—northern region. Fact sheet. GRDC, https://grdc.com.au/Resources/Factsheets/2013/05/Cereal-fungicides

- For many pathogens, stubble is the source of the infection each year. By removing stubble before sowing, there is a substantial reduction of pathogen population size.
- Removing stubble reduces all forms of the pathogen irrespective of resistance, and reduces the initial establishment of disease.
- To avoid rapid disease build-up, do not sow wheat on wheat or barley on barley.

2. Variety choice.

- Under high disease pressure, a variety rated MR–MS can substantially reduce the leaf-area loss. Where possible, choose a more resistant variety.
- Host resistance reduces all forms of the pathogen irrespective of resistance, and reduces the need for multiple applications of canopy fungicides.
- Resistance ratings do change, so crops must always be monitored during the season for higher than expected reactions. Check each year for updates to disease ratings.

3. Fungicide choice and use.

- Do not use the same triazole-active ingredient more than once in a season. Do not use a strobilurin or succinate dehydrogenase inhibitors (SDHIs) more than once in a season.
- Aim for early control of necrotrophic diseases in high-rainfall years. Reducing the disease in the lower canopy slows the upward movement of disease and ultimately the leaf area lost.
- Follow label instructions at all times.

The timing of the application in the disease epidemic is critical to getting the most out of chemical products. [74]

MORE INFORMATION

GRDC Cereal fungicides fact sheet

9.10 Disease following extreme weather events

9.10.1 Cereal disease after drought

Drought reduces the breakdown of plant residues. This means that the inoculum of some diseases, such as crown rot. does not decrease as quickly as expected, and will carry over for more than one growing season. The expected benefits of crop rotation may not occur, or may be limited. Inversely, bacterial numbers decline in dry soil. Some bacteria are important antagonists of soil-borne fungal diseases such as common root rot. These diseases can be more severe after drought.

During the drought year, the inoculum of some diseases favoured by a wet season may not increase as expected.

Large amounts of seed produced in abandoned crops, or pinched seed from drought stress, will fall to the ground. If there are summer rains, large numbers of volunteers will provide a summer green bridge and autumn green ramp for rusts, viruses and virus vectors, and many other pathogens.

Low stock numbers make it difficult to control volunteers.

Weeds that harbour diseases are harder to kill.

Soil water and nitrogen may be unbalanced and these are likely to impact on diseases. [75]

9.10.2 Cereal disease after flood

For disease to occur, the pathogen must have virulence to the particular variety, inoculum must be available and easily transported, and there must be favourable conditions for infection and disease development.

74 A Milgate (2016) Cereal disease update and risks for southern NSW crops in 2016. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/Cereal-disease-update-and-risks-for-southern-NSW-crops-in-2016

75 G Murray, T Hind-Lanoiselet, K Moore, S Simpfendorfer, and J Edwards (2006) Crop diseases after drought. Primefact 408. NSW DPI.

One of the legacies of floods and much rain is the transport of inoculum (e.g. in crown rot, nematodes and leaf spots through the movement of infected stubble and soil) (Photo 20). Other effects are the development of sexual stages (in leaf spots and head blights), the survival of volunteers (unharvested material and self-sown plants in double-crop situations), and weather-damaged seed. [76]

Photo 20: *Tan spot-infected stubble following flood.*

Photo: Rachel Bowman, Seedbed Media

76 DAF Queensland (2013) Winter cereals pathology. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/winter-cereals-pathology