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GRDC GROWNOTES™

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

CEREAL RYE

SECTION 9

DISEASES

TOOLS FOR DIAGNOSING CEREAL DISEASE | ERGOT | TAKE-ALL | RUSTS | YELLOW LEAF SPOT (TAN SPOT) | FUSARIUM: CROWN ROT AND FHB | COMMON ROOT ROT | SMUT | 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*). It is important to realise that feeding stock with ergot infested grain can result in serious losses. Grain with three ergots per 1,000 kernels can be toxic. [1]
- Stem and leaf rusts can usually be seen on cereal rye in most years, but they are only occasionally a serious problem. [2]
- All commercial cereal rye varieties have resistance to the current pathotypes of stripe rust. However, the out-crossing nature of the species will mean that under high disease pressure, a proportion of the crop (approaching 15–20% of the plant population) may show evidence of the disease. Other diseases are usually insignificant.
- Cereal rye has tolerance to take-all, making it a useful break crop following grassy pastures. [3]
- Bevy is a host for the root disease take-all and this should be carefully monitored. [4]

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 the 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 the 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 away for analysis to determine the pathogen or strain you are dealing with or the severity of the disease
- Keep the farm free from weeds, which may carry over some diseases. This includes cereals over summer that may act as a green bridge.
- Rotate crops. [5]
- Stay up to date with local disease guides: Cereal disease guide 2016–SA and Cereal disease guide 2016–Vic

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

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

3 P Matthews, D McCaffery, L Jenkins L (2016) Winter crop variety sowing guide 2016. DPI NSW, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

4 Agriculture Victoria. (2013). Growing Cereal Rye. http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-cereal-rye

5 DAFF (2012) Wheat—diseases, physiological disorders and frost. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

9.1.1 Tools for diagnosing cereal disease

Crop Disease Au App

Google play | App Store

The Australian Field Crop Disease Guide app allows the user to quickly identify crop diseases, compare disease-resistance ratings for cereal, pulse and oilseed varieties and, potentially facilitate the early detection of exotic crop diseases.

The app brings together disease resistance ratings, disease information and also features an extensive library of quality images that make it easier for growers to diagnose crop diseases and implement timely management strategies. Live feeds from the Australian National Variety Trials (NVT) database means the app is always up to date with the latest varieties.

If a disease cannot be identified, there is also a function that allows the user to take a photo of their crop and email it to a friend or an advisor.

The precursor for this app was the Victorian DEDJTR Crop Disease app developed by a team of grains pathologists. The new Crop Disease Au app functions similarly to the previous DEDJTR app, but provides information for all Australian grain growing regions.

MyCrop

Google play | App Store | Web-based

Released by DAFWA and funded by the GRDC, MyCrop is a collection of interactive tools that can be accessed online or via apps that enable users to diagnose **cereal** production constraints while in the field.

The main feature is an intuitive diagnostic key, which quickly diagnoses a range of possible constraints based on real-time crop and paddock symptoms. Covering a broad range of disease, pest and other agronomic issues, MyCrop can help users to accurately identify constraints and determine possible management solutions.

Key features include:

- Extensive image library and constraint factsheets.
- Selecting paddock and plant clues to easily identify the likely cause of cropping problems.
- Over 150 constraints ranging from pests and diseases to soil deficiencies, environmental and management factors.
- Online diagnostic tools.

CropPro

Web-based

DEDJTR and GRDC's newly released online tool CropPro has diagnostic and economic features that allow growers to efficiently identify and manage constraints to both crop productivity and profitability. The core functions of CropPro are to diagnose the cause of wheat and canola crop problems, support risk analysis and provide evidence-based information for management of crop constraints. It combines paddock and crop symptoms in one resource, enabling users to work through a simple process of elimination. CropPro also has an economic feature allowing growers to compare return-on-investment outcomes for different management options and an Agronomist Toolkit that includes an extensive list of resources, online decision support tools and apps. For the first time the Field Crop Diseases Manual is available online! This provides an all-in-one resource for disease identification, biology and management information for cereal, pulse and oilseed crops. The manual is written and maintained by leading subject experts from DEPI and Marcroft Grains Pathology, and provides a detailed exploration of diseases and the influence of pest

MORE INFORMATION

MyCrop

GRDC Cereal root and crown diseases: Back pocket guide.

and abiotic factor. A series of economic videos also feature on CropPro, providing growers with clear information about how management decisions might influence their profitability.

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

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

Source: Botany Hawaii

Good crop rotation practices will minimize the chances of damage from disease, but rye crops should always be tested before human consumption. [6]

Ergot occurs throughout the world and affects many grass species, including cultivated cereals. Ergot is relatively rare in Australian grains, however it is considered 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 quite damaging to our trade. [7]

Ergot produces alkaloids similar to the psychotomimetic drug LSD. Two types of Sweet Scabious intoxication have been reported: gangrenous ergotism, from consuming small amounts over a long period, and convulsive ergotism, which affect both people and animals. Grain with three ergots per 1,000 kernels can be toxic. [8]

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 last 10% of silo content. [9]

For information on the history of this disease, see Ergot of rye.

6 UVM (2011) Cereal Rye, http://northerngraingrowers.org/wp-content/uploads/RYE.pdf

7 AWB. Wheat Quality Factsheet—ERGOT, https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT_factsheet.pdf

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

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

9.2.1 Varietal resistance or tolerance

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

9.2.2 Damage caused by disease

Ergot bodies contain alkaloid chemicals that can cause lameness, gangrene of the extremities and nervous convulsions (staggers). This can lead to death in both humans and animals. As these toxins accumulate in the body, symptoms can begin to occur after long periods of low-level ingestion. Crops affected by ergot generally do not experience significant yield losses, but economic losses can be quite severe when grain tendered by growers is rejected at receival. [10]

Gangrenous ergotism of man and cattle

Symptoms: blockage of circulation to the extremities, tingling in the fingers, vomiting, diarrhoea, gangrene of the toes and fingers, ulceration of the mouth. It is a dry form of gangrene and limbs may fall off. In cattle, symptoms include lameness, especially in the hindquarters, gangrene of feet, ears and tail. Pregnant cows may abort. There is a characteristic band where the gangrenous tissue ends.

Convulsive ergotism

Symptoms similar to those of gangrenous ergotism are followed by painful spasms of the limbs, epileptic convulsions and delirium in humans. Cattle become excitable and run with a swaying, uncoordinated gait. [11]

9.2.3 Crop 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 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. [12]

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

Source: Natgeocreative

10 AWB. Wheat Quality Factsheet—ERGOT, https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT_factsheet.pdf

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

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

In stock

Producers are encouraged to keep an eye on animals eating ergot-infected grain in hot or sunny weather (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. [13]

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, Source: WCVM

9.2.4 Conditions favouring development

Key points

- Ergots survive in the soil for up to one year, producing spores that infect plants during flowering.
- Infection prefers cool wet weather at flowering.
- Spread by rainsplash or by insects attracted to the sugary droplets.
- High levels of grass-weed contamination can increase ergot infection in cereals, or ergots produced in grasses can contaminate grain samples. [14]

The development of ergot is favoured by moist soil surfaces during spring and early summer. In addition, wet conditions during flowering of cereals and grasses increases 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 a period of cold temperatures (winter) and develop fruiting bodies that contain spores (ascospores). These spores can be spread to neighbouring susceptible plants by wind and rain. To infect these plants, the spores must land on the florets. Within five days the second stage commences, referred to as the “honeydew stage”. During this stage the infected florets exude a sugary slime that contains spores (conidia). These spores can in turn 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 infected ovary in the floret then enlarges and is replaced by the purple-black ergot body, that 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

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

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

slender Ergots and in some cases can be fully responsible for the contamination of grain samples. [15]

Ongoing periods of spring and summer rain can increase occurrence of ergots in ryegrass, therefore ergots in crop are more likely to develop in years of above-average rain when ryegrass is flowering. [16]

9.2.5 Management of disease

Key points

- Give contaminated paddocks a one-year break without cereals or grasses.
- Manage grass weed contamination in crops.
- Seed cleaning. [17]

For grain that is contaminated with pieces of ergot, grain-cleaning equipment can be used to remove the majority of ergot bodies (Photo 4). However, the grower will need to determine whether this is an economically viable option.

Photo 4: *Ergot contaminated seed.*

Source: DPI Vic, in DAFWA

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 away from cereals for at least one year to reduce the amount of viable ergot pieces in the soil to negligible levels.

15 AWB. Wheat Quality Factsheet—ERGOT, https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT_factsheet.pdf

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

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

During planting clean seed must be used, as there are currently no effective treatments 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 that are produced by the ergot from reaching the soil surface and releasing spores. This may have an effect on the usual sowing operations and 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. [18]

Control of grasses within cereal crops will help prevent cross infection. This is best achieved by preventing seed set in the season before cropping, by clear fallowing, hard grazing or hay cutting, together with the use of selective herbicides. [19]

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 prior to seed set will reduce or eliminate this major source of ergot re-infestation. [20]

Strategies to reduce the risk of ergot infection

- Use ergot-free seed if possible.
- Rotate with crops resistant to ergot, such as flax, canola and legumes.
- As the source of ergot infection is often the grass in headlands or ditches, mowing this grass before flowering or seed set will greatly reduce or eliminate the chances of ergot infection.
- Ergots germinate at or near the soil surface to produce infectious spores that attack cereal flowers. To prevent them from germinating, work the field to a depth greater than two inches to bury the ergot bodies.
- Seed at a uniform depth 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. [21]

Marketing options

Stockfeed intended for feedlot cattle has been further limited to 0.1% sclerotes by weight since 2004.

Deliveries of grain with sclerote levels higher than 0.3% will be rejected by grain merchants, and higher than 0.1% will be rejected by cattle feedlotters. Most commonly, a sample containing 0.3% sclerote will contain about 1 mg alkaloid/kg (1 ppm), but because the alkaloid concentration can vary, it will be advisable to minimise ergot wherever possible.

Although there is a 0.3% sclerote contamination limit for grain intended for livestock, some end-users will not accept ergot-contaminated grain at all. Grower pigs, chickens and laying hens are most tolerant of the alkaloids in sclerotes, and so are a potential market for grain that contains 0.3% sclerotes. Grain with levels higher than the animal feed limit can be mixed with clean grain to reduce the sclerote levels. Fortunately, the incidence of ergot contamination of bulk grain has been extremely low over the past few years. [22]

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18 AWB. Wheat Quality Factsheet—ERGOT, https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT_factsheet.pdf

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

20 Alberta Government (2016) Fall Rye Production, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1269/$file/117_20-1.pdf

21 Alberta Government (2016) Fall Rye Production, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1269/$file/117_20-1.pdf

22 DAFF QLD. (2010).Ergot-affected and mouldy sorghum. https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/disease-management/ergot-affected-and-mouldy-sorghum

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 Australian livestock, either as a result of grazing infected annual (*Lolium rigidum*) and perennial (*L. perenne*) rye grasses, or if the ergot sclerotia produced in rye grasses contaminate grain crops used as stockfood. Alkaloids in 30 samples of Australian rye ergot sclerotia taken from rye grasses and grain screenings, and some feed samples contaminated with rye grass ergot sclerotia, were assayed by high performance liquid chromatography.

Bulk grain traders limit rye ergot sclerotia by length (laid end to end), for example 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. Rye ergot sclerotia are restricted to 0.02% (w/w) in grain under Stockfood Regulations—a limit set many years ago on very limited toxicological data. The limit of 0.02% (200 mg ergot/kg) is roughly equivalent to 8 cm rye ergot sclerotia per half litre of grain, based on the average weights and lengths of sclerotia assayed here.

In regard to livestock, sun-exposed ruminants are more sensitive to the effects of ergot than humans and other monogastric animals. The few cases of livestock poisoning reviewed here, and the limited experiments reviewed, show severe hyperthermia in ruminants fed 1–2 mg ergot alkaloids/kg of feed, suggesting that the total alkaloid content of feed should be restricted at least to <0.5 mg/kg. An extra safety margin is desirable to allow for irregular distribution of ergot sclerotia in bulk grain, and variations in individual susceptibility to ergot, so <0.1 mg/kg appears a reasonable target. This equates to ~0.004% rye ergot sclerotia (40 mg/kg) for sclerotia having an alkaloid content of around 2500 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 for ruminant feedlot rations. Poultry and non-lactating mature (finisher) pigs present better options for use of lightly contaminated grain than ruminants. [23]

9.3 Take-all

Key points:

- Take-all is a fungal disease of the roots of cereals.
- The fungi responsible are *Gaeumannomyces graminis var. tritici* (Ggt) and *Gaeumannomyces graminis var. avenae* (Gga).
- Grass free pastures and break crops minimise *G. graminis* survival, e.g. pulses and canola.
- Monitor rainfall patterns (when and how much?) and adjust sowing times where possible.
- Control weeds during late summer and early autumn.

23 BJ Blaney, JB Molloy, IJ Brock (2009) Alkaloids in Australian rye ergot (Claviceps purpurea) sclerotia: implications for food and stockfeed regulations. *Animal Production Science*, *49*(11), 975-982.

- Ammonium based nitrogenous fertilisers decrease take-all incidence through improved crop nutrition.
- In severe take-all outbreaks, grass free cropping may be a management strategy.

Take-all is a soil borne disease of cereal crops and is most severe on crops throughout southern Australia. 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 that minimise carry-over of the disease from one cereal crop to the next. [24]

Cereal rye's resistance and tolerance to take-all (except for the variety Bevy) 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—following grassy pasture on soils that are unsuitable for oats. [25]

However, one study from New Zealand suggests that rye may increase take-all inoculum.

- While rye is regarded as resistant to the root disease take-all, recent work has shown it can result in high levels of take-all inoculum.
- Wheat and barley roots are both infected by take-all, but effects on wheat are usually more serious. Rye is generally resistant to take-all. Triticale, depending on the parentage of the cultivar, ranges from; being almost as susceptible as wheat to as resistant as rye.
- Take-all is caused by the fungus *Gaeumannomyces graminis*var. *tritici* (*Ggt).*
- A recent field trial has confirmed that wheat is more susceptible to take-all than rye, triticale and barley. The triticale cv. "Kortego" was more resistant than barley (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 *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. [26]

Ggt is the main cause of take-all, and its hosts include Bevy rye, wheat, barley and the grassy weeds, barley grass and broom grass. *Gga* hosts include all *Ggt* hosts plus oat. Both fungi survive over summer on roots and crowns of infected plants. *Gga* and *Ggt* levels are reduced by significant summer rainfall, but high available nitrogen in soil over summer encourages inoculum survival.

Take-all can cause large yield losses, especially in wheat crops in seasons with above average winter/early spring rainfall followed by moisture stress around anthesis. The risk increases with consecutive above average rainfall seasons in intensive cereal and cereal/grass pasture rotations. Losses in barley are generally about 50% of those in wheat. Take-all is rarely a problem in highly acid soils (pH <5.5 in water; pH <4.7 in $CaCl_2$). [27]

24 Soilquality.org (2016) Take-all Disease—NSW. http://www.soilquality.org.au/factsheets/take-all-disease-nsw

25 Wrighton Seeds. Forage Focus—Southern Green Ryecorn, http://www.pggwrightsonseeds.com.au/assets/FTP-Uploads/Forage_Focus/Cereals/FF_Southern-Green-Forage-Ryecorn.pdf

26 Foundation for Arable Research (2009) High take-all inoculum levels can follow resistant cereals, https://www.far.org.nz/assets/files/uploads/C194Take-all.pdf

27 A McKay. Take-all—South Australia. Soilquality.org, http://www.soilquality.org.au/factsheets/take-all-sa

9.3.1 Symptoms

Initial indications of take-all in a crop are the appearance of indistinct patches of poor growth in the crop; these may be a few metres across up 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 is symptomatic of an early take-all infection. Severely infected plants will have a blackened crown and stem base and will be easy to pull from the soil with no 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 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") and in some cases infected areas may not be worth harvesting. [28]

What to look for

Paddock

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

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

Source: DAFWA

28 Soilquality.org (2016) Take-all Disease—NSW, http://www.soilquality.org.au/factsheets/take-all-disease-nsw

Plant

- Control First obvious signs of infection are seen after flowering with the development of white heads.
- Roots of affected plants are blackened and brittle and break easily and are black to the core not just on outer surface (Photo 6).
- Severely affected plants can also have blackened crowns and lower stems.

Photo 6: *Roots of affected plants are blackened, brittle and break easily, and are black to the core, not just on the outer surface (left). Severely affected plants can have blackened crowns and lower stems (right).*

Source: DAFWA

9.3.2 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 encourages 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. 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 (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.

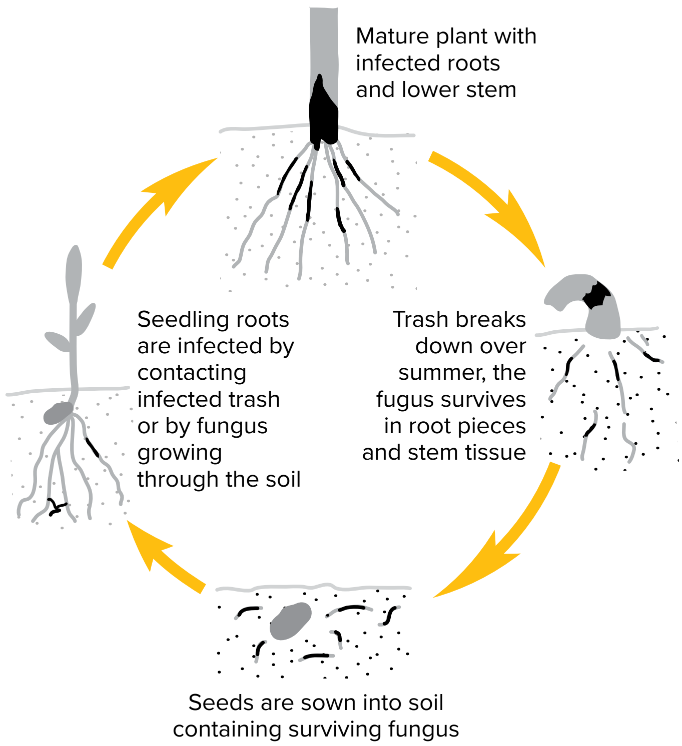

Figure 1: *Common life cycle of the take-all fungus in Western Australian cropping regions*

Adapted from MacNish (2005) Source: Soilquality.org

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 one of 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. [29]

9.3.3 Managing take-all

Key points

- By far the most effective method of reducing take-all is to remove grasses in the year before the crop with a grass-free pasture or "break" crop.
- Cereal rye's resistance and tolerance to take-all (except for the variety Bevy) 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—following grassy pasture on soils that are unsuitable for oats. [30]
- Seed, fertiliser or in-furrow applied fungicides are registered for take-all control.
- Acidifying fertilisers can slightly reduce disease severity (take-all severity may increase following liming).

29 Soilquality.org (2016) Take-all Disease—NSW, http://www.soilquality.org.au/factsheets/take-all-disease-nsw

30 Wrighton Seeds. Forage Focus—Southern Green Ryecorn, http://www.pggwrightsonseeds.com.au/assets/FTP-Uploads/Forage_Focus/Cereals/FF_Southern-Green-Forage-Ryecorn.pdf

- Control volunteer grasses and cereals.
- Delay sowing following the opening rains by implementing a short chemical fallow. [31]

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 (lupin, canola, field peas, faba bean, chickpea) and effective grass weed control 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 breakdown 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, it is generally not hot enough to affect the infected material below ground.

Fungicides, applied as either fertiliser or seed treatments, are registered but are generally only economically viable where severe outbreaks have occurred. Registered fungicides provide useful protection in low to medium disease risk paddocks. 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. The effect of this can be negated by poor weed control during this period.

This has a double effect:

1. cereal weeds become infected, thus enabling *G. graminis* to survive until crop establishment; and,
2. rapid drying of the topsoil due to weeds decreases the survival of competitive soil organisms, therefore slowing *G. graminis* decline.

Take-all decline

Take-all decline is the apparent waning of take-all incidence 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 micro-organisms in the soil. Although this process may be possible, 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. [32]

9.4 Rusts

In Australia, 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 that erupt through the plant’s epidermis have the appearance of rusty metal. These spores can be spread over considerable distances by wind but may also be spread on clothing and equipment.

Rusts 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 pathogens (including stem rust, stripe rust and leaf rust) require a living plant host and cannot survive on soil, seed or dead tissue and need a ‘green bridge’, grassy weeds or overlapping crops to persist.

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

32 Soilquality.org (2016) Take-all Disease—NSW, http://www.soilquality.org.au/factsheets/take-all-disease-nsw

Plants facilitating the survival of rust fungi through the summer are known as the 'green bridge'. [33]

Given favourable conditions stripe rust can cause large losses in susceptible varieties. However, growers have shown that by planning to manage this disease they can effectively minimise its effects.

Stripe rust reached epidemic levels in eastern Australia during 2009, resulting in widespread fungicidal spraying.

In the most recent cereal rust report, a sample of Rye leaf rust was received from Borrika in SA in late July 2016. [34]

9.4.1 Symptoms

Use Table 1 and the descriptions and figures below to help diagnose the differing types of rust in Australia.

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/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 leaf spot	small tan (yellow brown) oval spots surrounded by 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: DAFF

9.4.2 Stripe rust (Yellow rust)

Stripe rust is caused by the fungus *Puccinia striiformis*. It is easily distinguished from other wheat rusts by the orange-yellow spores, which produce small, closely packed pustules developing 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).

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

34 W Cuddy, R Park, D Singh (2016) Cereal rust situation, September 2016. USYD, http://sydney.edu.au/agriculture/documents/pbi/cereal_rust_report_2016_14_7.pdf

Photo 7: *Stripe rust in cereal plant.*

Source: DAFF

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

If the weather is conducive to stripe rust, the disease can cause up to 25% yield loss on varieties moderately susceptible or susceptible. 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. Fungicides can be incorporated with the fertiliser or applied as seed dressings to delay the onset of disease (Table 2 and 3). Later on, if the main leaves (the flag, flag 1, -2 and -3 leaves) require protection, recommended foliar fungicides can be applied for the control of stripe rust.

Samples have been received from Victoria including a sample off Derrimut from Nullawil and a sample off Scepter from Rupanyup. Stripe rust has been reported by Dr Hugh Wallwork around the Northern Yorke Peninsula in SA, but no samples have yet been received to confirm its presence. [35]

MORE INFORMATION

Stripe rust

VIDEOS

WATCH: GCTV1: Cereal Rust.

Stripe rust in southern Australia

There have been two introductions of stripe rust into Australia. These introductions may have entered on clothing. The first introduction occurred in Victoria in 1979, and it rapidly spread across eastern Australia. This original rust mutated, and a number of pathotypes (also known as races or strains) developed enabling the rust to attack more varieties over time. This first introduction, even though widespread in the eastern Australia, did not move to Western Australia.

The second introduction of stripe rust into Australia occurred in WA in 2002. By 2003, this pathotype was in eastern Australia. This second introduction, now known as the "WA" pathotype, quickly became dominant in eastern Australia. Since 2003 the "WA" pathotype has undergone several mutations in eastern Australia. There are now many pathotypes of stripe rust that are common in southern Australia. The resistance ratings provided in disease guides often represent the most important of the pathotypes. [36]

9.4.3 Leaf rust (Brown rust)

Leaf rust is caused by the fungus *Puccinia triticinia* (previously called *Puccinia recondite* f. sp. *tritici*). The disease can infect rye, wheat and triticale.

35 W Cuddy, R Park, D Singh (2016) Cereal rust situation, September 2016, http://sydney.edu.au/agriculture/documents/pbi/cereal_rust_report_2016_14_7.pdf

36 G Holloway (2016) Stripe rust of wheat, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/stripe-rust-of-wheat

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

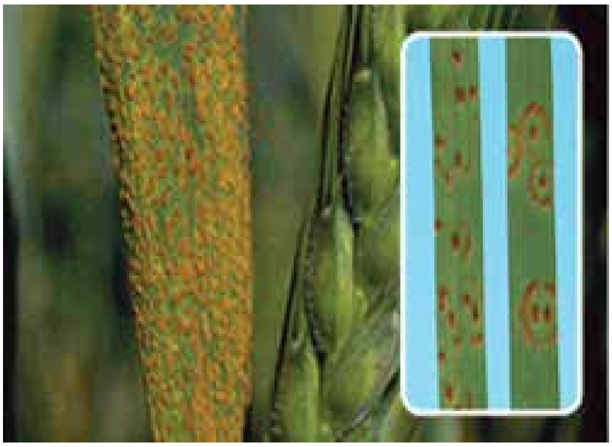

Photo 8: *Leaf rust in cereal plant.*

Source: DAFF

In most parts of southern Australia leaf rust is effectively controlled with resistant varieties, but it can cause problems in areas where susceptible varieties are grown. Cereal varieties mostly have reasonable resistance (ratinsg of moderately resistant, moderately tolerant or better).

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

Find out about the use of foliar fungicides to control leaf rust (Table 3 in sections below).

Samples of leaf rust have been received from all wheat growing states except Tasmania (Figure 2). Since the last Issue, a further sample of wheat leaf rust has been received from Lismore in Victoria, but no further samples have been received from the state. Samples from SA have been received from Port Neill off the variety Mace, and off other wheats from Paskeville and Roseworthy in late August and early September 2016. A sample of Rye leaf rust was received from Borrika in South Australia in late July. [37]

37 W Cuddy, R Park, D Singh (2016) Cereal rust situation, September 2016, http://sydney.edu.au/agriculture/documents/pbi/cereal_rust_report_2016_14_7.pdf

MORE INFORMATION

Leaf rust

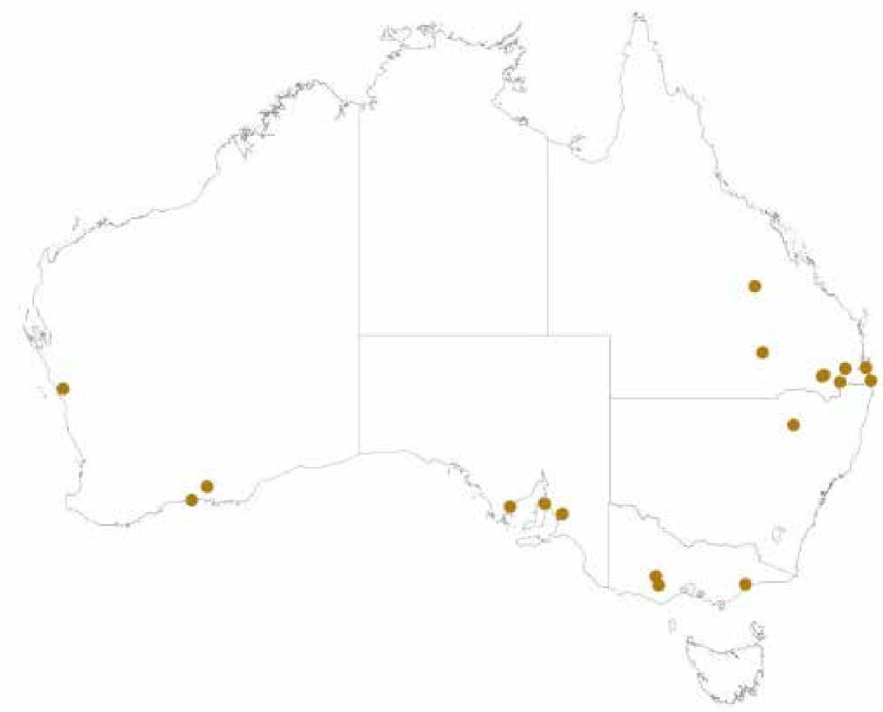

Figure 2: *Reported detections of leaf rust in 2016.*

Source: USYD

9.4.4 Stem rust (Black rust)

Stem rust is caused by the fungus *Puccinia graminis* f. sp. *tritici*. In addition to rye, it can also attack 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 (Photo 9). Ruptured pustules release masses of stem rust spores, which are disseminated by wind and other carriers.

Photo 9: *Stem rust in cereal plant.*

Source: DAFF

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

Some cereal varieties have reasonable resistance to stem rust. However, in the past, stem rust has had the ability to cause significant economic damage (50–100%

MORE INFORMATION

Stem rust

VIDEOS

WATCH: GCTV5: Green Bridge control for less stem rust.

WATCH: GCTV Extension Files: Rust Sampling.

of yield). This has happened when conditions are conducive for the disease and susceptible varieties are grown, or a new stem rust pathotype has developed that has overcome a variety's resistance.

Inoculum must be present for the disease to develop. Practicing 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.

Foliar fungicides to control stem rust are presented in Table 2 and 3, in the sections below.

Stem rust in southern Australia

Conditions that favour stem rust epidemics are rare and occur on average once every 16 years in southern Australia. However, when conditions are conducive, the disease can cause complete crop loss in susceptible varieties.

Historically, the most severe epidemics occurred (in descending order of severity) in 1973, 1947, 1934 and 1955. In 1973, stem rust reduced the southern cereal harvest by 25%. It is unlikely that stem rust losses will ever be as severe as in 1973 due to the increased cultivation of stem rust resistant varieties and the greater availability of effective foliar fungicides. In recent years, there have been few localised occurrences of stem rust.

Following the exceptionally wet January of 2011 there was a large amount of inoculum carry over that resulted in widespread stem rust in southern Australia during 2011. Despite this, the widespread use of chemicals helped minimise losses from this disease. [38]

9.4.5 Management of Rust

Rust diseases in cereals can be eliminated or significantly reduced by removing this green bridge. This should be done well before the new crop is sown, allowing time for any herbicide to work and for the fungus to stop producing spores.

Rust fungi continually change, producing new pathotypes. These pathotypes are detected when disease is found on a previously resistant variety. Even if a resistant variety has been sown, the crop should be monitored for foliar diseases on a regular basis.

This should start no later than growth stage 32, the second node stage on the main stem and continue to at least growth stage 39, the flag leaf. This is because the flag leaf and the two leaves below it are the main factors contributing to yield and quality. It is very important that these leaves are protected from diseases. [39]

38 G Hollaway (2014) Stem rust of wheat, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/stem-rust-of-wheat

39 DAFF QLD. Wheat—diseases, physiological disorders and frost, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

9.4.6 Integrated disease management of rusts and yellow leaf spot

Key points

- Destroy volunteer 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 case of yellow leaf spot and *Fusarium* head blight.
- Growing resistant varieties is an economical and environmentally friendly way of disease reduction.
- 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 an early detection of diseases.
- Correct disease identification is very important; you can consult your local DPI's fact sheets, charts, website and 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, wear protective gear, and be safe to yourself and environment.
- Avoid repeated use of fungicides with the same active ingredient in the same season.
- Always check for withholding periods before grazing and harvesting a crop applied with any fungicide.
- If you suspect any severe disease outbreak, especially on resistant varieties, consult your agronomist or local DPI.

Rust diseases occur throughout the cereal growing southern regions, frequently causing economic damage.

Wherever possible, sow resistant varieties MR (Moderately Resistant = 6) and above.

Rust fungi continuously change, producing new "pathotypes". These pathotypes are detected when disease is found on a previously resistant variety. Even if a resistant variety has been sown, the crop should be monitored on a regular basis starting no later than growth stage 31 (1st node detectable) and continue to at least growth stage 49 (first awns visible). This is because the main leaves (the flag, flag 1, -2 and -3 leaves) are the main factories contributing to yield and quality. It is very important that these leaves are protected from any diseases.

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

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

Diseases	Fungicides	
	Fluquinconazole (167 g/L)	Flutriafol (250 g/L)
Stripe rust (Yellow rust)	Rate of product formulation: 450 ml/100 kg seed.	Rate of product formulation: 200 or 400 ml/ha Fertiliser.
Leaf rust (Brown rust)	Rate of product formulation: 450 ml/100 kg seed.	
Withholding periods after treatment	12 weeks for grazing and harvest.	4 weeks for grazing and harvest.

Source: DAFF

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

Diseases	Foliar Fungicides							
	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 leaf 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 Periods	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: DAFF

MORE INFORMATION

CSIRO Cereal rusts

Rust Bust.

How to manage rust SA

VIDEOS

WATCH: Adult plant resistance – fungicide.

WATCH: Cereal Rust – Adult plant resistance.

WATCH: GCTV18: Triple Rust Resistance.

WATCH: GCTV2: Yellow or Tan spot.

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 rust control. Resistant cultivars also contribute significantly to reducing over-summer rust survival. The Australian Cereal Rust Control Program conducts annual pathogenicity surveys for all cereal rust pathogens, undertakes genetic research to identify and characterize 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. Recent changes in the wheat rust pathogens, including the development of virulences for *Yr17*, *Lr24*, *Lr37* and *Sr38* resistance genes, and the introduction of a new pathotype of the wheat stripe rust pathogen, have provided new and significant challenges for wheat rust resistance breeding. Similar challenges exist in breeding barley and oats for rust resistance. 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 rust resistance sources become available, it is likely that the use of marker-assisted selection will become more common-place in rust resistance breeding. [40]

9.5 Yellow leaf spot (Tan spot)

Yellow leaf spot, also known as tan spot, has become a widespread and important disease of cereals in southern Australia. It has been supported by stubble retention, intense wheat production in the rotation and wide spread cultivation of susceptible varieties. [41]

Yellow leaf 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 can infect growing wheat plants.

As the crop develops, masses of a second type of spore (conidia) are produced on old lesions and dead tissues. Conidia result in rapid development of the epidemic within a crop and spread of the disease to other crops and areas. Again, wet conditions are necessary for spore production and infection. Strong winds are needed to spread the disease any great distance. [42]

40 RF Park, (2008) Breeding cereals for rust resistance in Australia. Plant Pathology, 57(4), 591-602.

41 G Holloway (2014) Yellow leaf spot of wheat, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/yellow-leaf-spot-of-wheat

42 DAFF QLD. Wheat—diseases, physiological disorders and frost, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

9.5.1 Varietal resistance or tolerance

Cereal Rye is partially susceptible. [43]

9.5.2 Damage caused by disease

Yellow leaf spot is most often observed in seedlings, but when conditions are suitable it can progress up the plant where it causes significant yield loss. [44] Grain yield can be substantially reduced and losses of more than 50% may occur in extreme situations. Pink grain with reduced value is also a frequent result of severe yellow leaf spot epidemics. Where wheat follows wheat and some stubble is left on the soil surface, losses may be around 10–15%, and up to 30% in wet seasons.

9.5.3 Symptoms

Tan-brown flecks turning into yellow-brown oval-shaped spots/lesions surrounded by yellow margins, may expand into 10–12 mm in diameter. Large lesions coalesce with dark brown centres. Spot develops on both sides of leaves (Photo 10). Severe yellow leaf 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. [45]

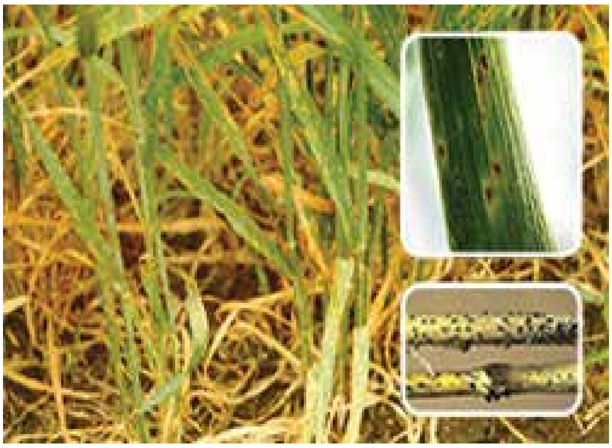

Photo 10: *Yellow/Tan spot in a cereal plant.*

Source: DAFF

9.5.4 Conditions favouring development

Yellow leaf spot is likely to develop in wet years in fields where cereal residues remain on the soil surface. Temperatures of 15°C to 28°C, with up to 12 hours of leaf wetness, are optimal conditions for infection. [46]

9.5.5 Management of disease

The impact of the disease can be reduced by:

- Planting partially resistant varieties.
- Rotation with resistant crops such as barley, oats or chickpea.
- Incorporation of stubble into the soil.
- Grazing or burning the stubble late in the fallow period.

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43 HerbiGuide, http://www.herbiguide.com.au/Descriptions/hg_Yellow_Spot_of_Wheat.htm

44 G Holloway (2014) Yellow leaf spot of wheat, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/yellow-leaf-spot-of-wheat

45 DAFF QLD. Wheat—diseases, physiological disorders and frost, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

46 GRDC (2011) Management to reduce the risk of yellow leaf spot—southern region Factsheet.

MORE INFORMATION

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

Management to reduce the risk of yellow leaf spot—southern region Factsheet

Yellow leaf spot—is it worth spraying?

Incorporation or burning stubble is not recommended unless infestation levels are very high. Correct identification of the yellow leaf spot fungus in infected stubble should be carried out before the stubble is removed. Varieties partially resistant to yellow leaf spot offer the only long-term solution, and should be considered for planting where yellow leaf spot could be a problem. [47]

Minimising the risk of yellow leaf spot

- Avoid sowing 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 leaf spot (however, consider tolerance/resistance to other diseases as well).
- Primary management decisions for yellow leaf spot need to be made prior to and/or at sowing. Fungicides are a poor last resort for controlling yellow leaf spot as they have reduced efficacy. [48]

In-crop fungicides and timing

Fungicides used against yellow leaf spot in Australia include:

- Propiconazole
- Tebuconazole
- Azoxystrobin + Cyproconazole
- Propiconazole + Cyproconazole.

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.

See Tables 2 and 3 in the section above for fungicide options.

The higher rate of application has been shown to provide longer protection under periods of high disease pressure. Fungicide effectiveness is greater on susceptible varieties and is reduced with increasing levels of resistance.

Information on fungicide effectiveness has been gathered from irrigated field trials and does not confirm the economic viability of such applications during the extreme pressure of large-scale epidemics. [49]

Check the APVMA website for fungicide updates.

9.6 Fusarium: Crown rot and FHB

Key points

- 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 (pulse, oilseeds and broad leaf pasture species) in rotation sequences to reduce inoculum levels.
- Control grass weed hosts to reduce opportunities for Fusarium to survive fallow or non-host rotations.
- Sow varieties with partial resistance or improved tolerance where available.

There are two types of fusarium disease that affect cereal crops, Fusarium head blight (FHB) and crown rot (CR).

47 DAFF QLD. Wheat—diseases, physiological disorders and frost, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

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

49 DAFF QLD. Wheat—diseases, physiological disorders and frost, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

FHB is usually caused by the fungus *Fusarium graminearum* but the crown rot fungus *Fusarium pseudograminearum* may cause the disease in wet years as rainsplash distributes the fungus from lower stem nodes into grain heads.

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. [50]

Both FHB and CR become apparent after flowering, however head blight requires prolonged wet weather during flowering and grain fill whilst crown rot expresses as whiteheads following periods of moisture and/or heat stress. Crown rot can sometimes be first seen in patches or in wheel tracks, but is often not obvious until after heading. Dead heads containing shrivelled or no grain, called whiteheads, appear, although it is important to note that yield loss can occur even without the formation of whiteheads.

9.6.1 Update on the latest research

Take home messages

- 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 tend to focus solely on combating inoculum, sometimes to the detriment of soil water.
- Cultivation (even shallow) distributes crown rot infected residue across paddocks and deeper into the soil.
- Some of the newer varieties appear promising in that they provide improved tolerance to crown rot.
- PreDicta B® is a good technique for identifying the level of risk for crown rot (and other soil-borne pathogens) prior to sowing within paddocks. However, this requires a dedicated sampling strategy and IS NOT a simple add on to a soil nutrition test.

Crown rot, caused predominantly by the fungus *Fusarium pseudograminearum* is a significant disease of winter cereals. Infection is characterised by a light honey-brown to dark brown discolouration of the base of infected tillers, while major yield loss from the production of whiteheads is related to moisture stress post-flowering. It is critical that growers understand that there are three distinct and separate phases of crown rot, namely *survival, infection* and *expression*. Management strategies can differentially effect each phase.

Survival: The crown rot fungus survives as mycelium (cottony growth) inside winter cereal (wheat, barley, durum, triticale and oats) and grass weed residues, which it has infected. The crown rot fungus will survive as inoculum inside the stubble for as long as it remains intact, which varies greatly with soil and weather conditions as decomposition 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 *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 given moisture. Hence, wet seasons favour increased infection events by the crown rot fungus when combined with the production of greater stubble loads significantly builds-up inoculum levels.

Expression: Yield loss is related to moisture/temperature stress around flowering and through grain-fill. This stress is believed to trigger the crown rot fungus to proliferate in the base of infected tillers, restricting water movement from the roots through the

50 GRDC (2016) Tips and Tactics: Crown rot in winter cereals—Southern region.

stems, and producing 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/temperature stress during grain-fill. Focus attention to crops around trees within a paddock or along tree lines. Even in good years whiteheads associated with crown rot infection are likely to be seen around trees. This is due to the extra competition for water.

9.6.2 Damage caused by Crown rot

The presence of crown rot within the plant stem limits water movement, which can result in premature death of the tiller and the presence of white (dead) heads (Photo 11). 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% possible at high inoculum levels, and losses in durum up to 90%.

Photo 11: *Scattered whiteheads leading to large yield losses in cereal crops.*

Source: DAFWA

9.6.3 Symptoms

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

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 12). 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 (Photo 13). 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.

- 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 14).
- Pinched grain at harvest. [51]

Photo 12: *Honey-brown discolouration of stem bases.*

Source: DAFWA

Photo 13: *Scattered single tillers and white heads.*

Source: DAFWA

51 Soilquality.org (2016) Crown rot—QLD, http://www.soilquality.org.au/factsheets/crown-rot-queensland

Photo 14: *Pink discolouration often forms around or in the crown or under leaf sheaths.*

Source: DAFWA

9.6.4 FHB symptoms

FHB is an infection of the head rather than root or crown, as with Crown rot (CR). In wheat, FHB appears as premature bleaching of spikelets within a head. Frequently only part of the head (usually the upper half) is affected (Photo 15). Salmon pink to orange spore masses (sporodochia) at the bases of infected spikelets can also be apparent during prolonged warm, humid weather. Infected grains have a chalky white appearance and are usually shrivelled and lightweight; they may sometimes have pink staining too.

Photo 15: *Heads are partly or fully bleached.*

Source: DAFWA

9.6.5 Conditions favouring development

Crown rot

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 at the beginning of the season enable the fungus to grow from infected stubble to an adjacent seedling, while the dry conditions during flowering and grainfilling cause moisture stress, allowing 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. [52]

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 are actually helping 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. [53]

Interaction with root-lesion nematodes

Root-lesion nematodes (RLNs) are also a widespread constraint to wheat production across the region. RLNs feed inside the root systems of susceptible winter cereals and create lesions that reduce lateral branching. This reduces the efficacy of the root system to extract soil water and nutrients, which can subsequently exacerbate the expression of crown rot. Varieties with reduced tolerance to *Pratylenchus thornei* can

52 Soilquality.org (2016) Crown rot: Qld. Factsheet, Soilquality.org, http://www.soilquality.org.au/factsheets/crown-rot-queensland

53 T Dixon (2013) Balancing crown rot and nematodes in wheat. Ground Cover. No. 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

suffer significantly greater yield loss from crown rot if both of these pathogens are present within a paddock.

See Section 8.3 Nematodes and crown rot in Section 8: Nematodes for more information.

FHB

FHB 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 deadheads or whiteheads in the crop. These heads contain pinched seed or no seed at all.

9.6.6 Management

Key points:

- *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.
- *Test.* A pre-sowing PreDicta B™ soil test will 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 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. [54]

Photo 16: *The GRDC's "Stop the crown rot" campaign.*

Source: GRDC

The disease may be controlled through planting more resistant varieties and using 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 chickpea, oats or any summer crop may be used as a disease-free rotation crop. [55]

Crop rotation

The most effective way to reduce crown rot inoculum is to include non-susceptible crops in the rotation sequence. The crown rot 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 crown rot fungus. Stubble decomposition varies with the type of break crop grown: canopy density and rate of the canopy closure as well as row spacing, the amount of soil water they use and seasonal rainfall.

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54 GRDC (2016) Tips and Tactics: Crown rot in winter cereals—Southern region.

55 DAF Qld (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

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, can be particularly effective, as these help to maintain a moist soil surface, which further promotes 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 decay of residue. However, it also spreads infected residue, which may increase plant infection rates in following crops, thus counteracting any benefits from increased rate of breakdown.

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

Variety selection

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

Where growers are aware their paddocks are infected with crown rot, resistant varieties can be used to limit yield loses. Growers need to be aware of the levels of crown rot disease in their paddocks, as even the most resistant crops can suffer yield loss under high levels of the disease. At intermediate levels of disease, the grower can take a calculated risk about returns versus yield loss by growing only resistant varieties. However, where high levels of disease are present even resistant varieties may be affected, and a break crop may be required.

NSW DPI trials at 23 sites in 2013–14 indicate that susceptibility can represent a yield benefit of around 0.50 t/ha in the presence of high levels of crown rot infection. However, variety choice is NOT a solution to crown rot with even the best variety still suffering up to 40% yield loss from crown rot under high infection levels and a dry/hot seasonal finish. [56]

Crop management

Stressed plants are most susceptible to the effects of crown rot. Thus, the use of management practices to optimise soil water and ensure good crop nutrition can help reduce the impacts of crown rot. Effective strategies 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.

Cultivation

The effect of cultivation on crown rot is complex, as it potentially impacts on all three phases of the disease cycle.

- Survival—stubble decomposition is a microbial process driven by temperature and moisture. Cultivating stubble in theory increases the rate of decomposition as it reduces particle size of stubble, buries the particles in the soil where microbial activity is greater and the soil environment maintains more optimal moisture and temperature conditions compared to the soil surface or above

56 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

VIDEOS

WATCH: GRDC, Grains research updates: Crown rot tolerance in new cereal cultivars

MORE INFORMATION

Tips and Tactics: Crown rot in winter cereals, southern region

Understanding crown rot underpins effective management, southern and western regions ground. However, cultivation also dries out the soil in the cultivation layer, which immediately slows down decomposition. Decomposition of cereal stubbles is a very slow process that requires adequate moisture for an extended period of time to occur completely. One summer fallow, even if extremely wet and stubble has been cultivated, is *not* long enough!

- Infection—the cultivation of winter cereal stubble harbouring the crown-rot fungus breaks the inoculum into smaller pieces and spreads them more evenly through the cultivation layer across the paddock. Consequently, the fungus is given a much greater chance of coming into contact with seedlings when the next winter cereal crop germinates and starts to grow. 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 sheaths at the soil surface, thus greatly reducing infection. 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 cultivation and reduces the water infiltration rate due to the loss of structure (e.g. macropores). The lack of cereal stubble cover can also increase soil evaporation. With poorer infiltration and higher evaporation, fallow efficiency 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

As stubble burning removes the above-ground portion of crown rot inoculum but the fungus will still survive in infected crown tissue below ground, burning is **NOT** a quick fix for high-inoculum situations. The removal of stubble by burning increases evaporation from the soil surface and makes fallow less efficient. A ‘cooler’ autumn burn is preferable to an earlier hotter burn as it minimises the loss of soil moisture while still reducing inoculum levels.

Reducing water loss

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

Grass-weed management

Grass weeds should be controlled in fallows and in crops, 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.

Sowing time

Earlier sowing within the recommended window for a given variety and region can bring the grainfill period forward and reduce the probability of moisture and temperature stress during grainfill. Earlier sowing can increase root length and depth and provide greater access to deeper soil water later in the season, which buffers against the expression of crown rot. This has been shown in NSW DPI research across seasons to reduce yield loss from crown rot. However, earlier sowing can place a crop at risk of frost damage during its most susceptible time.

Sowing time is a balancing act between the risk of frost and heat stress. However, when it comes to crown rot, increased disease expression with delayed sowing can have just as big an impact on yield as frost. The big difference from NSW DPI trial work is the additional detrimental impact of later sowing on grain size in the presence of crown rot infection.

Row placement

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 sheaths 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 a no-till cropping system. Further research conducted by NSW DPI has also demonstrated the benefits of row placement in combination with crop rotation and the placement of break crop rows and winter cereal rows in the sequence to limit disease and maximise yield. Sowing break crops between standing rows, which are kept intact, then sowing the following cereal crop directly over the row of the previous year's break crop, ensures four years between wheat rows being sown in the same row space. This substantially reduces the incidence of crown rot in cereal crops, improves establishment of break crops (especially canola), and chickpeas will benefit from reduced incidence of virus in standing stubble.

Soil type

The soil type does not directly affect the survival or infection phases of crown rot. However, the water-holding capacity of each soil type does affect the expression of crown rot by the degree to which it buffers triticale plants against moisture stress late in the season. Hence, yield loss can be worse on red soils than black soils due to the generally lower water-holding capacity of red soils. On top of this, other sub-soil constraints, e.g. sodicity, salinity or shallower soil depth, can also reduce the level of plant-available water, which can increase the expression of crown rot. [57]

Soil testing

In addition to visual symptoms, the DNA-based soil test PreDicta B can be used to assess the level of crown rot in the paddock. 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 varieties, and for assessing the risk after a non-cereal crop. [58]

PreDicta B has been developed for broadacre cropping regions in Australia and includes tests for:

- cereal cyst nematode (CCN)
- take-all
- Rhizoctonia barepatch
- crown rot
- root-lesion nematode
- stem nematode

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 to your local plant pathology laboratory. In order to get an accurate result, it is important to follow the PreDicta B sampling protocol precisely (Photo 17). [59]

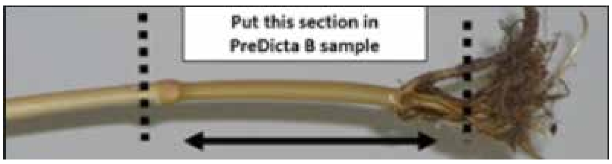

Photo 17: *It is important to follow the PreDicta B sampling protocol precisely.*

Source: GRDC.

MORE INFORMATION

PreDicta B

VIDEOS

WATCH: GRDC, Grains research updates: Improving PreDicta B

57 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

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

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

9.7 Common root rot

Common root rot (*Bipolaris*) is a soil-borne fungal disease that attacks cereals. 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 cereal sequences.

Common root rot symptoms:

- A dark-brown to black discolouration of the stem just below the soil surface.
- Black streaks on the base of stems.
- Slight root rotting.

One set of trials conducted by SARDI in the SA Mallee found that cereal rye increased *Bipolaris* inoculum levels in a paddock far greater than in volunteer pasture. Bipolaris inoculum levels at the Wynarka site after Bevy rye averaged 88 pgDNA/g in December compared to 18 pgDNA/g following the volunteer pasture. By seeding time these levels had grown to an average 163 pgDNA/g after the Bevy rye, and only 35pgDNA/g after volunteer pasture across 32 soil tests. As the wheat crop ripened in mid-October white heads marked the cereal rye strips, resulting in a 33% yield loss compared to the volunteer pasture (Photo 18). Generally cereal rye is an important break crop in the Mallee to improve soil health, and bipolaris is generally not a strong consideration when planning rotations. This problem was unexpected and suggests further work is needed in this area. [60]

MORE INFORMATION

No-till into pasture, SA Mallee.

Photo 18: *Crop after volunteer pasture (left) and crop after Bevy rye pasture (right) showing white heads in wheat and leading to ~30% yield loss.*

Source: PIRSA

9.7.1 Damage caused by disease

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

9.7.2 Symptoms

Paddock

- Affected plants tend to be scattered over a paddock, and they may be slightly stunted, have fewer tillers and produce smaller heads.
- There may be no distinct paddock symptoms, although the crop may lack vigour.

Plant

- Browning of roots and sub-crown internode (the piece of stem emerging from the seed to the crown) (Photo 19).
- Blackening of sub-crown internode in extreme cases.

60 C McDonough (2014) No-till into pasture, SA Mallee, http://23ha8gmx47t1jcm5w1sd58s7.wpengine.netdna-cdn.com/wp-content/uploads/2014/11/2012-62.-No-till-into-pasture-SA-Mallee.pdf

Photo 19: *Blackening of sub-crown internode in extreme cases.*

Source: SARDI in DAFWA

9.7.3 Conditions favouring development

Key points:

- Can occur from tillering onwards, but most obvious after flowering.
- Appears more prevalent in paddocks that are nitrogen (N) deficient. 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.
- The disease can be widespread through the grain belt; 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.

9.7.4 Management

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. [62]

Strategies for management:

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

62 DAF QLD (2015) Wheat—diseases, physiological disorders and frost, 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 pea, faba bean and canola.
- 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 SCI (sub-crown internode).
- Ensure adequate nutrition especially of phosphorus which reduces severity.
- Burning does not decrease spore levels in the soil. [63]

9.8 Smut

9.8.1 Bunt or stinking smut

This disease 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 and have darker green ears and gaping glumes than healthy plants (Photo 20). Bunt is usually only noticed at harvest when bunt balls and fragments are seen in the grain. Grain deliveries with traces of bunt balls are unlikely to be accepted at receival.

Photo 20: *Common bunt in cereal head showing glumes containing bunt balls.*

Source: 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.

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.

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

- All seed 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. [64]

9.8.2 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 21).

Photo 21: *Close up view of barley heads affected with loose smut.*

Source: DAFWA

If the spores settle on healthy flowers, they may germinate and infect the embryo of the developing seed. When this seed is planted, the smut grows inside the plant until flowering when the disease appears. Because loose smut is carried inside the seed, systemic seed dressings are needed to control it. These are more expensive than the others and should be used only when a high incidence of loose smut is expected. [65]

Managing 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. [66]

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

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

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

9.9 Rhizoctonia root rot

Key points:

- Rhizoctonia 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 is a fungal disease affecting 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 (*Rhizoctonia solani* Kuhn) in the soil prior to emergence. Minimum tillage practices decrease the rate of organic matter breakdown, thereby providing a habitat for *Rhizoctonia* over summer. The disease affects most major crops to varying degrees, with barley being most susceptible and oat crops are least susceptible. Bare patch and root rot of cereals, and damping off and hypocotyl rot of oilseed and legumes are all caused by differing strains of *R. solani*. [67]

In a trial in the SA Mallee, cereal rye was found to decrease levels of Rhizoctonia in a paddock from 43 pgDNA/g in December to 12 pgDNA/g in May. [68]

Rhizoctonia solani inoculum DNA levels were highest at late anthesis within the rotation crops. Inoculum levels were higher in wheat and cereal rye crops compared to that in non-cereal crops. Although cereal rye plants did not show visible Rhizoctonia damage above ground, the pathogen inoculum levels in the soils were similar to that in wheat. [69]

MORE INFORMATION

Karoonda break crops trails—soil biology and rhizoctonia disease.

9.9.1 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. [70]

VIDEOS

WATCH: Over the Fence: Improving soil health helps fight against rhizoctonia.

What to look for

Paddock

- Severely stunted plants occur in patches with a distinct edge between diseased and healthy plants.
- Patches vary in size from less than half a metre to several metres in diameter.

67 Soilquality.org (2016) Rhizoctonia—NSW, http://www.soilquality.org.au/factsheets/rhizoctonia-nsw

68 C McDonough (2014) No-till into pasture, SA Mallee, http://23ha8gmx47t1jcm5w1sd58s7.wpengine.netdna-cdn.com/wp-content/uploads/2014/11/2012-62.-No-till-into-pasture-SA-Mallee.pdf

69 V Gupta, S Kroker, D Smith, B Davoren, R Llewellyn, A Whitbread A (2011) Karoonda break crops trails—soil biology and rhyzoctonia disease, https://publications.csiro.au/rpr/download?pid=csiro:EP111477&dsid=DS3

70 Soilquality.org (2016) Rhizoctonia—NSW, http://www.soilquality.org.au/factsheets/rhizoctonia-nsw

- Patches of uneven growth occur from mid-winter when seminal roots have established (Photo 22).

Photo 22: *Patches vary in size from less than a metre to several metres in diameter. Stunted plants occur in patches with a distance edge between diseased and healthy plants.*

Source: DAFWA

Plant

- Affected plants are stunted with stiff, rolled leaves and are sometimes darker green than healthy plants (Photo 23).
- Roots of affected plants are short with characteristic pinched ends: 'spear tips' (Photo 24).

Photo 23: *Affected plants are stunted with stiff, rolled leaves that are sometimes darker than those of healthy plants.*

Source: DAFWA

VIDEOS

WATCH: How to diagnose Rhizoctonia root rot.

Photo 24: *Roots of affected plants are short with characteristic pinched ends or "spear tips".*

Source: DAFWA

9.9.2 Conditions favouring development

Rhizoctonia solani survives best in organic matter just below the surface of an undisturbed soil. The fungus benefits from summer rainfall events by infecting and multiplying on weeds, and has a limited ability to survive on the residue of previous seasons crops. The break of season initiates the development of the fungus in soil, thereby priming itself for infection of germinating seeds. Infection by the pathogen is encouraged by factors that restrict root growth, such as low soil fertility and 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* is most likely to be a severe problem where the plant is under stress from factors other than the disease, for example, low rainfall or poor nutrition.

Factors Affecting Rhizoctonia

There are certain soil conditions that favour *Rhizoctonia* development 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* infections.

Soil Disturbance

Rhizoctonia is sensitive to cultivation, with cultivation after rain and before sowing most effective at reducing infection. Disturbing the soil does not allow the fungus to prime itself for infection of the emerging crop.

Soil Moisture

Under moisture stress the crop becomes more susceptible to *R. solani* infection and has a decreased ability to get ahead of the disease. Rhizoctonia appears worse in crops emerging in dry cold growing conditions in light textured low nutrient soils.

Weeds

Poor weed management following late summer and early autumn rain allows *Rhizoctonia* to infect grass weeds, thereby allowing the fungus to multiply in preparation for the crop.

Herbicides

Sulfonylurea herbicides can sometimes worsen *Rhizoctonia*, and this is attributed to minor herbicidal effects on the crop. [71] Ensure soil Zinc levels are adequate or apply foliar zinc to help alleviate Group B herbicide effects.

9.9.3 Managing Rhizoctonia

Where reduced tillage is practiced, *Rhizoctonia* bare patch is best controlled through effective management of weeds and maintaining adequate nutrition for the establishing crop. Spraying weeds with a fast acting knock down 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.

Best tillage practices involve deep cultivation and shallow sowing, with minimal time between each event. 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*. The establishment of *R. solani* 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 a number of products on the market with claims for Rhizoctonia barepatch control. 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]

9.10 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.

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

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71 Soilquality.org (2016) Rhizoctonia—NSW, http://www.soilquality.org.au/factsheets/rhizoctonia-nsw

72 Soilquality.org (2016) Rhizoctonia—NSW, 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, and if growing susceptible varieties have the right chemicals on hand.
- 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).

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

Group	Active Ingredient	Example Product Name	Foliar (F), seed (S) or in-furrow (IF)
	Triadimefon	Triad®	F and IF
	Propiconazole	Tilt®	F
	Propiconazole + cyproconazole	Tilt® Xtra	F
	Tebuconazole	Folicur®	F and S
	Flutriafol	Impact®	F and IF
3 - DMI	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: R Oliver, Curtin University. In GRDC

VIDEOS

WATCH: GCTV9: Banding Fungicide in Cereals.

9.10.1 Fungicide stewardship

A number of pathogens, such as Septoria tritici blotch, have recently developed a level of fungicide insensitivity/resistance in Australia. The occurrence of these highlights the important role all growers play in fungicide resistance management.

To help achieve fungicide resistance management and disease management, there are three important steps growers need to implement:

1. Remove the source of infection.

- 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.

- This reduces all forms of the pathogen irrespective of resistance and reduces the initial establishment of disease.
- Do not sow wheat on wheat or barley on barley to avoid rapid disease build-up.

2. Variety choice.

- Under high disease pressure, a variety rated MR-MS can reduce the leaf area loss substantially. Where possible, choose a more resistant variety.
- Host resistance reduces all forms of the pathogen irrespective of resistance and reduces the need for multiple canopy fungicide applications.
- But resistance ratings do change, so crops must still be monitored in season for higher than expected reactions and 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 (SDHI) 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.

Timing of application in the disease epidemic is critical to getting the most out of these products. [73]

MORE INFORMATION

GRDC Cereal Fungicides Factsheet.

Crop diseases after drought.

9.11 Disease following extreme weather events

9.11.1 Cereal disease after drought

Drought reduces the breakdown of plant residues. This means that inoculum of some diseases does not decrease as quickly as expected, and will carry over for more than one growing season, such as with crown rot. 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.

Within the drought year, 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.

Low stock numbers make it difficult to control these volunteers, which provide a green bridge for rusts, viruses and virus vectors, and many other pathogens.

Weeds that harbour diseases are harder to kill.

Soil water and nitrogen may be unbalanced and these are likely to impact on diseases. [74]

9.11.2 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.

The legacy of the floods and rain included transport of inoculum (crown rot, nematodes, leaf spots through movement of infected stubble and soil) (Photo 25),

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

74 G Murray, T Hind-Lanoiselet, K Moore, S Simpfendorfer, J Edwards (2006) Crop diseases after drought. Primefacts 408. NSW DPI, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/123718/crop-diseases-after-drought.pdf

development of sexual stages (leaf spots, head blights), survival of volunteers (unharvested material and self-sown plants in double-crop situations), and weather damaged seed. [75]

Photo 25: *Tan spot infected stubble following flood.*

Photo: Rachel Bowman. Source: Seedbed Media

75 DAFF (2013) Winter cereals pathology. Department of Agriculture, Fisheries and Forestry Queensland, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/winter-cereals-pathology