SOUTHERN
SEPTEMBER 2018

GRDC GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

BARLEY

SECTION 9

DISEASES

CAUSES OF CEREAL DISEASES | THE DISEASE TRIANGLE | VARIETY RESPONSE | ENVIRONMENTAL FACTORS | MANAGEMENT OPTIONS | FOLIAR DISEASES | ROOT AND CROWN DISEASES

SECTION 9

Diseases

More information

[GRDC: Current and potential costs from diseases of barley in Australia]

Barley diseases cause an estimated current average annual loss of AU$252 million, or $66.49 per hectare, to the Australian barley industry. In the decade to 2009, this loss represented 19.5% of the average annual value of the barley crop. [1] In the Southern Region, cereal cyst nematode, net blotch (spot form), leaf rust, net blotch (net form) and barley grass stripe rust are the main diseases affecting barley (Table 1). They can all have serious impacts on grain yield and quality. [2]

Diseases occur when a susceptible host is exposed to a virulent pathogen under favourable environmental conditions. Control is best achieved by knowing the pathogens involved and manipulating the interacting factors. Little can be done to modify the environment, but growers can minimise the risk of diseases by sowing resistant varieties and adopting management practices to reduce inoculum levels. Rotate barley crops with non-hosts such as legumes, avoid sowing barley on barley, and maintain clean fallows. Sowing out of season favours disease development and can build up inoculum early in the season. [3]

Table 1: Five major diseases by potential loss in Southern Region

Disease	$/ha	$ million
Cereal cyst nematode	62.64	148
Net blotch, spot form	55.23	131
Leaf rust	30.49	72
Net blotch, net form	22.87	54
Barley grass stripe rust	22.73	54

Diseases can severely affect yield and quality in barley. In some cases, diseases are controlled through simple cultural practices and good farm hygiene. One of the major practices used in the control of diseases is crop rotation.

To minimise the effect of diseases:

- 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 which crop is grown in which paddock the following year.
- Conduct in-fallow disease audits to determine the severity of the disease (e.g. crown rot, cereal cyst nematode, Rhizoctonia bare patch). This can also be used as a tool to determine which crop is grown in which paddock the following year.
- Send plant or stubble samples away for analysis to determine the pathogen or strain, or the severity of the disease.

1 G Murray, JP Brennan (2009) The current and potential costs from diseases of barley in Australia. GRDC, http://www.grdc.com.au/~/media/CF32E282F9E241488125CD98A6567EB8.pdf

2 UNE Sustainable Grains Production course notes.

3 DAF Qld (2012) Barley diseases. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/barley/diseases

More information

[GRDC: The current and potential costs from diseases of barley in Australia]

[GRDC Fact Sheets: Green bridge control is integral to pest and disease management]

- Keep the farm free from weeds, which may carry over some diseases. This includes self-sown cereals over summer that may act as a green bridge.
- Rotate crops. [4]

Disease epidemics develop when susceptible varieties are sown over wide areas in the presence of plentiful inoculum under favourable environmental conditions. The year 2010 provided the most favourable conditions for the development of foliar diseases for 12 years, and generated epidemics of yellow spot in wheat, and spot form of net blotch, leaf scald and leaf rust in barley. After several years of relatively low levels of these diseases, all of these factors contributing to epidemic development combined to initiate epidemics quite early in crop development. [5]

Some diseases are easily identifiable visually and others require stubble or soil tests to identify inoculum types and infestations in paddocks. Selecting suitable varieties as part of your rotation is essential to combat yield and/or quality losses and even disease epidemics on-farm.

For more information on variety characteristics and reaction to diseases, see the NSW Department of Primary Industries (DPI) publication: Winter crop variety sowing guide 2015.

9.1 Causes of cereal diseases

Cereal diseases are caused by fungi, viruses, bacteria and nematodes.

These pathogens (disease-causing organisms) often reduce grain yields by damaging green leaves, preventing them from producing the sugars and proteins needed for growth. In other cases, they block or damage the plant's internal transport mechanisms, reducing the movement of water and sugars through the plant. Yields are also reduced when the pathogen diverts the plant's energy into reproducing more of the pathogen at the expense of plant growth or grain formation.

9.1.1 Fungi

Fungi come in a diverse variety of forms. They spread by producing one or more types of spores, which may be carried by wind, through raindrop splashes or, in the case of smuts, by mechanical movement and mixing during harvest. Some fungi survive as spores in the soil, on seed or on plant debris. Others survive as fine threads of growth inside plant debris or seed, and produce fresh spores in the following season. Spores are sometimes produced inside small fruiting bodies on infected plant tissue or stubble. Some diseases such as rust require continuous green host plants to survive from one season to the next.

9.1.2 Viruses

Viruses are invisible to the eye and even through a conventional microscope. Unlike other pathogens, viruses are totally dependent on the host for growth and multiplication. They cannot survive outside the plant, except in an insect or other animal that transmits the disease. They often damage plants by blocking its transport mechanisms. *Barley yellow dwarf virus* (BYDV) is a virus that affects all of the cereals.

9.1.3 Bacteria

Bacteria differ from fungi in that they do not form fine threads of growth, but instead multiply rapidly by continually dividing. They grow best under damp conditions and do not survive as well as fungi under dry conditions.

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

[5] G Platz (2011) Yellow spot in wheat; leaf rust and net blotch diseases in barley—lessons from 2010 for better management in 2011. GRDC Update Papers 19 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Yellow-spot-in-wheat-leaf-rust-and-net-blotch-diseases-in-barley-lessons-from-2010-for-better-management-in-2011

A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

9.1.4 Nematodes

Nematodes are worm-like animals that cause various diseases in cereals. Most nematodes attack the plant roots or lower stems. An exception is the seed gall nematode, which causes cockles in wheat. Nematodes feeding on plants cause direct damage by reducing root area, damaging the transport mechanism, or, in the case of the seed gall nematode, by replacing the grain with galls full of nematodes. [6]

9.2 The disease triangle

Plant pathologists talk about the occurrence of disease in terms of the '*disease triangle'* (Figure 1)—an interaction of host, pathogen and environment. Alteration to any of these components of the disease triangle will influence the level of disease.

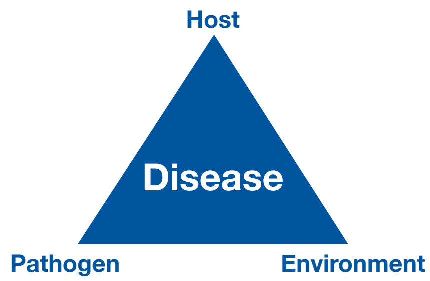

Figure 1: The disease triangle.

For disease to occur, there must be a susceptible host and a virulent pathogen, and the environment must be favourable. Some important examples of interactions of environmental conditions with diseases of grain crops are as follows:

- Low temperatures reduce plant vigour. Seedlings, especially of summer crops, become more susceptible to *Pythium*, *Rhizoctonia* and other root and damping-off pathogens if they are emerging in soils at below their optimum temperature.
- Pathogens have different optimum temperature ranges. For example, hatching in nematodes tends to occur over narrow soil temperature ranges, 10–25°C and optimal at 20°C, whereas take-all fungus *Gaeumannomyces graminis* var. *tritici* is more competitive with the soil microflora in cooler soils. This can lead to diseases being more prevalent in certain seasons or in different areas, such as wheat stem rust in warmer areas and stripe rust in cooler areas.
- Fungi such as *Pythium* and *Phytophthora* that have swimming spores require high levels of soil moisture in order to infect plants; hence, they are most severe in wet soils.
- Foliar fungal pathogens such as rusts require free water on leaves for infection. The rate at which most leaf diseases progress in the crop depends on the frequency and duration of rain or dew periods.
- Diseases that attack the roots or stem bases, such as crown rot, reduce the ability of plants to move water and nutrients into the developing grain. These diseases generally have more severe symptoms and larger effects on yield if plants are subject to water stress. [7]

Information on the main diseases affecting wheat, including their control, is presented in Table 2.

[6] H Wallwork (2000) Cereal leaf and stem diseases. GRDC.

[7] UNE Sustainable Grains Production course notes.

Table 2: Barley disease guide

Table has been developed from information in the publications: H Wallwork (Ed) (2000) Cereal root and crown diseases (GRDC, SARDI) and H Wallwork (Ed) (2000) Cereal leaf and stem diseases (GRDC, SARDI).

Disease	Organism	Symptoms	Occurrence	Inoculum source	Control
Foliar					
Scald	*Rhynchosporium secalis*	Water-soaked areas on leaves. Lesions appear grey-green then bleached with brown margins	Years with frequent rain, and early sown crops	Residues of barley and barley grass. Can be seed-borne. Spores spread by rain-splash	Resistant varieties, clean seed, managing barley and barley grass debris. Seed and foliar fungicides
Net blotch spot form	*Pyrenophora teres* f. *maculata*	Dark brown spots to 10 mm, with yellow margins	Infection from stubble especially in wet autumn conditions.	Barley and barley grass stubble, also airborne spores from infected crops.	Control barley grass and manage barley stubble. Avoid very susceptible varieties. Foliar fungicides
Net blotch net form	*Pyrenophora teres* f. *teres*	Small brown spots that develop into dark brown streaks on leaf blades that have net like appearance	Spores can be produced for >2 years on stubble. Moist conditions, temperatures in the 15–25°C range	Survives on infected barley and barley grass residues. Wind borne spores	Resistant varieties, crop rotation and stubble management
Powdery mildew	*Blumeria graminis* f.sp. *hordei*	White powdery spores on upper leaf surfaces, underside of leaves turn yellow to brown	Favoured by high humidity and temperature of 15–22°C. Worse in high-fertility paddocks and early sown crops	Volunteer barley, barley grass and crop residue. Airborne spores	Resistant varieties. Seed and foliar fungicides
Leaf rust	*Puccinia hordei*	Small circular orange pustules on upper leaf surface	Moist conditions with temperatures in the range 15–22°C	Living plant hosts including barley, barley grass and Star of Bethlehem	Use resistant varieties and control volunteer barley and barley grass over summer–autumn
Stem rust	*Puccinia graminis*	Large red-brown pustules. Rupture of leaf and stem surface	Infection requires temperatures in the 15–30°C range and moist conditions	Living plant hosts including volunteer cereals (wheat, barley, triticale and rye)	Use resistant varieties and control volunteer wheat, triticale and barley over summer–autumn
BGSR (barley grass stripe rust)	*Puccinia striiformis*	Yellow powdery pustules in stripes on the leaves	Can develop throughout the growing season	Barley grass and susceptible barley varieties	Avoid susceptible varieties
BYDV	*Barley yellow dwarf virus*	Yellow stripes between leaf veins, some leaves red. Sterile heads and dwarfing plants	Virus is transmitted by aphids	Hosts include all cereals and many grasses	Resistant varieties. Chemical control of aphids may be suitable for high value crops
Wirrega blotch	*Drechslera wirreganensis*	Brown blotches often with hole in centre	Minor occurrence	Range of grass weeds and cereal stubble	Crop rotation. Avoid growing susceptible varieties, control grass weeds
Ringspot	*Drechslera campanulata*	Small brown rimmed spots on leaves	Common and widespread in southern Australia	Wide range of cereals and grass weeds. Barley seed in crop residue infected with fungus	Crop rotation and weed control
Halo spot	*Pseudoseptoria stomaticola*	Small white-brown lesions.	Cool, moist conditions	Residues of barley and grasses. Rain-splash	Disease is not of economic importance
Grain					
Covered smut	*Ustilago segetum* var. *hordei*	Dark, compacted heads, grain replaced by smut balls	Spores germinate in infected grain when temperatures are 14–25°C	Infected seed	Use disease free seed, resistant varieties, seed treatments

Disease	Organism	Symptoms	Occurrence	Inoculum source	Control
Loose smut	*Ustilago tritici*	Dark brown powdery spores replace grain	Moist conditions at flowering and when temperatures are 16–22°C	Infected seed	Use disease-free seed and seed treatments. Avoid susceptible varieties
Root/crown					
Crown rot	*Fusarium pseudograminearum, F. culmorum*	'Whiteheads' or deadheads most obvious after flowering, pink discoloration under leaf sheaths	Most common on heavy or poorly drained soils. Favoured by moist, humid conditions with temperatures 15–30°C	Survives in infected stubble residue for up to 2 years. Hosts include wheat, barley, triticale and some grasses	Crop rotation, stubble removal, cultivation
Pythium root rot (Damping off)	*Pythium* spp.	Stunted seedlings, reduced tillering, pale stunted or stubby roots with light brown tips	Favoured by wet conditions. Increased risk where high rainfall occurs after sowing	Spores survive in soil or plant debris for up to 5 years	Avoid deep sowing into cold wet soils, especially when direct drilling. Ensure good nutrient levels
Common root rot	*Bipolaris sorokiniana*	Brown discoloration of roots, sub-crown internode and crown. Plant stunting, brown spots on leaves and reduced tillers	Scattered through crop	Wheat, barley, triticale and rye	Crop rotation
Cereal cyst nematode (CCN)	*Heterodera avenae*	Yellow, stunted plants. Knotted roots	Light soils and well-structured clays where cereals are commonly grown	Present in most soils in the southern region	Resistant varieties, break from susceptible cereals and grasses, particularly wild oats
Root lesion nematode (RLN)	*Pratylenchus thornei*. *P. neglectus*	Reduced tillering, ill thrift; lesions on roots, lack of branching of root system	Favoured by cereals in rotation with chickpeas, medic and vetch	Survives as dormant nematodes in the soil	Crop rotation using resistant crops and resistant varieties
Take-all	*Gaeumannomyces graminis* var. *tritici* (*Ggt*)	Stunted or yellowing plants, 'whiteheads' at heading	Fungus thrives under warm, damp conditions	Fungus survives over summer in crowns and roots of wheat, barley and grass plants	Crop rotations, at least one year free of hosts (cereals and grasses, especially barley grass). Fungicide applied to seed or fertiliser

9.3 Variety response

Barley varieties carry varying tolerance and resistance to diseases (Table 3).

Table 3: Barley variety disease ratings

BGSR, Barley grass stripe rust. Varieties marked may be more susceptible if alternative strains are present; p, rating provisional (treat with caution); R, resistant; R-MR, resistant to moderately resistant; MR, moderately resistant; MR-MS, moderately resistant to moderately susceptible; MS, moderately susceptible; MS-S, moderately susceptible to susceptible; S, susceptible; S-VS, susceptible to very susceptible; VS, very susceptible

	Leaf scald	Net blotch		Powdery mildew	Leaf rust	BYDV	CCN resis.	RLN resistance		BGSR
		Spot form	Net form					*P. neglectus*	*P. thornei*	
Malting barley										
Baudinⓓ	S-VS	MS-S	MR-MS#	VS	VS	MR	S	MR	–	R
Bulokeⓓ	MS	S	MR	MR	S-VS	MR-MS	S	MR-MS	MR-MS	R
Commanderⓓ	S	MSS	MS-S	MR-MS#	S	MR-MS	R	MR-MS	MR-MS	R
Fairviewⓓ	S-VS	S	S	R-MR	MRp	MR	–	–	–	R
Gairdner	S-VS	S	MR-MS	S	S	S	S	MR-MS	MS	R
GrangeRⓓ	S	S-VS	MS	MR	MR#	MR-MS	R	MR	MR	R
Navigatorⓓ	MR-MS	MR-MS	MR#	R	VS	S	R	MR-MS	MR-MS	R
Scope CLⓓ	MS-S	MSS	MR	R#	S-VS	MR	S	MR-MS	MR-MS	R
Westminsterⓓ	R#	S	MS-S	R	MR-MS	MR-MS	–	MR-MS	MR-MSp	R
Wimmeraⓓ	MS-S	S	MS-S	S	MR#	MR-MS	S	MR-MS	MR-MS	MR
Feed barley										
Capstanⓓ	S	MS	MS-S	MR	MR-MS	S	R	–	–	MR-MS
Fathomⓓ	MR#	MR	MS	MR-MS	MS-S	MR-MS	R	MR-MS	MR-MS	R
Fleetⓓ	MS-S	MR	MR-MS#	MR	MS-S	MR-MS	R	MR-MS	MR-MS	R
Hindmarshⓓ	S-VS	S-VS	MR	MR-MS#	MS-S	S	R	MR-MS	MR-MS	R
Keelⓓ	MS	MR	MR#	MS	VS	S	R	–	–	MS
Oxford	MS-S#	S	MS	R	MR	MS	S	MR	MR-MS	R
Barley under malt evaluation										
Compassⓓ	MS#	MS-S	MR#	MR#	VS	MR	R	MR	MR	R
Flindersⓓ	S	S	S	R-MR	MS	MR-MS	S	MR-MS	MR	R
La Trobeⓓ	VS	S	MR	MR-MS#	MS-S	S	R	MR	MR	R
Skipperⓓ	S	MR-MS	MR	MR	SVS	MR	R	MR-MS	MR-MS	R
SY Rattlerⓓ	MS#	SVS	MR#	R	MR-MS	S	–	RMR	MR-MS	R

9.4 Environmental factors

9.4.1 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 occurs with crown rot, net blotches and leaf scald. The expected benefits of crop rotation may not occur or may be limited. Conversely, bacterial numbers decline in dry soil. Some bacteria are important antagonists of soilborne fungal diseases such as common root rot, and these diseases can be more severe after drought.

For information, see the NSW DPI information sheet: Cereal diseases after drought. [8]

[8] G Murray, T Hind-Lanoiselet, K Moore, S Simpfendorfer, J Edwards (2006) Cereal diseases after drought. Primefacts. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/123718/crop-diseases-after-drought.pdf

9.4.2 Cereal disease after flood events

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 floods and rain includes transport of inoculum (crown rot, nematodes, leaf spots through movement of infected stubble and soil), 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.

Cereal diseases that need living plants over-season on volunteer (self-sown) crops. This is particularly so for rusts and mildews. Diseases such as yellow spot, net blotches and head blights survive on stubble. Crown rot and nematodes over-season in soil.

Problems are recognised by inspecting plants. Leaf and stem rusts produce visible pustules on leaves, whereas stripe rust survives as dormant mycelium, with spores not being produced until temperatures favour disease development.

The presence of leaf spots is recognised by the occurrence of fruiting bodies (pseudothecia) on straw and lesions on volunteers. Head blights produce fruiting bodies (perithecia) on straw, and crown rot survives mainly as mycelia in straw. Soilborne nematodes are detected through soil tests. [9]

9.5 Management options

Management options for disease control include elimination of volunteers, if possible having a 4-week period that is totally host-free, crop rotation with non-hosts, growing resistant varieties, reduction of stubble, and use of fungicides.

Fungicides are far more effective as protectants than eradicants, so are best applied prior to, or very soon after, infection. Systemic fungicides work within the sprayed leaf, providing 3–5 weeks of protection. Leaves produced after this spraying are not protected. Spray to protect the upper three or four leaves, which are the most important because they contribute to grainfill. In general, rusts are easier to control than leaf spots. Fungicides do not improve yield potential; they can only protect the existing yield potential.

The application of fungicides is an economic decision, and in many cases, a higher application rate can give a better economic return through greater yield and higher grain quality. Timing and rate of application are more important than product selection. Stripe-rust ratings in variety guides are for adult plant response to the pathogen and may not accurately reflect seedling response. [10]

9.5.1 Strategies

The incidence and severity of disease will depend on the environment, but with plentiful inoculum present, even in a season with average weather, disease risks will be significant.

Strategies include:

- using the best available seed
- identifying your risks
- formulating management strategies based on perceived risk
- monitoring crops regularly
- timely intervention with fungicides [11]

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

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

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

FAQ

9.6 Foliar diseases

9.6.1 Rusts

Rusts are important diseases of barley and can cause severe crop damage in susceptible varieties when conditions are conducive. The rusts can, however, be effectively controlled with resistant varieties and cultural management methods such as controlling volunteers between seasons and the use of foliar fungicides.

Four rusts can attack barley:

- Leaf rust (caused by *Puccinia hordei*) is the most common.
- Stem rust (caused by *Puccinia graminis*) is less common but can cause severe crop loss in favourable years.
- Barley grass stripe rust (causal agent currently unnamed) is common and infects some susceptible varieties.
- Barley stripe rust (caused by *Puccinia striiformis*) is an exotic disease.

Leaf rust occurs in susceptible varieties in most years, especially in high-rainfall regions. Early infections (June–July) can result in yield losses of up to 20%. Stem rust is potentially the most devastating disease of the rusts and is able to cause complete crop loss; however, suitable conditions for a severe outbreak are rare. Barley grass stripe rust can cause yield loss in susceptible varieties when conditions are favourable. The exotic pathogen barley stripe rust will cause severe losses in most varieties if it is introduced to Australia. [12]

More information

CropPro: Foliar diseases of barley

Plants facilitating the survival of rust fungi through the summer are known as the 'green bridge'. These are alternative hosts or volunteer cereals.

Rust diseases can be 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.

Wherever possible, varieties that are resistant should be sown (i.e. MR, moderately resistant and above).

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 regularly monitored for foliar diseases. See the University of Sydney's Plant Breeding Institute (PBI) site and their publications for more information.

Monitoring should start no later than Zadoks growth stage (GS) 32, the second node stage on the main stem, and continue to at least GS39, the flag-leaf stage. This is because the flag leaf and the two leaves below it are the main factories contributing to yield and quality. It is most important to protect these leaves from diseases. [13]

Some areas of South Australia are very prone to barley leaf rust and infections can show up earlier than GS 32.

Agronomist's view

To keep up to date with rust incursions throughout the winter crop season, subscribe to the PBI Cereal Rust Report.

[12] CropPro. Foliar diseases of barley. GRDC/State Government Victoria, http://www.croppro.com.au/crop_disease_manual/ch02s04.php

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

The PBI also offers a rust-testing service for growers and agronomists. For more details, see the Dispatch forms at: http://sydney.edu.au/agriculture/plant_breeding_institute/cereal_rust/reports_forms.shtml#df.

Key points to reduce the risk of rusts in cereals

- Destroy volunteer cereal plants by March, because they can provide a green bridge for rust carryover.
- Community effort is required to eradicate volunteers from roadsides, railway lines, bridges, paddocks and around silos.
- Growing resistant varieties is an economical and environmentally friendly means of disease reduction.
- Seed or fertiliser treatment can control stripe rust up to 4 weeks after sowing and suppress it thereafter.
- During the growing season, active crop monitoring is important for early detection of diseases.
- Correct disease identification is crucial; you can consult state agricultural department fact sheets, charts, websites and experts.
- When deciding whether 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 important.
- Read the label and wear protective gear; protect yourself and the environment.
- Avoid repeated use of fungicides with the same active ingredient in the same season.
- Check for withholding periods before grazing and harvesting a crop that has received any fungicide application.
- If you suspect a severe disease outbreak, especially on resistant varieties, contact your state agricultural department.

Adult plant resistance (APR) is a useful trait to consider in variety selection, especially for rust resistance. Understanding how it works can make fungicide application decisions easier. APR to cereal fungal diseases provides protection in a crop's post-seedling stages (typically between tillering and booting, GS20–GS49).

Seedling resistance, by comparison, is effective at all growth stages. APR can complement a fungicide strategy by protecting from rust those parts of the plant most responsible for yield. When selecting a variety, choose one rated at least MR–MS (moderately resistant–moderately susceptible, the minimum disease resistance standard). In high-risk regions, varieties rated at least MR are recommended.

Where the more susceptible varieties are used, ensure that a suitable fungicide strategy is in place, with the right chemicals available at short notice. Fungicides are better at protecting than curing. Fungicide applications on badly infected crops provide poorer control and do not restore lost green leaf area. [14]

Recommended fungicides for rusts

To keep up to date with the latest recommended fungicides for rusts, visit: Australian Pesticides and Veterinary Medicines Authority.

More information

GRDC Fact Sheets: Adult plant resistance

More information

GRDC Update Papers: Stripe rust—prevention is generally best

GRDC Update Papers: Fungicide management of stript rust in wheat: up-front vs in-crop options

[14] GRDC (2012) Adult plant resistance. Northern, Western and Southern Regions. GRDC Fact Sheet, 2 Nov. 2012, http://www.grdc.com.au/GRDC-FS-AdultPlantResistance

9.6.2 What to look for

Leaf rust of barley

Pustules of leaf rust are small and circular, producing a mass of orange-brown powdery spores predominantly on the upper leaf surfaces (Figure 2). Later in the season, pustules also develop on leaf sheaths. The pustules easily rub off on a finger. As the crop matures the pustules turn dark and produce black spores embedded in the old plant tissues. Leaf and stem rust may be confused but are distinguished by their colour and size, leaf rust being lighter coloured, smaller and rounder than stem rust.

Figure 2: Leaf rust symptoms on barley leaf.

Stem rust of barley

The large pustules are oval to elongated, and are often surrounded by a characteristic torn margin (Figure 3). The pustules are full of reddish brown spores, which fall away easily. They can occur on stems, leaf surfaces, the leaf sheaths and heads. As a plant matures, the pustules produce black spores that do not dislodge.

Figure 3: Stem rust symptoms on barley.

Barley grass stripe rust

Symptoms are very similar to stripe rust in wheat. Bright yellow-orange spores form pustules, which occur in stripes along the leaves (Figure 4). In young leaves, the pustules tend to be scattered across the leaf. Spores rub off easily onto a finger. Barley grass stripe rust and barley stripe rust have the same symptoms. If barley stripe rust is suspected check the Agriculture Victoria Cereal disease guide for a resistance rating. It should be reported to Department of Primary Industries pathology staff.

Figure 4: Barley grass stripe rust symptoms on barley.

9.6.3 Disease cycle

Leaf rust of barley

The primary source of inoculum for leaf rust is green volunteer barley plants that survive over summer. However, the 'Star of Bethlehem' (*Ornithogalum umbellatum*) weed (Figure 5) can also be a source of inoculum through teleospores, which are able to undergo a sexual reproductive cycle that produces a new generation of spores to re-infect barley.

Figure 5: Star of Bethlehem, a source of inoculum for leaf rust.

The existence of a sexual cycle means that new strains of rust can occur, thus increasing the chance of the rust overcoming current resistance. Currently the Star of Bethlehem weed occurs in South Australia, with isolated occurrences through the Victorian cropping zone. Development of leaf rust is most rapid during warm (15–20°C) moist (rain or dew) weather. Crops sown before May, when nights are still warm, are often more severely infected.

Stem rust of barley

Stem rust survives the summer on volunteer wheat, barley, triticale and grasses, including common wheat grass and barley grass. Spores are spread from these hosts to the new crop by the wind. High humidity and heavy dew favour its development. It is most rapid at temperatures near 20°C and is markedly reduced by temperatures ≤15°C and ≥40°C. Wet summer weather causes growth of self-sown wheat and other hosts of stem rust. These plants can become heavily infected with stem rust in autumn and be a source of rust for the new season's barley or wheat crop. If these conditions are followed by a mild winter and a warm wet spring, the chances of a stem rust epidemic are high.

Barley grass stripe rust

Barley grass stripe rust survives over summer on self-sown barley and barley grass. Little is known about the conditions that favour its infection.

9.6.4 Management of barley rusts

Resistant varieties

The most effective way to control the three rusts of barley is to grow varieties with resistance to each disease. It is important to note that these rusts are able to produce new races, which are capable of attacking varieties that were resistant when they were first released. To select varieties with resistance, it is essential to consult an updated Agriculture Victoria Cereal disease guide. By growing resistant varieties, the amount of disease in a crop and neighbouring crops is reduced, the chance of the rusts mutating, enabling them to attack previously resistant varieties is reduced, and the resistances currently available are better protected.

Cultural practices

It is important to remove the inoculum provided by self-sown barley over summer where possible. These rusts survive predominantly on summer volunteers, which provide significant inoculum loads if left unmanaged. Even small amounts of rust not destroyed in the autumn can multiply to cause serious yield losses if spring weather conditions are favourable for diseases. Use grazing or herbicides to remove green growth, especially during wet summers.

Seed treatment

Several seed treatments are registered for rust control in barley; however, efficacy varies between active ingredients, so it is strongly recommend that a cereal seed treatment guide, such as PIRSA's Cereal seed treatments 2016, be consulted.

Fungicides

A range of fertiliser and foliar applied fungicides is available that will give disease suppression of leaf rust in barley. Research has shown that the most effective suppression of leaf rust was achieved when foliar fungicides were applied early in epidemic. Additional applications may also be required where rust pressure is sustained during a wet spring. Fertiliser-applied fungicides can also provide suppression of barley leaf rust; however, their effectiveness is restricted to the seedling stages of crop development and additional application/s of foliar fungicide may be required.

Systiva® (from BASF) is being marketed as a seed-applied foliar fungicide.

Agronomist's view

Figure 6: Scald of barley. Early water-soaked, grey-green symptoms compared with later straw-coloured lesions with a distinctive brown margin.

Scald of barley

Barley scald is caused by the fungus *Rhynchosporium secalis* and is common in Victorian barley crops in most seasons. Its severity varies between crops and seasons, but in general, it is more prevalent in high-rainfall areas. Field experiments have estimated grain yield losses due to scald to be 10–20% in susceptible varieties, and individual losses as high as 45% have been recorded.

What to look for

The disease causes scald-like lesions of the leaf blades and sheaths. At first, the lesions are water-soaked, but they change from grey-green to a final straw colour with a distinctive brown margin, and are ovate to irregular in shape (Figure 6). In severe infections, the disease may virtually cause defoliation by coalescing of the lesions (Figure 7). The size and colour of the lesions and their presence on the older leaves distinguishes scald from numerous other lesions, often non-parasitic, which may be seen on barley after heading.

Figure 7: Severe scald of barley: Note the scald-like lesions can coalesce and cause complete leaf loss.

Disease cycle

Rhynchosporium secalis survives over summer on stubble of infected plants. During the growing season and in wet weather, spores are produced on the stubble and are dispersed by rain splash into the new season's crop, where they start the primary infection (Figure 8). Scald is usually first observed in isolated patches in the crop when plants are tillering. Further spread is caused by splash dispersal of spores, which is more rapid in the warmer months. By the end of the growing season scald is usually evenly distributed within the crop with distinct hotspots. The disease is more severe in seasons of above average rainfall, particularly during the spring.

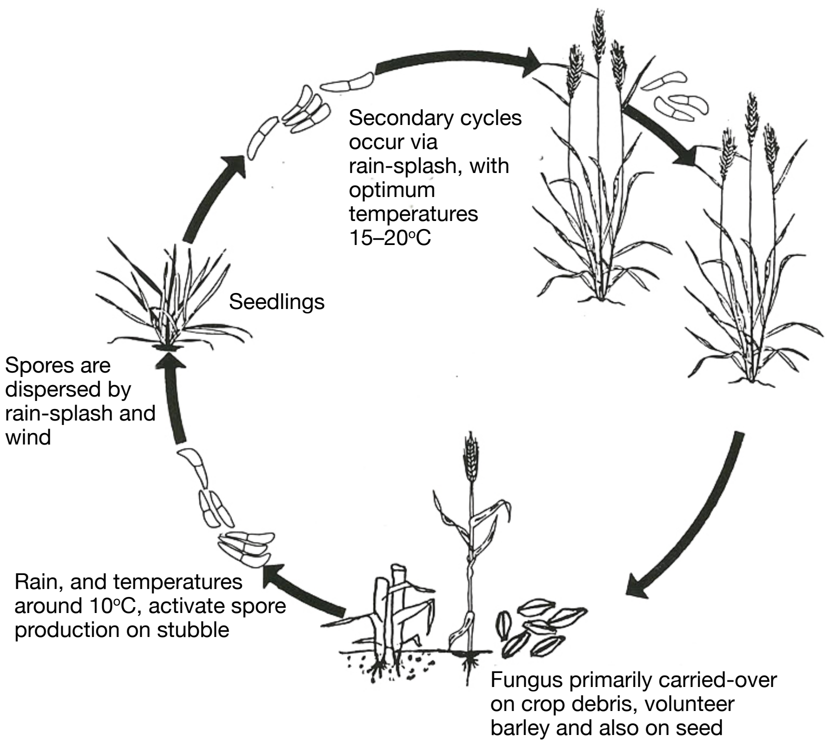

Figure 8: Disease cycle of barley scald.

Hosts

Scald can be seed-borne, infect barley grass and survive on volunteers. These sources are not as important as infected stubble but can be an inoculum source for barley crops, especially during seasons with favourable climatic conditions.

Management

- Cultural practices. Reducing infected stubble and barley grass by grazing, burning or cultivation decreases the carry-over of the fungus between crops. However, these practices will not eliminate the disease altogether because scald will survive on any remaining residue. Rotations involving consecutive barley crops should be avoided, with up to 2 years required between crops for residue to break down sufficiently. Scald is also worse in early-sown crops, so avoiding early sowing of susceptible varieties, especially in high-rainfall areas, will reduce the loss caused by scald.
- Resistant varieties. Cultivation of resistant varieties gives the best long-term control of the disease. The risk of grain yield and quality loss is also greatly reduced by avoiding growing susceptible and very susceptible varieties. However, the fungus is pathogenically variable, with resistance being broken down over time. The most recent example is the variety Hindmarsh⊕, which was initially resistant but is now susceptible to scald. It is important to check the Agriculture Victoria Cereal disease guide for the resistance status of varieties.
- Fungicides. A range of foliar fungicides is available that will provide suppression of scald. Experiments conducted during 2010 and 2011 showed that the best suppression of scald was achieved when foliar fungicides were applied between the beginning of stem elongation (GS31) and flag leaf emergence (GS39). A single application of foliar fungicide may be insufficient to eliminate grain yield and quality loss. In some cases, a two-application strategy at both GS31 and GS39 may be warranted. Application of foliar fungicides at ear emergence (GS50) is likely to provide reductions in losses; however, this may not be economically viable. Fertiliser- and seed-applied fungicides are also available for suppression of scald;

however, with the exception of Systiva® (active ingredient fluxapyroxad), they are effective only at the seedling stages and therefore crops need to be monitored and foliar fungicides applied as necessary.

Net blotch

There are two forms of net blotch present in Australia. The net form of net blotch, caused by the fungus *Pyrenophora teres* f. *teres*, is currently less common in south-eastern Australia because the majority of barley varieties are resistant, but it can be more damaging. The spot form of net blotch, caused by *Pyrenophora teres* f. *maculata*, is more common, due to the widespread cultivation of susceptible varieties, especially in Victoria where recent surveys have estimated it to be present in >95% of crops. However, losses to spot form of net blotch are minimal in most cases.

Spot form of net blotch—what to look for

Symptoms are most commonly found on leaves, but occasionally on leaf sheaths. Symptoms develop as small circular or elliptical dark brown spots surrounded by a chlorotic zone of varying width (Figure 9). These spots do not elongate to form the net-like pattern characteristic of the net form. The spots may grow in diameter to 3–6 mm. Older leaves will generally have a larger number of spots than younger.

Figure 9: Typical symptoms of spot form of net blotch.

Net form of net blotch—what to look for

The net form of net blotch starts as pinpoint brown lesions, which elongate and produce fine, dark-brown streaks along and across the leaf blades, creating a distinctive net-like pattern. Older lesions continue to elongate along leaf veins, and often are surrounded by a yellow margin (Figure 10).

The fungal disease net form of net blotch is becoming more virulent and barley growers need to check variety disease guides and sowing guides when planning what to sow next season.

Figure 10: Typical netting symptoms of net form of net blotch.

Disease cycle

The disease cycles for the two forms of net blotch differ, in that the net form can be carried over on seed, whereas the spot form is not seed-borne. Carryover of net form of net blotch occurs when humid conditions are present at crop maturity (Figure 11). Primary inoculum of both forms of net blotch comes from infected stubble. Net blotch can survive on infected barley stubble as long as the stubble is present on the soil surface. However, the inoculum levels are typically significantly reduced after 2 years.

Ascospores are produced by pseudothecia on the stubble residues (Figure 12), which are spread by rain-splash or wind to infect neighbouring plants. Most of these ascospores travel only short distances within the crop. Infection requires moist conditions with temperatures ≤25°C, but is most rapid at 25°C.

Secondary infection is provided by conidia produced from lesions on leaves. These lesions usually start on the lower leaves, which then infect the upper leaves during moist conditions. Unlike the ascospores, conidia are wind-dispersed and therefore can travel considerable distances. The likelihood of infection decreases with distance from the source. As the barley plant begins to senesce, the fungus grows into the stem as a saprophyte. After harvest, it survives on the stubble and it will begin to produce ascospores when cool moist conditions are present. There is a positive relationship between the quantity of ascospores produced and stubble load. Stubble breakdown and inoculum production may be prolonged during seasons with dry summer months.

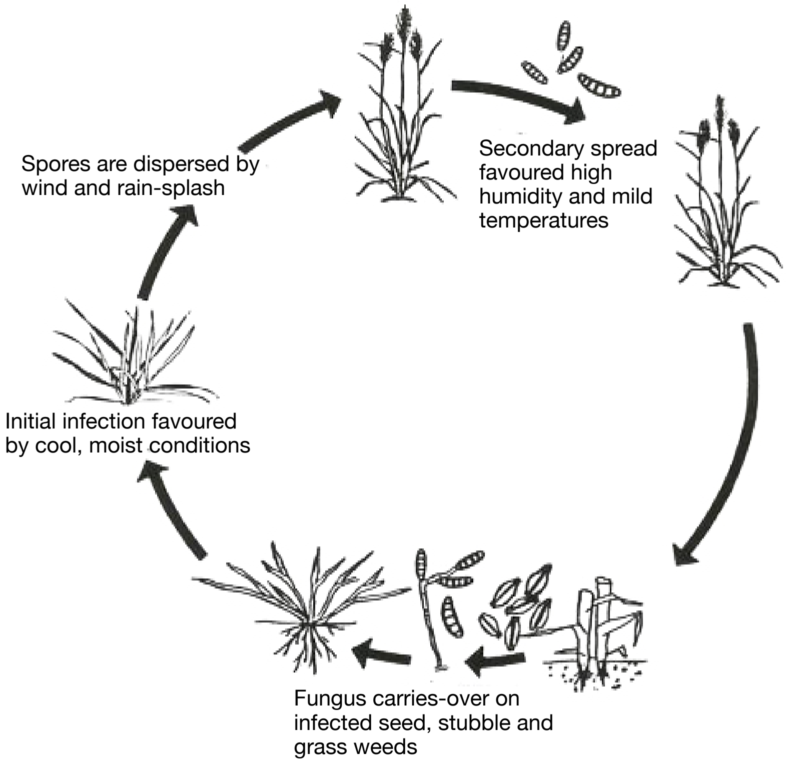

Figure 11: Disease cycle of net form of net blotch of barley.

Figure 12: Pyrenophora teres (a) stubble with pseudothecia, (b) ascospore, (c) conidia.

Economic importance

When a net blotch epidemic is severe, it can cause significant reductions in grain yield and quality, leading to downgrading of grain from malting quality to feed. In general, the flag and flag-1 leaves must be infected for yield loss to occur, with losses from the net form generally ranging between 10% and 20%, and losses of >30% reported. Spot form of net blotch, although common early in the season, rarely develops sufficiently in spring to cause significant yield loss. If yield losses do occur, they are generally <10%, but in severe outbreaks can exceed 20%. Spot form of net blotch more commonly causes reductions to grain quality through reduced grain size.

Management

- Varietal selection. Avoid susceptible (S) and very susceptible (VS) varieties; growing a variety with a rating of moderately susceptible (MS) or better will significantly reduce the likelihood of grain yield and quality loss. Consult the current [Agriculture Victoria Cereal disease guide]() when selecting varieties. The widespread use of varieties with resistance to net form of net blotch has effectively managed this important disease in Victoria for 20 years.

- Crop rotation. Avoid growing susceptible barley varieties in successive years in the same paddock, because net blotch inoculum will become established. Initially, wind-borne conidia from neighbouring crops or seed-borne inoculum (net form only) will provide infection into the new barley crop. Once net blotch is established, inoculum levels will build up in the stubble residue and produce ascospores and conidia. Paddocks close to infected stubble will receive more inoculum than those more distant. Disease levels will be higher in crops in districts where barley crops are grown in close rotation.
- Seed dressings. Seed dressings are ineffective for control of the spot form of net blotch. Seed treatments containing the active ingredient thiram can reduce severity of net form of net blotch in seedlings. Seed treatments containing difenoconazole + metalaxyl can reduce the carryover of seed-borne net form of net blotch. Seed-borne infection is acquired only where the seed source was heavily infected late in the growing season.
- Time of sowing. Early sowing favours the development of net blotch and can increase the potential for losses; however, this increased risk of disease should be weighed up against other agronomic factors.
- Foliar fungicides. Several products are registered for suppression of net form and/or spot form of net blotch. Monitor barley crops and apply a registered fungicide if required. Research has shown that best suppression of the net blotches is provided by application of foliar fungicide between the beginning of stem elongation (GS31) and flag leaf emergence (GS39). A single application of foliar fungicide may be insufficient to eliminate loss of grain yield and quality in severe cases, and a second application may be warranted. Application of foliar fungicide up until head emergence (GS59) may be economical, but will provide less benefit than if applied prior to flag emergence. [15]

9.6.5 Barley yellow dwarf virus (BYDV)

Growers in high-rainfall zones should be proactive and develop a BYDV management plan that includes crop monitoring, green-bridge management, foliar pesticide sprays and pre-sowing seed treatment. These actions will control the aphid populations that spread BYDV.

BYDV transmission

The virus is transmitted from plant to plant by aphids. When aphids feed on plants, their mouthpart, called the stylet, penetrates the leaf epidermis and enters the plant's vascular system (the phloem). Within 15 minutes of feeding, the aphid either contracts the virus (if the plant is already infected) or transmits the disease to the uninfected plant. The infection is restricted to the phloem, where it replicates and blocks phloem tissues, reducing transport of sugars through the leaves. BYDV is a persistent virus, which means an infected aphid will transmit the virus for the rest of its life.

The virus survives from one season to the next in infected summer crops, weeds and host volunteer plants. It can only survive in living tissues and does not survive in stubbles or soils. It is not airborne.

Five species of aphids transfer different types of BYDV. In the southern grain-growing region, the most common species are the oat aphid (*Rhopalosiphum padi*), the corn aphid (*R. maidis*) and rose grain aphid (*Metopolophium dirhodum*). Trials have found that the oat and rose grain aphids occur on wheat and barley and the corn aphid favours barley and is rarely found on wheat. [16]

[15] CropPro. Foliar diseases of barley. GRDC/Government of Victoria, http://www.croppro.com.au/crop_disease_manual/ch02s04.php

[16] GRDC (2013) Management tips to avoid yield penalties. Southern Region. Barley Yellow Dwarf Virus Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-BYDV

Symptoms

Symptoms of BYDV infection may take at least 3 weeks to appear. When assessing a paddock for an outbreak, growers should look for the following:

- Sporadic patches of plants that have turned yellow, most defined at the tip of the leaf, extending to the base. Plants may also appear stunted.
- Damage to crops along the fenceline. If aphids are moving into the crop from a 'bridge' of adjoining pastures, crops, weeds or grasses, they are likely to attack plants near fencelines first.
- Aphids on the crown and lower stem, then leaves. If left untreated, damage will radiate outwards as wingless juvenile aphids crawl to the next plant to feed, spreading the virus. [17]
- Leaves may show a slight mottling to a bright yellow colour starting at the tips and moving down to the base of the leaf. Plants will be dwarfed (Figure 13).

Figure 13: BYDV symptoms in barley. Note the yellowing of the leaf tip. (Photo. Hugh Wallwork, SARDI)

Yield loss

All early BYDV infections of cereal plants will result in less aboveground biomass and a less extensive root system. Grain size can be smaller or grain can become shrivelled, which causes lower yields, higher screenings and reduced marketing options.

Research by the Victorian Department of Primary Industries Field Crops Pathology Group at Horsham in 1984 found that yield losses of 9–79% occurred when plants were infected early in the growing season (before the end of tillering) and losses of 69% may occur when plants are infected after tillering.

A trial conducted in the South East of South Australia by Trent Potter also investigated yield losses in wheat caused by BYDV. Losses varied from nil in 1990 and 2002 up to 40% in 2008. In other years, the yield losses were 10–20%. Even where large yield

[17] GRDC (2013) Management tips to avoid yield penalties. Southern Region. Barley Yellow Dwarf Virus Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-BYDV

losses due to BYDV have occurred, trial results showed no difference in protein content between sprayed and untreated plots. [18]

Additional yield loss by aphid feeding

Growers in high-rainfall areas are encouraged to check for aphids on a regular basis, especially early in the season (autumn) when winged aphids migrate into cereal crops. The autumn flight is most significant because plants are most vulnerable to damage in their early growth phase.

If aphids are observed and there is a concern about aphid feeding damage, it is suggested that you walk throughout the crop and pull up 10–20 plants from a range of locations. Inspect the crown, lower stem and leaves for aphids. In barley, check inside the unfurled leaf at the top of the tiller.

If plants average ≥10 aphids per tiller, a foliar insecticide spray should be considered. It is likely to be too late for control of BYDV, but yield loss can be reduced. [19]

Predicting infection

The prevalence of BYDV depends on environmental conditions, host–pathogen dynamics and aphid populations.

The virus is generally worse in seasons with a wet summer (which allows for significant volunteer or green-bridge growth) followed by a mild autumn and winter. However, the aphids are able to survive hot summers in perennial grasses such as perennial ryegrass, kikuyu, paspalum, couch grass and African love grass in permanent or irrigated pasture areas and along waterways.

Winged aphids are able to migrate around the southern grain-growing region regardless of summer conditions. Growers should not be complacent in dry summers.

BYDV can be caused by relatively few infected aphids if they arrive early in the growing season and are very mobile through the crop. [20]

Management

For grain growers who decide to manage aphids, it is critical to have a control strategy and put it in place before sowing. Do not wait until aphids are found, because infection or damage will have already occurred.

Growers in high-risk areas should treat each year as a 'BYDV year' unless there has been low rainfall over summer and autumn. [21]

More information

[Australian Pesticides and Veterinary Medicines Authority]

Seed dressings

Seed dressings with imidacloprid have been shown to reduce aphid numbers in cereal crops at the early stage of growth when cereals are most susceptible to BYDV. Do not graze treated cereal crops within 9 weeks of sowing. In high-risk areas, a top-up spray (see below: *Insecticides*) is recommended at 6–8 weeks after sowing. [22]

Insecticides

Growers must work to prevent the spread of BYDV early after crop emergence, when plants are most vulnerable.

[18] GRDC (2013) Management tips to avoid yield penalties. Southern Region. Barley Yellow Dwarf Virus Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-BYDV

[19] GRDC (2013) Management tips to avoid yield penalties. Southern Region. Barley Yellow Dwarf Virus Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-BYDV

[20] GRDC (2013) Management tips to avoid yield penalties. Southern Region. Barley Yellow Dwarf Virus Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-BYDV

[21] GRDC (2013) Management tips to avoid yield penalties. Southern Region. Barley Yellow Dwarf Virus Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-BYDV

[22] GRDC (2013) Management tips to avoid yield penalties. Southern Region. Barley Yellow Dwarf Virus Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-BYDV

A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

In high-risk areas, such as the long-season areas of South Australia and Victoria, which may have received high summer rainfall, growers can apply insecticides before aphids and/or BYDV symptoms are evident. This is considered a risk-based application. The insecticides will help to kill and repel the aphids, leading to increased yields, particularly when plants are young and small. Growers can utilise a range of approved insecticides to manage the aphids. As well as pyrethroids, other spray options can have less impact on non-target insects. These may suit farmers trying to incorporate integrated pest management into their system. Advice prior to spraying is essential.

Trial results have led to the recommendation that sprays are applied at 3 and 7 weeks after crop emergence. This is because BYDV symptoms are usually not obvious until 3 weeks after the aphids have fed on plants. These applications will enable aphid populations to be managed before the problem has been noticed and the aphids have spread even further.

Considerable BYDV spread can occur even when aphid numbers are low. Symptoms can be hard to see in winter. Consultation with an agronomist or crop pathologist is recommended.

In years conducive to aphid build-up, a follow-up insecticide application in spring, in addition to the early foliar or seed treatment strategies, may be required to limit feeding damage. The effect of late BYDV infection by itself is generally not sufficient to warrant spraying in spring, so the decision should be purely based on aphid pressure. [23]

BYDV resistance

There is some level of resistance to BYDV in cereals. The barley varieties Gairdner, Bass ⦶, Flinders⦶ and Macquarie⦶ contain the *Yd2* gene, which gives moderate resistance to BYDV. [24]

Delayed sowing

Delayed sowing avoids the main autumn peak of aphid flights and can reduce the incidence of BYDV. However, other yield penalties associated with late sowing mean that this option is generally considered a poor choice over use of insecticides. Growers in the late-sown high-rainfall areas should note that late sowing might coincide with peak spring flights of aphids, resulting in more severe damage. [25]

Green bridge

Management of the green bridge (volunteer cereals and grass weeds) with appropriate herbicides is important for managing BYDV, in addition to the associated benefits of moisture and nutrient conservation. After summer weed control, spraying out perennial grasses near and around cereal paddocks at least 3 weeks before sowing may reduce aphid numbers. [26]

9.6.6 Powdery mildew

Powdery mildew is currently under effective control in the Southern Region when treated seed or fertiliser is used and resistant cultivars are grown. However, care is needed to maintain this situation to minimise the risk of the pathogen developing into a threat to the industry. [27]

More information

Cereal Leaf and Stem Diseases (2000 Edition) (GRDC012) GRDC Bookshop Free Phone: 1800 110044 Email: ground-cover-direct@canprint.com.au; also available from the National Library of Australia.

Agriculture Victoria Notes: Barley yellow dwarf virus

Agriculture Victoria: Victorian winter crop summary

GRDC Fact Sheets: Barley yellow dwarf virus

MFMG: Wheat agronomy trials

PIRSA: Cereal seed treatments

[23] GRDC (2013) Management tips to avoid yield penalties. Southern Region. Barley Yellow Dwarf Virus Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-BYDV

[24] GRDC (2013) Management tips to avoid yield penalties. Southern Region. Barley Yellow Dwarf Virus Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-BYDV

[25] GRDC (2013) Management tips to avoid yield penalties. Southern Region. Barley Yellow Dwarf Virus Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-BYDV

[26] GRDC (2013) Management tips to avoid yield penalties. Southern Region. Barley Yellow Dwarf Virus Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-BYDV

[27] GRDC (2014) Powdery mildew in barley and wheat. Southern Region. Barley Powdery Mildew Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-PowderyMildewBarleyWheat

Disease life cycle

Barley powdery mildew is caused by *Blumeria graminis* f. sp. *hordei* and is specific to barley and barley grass.

Infections appear as white fluffy patches on the surface of leaves, leaf sheaths, glumes and awns (Figure 14). These colonies produce windborne spores that spread the disease during the growing season (Figure 15).

Mildew that survives over summer on stubble releases new spores under cool, wet conditions during autumn to infect the new crop. The disease can increase rapidly from early tillering.

The fungus consumes carbohydrates needed by the plant for grain filling. Severe early infections of susceptible varieties can result in costly yield losses and quality downgrades from tiller abortion, reduced grain size and crop lodging through weakened stems. [28]

Figure 14: Barley powdery mildew infections appear as white fluffy patches on the leaf surface. These colonies produce windborne spores that spread the disease during the growing season. (Photo. Ryan Fowler, DAF Qld)

[28] GRDC (2014) Powdery mildew in barley and wheat. Southern Region. Barley Powdery Mildew Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-PowderyMildewBarleyWheat

Figure 15: A powdery mildew infection showing the black fruiting bodies (cleistothecia) that allow the disease to survive on stubbles.

Disease conditions

Most infection occurs during early crop growth in autumn and winter. The disease tends to diminish as temperatures rise and humidity declines.

Powdery mildew epidemics are favoured by the following factors:

- infection in the previous season's barley or wheat crop and the fungus carrying over on stubble (only a risk in wheat-on-wheat or barley-on-barley situations)
- infected barley volunteers (for barley crops) or wheat volunteers (for wheat crops), which produce inoculum early in the season
- susceptible varieties
- cool, wet conditions, which activate the release of stubble-borne spores
- mild temperatures (15–22°C)
- high humidity of >70% (note dew or rainfall not needed for infection)
- low light intensity
- high N nutrition
- dense crop canopies
- growers upwind not using control treatments at seeding

Powdery mildew also occurs where thick crops allow high humidity to be maintained over extended periods. [29]

[29] GRDC (2014) Powdery mildew in barley and wheat. Southern Region. Barley Powdery Mildew Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-PowderyMildewBarleyWheat

Choose the best variety

The best way to minimise losses and slow or prevent the development of fungicide resistance is to plant the varieties that are more resistant and thereby minimise the need for foliar sprays.

However, the pathogen is capable of evolving and overcoming the resistance of some varieties. This is more likely if the disease is not controlled, because higher populations of the fungus will result in more mutations, which may lead to loss of resistance.[30]

Monitor the crop

Crops of susceptible varieties should be monitored for powdery mildew when conditions for infection are favourable. Early protective fungicide sprays are much more effective at controlling the disease than sprays aimed at eliminating or reducing existing infections.

This is particularly the case where mildew occurs on the leaf sheaths around the lower stems or low in a thick crop canopy. Mildew in the head can be very damaging and it can be effectively treated only if it is controlled in the crop canopy beforehand. If the disease is detected in the early stages, treat to protect the upper leaves and reduce head infection.

At later stages, consider the individual crop and its circumstances including growth stage, potential yield, level of infection and weather when deciding whether to treat. [31]

Fungicides and treatment of crops

Yield losses can be significant if an early infection is not properly brought under control. Fungicides are more efficient as protectants than eradicants, so apply them before the disease becomes established.

All barley crops, except varieties that are rated Resistant, should be treated with a fungicide at seeding. This prevents epidemics starting in autumn and greatly reduces the need for any later sprays. It also reduces the chance of the fungus evolving new virulences or resistance to fungicides.

Treatments applied at seeding (on seed or in-furrow) can give protection for 6–12 weeks from sowing.

If powdery mildew is detected in crops where the variety is rated MS or lower, consider applying an appropriate fungicide immediately to slow the epidemic. A second spray may be required where the fungus persists.

More information

Australian Pesticides and Veterinary Medicines Authority

Where a fungicide is required, use a different chemical from that used at seeding or used previously as a spray. Always use recommended label rates. This will help to reduce the risk of fungicide resistance developing.

A good option is a QoI–DMI (quinone outside inhibitor–demethylation inhibitor) mix for the first foliar spray and a DMI for the second.

Fungicide resistance in the Southern Region

In Western Australia, resistance to some of the older fungicides has already developed in powdery mildew populations in barley. This situation arose from the low adoption of effective seed treatments, repeated use of the DMI fungicides tebuconazole, flutriafol and triadimenol as foliar sprays, and widespread use of varieties rated VS. [32] Similar changes are likely to occur in eastern Australia.

30 GRDC (2014) Powdery mildew in barley and wheat. Southern Region. Barley Powdery Mildew Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-PowderyMildewBarleyWheat

31 GRDC (2014) Powdery mildew in barley and wheat. Southern Region. Barley Powdery Mildew Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-PowderyMildewBarleyWheat

32 GRDC (2014) Powdery mildew in barley and wheat. Southern Region. Barley Powdery Mildew Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-PowderyMildewBarleyWheat

Growers can significantly reduce the chances of this happening, or at least delay the occurrence, by avoiding the use of susceptible varieties, using effective fungicide treatments at seeding, and taking care over the use of foliar fungicides.

Growers should avoid using 'weaker' Group 3 DMI foliar fungicides (triadimefon, flutriafol, tebuconazole and triadimenol) for control of powdery mildew (Figure 16) and instead consider triazole fungicides such as epoxiconazole, prothioconazole, propiconazole or cyproconazole.

The Group 11 QoIs such as azoxystrobin and pyraclostrobin can also be used in combination with triazoles. Experience in Europe shows that the Group 11 QoIs can lose their effectiveness very quickly if used alone. [33]

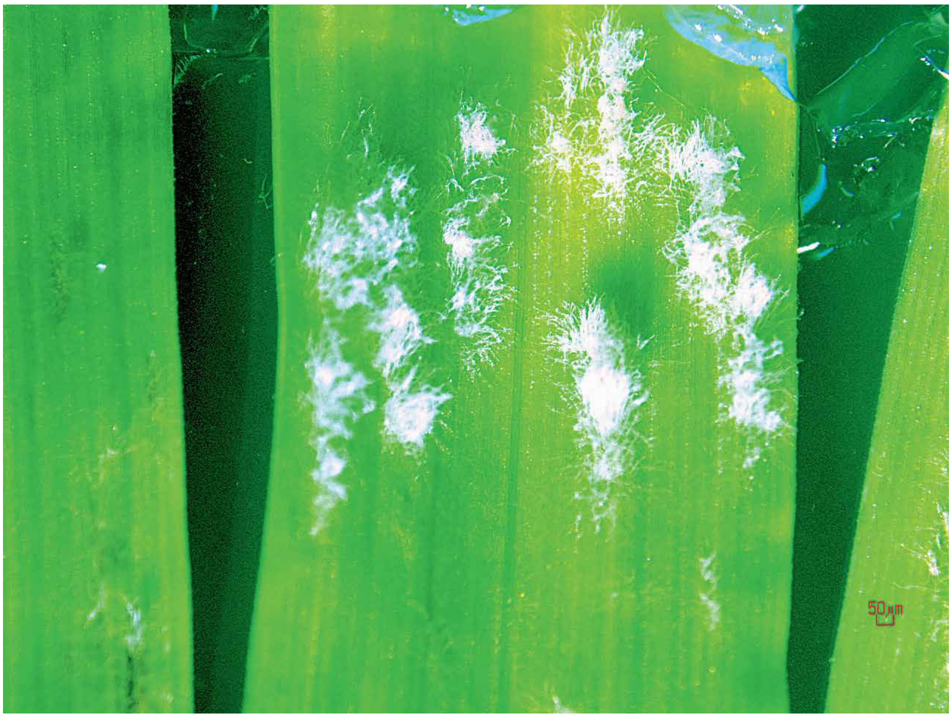

Figure 16: Triazole resistance in powdery mildew means that barley growers should not use tebuconazole alone, flutriafol, triadimefon or triadimenol if powdery mildew is the target disease or if there is a likelihood of it occurring in the season. (Photo: Richard Oliver, Curtin University)

More information

[Agriculture Victoria Notes: Wheat disease management in the Wimmera]

9.6.7 *Wheat streak mosaic virus* (WSMV)

Wheat streak mosaic virus (WSMV) is a seed- and mite-borne virus that infects cereals (including wheat and barley) and grasses. WSMV is spread by the wheat curl mite (*Aceria tosichella*), which is ~0.2 mm long and can only be seen with magnification. The mite consumes plant sap from a diseased plant and the virus remains alive in the mite's mouthparts, being transmitted to other plants as the mite feeds and moves between plants. Wheat curl mites cannot survive for long away from living plant material.

WSMV requires a green-bridge to survive between growing seasons. Substantial yield losses are likely if infection occurs early.

What to look for:

- Symptoms are seen in warm growing conditions, generally before June or from early spring.
- Wheat is the most important host of WSMV and all varieties are susceptible; leaves of newly infected wheat plants have broken yellow stripes that merge as the plant ages to be pale yellow streaks. In older leaves, yellowing is toward tips.

33 GRDC (2014) Powdery mildew in barley and wheat. Southern Region. Barley Powdery Mildew Fact Sheet, GRDC, http://www.grdc.com.au/GRDC-FS-PowderyMildewBarleyWheat

- Barley is less severely affected than wheat and varieties differ in their susceptibility to infection.
- Barley leaves have necrotic flecks and pale green streaks with older leaves showing yellow along the length (Figure 17).
- Early infected wheat and barley plants are stunted with multiple tillers and have seed heads that contain shrivelled or no grain. [34]

Figure 17: Symptoms of wheat streak mosaic virus in barley; flecks enlarge and form green to yellow streaks. (Photo: DAFWA)

Disease management should involve eliminating the 'green bridge' by controlling:

- wheat volunteers between crops
- grass hosts growing on the borders of areas to be sown to wheat
- grasses in fallows

This means that any green plant material should be dead at least 2 weeks before sowing the next cereal crop. [35]

More information

GRDC: Wheat streak virus

GRDC Fact Sheets: Wheat curl mite

GRDC Update Papers: Cereal disease update—net blotch, eyespot, wheat streak mosaic virus and white grain

GRDC: Protecting the Australian wheat industry for the Wheat streak mosaic virus

34 MyCrop (2015) Diagnosing wheat streak mosaic virus. Department of Agriculture and Food, WA, https://www.agric.wa.gov.au/mycrop/diagnosing-wheat-streak-mosaic-virus

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

9.6.8 Barley stripe

Barley strip is a very rare fungal disease that is most often found in irrigated barley.

What to look for:

- Yellow stripes on the base of leaves extend, turn dark brown, and eventually die.
- Dying leaves tend to split and fray along the stripes leading to a shredded appearance (Figure 18).
- Symptoms occur on the second or third leaf of seedlings then each subsequent leaf.
- Infected plants are stunted and heads often fail to emerge or emerge twisted and brown. [36]

Figure 18: Symptoms of barley stripe: dying leaves tend to split and fray along the stripes. (Photo: DAFWA)

More information

[DAFWA: Diagnosing barley stripe]

[CropPro: Foliar diseases of barley]

[VirginiaTech: Barley stripe]

[Agriculture Victoria: Rusts of barley]

9.7 Root and crown diseases

Most cereal root and crown diseases (take-all, crown rot, cereal cyst nematode and root-lesion nematode) can be controlled with a 1- or 2-year break from susceptible hosts. Break crops must be kept free of grass weeds to be effective. [37]

Barley can incur root and crown diseases, including:

- take-all
- crown rot
- *Pythium*
- *Rhizoctonia*
- cereal-cyst nematode
- root-lesion nematode
- common root rot

9.7.1 Diagnosing root diseases in your crop

Look at the distribution of symptomatic plants throughout the whole crop. To determine whether a fungal or nematode root disease is affecting a cereal crop, look for patchy areas of poor crop growth associated with localised disease build-up.

36 MyCrop (2015) Diagnosing barley stripe. Department of Agriculture and Food WA, https://www.agric.wa.gov.au/mycrop/diagnosing-barley-stripe

37 G Hollaway, M McLean, J Fanning (2015) Cereal disease guide. AG1160. Revised February 2015. DEDJTR Victoria, http://agriculture.vic.gov.au/__data/assets/pdf_file/0007/252664/Vic-Cereal-Disease-Guide-AG1160-Feb-2015-V2.pdf

More information

[Soil Quality Fact Sheets: Take-all disease]

Next, carefully dig up samples of apparently diseased, as well as nearby healthy, plants. Thoroughly wash the soil from the roots and then examine them for indicative symptoms of root and crown diseases. Unthrifty plants may have smaller root mass, fewer root branches, root browning, root clumping or damaged root tips (spear tips) compared with thrifty or well-grown plants nearby. If you are sending plant samples to a diagnostic laboratory, send plants that have not been washed. [38]

9.7.2 Take-all

Take-all is a soilborne disease of cereal crops and is most severe on cereal crops throughout southern Australia, in the high-rainfall areas of the agricultural region and areas closer to the coast. The disease is caused by two variants of the fungus *Gaeumannomyces graminis* var. *tritici* (Ggt). 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.

The take-all fungus survives the Australian summer in the residue of the previous season's grass host. Cooler temperatures and rainfall in late autumn–early winter encourage 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. Lower soil moisture will decrease the chance of severe development of take-all in susceptible plants.

Take-all is suppressed in low pH soils; consequently, paddocks may suffer a sudden increase in take-all severity after they are limed to alleviate soil acidity. Growers planning to apply lime should check the take-all status of paddocks so that they can plan to manage these risks in future cereal crops.

Affected plants tend to occur in patches that vary in size from a few plants up to several metres across. Infection causes stunting, with the degree depending on severity. Severe infections may cause premature death of plants after head emergence when the crop becomes water-stressed, resulting in dead plants in an otherwise green crop. In the paddock, take-all is much more obvious on wheat than on barley.

Roots of affected plants are dark brown to black through fungal invasion (Figure 19). As the plant matures, the roots become rotten and brittle and the plant can be easily pulled from the soil. Infected plants may have dark brown to black streaks or spots on the base of the stem when the infection is severe.

Take-all causes a blackening of the sub-crown internodes, and of primary and secondary roots. It is best identified by breaking a piece of infected root and observing that the core is jet black. (Common root rot specifically attacks the sub-crown internode causing it to darken brown.)

Whiteheads occur where the head is starved of adequate moisture and nutrients. Both take-all and crown rot cause such extensive damage to the plant roots or lower stems that they are unable to transport these essential supplies up the plant. Take-all damage affects the whole plant and, in the paddock, usually occurs in patches, whereas whiteheads caused by crown rot are frequently confined to single tillers on plants and patches are less obvious, and the crowns are distinctly golden brown. Whiteheads can also be caused by drought, zinc deficiency or early frosts, and will not have the crown or root symptoms caused by disease. [39]

For images and detailed information on identifying cereal root and crown diseases, see the GRDC Cereal root and crown diseases: Back Pocket Guide.

38 GRDC (2014) Take-all. GRDC Media Centre, 26 June 2014, http://grdc.com.au/Media-Centre/Hot-Topics/Take-all

39 GRDC (2014) Take-all. GRDC Media Centre, 26 June 2014, http://grdc.com.au/Media-Centre/Hot-Topics/Take-all

Figure 19: The sub-crown internode is the narrow portion of stem that links the old seed and primary root system to the crown and secondary root system just below the soil surface. (Source: GRDC Cereal and root and crown diseases: The Back Pocket Guide)

Control

No varieties of wheat and barley are available that are resistant to take-all. By far the most effective method of reducing take-all is to remove grasses early in the year before the crop, with a grass-free pasture or break (non-host) crop.

Widespread adoption of minimum tillage has significantly increased the time required for residue to breakdown, and take-all management must reflect this. Burning decreases only the amount of surface residue but does not affect the infected material belowground.

Fungicides, applied as fertiliser, in-furrow or seed treatments, are registered for use and they suppress take-all.

Acidifying fertilisers can reduce disease severity but not control the disease. The ammonium form of nitrogenous fertiliser reduces take-all.

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, but the effect can be negated by poor weed control during this period. Cereal weeds become infected, enabling *G. graminis* to survive until crop establishment. In addition, rapid drying of the topsoil by weeds decreases the survival of competitive soil organisms, thereby slowing *G. graminis* decline.

Any practice that encourages crop growth will help to overcome the effects of take-all. These include good weed control and the application of adequate fertiliser.

More information

[NSW DPI: Winter crop variety sowing guide]

[GRDC: NVT Queensland wheat variety trial 2015]

[Research paper: Effect of rotation with barley and oats on crown rot of wheat in the northern wheat belt of New South Wales]

More information

[GRDC Update Papers: Crown rot: be aware of the balancing act or the fall may be harder]

[GRDC Fact Sheets: Crown rot in cereals—southern and western regions]

[GRDC video: Crown rot—it's all a balancing act]

9.7.3 Crown rot

Crown rot is caused predominantly by the fungus *Fusarium pseudograminearum*. Crown rot affects wheat, barley and triticale. [40] It survives from one season to the next in the stubble remains of infected plants and grassy hosts. The disease is more common on heavy clay soils.

Infection is favoured by high soil moisture in the 2 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. [41]

The disease may be managed through planting partially resistant varieties, inter-row sowing or crop rotation. If the disease is severe, rotation to a non-susceptible crop for at least 2 years, and preferably 3 years, is recommended.

Damage caused by crown rot

The impact of crown rot on yield and quality is influenced by inoculum levels and available soil water. The primary factor increasing the impact of crown rot is moisture stress at grainfill, yet most management strategies focus heavily on combating inoculum, sometimes to the detriment of soil water storage or availability, which in turn exacerbates the effect of moisture stress.

Any management strategy that limits storage of soil water or creates constraints (e.g. nematodes or sodicity) that reduce the ability of roots to access water increases the probability of moisture stress during grainfill and therefore the severity of crown rot.

Symptoms

- Tiller bases are always brown, often extending up 2–4 nodes.
- Some tillers on diseased plants may not be infected.
- Whitehead formation is most severe in seasons with a wet start and dry finish.
- Plants often break off near ground level when pulled up.
- Plants are easy to pull up in good moisture situations because they have little root structure.
- Cottony fungal growth may be found inside tillers.
- Pinkish fungal growth may form on lower nodes, especially during moist weather.

[40] S Simpfendorfer, M Gardner (2013) Crown rot: be aware of the balancing act or the fall may be harder. GRDC Update Papers, 25 February 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Crown-rot-be-aware-of-the-balancing-act-or-the-fall-may-be-harder

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

- Pinched grain is observed at harvest. [42]

Infection is characterised by a light honey-brown to dark brown discoloration of the base of infected tillers (Figure 20). In moist weather, a pink-purple fungal growth forms inside the lower leaf sheaths and on the lower nodes.

Major yield loss from the production of whiteheads is related to moisture stress post-flowering. [43]

Figure 20: Basal browning indicating crown rot infection.

More information

NSW DPI: Northern grains region trial results. Autumn 2013. Impact of sowing time on crown rot in barley, bread and durum wheat—Walgett 2012 (pp. 24–26)

GRDC Ground Cover: Seedborne fusarium tests crown rot strategies

Effect of sowing time

Earlier sowing within the recommended window of a given variety for a region generally brings the grainfill period forward to where the probability of moisture stress during grainfill is reduced. Earlier sowing may also increase the extent of root exploration at depth, which could provide greater access to deeper soil water later in the season, buffering against crown rot expression. This has been shown in NSW DPI research across seasons to reduce yield loss from crown rot. [44]

Agronomists report anecdotal accounts of early sowing dates with long-season varieties resulting in greater soil moisture deficits during grainfill than later sowing dates. They say this combination has resulted in major yield loss and they reported a number of cases of this in 2013.

Crown rot phases

There are three distinct and separate phases of crown rot—survival, infection and expression. Management strategies can differentially affect these phases:

42 K Moore, B Manning, S Simpfendorfer, A Verrell (2005) Root and crown diseases of wheat and barley in northern NSW. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/159031/root-crown-rot-diseases.pdf

43 S Simpfendorfer, M Gardner (2013) Crown rot: be aware of the balancing act or the fall may be harder! GRDC Update Papers, 25 February 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Crown-rot-be-aware-of-the-balancing-act-or-the-fall-may-be-harder

44 UNE Sustainable Grains Production course notes.

- Survival. The crown rot fungus survives as mycelium (cottony growth) inside winter cereal (wheat, barley, triticale and oats) and grass weed residues that it has infected. The crown rot fungus will survive as inoculum inside the stubble for as long as the stubble remains intact, which varies greatly with soil and weather conditions; decomposition is generally 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 the 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, and when combined with the production of greater stubble loads, disease inoculum levels build up significantly.
- Expression. Yield loss is related to moisture and temperature stress around flowering and through grainfill. Expression is also affected by variety and crop type. Moisture 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 stems, and producing whiteheads that contain either no grain or lightweight, shrivelled grain. The expression of whiteheads (Figure 21) in plants infected with crown rot (i.e. that still have basal browning) is restricted in wet seasons and increases greatly with increasing moisture stress during grainfill. [45]

More information

extensionAUS: Crown rot in winter cereals

Research paper: Monitoring fusarium crown rot populations in spring wheat residues using quantitative real-time polymerase chain reaction

Research paper: Decomposition and chemical composition of cereal straw

Figure 21: The expression of whiteheads is restricted in wet seasons, so they are not considered the best indicator of crown rot; look for signs of basal browning instead.

Management

Managing crown rot requires a three-pronged attack:

1. Rotate crops.
2. Observe plants for basal browning.
3. Test stubble and/or soil.

[45] S Simpfendorfer, M Gardner (2013) Crown rot: be aware of the balancing act or the fall may be harder! GRDC Grains Update Papers, 25 February 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Crown-rot-be-aware-of-the-balancing-act-or-the-fall-may-be-harder

Top tips:

- Although many growers look for whiteheads to indicate crown rot, basal browning is a better indicator of the presence of inoculum.
- Keep crown rot inoculum levels low by rotating with non-host crops and ensuring a grass-free break from winter cereals. Consider crops with dense canopies and early canopy closure such as mustard, canola or faba beans.
- If growing cereals in crown-rot-affected paddocks, select types with lower risk of yield loss such as barley and some bread wheats. Avoid all durum varieties.
- Match N application to stored soil moisture and potential yield.
- Limit N application prior to and at sowing to avoid excessive early crop growth.
- Ensure zinc nutrition is adequate.
- Sow on the inter-row if possible when sowing cereal after cereal. [46]
- Current seed treatments do not offer any control.

Crop rotation

Growing non-host break crops remains an important tool for managing crown rot, because break crops allow time for decomposition of winter cereal residues that harbour the crown rot inoculum. Canopy density and rate of canopy closure can affect the rate of decomposition and these vary with different break crops (i.e. faba bean and canola). Crops that are sparser in nature, such as chickpeas, are not as effective.

Row spacing and seasonal rainfall during the break crop also affect decomposition and hence survival of the crown rot fungus. Break crops can further influence the expression of crown rot in the following winter cereal crop through the amount of soil water they use (and therefore leave) at depth and their impact on the build-up of root-lesion nematodes.

Growing barley before wheat in paddocks with high crown rot inoculum is not an option because of risk of yield loss. All current barley varieties are very susceptible and they will encourage considerable build-up of inoculum. However, barley rarely suffers significant yield loss from crown rot, largely because its earlier maturity limits the impact of the moisture-stress interactions with infection that result in the production of whiteheads. [47]

Inter-row sowing

Northern Grower Alliance (NGA) research shows:

- Inter-row sowing will reduce the level of crown rot incidence and severity (measured as inoculum in residues, not as whitehead expression), on average, by ~50%.
- Inter-row sowing provides increased disease-management benefit under conditions of low disease.
- Inter-row sowing will provide best benefit by incorporation into a crown rot disease-management package based on sound crop rotation. [48]

Stubble burning

Burning removes the aboveground portion of crown rot inoculum but the fungus will still survive in infected crown tissue belowground; therefore, stubble burning is not a 'quick fix' for high-inoculum situations. Removal of stubble residues through burning will increase evaporation from the soil surface and affect fallow efficiency. A 'cooler' autumn

More information

Thesis: Crown rot (*Fusarium pseudograminearum*) symptom development and pathogen spread in wheat genotypes with varying disease resistance

GRDC Update Papers: Economics of phosphorus and zinc nutrition

More information

Research paper: Effect of previous crops on crown rot infection and yield of wheat

More information

GRDC Ground Cover: Crown rot stubble avoidance lessens crown rot

NGA: GRDC Update Papers—diseases

NGA Results and Publications: Complete summary

Videos

GRDC GCTV9: Crown rot & root lesion nematodes

Podcast

GRDC Podcasts: Crown rot, root disease and WeedSmart

[46] GRDC (2011) Stop the rot: rotate, observe, test. GRDC Media Centre, 22 February 2011, http://www.grdc.com.au/Media-Centre/Media-News/National/2011/02/Stop-the-crown-rot-Rotate-Observe-Test

[47] K Moore, B Manning, S Simpfendorfer, A Verrell (2005) Root and crown diseases of wheat and barley in northern NSW. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/159031/root-crown-rot-diseases.pdf

[48] G Rummery, R Daniel, S Simpfendorfer (2007) Inter-row crown rot management—the results are in. Northern Grower Alliance, http://www.nga.org.au/results-and-publications/download/42/australian-grain-articles/diseases-1/crown-rot-inter-row-sowing-results-march-2007-.pdf

More information

[GRDC Fact Sheets: Stubble management—strategies to manage winter crop stubbles without reaching for the matches](#)

[GRDC Ground Cover: Stubble management still a burning question](#)

More information

[GRDC Update Papers: Root lesion nematode and crown rot—double trouble](#)

burn is therefore preferable to an earlier, 'hotter' burn because it minimises the negative impacts on soil moisture storage while still reducing inoculum levels.

Varietal resistance or tolerance

Resistance is the ability to limit the development of the disease, whereas tolerance is the ability to maintain yield in the presence of the disease. Published crown rot ratings are largely based on the evaluation of resistance.

9.7.4 Pythium root rot

Pythium root rot (caused by several species of *Pythium*) is a widespread fungal root disease that attacks seedlings but rarely causes large yield losses.

Symptoms

In the paddock, look for patches or whole paddocks of very poor growth (Figure 22, left). Affected plants occur in patches where soil is wetter.

Seedlings are pale and stunted (Figure 22, middle). Older plants have fewer tillers and may rot and die. Roots are stunted, short and stubby with few laterals (Figure 22, right). Root tips often water-soaked and develop a soft yellow to light brown rot.

Figure 22: Symptoms of Pythium root rot: left, patches of poor growth; middle, seedlings are pale and stunted; right, roots are stunted.

What else could it be?

Rhizoctonia root rot in cereals presents similar patches of stunted plants and dead roots. However, Rhizoctonia root rot has 'spear-tipped' roots and patches are more distinct.

Waterlogging in cereals causes stunted plants with dead or dying roots similar to Pythium root rot. However, waterlogged roots are not stubby and have water-soaked tips.

Where does it occur?

Pythium root rot occurs:

- in cold, wet situations
- in wet soils and areas of poor drainage
- where seeding is done directly into areas of dense, dying weeds

Management strategies

Use good weed control in the paddock and delay seeding until weeds have decomposed.

Fungicide seed dressings with a *Pythium*-selective chemical such as metalaxyl-M can be applied. [49]

[49] DAFWA (2015) Diagnosing Pythium root rot in cereals. Department of Agriculture and Food Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-pythium-root-rot-cereals

9.7.5 Rhizoctonia disease

Rhizoctonia root rot is an important disease of cereals in both the southern and western regions of the Australian grainbelt. This is especially the case in the lower rainfall zones and on lighter soils.

Yield losses in crops affected by bare patches can be >50%, and crops with uneven growth (Figure 23) may lose up to 20%. The disease is caused by *Rhizoctonia solani* AG8, a fungus that grows on crop residues and soil organic matter and is adapted to dry conditions and lower fertility soils.

The fungus causes crop damage by pruning newly emerged roots (spear-tipped roots), and this can occur from emergence to crop maturity (Figure 24). The infection results in water and nutrient stress to the plant, because the roots have been compromised in their ability to translocate both moisture and nutrients. [50]

Severe seedling infection causes patches of poor crop growth from very small to several metres across (Figure 25). This can occur in cold or dry soils and conditions that restrict seminal root growth (e.g. compaction, lack of moisture, herbicide residues).

Warmer soil temperatures and adequate moisture are less conducive to the disease because crops escape seminal root infection, but crown roots can be affected by Rhizoctonia disease under low soil temperatures and poor nutrition, leading to uneven growth at tillering.

Figure 23: Aboveground symptoms of crop unevenness are seen when Rhizoctonia damages crown roots.

50 GRDC (2016) Rhizoctonia. Southern Region. GRDC Tips and Tactics.

Figure 24: Symptoms of Rhizoctonia disease: left, healthy roots; middle, seedling severely infected; right, crown root fully infected. (Photos: Sjaan Davey)

Figure 25: Rhizoctonia infection of seminal roots results in distinct patches of poor growth. (Photo. Gupta Vadakattu)

Management options

Summer weed control

Summer weed control will reduce inoculum levels and the disease in the following winter by decreasing the availability of living host plants of the disease. This complements the moisture- and N-conservation benefits of summer weed control.

Crop choice and rotations

Cereals (especially barley) and grassy fallows promote the build-up of *Rhizoctonia* inoculum.

Crop rotation with a grass-free, non-cereal crop is one of the best available management strategies to reduce the impact of Rhizoctonia disease (Table 4). Trials across the lower rainfall cropping region of southern Australia have indicated that grass-free oilseeds, pulses, pasture legumes and fallow can result in significant reductions in *Rhizoctonia* inoculum in a cropping sequence.

Non-cereal crops can be infected by *Rhizoctonia*; however, most do not allow the build-up of inoculum. Lupins may be a less effective break crop and can suffer from yield damage in the presence of *Rhizoctonia*. The beneficial effect of rotation on reducing inoculum generally lasts for one cereal-crop season.

Fungicide treatments

Fungicide treatments need to be used as part of an integrated management strategy.

Responses in barley are greater than in wheat. Yield responses can vary between seasons, with the greatest responses occurring when spring rainfall is above average. In GRDC-funded trials in southern Australia and Western Australia, on average, seed treatments gave yield responses of 5% (0–18%) in wheat and barley.

Several products have been registered for liquid banding. GRDC-funded research showed that product(s) registered for dual-banding (in-furrow 3–4 cm below the seed and on the surface behind the press-wheel) gave the most consistent yield and root-health responses across seasons.

Seed treatment combined with in-furrow application can provide intermediate benefit between seed treatment alone and split application.

Nitrogen

Nitrogen-deficient crops are more susceptible to Rhizoctonia disease. Intensive cropping with cereals and stubble retention result in very low levels of mineral-N over summer because soil microbes temporarily utilise all available N while breaking down the low-N stubble residues.

Application of adequate N fertiliser at sowing is necessary to ensure early seedling vigour so that plants can push through the layer of inoculum concentrated in the top 10 cm.

Therefore, ensure good N nutrition. Crops with adequate N will be less affected by the disease.

Seeding systems and tillage

- Soil openers can have a significant influence on disease severity.
- Disturbance below seeding depth helps roots to escape infection and reduces disease impact.
- Disease risk is greater with single-disc seeders than knife-points.
- Tillage can redistribute inoculum to deeper in the soil. [51]

[51] GRDC (2016) Rhizoctonia. Southern Region. GRDC Tips and Tactics.

Table 4: *Management of Rhizoctonia disease in cereal crops*

Year 1 crop (Sept-Nov)	Summer (Dec-April)	Season break (April-May)	Year 2 crop (May-August)
Check for inoculum build-up	*Facilitate inoculum decline*	*Select appropriate crop*	*Manage infection and disease impact through management practices*
• Paddocks can often be identified in the previous spring by estimating the area of bare patches and/or zones of uneven growth during spring – verify that poor plant growth is due to *Rhizoctonia* disease	• In wet summers, early weed control will reduce inoculum. In dry summers, inoculum levels do not change • Adopt practices that prolong soil moisture in the upper layers (e.g. stubble retention and no cultivation) which helps maintain higher microbial activity • Consider soil testing for pathogen inoculum level (PreDicta B™ test in Feb-March), to identify high disease risk paddocks, if disease is not confirmed in the previous cereal crop, especially if planning to sow cereals back on cereals	• Select a non-cereal crop (e.g. canola or pulses) if you want to reduce inoculum levels • Remove autumn 'green bridge' before seeding with good weed control	• Sow early; early-sown crops have a greater chance of escaping infection • Use soil openers that disturb soil below the seed to facilitate root growth – knife points reduce disease risk compared to discs • Avoid pre-sowing SU herbicides, • Supply adequate nutrition (N, P and trace elements) to encourage healthy seedling growth • Avoid stubble incorporation at sowing to minimize N deficiency in seedlings • Consider seed dressings and banding fungicides to reduce yield loss • Remove grassy weeds early • Apply nutrient/trace elements, foliar in crop, if required

More information

GRDC Update Papers: Rhizoctonia control improved by liquid banding of fungicides

Australian Pesticides and Veterinary Medicines Authority

MSFP: Management of soilborne Rhizoctonia disease risk in cropping systems

Identifying risk

PreDicta B is a unique, DNA-based service that identifies soilborne pathogens such as *Rhizoctonia* so that cropping programs can be adjusted before seeding to include strategies to minimise soilborne risk.

Paddocks at high risk of Rhizoctonia disease can also be identified by examining crown roots of cereals in areas of poor growth (not necessarily bare patches) in the previous spring.

Why is Rhizoctonia disease a problem?

Rhizoctonia root rot is difficult to control because the fungus can survive in soil in the absence of a live plant host, on cereal stubbles; this is termed 'saprophytic ability'. [52]

Biology

Rhizoctonia solani AG8 generally occurs in the top 0–5 cm of soil on decaying crop residues. During the growing season, levels increase throughout the profile.

It grows through soil as a network of fungal hyphae or filaments. Inoculum levels increase on the roots of living host plants and decomposing crop residues. This ability to survive on crop residues is strongly influenced by soil conditions including soil type, fertility, moisture, temperature and biological activity.

Although Rhizoctonia disease has often been a problem in low-fertility, sandy or calcareous soils of southern and Western Australia, with the increased adoption of conservation tillage and intensive cereal cropping, it now occurs in a wider range of environments from Western Australia to southern New South Wales.

[52] GRDC (2016) Rhizoctonia. Southern Region. GRDC Tips and Tactics.

The pathogen can infect, and cause spear tips in, a wide range of crops and weeds, but multiplies most on cereals and grasses. Of the cereals, oats are most tolerant followed by triticale, wheat and then barley. [53], [54]

Key factors influencing occurrence and severity

Although the fungus is likely to be present in many soils, it does not necessarily cause disease symptoms. One reason for this is that beneficial soil microorganisms and high microbial activity have been shown to suppress the expression and reduce the level of disease.

The shift towards minimal tillage has resulted in conditions more favourable to the disease. Crown root infection late in the crop season results in the build-up of inoculum in cereal crops.

In cereals, *R. solani* AG8 inoculum builds up from sowing to maturity and generally peaks at crop maturity. Rain post-maturity of a crop and over the summer fallow causes a decline in inoculum (Figure 26).

In the absence of host plants including weeds, summer rainfall events of >20 mm in a week can substantially reduce the level of inoculum. Dry spells, on the other hand, offer little opportunity for pathogen inoculum to break down, with disease levels likely to remain stable if a host, or stubble, is present.

In cropping systems with stubble retention, suppressive activity has been shown to increase over 5–8 years. Biological suppression can provide complete control of Rhizoctonia disease and presently provides the best long-term control option. [55]

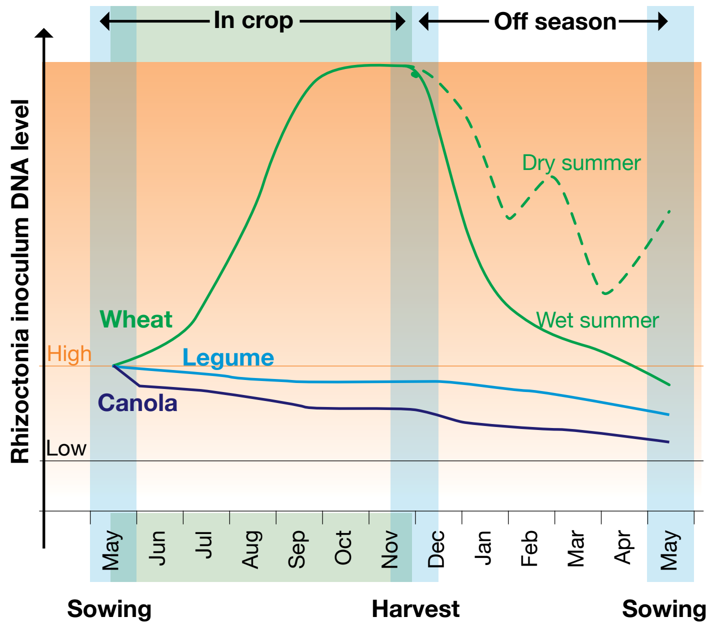

Figure 26: Rhizoctonia solani AG8 inoculum in soil builds up in-crop and declines during summer following rainfall under wheat. By comparison, inoculum levels decline in-crop under grass-free canola and legume crops.

9.7.6 Common root rot

Common root rot is a soil-borne fungal disease that attacks wheat, barley and triticale. It is caused by the fungus *Cochliobolus sativus*. It survives from one season to the next

[53] GRDC (2016) Rhizoctonia. Southern Region. GRDC Tips and Tactics.

[54] GRDC (2015) Rhizoctonia. Western Region. GRDC Tips and Tactics. https://www.grdc.com.au/~/media/Documents/Resources/Publications/Fact-sheets/TaTRhizoctoniaWestern.pdf

[55] GRDC (2016) Rhizoctonia. Southern Region. GRDC Tips and Tactics.

through fungal spores, which remain in the top layer of the soil. The disease increases in severity with continuous wheat or with wheat–barley sequences.

Barley increases the soil population of fungal spores rapidly. Infection is favoured by high soil moisture for 6–8 weeks after planting.

Symptoms of common root rot:

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

More information

GRDC: Cereal root and crown diseases. The Back Pocket Guide

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

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 2 years is recommended.

9.7.7 Smut

Seed treatments provide cheap and effective control of bunt and smut diseases. Seed should be treated every year with a fungicide. Without treatment, bunt and smut can increase rapidly, resulting in unsaleable grain. Good product coverage of seed is essential and clean seed should be sourced if a seedlot is infected. Note that fertiliser treatments do not control bunt and smuts, so seed treatments are still required.

Bunt or stinking smut or covered smut

Covered smut of barley is caused by the fungus *Ustilago segetum* var. *hordei (U. hordei)*. This is a different fungus from the cause of covered smut of wheat. This disease is generally well controlled because of the regular use of seed treatments.

What to look for

Affected plants usually do not show symptoms until ear emergence. Infected ears typically emerge at the same time or slightly later than that of the healthy stems. Also, infected ears often emerge through the sheath below the flag leaf. All of the florets of infected ears are replaced by masses of dark brown to black spores. The spores of covered smut are held more tightly than those of loose smut (Figure 27).

Figure 27: Covered smut on barley.

Life cycle

During harvest the spores of affected heads spread and contaminate healthy grain. At sowing the smut spores germinate at the same time as the seed and infect the germinating plant. Infection of seedlings is favoured by earlier sowing as the fungus prefers drier soils and temperatures of 15-21°C. The fungus grows systemically within the plant, usually without producing symptoms, and then it replaces the young grain with its own spores.

Receival standards

Grain Trade Australia's commodity standards have a nil tolerance for bunt in all grades of barley.

Control

Covered smut of barley can be effectively controlled by using fungicide seed treatments every year. Following infection, new seed should be obtained from a clean source. Resistant varieties are available. [56]

Loose smut

Loose smut of barley, like wheat, is caused by the fungus *Ustilago tritici* (U. *nuda*). However, the strain of loose smut that attacks wheat does not attack barley and vice-versa. Because of the widespread and regular use of seed treatments, loose smut of barley is not common in Victoria.

What to look for

Until ear emergence, affected plants often do not exhibit symptoms. Affected heads usually emerge before healthy ones and all of the grain is replaced with a mass of dark brown spores (Figure 28). Initially, the spores are loosely held by a thick membrane, which soon breaks, releasing the spores onto other heads. Finally, all that remains are bare stalks where the spores once were.

Life cycle

Ears of infected plants emerge early. The spores released from the infected heads land on the later emerging florets and they infect the developing seed. Infection during flowering is favoured by frequent rain showers, high humidity and temperatures of 16–22°C.

There are no visible signs of infection because the fungus survives as dormant hyphae in the embryo of the infected seed. When infected seed germinates, the fungus grows within the plant. As the plant elongates the fungus proliferates within the developing spike, and spores develop instead of healthy grain. Eventually the barley head is replaced by a mass of spores, ready to infect healthy plants.

[56] G Hollaway (2012) Bunts and smuts of cereals. AG1257 (updated July 2013). DEDJTR Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/bunts-and-smuts-of-cereals

Figure 28: Loose smut of barley.

Receival standards

The Grain Trade Australia commodity standards have a maximum tolerance of 0.1 gram of smut pieces per half litre in all grades of barley.

Control

Using systemic seed treatments every year will effectively control this disease. Following a loose smut outbreak in a crop, new clean seed should be sourced. [57]

Loose smut was observed in Hindmarsh⦶ barley crops despite use of seed treatment. Tests by Dr Wallwork (SARDI) showed that products with triadimenol, flutriafol, tebuconazole and ipconazole may not provide total control. The new SDHI products (EverGol Prime and Vibrance) appeared to provide good control at the high rates recommended for Rhizoctonia. Vitavax 200FF provided good control at both recommended rates. La Trobe⦶ is likely to be similar to Hindmarsh. [58]

57 G Hollaway (2012) Bunts and smuts of cereals. AG1257 (updated July 2013). DEDJTR Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/bunts-and-smuts-of-cereals

58 G Hollaway, M McLean, J Fanning (2015) Cereal disease guide. DEDJTR Victoria, http://agriculture.vic.gov.au/__data/assets/pdf_file/0007/252664/Vic-Cereal-Disease-Guide-AG1160-Feb-2015-V2.pdf