



WESTERN

SEPTEMBER 2018

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GRAINS RESEARCH
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CORPORATION

BARLEY

SECTION 9

DISEASES

CAUSES OF CEREAL DISEASES | THE DISEASE TRIANGLE | VARIETY RESPONSE
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RHIZOCTONIA DISEASE | COMMON ROOT ROT | SMUT

i MORE INFORMATION

[GRDC \(2009\) Current and potential costs from diseases of barley in Australia.](#)

[GRDC \(2010\) Green bridge control is integral to pest and disease management. Fact Sheet.](#)

Diseases

Barley diseases cause an estimated 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 WA, powdery mildew, net blotch (spot type), net blotch (net type), Rhizoctonia and *Pratylenchus neglectus* nematode 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 WA

Disease	\$/ha	\$ million
Powdery mildew	71.36	72
Net blotch, spot type	43.12	43
Net blotch, net type	41.15	42
Rhizoctonia barepatch	33.78	34
Pratylenchus neglectus	28.42	29

Source: GRDC

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
- Plan an in-crop fungicide regime
- Conduct in-crop disease audits to determine the severity of the disease and use as a tool to determine which crop is grown in which paddock the following year
- Conduct over summer disease audits to determine the severity of the disease (e.g. crown rot, cereal cyst nematode and Rhizoctonia bare patch) and assist in planning for the following year
- Send plant or stubble samples away for analysis to determine the pathogen or strain, or the severity of the disease
- Minimise the growth of self-sown cereals over summer that may act as a green bridge.
- Rotate crops⁴

¹ G Murray, JP Brennan (2009) The current and potential costs from diseases of barley in Australia. GRDC, <https://grdc.com.au/resources-and-publications/all-publications/publications/2009/11/the-current-and-potential-costs-from-diseases-of-barley-in-australia>

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>

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>

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.

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.

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.

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 cereals.

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.

Nematodes

The main species found in broadacre cropping in WA are *Pratylenchus neglectus*, *P. quasitereoides* (originally described as *P. teres*), *P. thornei* and *P. penetrans*.

When roots are damaged by RLN, the plants become less efficient at taking up water and nutrients, and less able to tolerate stresses such as drought or nutrient deficiencies. Depending on the extent of damage and the growing conditions, affected plants may partly recover if the rate of new root growth exceeds the rate at which nematodes damage the roots.⁵

See Section 8: Nematodes.

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.

MORE INFORMATION

Section 8: Nematode management

[DAFWA \(2016\) Diagnosing root lesion nematode in cereals.](#)

⁵ GRDC (2015) Tips and Tactics: Root-Lesion Nematodes, Western Region, Fact sheet, <http://www.grdc.com.au/TT-RootLesionNematodes>

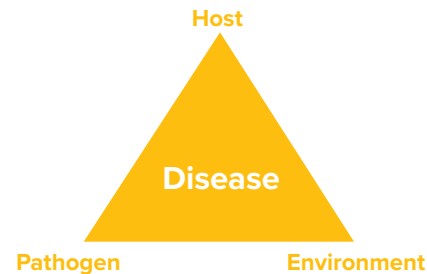


Figure 1: The disease triangle is an interaction of host, pathogen and environment.

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 become more susceptible to *Pythium*, *Rhizoctonia*, nematodes 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 ⁶

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

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Table 2: Barley disease guide

Disease	Organism	Symptoms	Occurrence	Inoculum source	Control
Foliar					
Scald	<i>Rhynchosporium secalis</i>	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	<i>Pyrenophora teres f. maculata</i>	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	<i>Pyrenophora teres f. teres</i>	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	<i>Blumeria graminis f.sp. hordei</i>	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	<i>Puccinia hordei</i>	Small circular orange pustules on upper leaf surface	Moist conditions with temperatures in the range 15–22°C	Living plant hosts including barley and barley grass	Use resistant varieties and control volunteer barley and barley grass over summer–autumn
Stem rust	<i>Puccinia graminis</i>	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 cereals over summer–autumn
BGSR (barley grass stripe rust)	<i>Puccinia striiformis</i>	Yellow powdery pustules in stripes on the leaves	Can develop throughout the growing season	Barley grass and susceptible barley varieties	Avoid susceptible varieties
BYDV	<i>Barley yellow dwarf virus</i>	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	<i>Drechslera wirreganensis</i>	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	<i>Drechslera campanulata</i>	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	<i>Pseudoseptoria stomaticola</i>	Small white-brown lesions.	Cool, moist conditions	Residues of barley and grasses. Rain-splash	Disease is not of economic importance

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Disease	Organism	Symptoms	Occurrence	Inoculum source	Control
Grain					
Covered smut	<i>Ustilago segetum</i> var. <i>hordei</i>	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
Loose smut	<i>Ustilago tritici</i>	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	<i>Fusarium pseudograminearum</i> , <i>F. culmorum</i>	'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)	<i>Pythium</i> 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	<i>Bipolaris sorokiniana</i>	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)	<i>Heterodera avenae</i>	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)	<i>Pratylenchus thornei</i> , <i>P. neglectus</i>	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	<i>Gaeumannomyces graminis</i> var. <i>tritici</i> (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

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).

9.3 Variety response

Most varieties have been stable in their adult disease rating since 2013, except where there has been a pathotype change resulting in a loss of a major resistance gene (e.g. Rph3 virulence in barley leaf rust). Disease status for varieties includes:

- Scald—risk likely to increase if significant areas of Granger[®] barley are sown
- Net type net blotch—risk not expected to change with the adoption of newer varieties
- Spot type net blotch—risk expected to continue to increase with greater plantings of Hindmarsh[®] and La Trobe[®]

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- Powdery mildew—overall risk is expected to decline until new pathotypes become dominant
- Barley leaf rust—growing varieties with adult plant resistance (APR) can reduce the risk, but fungicide spraying may still be required
- Barley yellow dwarf—risk expected to increase with increased plantings of Hindmarsh⁷ and La Trobe⁷

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

Table 3: Barley variety disease ratings

	Leaf scald	Net blotch Spot form	Net blotch Net form	Powdery mildew	Leaf rust	BYDV	CCN resis.	RLN resistance P. neglectus	P. thornei	BGSR
Malting barley										
Baudin ⁷	S-VS	MS-S	MR-MS#	VS	VS	MR	S	MR	–	R
Buloke ⁷	MS	S	MR	MR	S-VS	MR-MS	S	MR-MS	MR-MS	R
Commander ⁷	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 ⁷	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 ⁷	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 ⁷	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 ⁷	MR#	MR	MS	MR-MS	MS-S	MR-MS	R	MR-MS	MR-MS	R
Fleet ⁷	MS-S	MR	MR-MS#	MR	MS-S	MR-MS	R	MR-MS	MR-MS	R
Hindmarsh ⁷	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 ⁷	MS-S#	S	MS	R	MR	MS	S	MR	MR-MS	R
Barley under malt evaluation										
Compass ⁷	MS#	MS-S	MR#	MR#	VS	MR	R	MR	MR	R
Flinders ⁷	S	S	S	R-MR	MS	MR-MS	S	MR-MS	MR	R
La Trobe ⁷	VS	S	MR	MR-MS#	MS-S	S	R	MR	MR	R
Skipper ⁷	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

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

⁷ S Gupta and B Paynter et al. (2015) Change in adult foliar disease resistance profiles of barley varieties grown in Western Australia from 2013 to 2015. 2015 Agribusiness Crop Updates, Perth, 24–25 Feb 2015. <http://www.qiwa.org.au/2015-crop-updates>

MORE INFORMATION

[NSW DPI \(2006\) Cereal diseases after drought](#)

[GRDC \(2016\) Yield response to fungicide control of barley. GRDC Update Paper.](#)

[GRDC \(2016\) Yield response to fungicide control of barley spot type net blotch in Western Australia. GRDC Research Update.](#)

[DAFWA \(2016\) Managing barley leaf diseases in Western Australia.](#)

[DAFWA \(2015\) Diagnosing barley leaf rust.](#)

[The Rust Bust Western Australia](#)

[DAFWA \(2008\) Managing barley leaf diseases. Farmnote 288.](#)

[DAFWA \(2016\) Registered foliar fungicides for cereals in Western Australia.](#)

[GRDC \(2016\) New cereal rusts in WA and implications for management. GRDC Research Update.](#)

[GRDC \(2014\) Barley leaf rust in Western Australia.](#)

[CropPro \(2014\) Foliar diseases of barley.](#)

9.4 Environmental factors

9.4.1 Cereal disease after drought

Drought reduces the breakdown of plant residues. This means inoculum of some diseases such as crown rot, net blotch and leaf scald, does not decrease as quickly as expected, and will carry over for more than one growing season. The expected benefits of crop rotation may not occur or may be limited. 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.⁸

9.4.2 Cereal disease after significant rain 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.⁹

9.5 Management options

Management options for disease control include elimination of volunteers, ideally having a 4-week period that is totally host-free, crop rotation with non-hosts, growing resistant varieties, reduction of stubble, and the 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.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 fungicides¹¹

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

9.6 Rusts

Rusts are important diseases of barley and can cause severe crop damage in susceptible varieties when conditions are conducive. Rusts can 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 although this is rare in WA. The exotic pathogen barley stripe rust will cause severe losses in most varieties if it is introduced to Australia.¹²

Rust diseases can be significantly reduced by removing the 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.

Monitoring should start no later than Zadoks growth stage GS32, the second node stage on the main stem, and continue to at least GS39, the flag-leaf stage. This is because the flag to minus 1-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

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 four 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
- When deciding whether a fungicide spray is needed, consider crop stage and potential yield loss
- Select a recommended and cost-effective fungicide

¹² CropPro (2014) 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>

i MORE INFORMATION

Barley Variety sowing guide <https://www.agric.wa.gov.au/barley/2017-barley-variety-sowing-guide-western-australia>

[GRDC \(2012\) Adult plant resistance. Fact Sheet.](#)

[GRDC \(2008\) Stripe rust—prevention is generally best. GRDC Update Paper.](#)

- For effective coverage, the use of the right spray equipment and nozzles is important
- 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

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 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

9.6.1 What to look for

Barley leaf rust

Pustules of leaf rust are small and circular, producing a mass of orange-brown powdery spores predominantly on the upper leaf surfaces (Photo 1). 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.



Photo 1: Leaf rust symptoms on barley leaf.

Source: GRDC

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

Barley stem rust

The large pustules are oval to elongated, and are often surrounded by a characteristic torn margin (Photo 2). 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.



Photo 2: Stem rust symptoms on barley.

Source: GRDC

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 (Photo 3). 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.¹⁵



Photo 3: Barley grass stripe rust symptoms on barley.

Source: GRDC

9.6.2 Disease cycle

Barley leaf rust

Leaf rust requires a green host plant to survive the summer, so disease risk is highest when a green bridge allows the fungus to survive into the new season. Leaf rust can occur throughout the season and develops rapidly in moist conditions when temperatures are between 15–22°C.¹⁶

Stem rust of barley

Stem rust survives the summer on volunteer wheat, barley, triticale and grasses, including barley grass. Spores are spread from these hosts to the new crop by the wind, with 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.

¹⁵ CropPro (2014) Foliar diseases of barley. GRDC/Government of Victoria, http://www.croppro.com.au/crop_disease_manual/ch02s04.php

¹⁶ DAFWA (2015) Diagnosing barley leaf rust. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/h/2543>

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.¹⁷

9.6.3 Management of barley rusts

Resistant varieties

Barley rust is aggressive, difficult to control and can be a recurring problem in crops in the southern high rainfall zones of WA. Planting resistant varieties is one of the easiest ways to help control leaf rust. GRDC-funded research has led to the development of several resistant barley varieties, such as Fleet[®], Oxford[®], Granger[®] and Westminster also have good levels of leaf rust resistance.

See Table 3 for more information.

Cultural practices

Crop rotation with a non-host crop in the previous year will minimise initial inoculum levels for the current season's crop. To further reduce disease pressure, avoid sowing the current season's crop in paddocks adjoining those with barley stubble from the previous season. Cultural practices such as incorporating the residue into the soil or removing it completely (for example, by burning) will reduce the abundance of the pathogen and the disease pressure. Stubble may be reduced by baling and grazing; however, these methods only result in a small reduction in the disease pressure. Stubble reduction must be balanced against the increased risk of soil erosion by wind or water.

Barley leaf rust survives on barley volunteers. A green bridge of self-sown barley leading into the cropping season provides host material. Removing this green bridge as early as practicable before seeding will greatly reduce the risk of early crop infection.¹⁸

Seed treatment

New active ingredient fluxapyroxad (product Systiva[®]) is now registered as a seed dressing for the control of barley leaf rust. No in-furrow or seed dressing fungicides are currently registered for barley stem rust.¹⁹

Fungicides

Apply fungicide spray if disease threatens well grown crops. Where an early outbreak of leaf rust in barley occurs, the initial spray should be applied at the onset of the disease and followed by a second application three to four weeks later. Early foliar fungicide sprays are more effective than seed dressing or in-furrow fungicide application for control of early infections of barley leaf rust.²⁰

Changes in the barley leaf rust pathogen

A new pathotype of the barley leaf rust pathogen *Puccinia hordei* was detected in WA in 2013 from samples collected in the southern region (Boxwood Hill, Chillinup, Esperance, Kamballup and South Stirling).

¹⁷ CropPro (2014) Foliar diseases of barley. GRDC/Government of Victoria, http://www.croppro.com.au/crop_disease_manual/ch02s04.php

¹⁸ DAFWA (2016) Managing barley leaf diseases in Western Australia. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/343>

¹⁹ DAFWA (2016) Seed dressing and in-furrow fungicides for cereals in Western Australia. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/1794>

²⁰ GRDC (2014) Barley leaf rust in Western Australia. GRDC Media Centre, <https://grdc.com.au/Media-Centre/Hot-Topics/Barley-leaf-rust-in-Western-Australia>

The leaf rust responses of most of barley varieties grown in WA have not changed due to this pathotype. The concern was that it may have reduced leaf rust resistance in varieties known to carry resistance gene Rph3, in Oxford[®], Granger[®], Bass[®] and Compass[®]. Fortunately, two of these varieties (Granger[®], Oxford[®]) also carry the APR gene Rph20, and they remain resistant. Bass[®] is also considered to carry Rph20 in addition to Rph3, but its response appears to have shifted more towards susceptibility and it is now rated as being Moderately Susceptible.

It is important to monitor crops of vulnerable varieties for leaf rust and send samples for pathotype analysis to the [Australian Rust Survey](#). This service is free and is funded by the grower levy paid to the Grains Research and Development Corporation. ²¹

9.7 Barley scald

Barley scald is a stubble- and seed-borne fungal foliar disease which occurs more frequently in high rainfall cooler areas. It can cause grain yield losses up to 45% and reduce grain quality.

The optimum temperature for both spore production and infection is 15–20°C. Rain aids the spread of disease and the most rapid increase in disease is observed in early spring when the temperature and moisture conditions are ideal.

Early sown crops develop higher levels of scald. Early sown crops may be exposed to the heaviest release of spores from infected residues. The disease can develop in the upper leaves of the plant when conditions favour spread of disease.

Disease is more severe at higher levels of nitrogen supply. ²²

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 oval to irregular in shape (Photo 4). In severe infections, the disease may virtually cause defoliation by coalescing of the lesions (Photo 5). 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.

²¹ R Park (2016) New cereal rusts in Western Australia and implications for management. GRDC Grains Research Updates, 29 Feb–01 Mar 2016, <http://www.giwa.org.au/2016researchupdates>

²² DAFWA (2015) Diagnosing barley scald. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/2553>

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Photo 4: Barley scald. Early water-soaked, grey-green symptoms compared with later straw-coloured lesions with a distinctive brown margin.

Source: GRDC



Photo 5: Severe barley scald. 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 2). 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 spring.

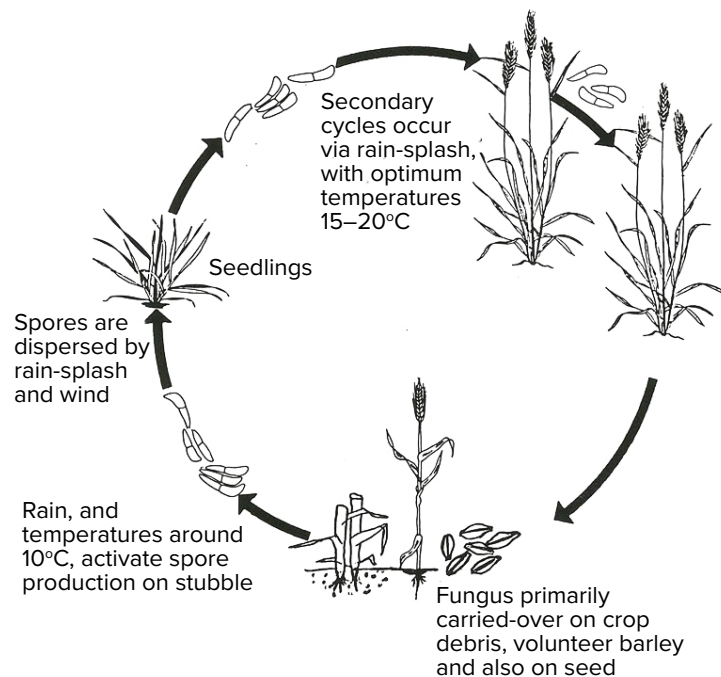


Figure 2: Disease cycle of barley scald.

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 two 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.

Fungicides

A range of foliar fungicides is available that will provide suppression of scald. Experiments conducted during 2010 and 2011 showed 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.²³

9.8 Net blotch

Net blotch is a stubble-borne fungal foliar disease occurring more frequently in the medium and high rainfall areas of the WA wheatbelt. It can reduce grain yield and quality.²⁴

There are two types of net blotch present in Australia. The net type net blotch (NTNB), 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 type net blotch (STNB), 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.

Spot type net blotch—symptoms

Symptoms are most commonly found on leaves, but occasionally on leaf sheaths and develop symptoms as small circular or elliptical dark brown spots surrounded by a chlorotic zone of varying width (Photo 6). 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 leaves.

²³ CropPro (2014) Foliar diseases of barley. GRDC/Government of Victoria, http://www.croppro.com.au/crop_disease_manual/ch02s04.php

²⁴ DAFWA (2015) Diagnosing net type net blotch. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/2551>



Photo 6: Typical symptoms of spot type net blotch

Source: GRDC

Net type net blotch—symptoms

The net type 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 (Photo 7).

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.



Photo 7: Typical netting symptoms of net type net blotch.

VIDEO

[GCTV15: Net form net blotch](#)



Disease cycle

The disease cycles for the two types of net blotch differ; net type can be carried over on seed, whereas spot type is not seed-borne. Carryover of NTNБ occurs when humid conditions are present at crop maturity (Figure 3). Primary inoculum of both types 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 (Photo 8), 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 $\leq 25^{\circ}\text{C}$, 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. 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.

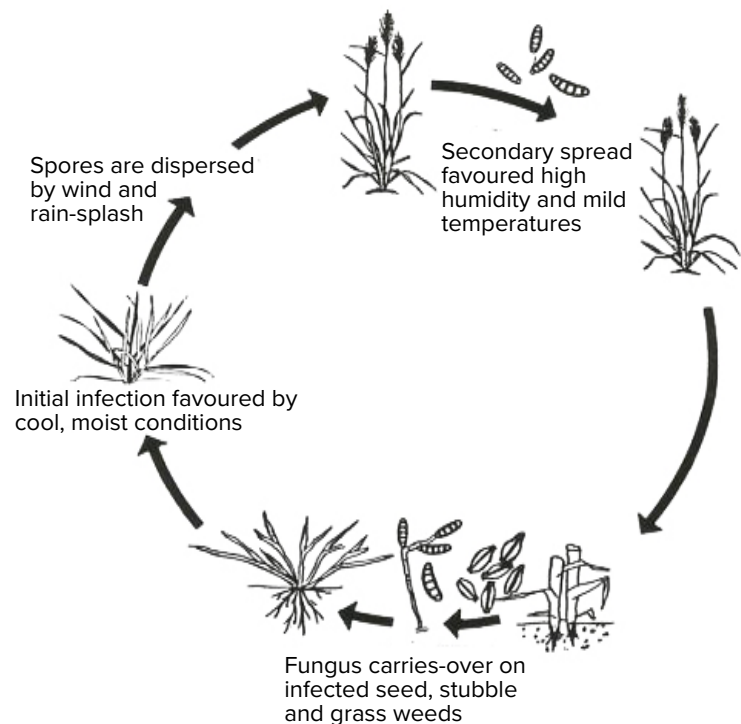


Figure 3: Disease cycle of net form of net blotch of barley.



Photo 8: *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 type generally ranging between 10% and 20%, and losses of >30% reported. Spot type 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 type 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.

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 type 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 STNB. Seed treatments containing the active ingredient thiram can reduce severity of NTN in seedlings. Seed treatments containing difenoconazole + metalaxyl can reduce the carryover of seed-borne NTN. 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 NTN and/or STNB. Monitor barley crops and apply a registered fungicide if required. Research has shown the 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.²⁵

²⁵ CropPro (2014) Foliar diseases of barley, GRDC/Government of Victoria, http://www.croppro.com.au/crop_disease_manual/ch02s04.php

i MORE INFORMATION

[DAFWA \(2016\) Managing net-type net blotch and spot-type of barley in Western Australia.](#)

[DAFWA \(2016\) Managing spot type net blotch in continuous barley.](#)

[DAFWA \(2016\) STNB barley risk increase prompts management warning.](#)

[GRDC \(2016\) Stubbles set scene for disease tactics. Ground Cover Issue 125.](#)

[Curtin University \(2016\) Researchers discover fungicide-resistant barley disease. Media release.](#)

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 \(2016\) Victorian winter crop summary.](#)

[DAFWA \(2015\) Managing barley yellow dwarf virus and cereal yellow dwarf virus in cereals.](#)

[DAFWA \(2015\) Diagnosing yellow dwarf virus.](#)

[GRDC \(2013\) Barley yellow dwarf virus. Fact Sheet.](#)

[SARDI \(2013\) Cereal seed treatments 2014.](#)

[Agriculture Victoria \(2011\) Barley yellow dwarf virus.](#)

Climate and control

Research from WA over 17 years has revealed that the likelihood of a yield response and improved returns from controlling even low levels of STNB is very good unless there is a dry spring; then the response halves.

The studies showed the crop yield response from fungicide applications tended to increase with growing season rainfall.

Spring rainfall, particularly rainfall and number of rainy days in September, determines the likelihood of a yield response to fungicide application. Growers in the medium and low rainfall areas need to take the spring rainfall outlook into account when deciding if a second fungicide application is necessary. In a dry spring there is no additional benefit from a second application.

Controlling STNB in medium and high rainfall areas was most profitable with a double spray at stem extension and then again from flag emergence to half head emerged.²⁶

Fungicide resistance

A study conducted by researchers at the Centre for Crop and Disease Management, Curtin University, has shown that NTNB has reduced sensitivity to the fungicide tebuconazole. Researchers also recorded a smaller reduction in sensitivity to other related fungicides, such as epoxiconazole, prothioconazole and propiconazole.

In order to have any chance of slowing down the rise of resistant mutations, growers and agronomists must think of chemical applications as complementary to disease prevention strategies, as relying solely on fungicides to control disease is no longer sustainable.

Researchers investigated the resistant NTNB fungal populations from barley grown in Kojonup, Beverley, Bakers Hill, West Arthur and Dandaragan.

They also found for the first time, a mutation within the fungal DNA that has changed the shape of the target enzyme, which means the fungicide binds to it less effectively.

They found the resistant NTNB populations are working against fungicides in two key ways: they are producing more fungicide targets (enzymes) and the shape of those targets have changed.

Epoxiconazole, prothioconazole and propiconazole are registered for the control of NTNB, however tebuconazole was not, and growers should be mindful that NTNB may be present when applying tebuconazole to control other barley diseases. This may contribute to NTNB resistance issues in subsequent seasons.

To manage the development of fungicide resistance, stubble management, rotating crops and growing disease resistant cultivars are key.

If fungicide resistance of any disease is suspected, contact the Fungicide Resistance Group by email frg@cutin.edu.au or phone (08) 9266 1204.²⁷

9.9 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.

26 A Hills et al. (2016) Yield response to fungicide control of barley spot type net blotch in Western Australia. 2016 GRDC Western Research Update, 29 Feb–01 Mar 2016. <http://www.giwa.org.au/2016researchupdates>

27 Curtin University (2016) Researchers discover fungicide-resistant barley disease. Media Release 9 September 2016, http://news.curtin.edu.au/media-releases/researchers-discover-fungicide-resistant-barley-disease/?utm_content=bufferdb9fa&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer

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. The most common species are the oat aphid (*Rhopalosiphum padi*), the corn aphid (*R. maidis*) and rose grain aphid (*Metopolophium dirhodum*). Trials have found the oat and rose grain aphids occur on wheat and barley and the corn aphid favours barley and is rarely found on wheat.²⁸

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 virus²⁹
- 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 (Photo 9)



Photo 9: BYDV symptoms in barley. Note the yellowing of the leaf tip.

Source: Hugh Wallwork, SARDI

²⁸ 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>

²⁹ 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>

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.³⁰

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 growers walk throughout the crop and pull up 10–20 plants from a range of locations, inspecting the crown, lower stem and leaves for aphids. In barley, check inside the unfurled leaf at the top of the tiller.

If plants average ≥ 20 aphids on every second 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 by preventing feeding damage.

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 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.

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.³¹

Insecticides

Strategic applications of insecticides can be used against the aphids that carry BYDV or cereal yellow dwarf virus (CYDV) to reduce its spread. It is important to protect the crop during the first 10 weeks after emergence. Apply the first pyrethroid spray at 3 weeks after emergence (or 2-leaf stage if aphids easily found). The second pyrethroid spray can be applied at 7 weeks after emergence. In high risk situations, seed dressings containing imidacloprid applied to seed before sowing are recommended for good early season control in addition to a follow-up pyrethroid spray.³²

BYDV resistance

30 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>

31 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>

32 DAFWA (2015) Managing barley yellow dwarf virus and cereal yellow dwarf virus in cereals. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/318>

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 \(2016\) Victorian winter crop summary.](#)

[DAFWA \(2015\) Managing barley yellow dwarf virus and cereal yellow dwarf virus in cereals.](#)

[DAFWA \(2015\) Diagnosing yellow dwarf virus.](#)

[GRDC \(2013\) Barley yellow dwarf virus. Fact Sheet.](#)

[SARDI \(2013\) Cereal seed treatments 2014.](#)

[Agriculture Victoria \(2011\) Barley yellow dwarf virus.](#)

There is some level of resistance to BYDV in cereals. The barley varieties Gairdner, Bass^o, Flinders^o and Macquarie contain the *Yd2* gene, which gives moderate resistance to BYDV.³³

Varietal resistance reduces the impact of the virus on plant growth but does not reduce the impact of aphid feeding on plant growth. Varietal resistance to BYDV therefore does not reduce the need to spray for aphids to prevent yield loss from feeding damage once they reach threshold levels in the crop (50% of tillers with 15 or more aphids).³⁴

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 this option is generally considered a poor choice over use of insecticides. Growers in the late-sown high-rainfall areas should note late sowing might coincide with peak spring flights of aphids, resulting in more severe damage.

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.³⁵

9.10 Powdery mildew

Powdery mildew is currently under effective control 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.³⁶ With the reduction of plantings of Baudin^o barley in WA, the incidence and pressure of powdery mildew has been significantly reduced.

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 (Photo 10). These colonies produce windborne spores that spread the disease during the growing season (Photo 11).

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.³⁷

33 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>

34 DAFWA (2016) 2017 Barley variety sowing guide for Western Australia. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/3766>

35 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>

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

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

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Photo 10: 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.

Source: Ryan Fowler, DAF Qld



Photo 11: A powdery mildew infection showing the black fruiting bodies (cleistothecia) that allow the disease to survive on stubbles.

Source: GRDC

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
- crops suffering from K deficiency
- high N nutrition leading to very 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.³⁸

Choose the best variety

The varieties with the highest risk of powdery mildew are Baudin^o and Litmus^o, although Oxford^o may now be susceptible in the lower Great Southern in the presence of the *MI(St)* virulence pathotype.

Genetic resistance is the best form of management against powdery mildew, especially since a mutation of the *CYP51* gene in powdery mildew has resulted in the compromised efficacy of many DMI fungicides (e.g. tebuconazole, triadimefon, flutriafol) in controlling powdery mildew at label rates. Higher value DMI fungicides and alternative modes of action, such as strobilurins (e.g. azoxystrobin), SDHI (e.g. fluxapyroxad) and amines (spiroxamine) have uncompromised activity against powdery mildew.³⁹

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 follows 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.⁴⁰

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

39 DAFWA (2016) 2017 Barley variety sowing guide for Western Australia. Department of Agriculture and Food, Western Australia, <https://agric.wa.gov.au/n/3766>

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

i MORE INFORMATION

[Australian Pesticides and Veterinary Medicines Authority.](#)

[DAFWA \(2016\) Management of powdery mildew in 2016–fungicide resistance.](#)

[DAFWA \(2015\) Diagnosing powdery mildew in cereals.](#)

[S Gupta et al. \(2015\) Change in adult foliar disease resistance profiles of barley varieties grown in Western Australia from 2013 to 2015. GRDC Update Paper.](#)

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 virulence 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. Most pathotypes of powdery mildew are resistant to the more common triazole fungicides. Products such as Prosaro® and Amistar® extra will provide improved control (see below for more details).

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.

In WA, 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.⁴¹



Photo 12: Triazole resistance in powdery mildew means 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.

Source: Richard Oliver, Curtin University

⁴¹ GRDC (2014) Powdery mildew in barley and wheat. Southern Region. Barley Powdery Mildew Fact Sheet, GRDC, <http://www.grdc.com.au/GRDC-FS-PowderyMildewBarleyWheat>

i MORE INFORMATION

[DAFWA \(2011\) Management of barley powdery mildew in the face of fungicide resistance. Farmnote 466.](#)

Integrated management of powdery mildew

Reduce reliance on fungicides by implementing an integrated disease management approach including:

- Reduce the proportion of area sown to barley varieties rated VS or S to powdery mildew. Where possible utilise varieties with better resistance which may not require fungicides for powdery mildew management. Buloke[®], which is rated MR, has the best level of resistance among current malting varieties
- Control volunteer barley prior to seeding, particularly of susceptible varieties, this will reduce inoculum of powdery mildew (and leaf rust) carried into the season
- Avoid sowing back into barley stubble from highly infected crops, mildew is carried as fruiting bodies on infested stubble
- Avoid growing extremely dense canopies. Dense canopies make it difficult to get adequate penetration of the fungicide and foster ideal conditions for powdery mildew development. Management practices which enhance canopy size include high rates of nitrogen at or just after seeding. Grazing crops before stem elongation can reduce canopy size and may reduce disease pressure without affecting crop yield
- Balance crop nutrition, particularly ensuring adequate potassium ⁴²

9.11 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 to infection
- Barley leaves have necrotic flecks and pale green streaks with older leaves showing yellow along the length (Photo 13)
- Early infected wheat and barley plants are stunted with multiple tillers and have seed heads that contain shrivelled or no grain ⁴³

42 DAFWA (2011) Management of barley powdery mildew in the face of fungicide resistance. Department of Agriculture and Food, Western Australia. Farmnote 466. April 11. https://www.researchgate.net/publication/274077218_Management_of_barley_powdery_mildew_in_the_face_of_fungicide_resistance

43 DAFWA (2015) Diagnosing wheat streak mosaic virus. Department of Agriculture and Food, Western Australia, <https://www.agric.wa.gov.au/mycrop/diagnosing-wheat-streak-mosaic-virus>

i MORE INFORMATION

[DAFWA \(2016\) Wheat streak mosaic virus and wheat curl mite.](#)

[DAFWA \(2015\) Diagnosing wheat streak mosaic virus.](#)

[GRDC \(2014\) Cereal disease update—net blotch, eyespot, wheat streak mosaic virus and white grain. GRDC Update Paper.](#)

[GRDC \(2009\) Wheat curl mite. Fact sheet.](#)

[DAFWA \(2015\) Diagnosing barley stripe.](#)

[CropPro \(2014\) Foliar diseases of barley.](#)

[Agriculture Victoria: Rusts of barley](#)



Photo 13: Symptoms of Wheat streak mosaic virus in barley; flecks enlarge and form green to yellow streaks.

Source: DAFWA

Disease management should involve eliminating the ‘green bridge’ by controlling:

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

This means that any green plant material should be dead at least two weeks before sowing the next cereal crop.⁴⁴

9.12 Barley stripe

Barley stripe is a very rare fungal disease that is most often found in irrigated barley. For more information, visit the DAFWA website.

9.13 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 one or two year break from susceptible hosts. Break crops must be kept free of grass weeds to be effective.⁴⁵

Barley can incur root and crown diseases, including:

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

⁴⁴ 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>

⁴⁵ G Hollaway, M McLean, J Fanning (2015) Cereal disease guide. AG1160. Revised February 2015. Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-disease-guide>

 **MORE INFORMATION**

[Soil Quality \(2017\) Take-all disease.
Fact Sheet.](#)

9.13.1 Diagnosing root diseases

To determine whether a fungal or nematode root disease is affecting a cereal crop, identify patchy areas of poor crop growth associated with localised disease build-up.

Collect samples of apparently diseased, as well as nearby healthy, plants, taking care not to damage the roots. 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. Do not send plant samples that have been washed to a diagnostic laboratory - follow their sampling instructions.⁴⁶

9.14 Take-all

Take-all is a soilborne disease of cereal crops and is most severe on cereal crops in high-rainfall areas. 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 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. 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.⁴⁷

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

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

i MORE INFORMATION

[D Hüberli et al. \(2015\) Crown rot yield loss variety trials – barley and wheat.](#)

[GRDC \(2016\) Tips and Tactics: Crown rot in cereals Western Region. Fact sheet.](#)

[GRDC \(2013\) Crown rot: be aware of the balancing act or the fall may be harder. GRDC Update Paper.](#)

[DAFWA \(2015\) Diagnosing crown rot of cereals.](#)

[DAFWA \(2015\) Diagnosing take-all in cereals.](#)

[DAFWA \(2015\) Diagnosing root rot in cereals.](#)

[D Hüberli et al. \(2015\) Crown rot yield loss variety trials – barley and wheat.](#)

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

Control

No varieties of barley 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 to 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.⁴⁸

9.15 Crown rot

Crown rot is caused predominantly by the fungus *Fusarium pseudograminearum* which affects wheat, barley and triticale.⁴⁹ 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 soils.

Infection is favoured by high soil moisture in the two months after planting. Drought stress during elongation and flowering will lead to the production of 'deadheads' or 'whiteheads' in the crop. These heads contain pinched seed or no seed at all.⁵⁰

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.

When infected plant residues come in contact with growing cereal plants, crown rot infection can occur. Even minute pieces of residue can infect plants and a paddock with little visible stubble may still have a crown rot risk. Infection is favoured by moderate soil moisture at any time during the season. Infection occurs through the coleoptile, sub-crown internode, crown and/ or outer leaf sheaths at the tiller bases. The fungus spreads up the stem during the season, with most inoculum being found near the base of the plant.⁵¹

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.

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

49 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>

50 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>

51 GRDC (2016) Tips and Tactics: Crown rot in cereals Western Region. GRDC Fact sheet, <https://grdc.com.au/Resources/Factsheets/2016/02/Crown-rot-in-winter-cereals>

- 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.
- Pinched grain is observed at harvest ⁵²

Infection is characterised by a light honey-brown to dark brown discoloration of the base of infected tillers (Photo 14). 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. ⁵³



Photo 14: Basal browning indicating crown rot infection.

Source: NSW DPI

MORE INFORMATION

[GRDC \(2012\) Seedborne fusarium tests crown rot strategies. GRDC Ground Cover Issue 98.](#)

Effect of sowing time

There is little impact of time of sowing on the incidence of crown rot infection. However, disease severity (as measured by basal browning) and yield loss increases with later sowing.

Sowing a variety early in its sowing window will help minimise the detrimental effects of any crown rot infection by bringing the grain filling period forward into slightly reduced evaporative stress conditions. However, this should be balanced against any increase in the risk of frost damage. ⁵⁴

Crown rot phases

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

- **Survival.** The crown rot fungus survives as mycelium (cottony growth) inside winter cereal and grass weed residues that it has infected. The crown rot fungus

⁵² 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

⁵³ 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>

⁵⁴ GRDC (2016) Tips and Tactics: Crown rot in cereals Western Region. GRDC Fact sheet, <https://grdc.com.au/Resources/Factsheets/2016/02/Crown-rot-in-winter-cereals>

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 (Photo 15) 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.⁵⁵



Photo 15: *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.*

Source: GRDC

Management

Managing crown rot requires a three-pronged attack:

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

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 canola, mustard or faba beans
- Match N application to stored soil moisture and potential yield
- Limit N application prior to and at sowing to avoid excessive early crop growth

⁵⁵ 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>

- Ensure zinc nutrition is adequate
- Sow on the inter-row if possible when sowing cereal after cereal ⁵⁶
- 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. canola and faba bean). 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. ⁵⁷

Inter-row sowing

Infection rates can be reduced by sowing between intact rows of previous standing cereal stubble. In WA inter-row sowing using accurate ± 2 cm differential GPS autosteer has been shown to decrease the number of infected plants by about 50%, resulting in a 5–10% yield advantage in the presence of crown rot. ⁵⁸

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 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.

9.16 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, patches or whole paddocks may have very poor growth with affected plants more obvious in wetter parts of a paddock (Photo 16, left). Affected plants occur in patches where soil is wetter.

MORE INFORMATION

[GRDC \(2011\) Stubble management Fact Sheet.](#)

[GRDC \(2013\) Stubble management still a burning question. GRDC Ground Cover Issue 107.](#)

⁵⁶ 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>

⁵⁷ 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

⁵⁸ GRDC (2016) Tips and Tactics: Crown rot in cereals Western Region. GRDC Fact sheet, <https://grdc.com.au/Resources/Factsheets/2016/02/Crown-rot-in-winter-cereals>

Seedlings are pale and stunted (Photo 16 middle). Older plants have fewer tillers and may rot and die. Roots are stunted, short and stubby with few laterals and root tips (Photo 16, right). Root tips often water-soaked and develop a soft yellow to light brown rot.



Photo 16: 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.⁵⁹

9.17 Rhizoctonia disease

Rhizoctonia root rot is an important disease of cereals in the WA grainbelt with yield losses up to 25% being reported. The disease is an ongoing problem in the low to medium rainfall areas, especially on sandy soils and in some areas of the high rainfall zone. Inoculum levels in the medium rainfall zone of the western region have been increasing in the last few years.

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) which can occur from emergence to crop maturity (Photo 17). The infection results in water and nutrient stress to the plant, as the roots have been compromised in their ability to translocate both moisture and nutrients.

Rhizoctonia can cause uneven crop growth and damage to crown roots. Field trials in WA, including a multi-year trial, showed the effective control of Rhizoctonia disease

⁵⁹ 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>

in cereal crops requires sound management practices spread over more than one cropping season.⁶⁰



Photo 17: Symptoms of Rhizoctonia disease: left, healthy roots; middle, seedling severely infected; right, crown root fully infected.

Photos: Sjaan Davey



Photo 18: Aboveground symptoms of crop unevenness are seen when Rhizoctonia damages crown roots.

60 GRDC (2016) Tips and Tactics: Rhizoctonia, Western Region. GRDC Fact sheet, <https://grdc.com.au/TT-Rhizoctonia>



Photo 19: *Rhizoctonia* infection of seminal roots results in distinct patches of poor growth.

Source: Gupta Vadakattu

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’.⁶¹

Biology

R. solani AG8 fungus 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 the soil conditions—soil type, fertility, moisture, temperature and biological activity.

Rhizoctonia disease is often a problem in low fertility, sandy or calcareous soils of western and southern Australia. *R. solani* AG8 can infect and cause spear tips in a wide range of crops including weeds, but multiplies greatest on cereals and grasses. It can cause losses in a range of crops including cereals, pulses, canola and pastures. Of the cereals, oats are the most tolerant followed by triticale, wheat and then barley.

Key factors influencing occurrence and severity

While *R. solani* AG8 fungus is likely to be present in many soils, it is not necessarily going to cause a problem. One reason for this is beneficial soil microorganisms and high microbial activity have been shown to suppress the expression of the disease and reduce the level of disease.

The move towards minimal till has resulted in conditions more favourable to the disease.

61 GRDC (2016) Tips and Tactics: *Rhizoctonia*, Western Region. GRDC Fact sheet, <https://grdc.com.au/TT-Rhizoctonia>

In cereals, *R. solani* AG8 inoculum builds up from sowing to crop maturity and generally peaks at crop maturity, while rain post-maturity of a crop and over the summer fallow causes a decline in inoculum (Figure 4).

Crown root infection late into the crop season results in the build-up of inoculum in cereal crops.

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 stubble breakdown, with disease levels likely to remain stable if a host, or stubble, are present. In cropping systems with stubble retention, suppressive activity has increased over five to eight year period.⁶²

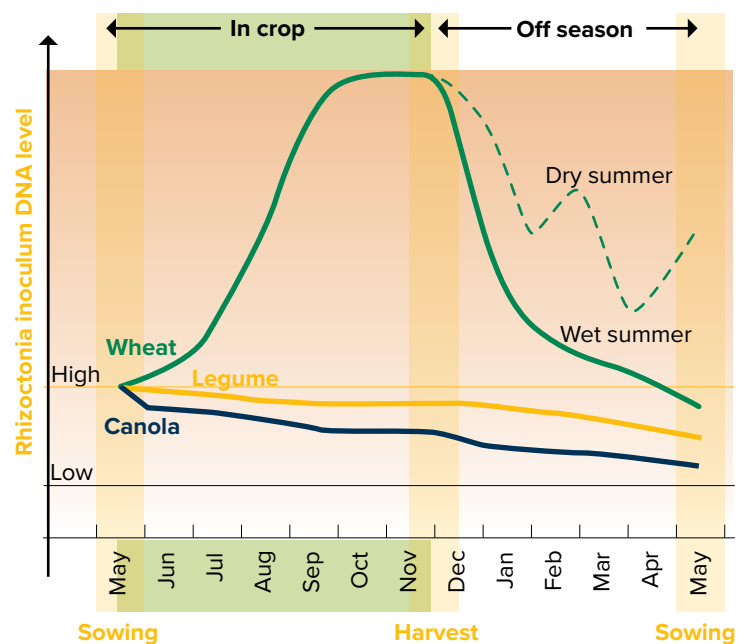


Figure 4: *Rhizoctonia solani* AG8 inoculum in soil builds up in-crop and declines during summer following rainfall under wheat (and similarly in barley). By comparison, inoculum levels decline in-crop under grass-free canola and legume crops.

Source: GRDC

Management strategies

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. This complements the moisture- and N-conservation benefits of summer weed control.

Crop choice and rotations

Cereals and grassy fallows promote the build-up of *Rhizoctonia* inoculum, with barley being the worst of these. Crop rotation with a grass-free, non-cereal crop is one of the best available management strategies to reduce *Rhizoctonia* disease impact (Table 4). Monitoring of 184 focus paddocks located mainly in the medium rainfall zone of WA over five cropping years (2010–2014) showed canola, fallow, and faba bean reduced *Rhizoctonia* inoculum levels.

62 GRDC (2016) Tips and Tactics: *Rhizoctonia*, Western Region. GRDC Fact sheet, <https://grdc.com.au/TT-Rhizoctonia>

i MORE INFORMATION

[DAFWA \(2016\) Diagnosing Rhizoctonia root rot in cereals.](#)

[GRDC \(2016\) Rhizoctonia. Fact Sheet.](#)

[GRDC \(2014\) Rhizoctonia control improved by liquid banding of fungicides GRDC Update Paper.](#)

[Australian Pesticides and Veterinary Medicines Authority](#)

Fungicide treatments

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

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

Several products have been registered for liquid banding. GRDC funded research has shown:

- 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 a split application

Nitrogen

Nitrogen deficient crops are more susceptible to Rhizoctonia disease. Very low levels of mineral-N over summer results from intensive cropping with cereals and stubble retention as 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.

Ensure good N nutrition as 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
- Ensure phosphate is placed close to the seed to help compensate for early root pruning⁶³

63 GRDC (2016) Tips and Tactics: Rhizoctonia, Western Region. GRDC Fact sheet, <https://grdc.com.au/TT-Rhizoctonia>

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)
<p>Check for inoculum build-up</p> <ul style="list-style-type: none"> 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 <i>Rhizoctonia</i> disease 	<p>Facilitate inoculum decline</p> <ul style="list-style-type: none"> 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 and especially if planning to sow cereals back on cereals 	<p>Select appropriate crop</p> <ul style="list-style-type: none"> Select a non-cereal crop (e.g. canola or pulses) to reduce inoculum levels Remove autumn ‘green bridge’ before seeding with good weed control 	<p>Manage infection and disease impact through management practices</p> <ul style="list-style-type: none"> 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

9.18 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* and it survives from one season to the next through fungal spores, which remain in the top layer of the soil. The disease increases in severity with continuous wheat and 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

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 two years is recommended.

9.19 Smut

Seed treatments provide cheap and effective control of bunt and smut diseases. Seed should be treated every year with a fungicide as 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 fertiliser treatments do not control bunt and smuts, so seed treatments are still required.

MORE INFORMATION

[GRDC Cereal root and crown diseases. The Back Pocket Guide.](#)

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.

Symptoms

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 (Photo 20).



Photo 20: 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

All barley seed should be treated with a fungicide for control of smuts each year to stop any buildup of smut in crops.⁶⁴

⁶⁴ G Hollaway (2012) Bunts and smuts of cereals. Agriculture Victoria, AG1257 (updated July 2013), <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/bunts-and-smuts-of-cereals>

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.

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 (Photo 21). Initially, the spores are loosely held by a thick membrane, which soon breaks releasing the spores onto other heads. Finally, all that remains is 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.



Photo 21: *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.

SECTION 9 BARLEY

TABLE OF CONTENTS

FEEDBACK

 MORE INFORMATION

[DAFWA \(2016\) Controlling barley loose smut in 2016.](#)

[DAFWA \(2015\) Smut and bunt diseases of cereal– biology, identification and management.](#)

<http://www.giwa.org.au/>

Control

Using systemic seed treatments every year will effectively control this disease. It is important to have good coverage of seed if growing a susceptible variety such as Hindmarsh⁶⁵.

Loose smut was observed in Hindmarsh⁶⁵ barley crops despite use of seed treatment. Tests by SARDI showed that products with triadimenol, flutriafol, tebuconazole and ipconazole may not provide total smut control. The new SDHI fungicide 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 Trobe⁶⁵ is likely to be similar to Hindmarsh⁶⁵.

⁶⁵ G Hollaway, M McLean, J Fanning (2015) Cereal disease guide. Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-disease-guide>