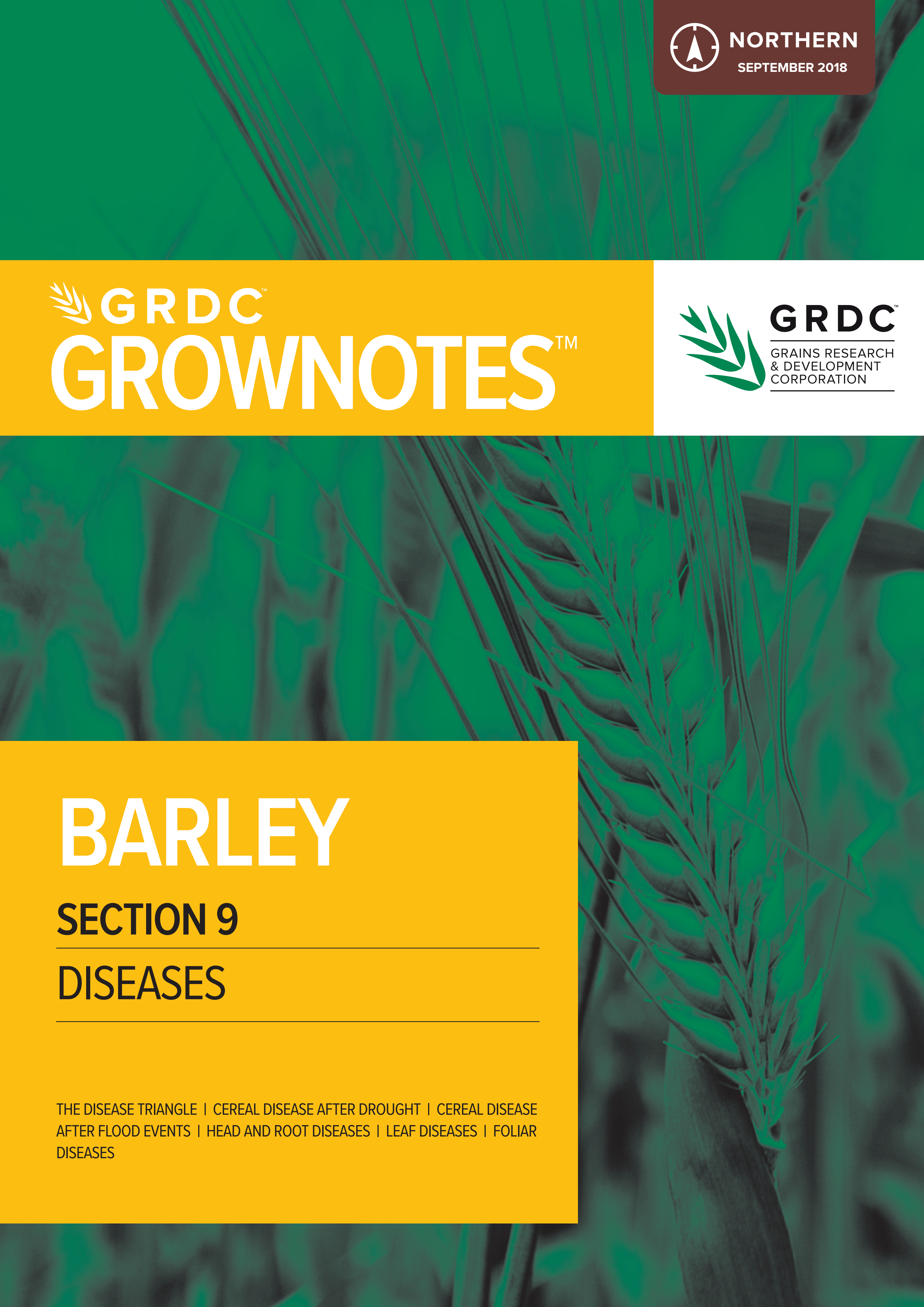

NORTHERN
SEPTEMBER 2018

GRDC GROWNOTES™

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

BARLEY

SECTION 9

DISEASES

THE DISEASE TRIANGLE | CEREAL DISEASE AFTER DROUGHT | CEREAL DISEASE AFTER FLOOD EVENTS | HEAD AND ROOT DISEASES | LEAF DISEASES | FOLIAR DISEASES

SECTION 9

Diseases

More information

http://www.grdc.com.au/~/media/CF32E282F9E241488125CD98A6567EB8.pdf

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Managing-barley-and-wheat-diseases-priority-issues-and-actions-for-2015

Barley diseases cause an estimated current average annual loss of AU$252 million, or $66.49 per hectare, to the Australian barley industry. In the decade to 2009, this loss represented 19.5% of the average annual value of the barley crop. [1] In the northern region, crown rot and Fusarium head blight (FHB) are the main diseases affecting barley grain. The most prevalent foliar diseases are rusts, blotches and powdery mildew. They can all have serious impacts on grain yield and quality.

Diseases in the broad sense can be caused by environmental factors, such as temperature or water stress and nutrient deficiencies, as well as living agents (pathogens). This section considers only diseases with a biotic (living) cause. [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 rates. Rotate barley crops with non-hosts such as legumes or summer crops, 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]

Tables 1 and 2 present major diseases and disease-loss ranking in the northern region. In addition to these diseases, leaf rust incursions have caused significant losses in the northern grains region in recent years, particularly the 2010 season.

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/LEAF-RUST-IN-BARLEY-LESSONS-LEARNT-IN-2009-AND-IMPLICATIONS-FOR-MANAGEMENT-PLANS-IN-2010

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Wheat-and-barley-disease-management-in-2011-Yellow-spot-and-head-diseases-in-wheat-Strategies-and-products-for-barley-leaf-rust

Table 1: Five major diseases by potential loss in northern region

Disease	$/ha	$ million
Crown rot	54.58	23
Net blotch-net form	50.42	21
Net blotch-spot form	42.40	18
Powdery mildew	21.11	9
Common root rot	16.49	7

Table 2: Northern region ranking of disease losses (1 = highest loss)

Disease	Potential	Present
Net blotch-spot form	3	1
Crown rot	1	2
Net blotch-net form	2	3
Covered smut	7	4
Powdery mildew	4	5

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

[2] UNE grains course notes.

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

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Yellow-spot-in-wheat-leaf-rust-and-net-blotch-diseases-in-barley-lessons-from-2010-for-better-management-in-2011

Disease epidemics develop when susceptible varieties are sown over wide areas in the presence of plentiful inoculum under favourable environmental conditions. The year 2010 provided the most favourable conditions for the development of foliar diseases for 12 years, and generated epidemics of yellow spot in wheat and spot form of net blotch and leaf rust in barley. After several years of relatively low levels of these diseases, all factors contributing to epidemic development combined to initiate epidemics quite early in crop development. [4]

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 (Table 3).

Table 3: Barley variety comparisons (2013)

	Commander	Fitzroy	Gairdner	Grange	Grimmett	Grout	Henley	Hindmarsh	Mackay	Navigator	Oxford	Shepperd	Westminster
Height	Medium-tall	Short	Medium-tall	Medium-tall	Medium-tall	Medium-tall	Short-medium	Short	Medium-tall	Short	Medium	Medium-tall	Medium
Standability	Medium-poor	Good	Medium	Good	Medium-poor	Medium	Good	Medium	Medium	Good	Good	Medium-good	Good
Post-ripe straw strength	Medium-poor	Medium-poor	Good	Good	Very good	Medium	Good	Medium-poor	Medium	Medium	Medium	Good	Medium
Maturity (days to flower)	Medium	Medium-late	Late	Late	Medium-late	Early	Medium-late	Early-medium	Medium	Late	Late	Early-medium	Late
Net blotch (net form)	MS/S*	MR	MR	MRMS/S	S-VS	MR/S	SVS/MR	MRMS	MRMS/S	MRMS/S	MS	MR/S	SVS/MR
Net blotch (spot form)	MSS	S	S-VS	S	S	S	S	VS	S-VS	MRMS	S	S-VS	S-VS
Leaf rust	S	S	S	MRR	S	VS	MR	S	MRMS	S	MR	MR	R
Stem rust	S	S	S	S	S	S	S	S	MS-S	S	S	S	S
Spot blotch	S	S	S-VS	VS	S-VS	S	S-VS	S-VS	MS-S	VS	VS	S	VS
Powdery mildew	MRMS	S	S	R	S	R/MS	R	MR	MR	R/MS	R	R/MS	R
Crown rot	MSS	MS-S	S		MS	MS		MRMS	S			MR-MS	

Foliar diseases - Management options

R - MR =: Very little to no disease found. Fungicide application not warranted.

MR-MS Monitor crops for disease development. Under high inoculum pressure fungicide application can be economic. Late occurrence of the disease may not require any action.

S-VS Fungicide application will be required to reduce yield loss in favourable seasons.

*Ratings separated by "/" indicate response to different strains in the disease population. First value indicates response to the most common strains.

(Foliar diseases have a wide range of pathotypes. Disease resistance ratings are based on current knowledge of pathogen populations in the northern Henley region).

See p. 43 of the '2013 Winter crop variety sowing guide' for more information on variety characteristics and reaction to diseases: http://www.grdc.com.au/NVT-NSW-CropVarietyGuide

GRDC Video

Greg Platz: http://www.youtube.com/watch?v=-BI1MF7MJrc

More information

http://www.grdc.com.au/NVT-NSW-CropVarietyGuide

http://www.daff.qld.gov.au/__data/assets/pdf_file/0018/53019/barley-planting-disease-guide.pdf

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

9.1 The disease triangle

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

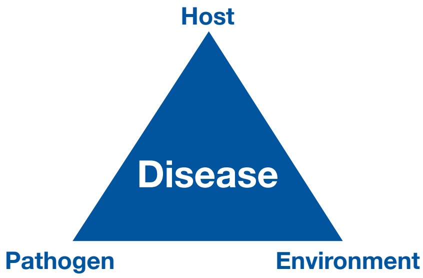

Figure 1: The disease triangle.

For disease to occur, there must be a susceptible host and a virulent pathogen, and the environment must be favourable. In practical terms, virulent pathogens are present in every field crop; however, some can be controlled through biosecurity measures, and seed-borne diseases can be controlled by the pathogen, i.e. seed treatments.

Some important examples of interactions of environmental conditions with diseases of grain crops are as follows:

- Low temperatures reduce plant vigour. Seedlings, especially of summer crops, become more susceptible to *Pythium*, *Rhizoctonia* and other root and damping-off pathogens if they are emerging in soils below their optimum temperature.
- Pathogens have different optimum temperature ranges. For example, hatching in nematodes tends to occur over narrow soil temperature ranges, within a 10–25°C range 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 (see below). 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. [5]

More information

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/123718/crop-diseases-after-drought.pdf

9.2 Cereal disease after drought

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

The NSW Department of Primary Industries (DPI) information sheet '*Cereal diseases after drought*' covers effects on crown rot, rhizoctonia root rot, inoculum, tan (yellow)

[5] UNE grains course notes.

spot, rusts, wheat streak mosaic and other cereal diseases, and burning stubble to control disease. [6]

9.3 Cereal disease after flood events

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

The legacy of the floods and rain included transport of inoculum (crown rot, nematodes, leaf spots through movement of infected stubble and soil) (Figures 2 and 3), development of sexual stages (leaf spots, head blights), survival of volunteers (unharvested material and self-sown plants in double-crop situations), and weather-damaged seed.

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

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

The presence of leaf spots is recognised by the occurrence of fruiting bodies (pseudothecia) on straw and lesions on volunteers. Head blights produce fruiting bodies (perithecia) on straw, while crown rot survives mainly as mycelia in straw. Soil-borne nematodes are detected through soil tests. [7]

More information

GRDC Fact Sheet: [http://www.grdc.com.au/greenbridge factsheet](http://www.grdc.com.au/greenbridgefactsheet)

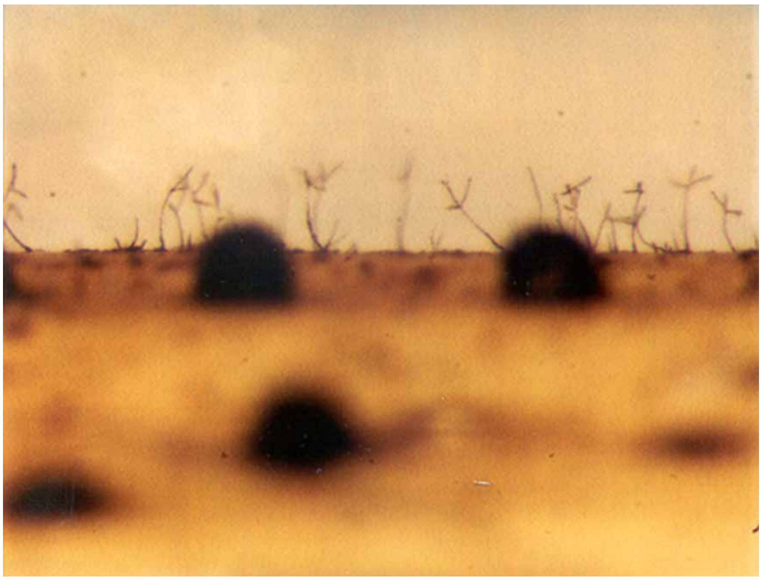

Figure 2: Barley stubble after incubation under high humidities shows disease spores. (Photo: Greg Platz, QDAFF)

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

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

Figure 3: Fruiting bodies on barley stubble. (Photo: Greg Platz, QDAFF)

9.3.1 Management options

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

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

The application of fungicides is an economic decision, and in many cases, a higher application rate can give a better economic return through greater yield and higher grain quality. Timing and rate of application are more important than product selection. Stripe rust ratings in variety guides are for adult plant response to the pathogen, and may not accurately reflect seedling response. [8]

9.3.2 Strategies

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

Strategies include:

- using the best available seed
- identifying your risks
- formulating management strategies based on perceived risk
- monitoring crops regularly
- timely intervention with fungicides [9]
- Seed and fertilizer treatments (e.g. Baytan, Impact, Systiva).

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

For the stubble-borne diseases—yellow spot (YS) and spot form net blotch (SFNB)—practical control measures are as follows.

Crop rotation

Avoid sowing wheat on wheat or barley on barley. Where possible, sow 2010 cereal country to an alternative cereal, chickpea or canola, or even fallow through for a summer crop.

Reduce surface stubble

The amount of early disease is directly related the quantity of stubble at sowing. Incorporation or removal of stubble delays disease onset and slows epidemic development. In very favourable seasons, <200 kg of infective stubble can result in high levels of yellow spot.

Resistant varieties

Where resistant varieties are available and agronomically suitable, they offer the most practical means of control. However, there no varieties are immune to YS and SFNB, so some disease will develop even in highly resistant varieties. Impact of disease on yield of these varieties should be minimal.

Monitor disease levels

Disease levels must be closely monitored if chemical intervention is being considered. Timely application of foliar fungicides is essential to maximise control and return on investment.

Fungicides give best control when applied as protectants, and duration of control is rate-dependent. A full-rate application of a recommended fungicide should give at least 30 days of control. In high-risk situations, a dual application strategy will give best results with sprays applied at about GS31–32 and again at GS39–49. Economics will dictate whether such a strategy is warranted. [10]

More information for specific diseases follows.

More information

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

http://www.grdc.com.au/Research-and-Development/National-Variety-Trials/Crop-Variety-Guides

KE Nelson, LW Burgess (1995) Effect of rotation with barley and oats on crown rot of wheat in the northern wheat belt of New South Wales. *Australian Journal of Experimental Agriculture* 35, 765–770: http://dx.doi.org/10.1071/EA9950765

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/159031/root-crown-rot-diseases.pdf

9.4 Head and root diseases

9.4.1 Crown rot

Crown rot, caused predominantly by the fungus *Fusarium pseudograminearum*, is the most damaging disease of winter cereals in the northern region. Crown rot affects wheat, barley and triticale. [11] It survives from one season to the next in the stubble remains of infected plants and grassy hosts. The disease is more common on heavy clay soils.

Infection is favoured by high soil moisture in the 2 months after planting. Drought stress during elongation and flowering will lead to the production of 'deadheads' or 'whiteheads' in the crop. These heads contain pinched seed or no seed at all. [12]

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. A winter chickpea or any

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

[11] S Simpfendorfer, M Gardner (2013) Crown rot: be aware of the balancing act or the fall may be harder! GRDC Update Papers 25 Feb. 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

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

summer crop may be used as a disease-free rotation crop but it must be kept clean of alternative grassy hosts. [13]

If forced into planting a cereal crop in a high crown rot risk situation then some barley varieties may provide a yield advantage over bread wheat in a season, as long as early stress does not occur. However, growing barley over bread wheat will not assist with the reduction of crown rot inoculum levels as barley is very susceptible to infection. Barley as a general rule also produces increased stubble loads compared to wheat so could actually be building up increased crown rot inoculum levels. [14]

Damage caused by crown rot

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

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

Symptoms

- Tiller bases are always brown, often extending up 2–4 nodes.
- Some tillers on diseased plants may not be infected.
- Whitehead formation is most severe in seasons with a wet start and dry finish.
- Plants often break off near ground level when pulled up.
- Plants are easy to pull up in good moisture situations as 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. [15]

Infection is characterised by a light honey-brown to dark brown discoloration of the base of infected tillers, while major yield loss from the production of whiteheads is related to moisture stress post-flowering. [16]

If the leaf bases are removed from the crowns of diseased plants, a honey-brown to dark brown discoloration (Figure 4) will be seen. In moist weather, a pink-purple fungal growth forms inside the lower leaf sheaths and on the lower nodes.

More information

GRDC Update Paper: 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

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Crown-rot-an-update-on-latest-research

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/High-crown-rot-risk-barley-vs-wheat

https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Improving-the-accuracy-of-PreDicta-B-soil-testing

GRDC Video

Steven Simpfendorfer's presentation: http://www.grdc.com.au/Media-Centre/GRDC-Gallery/Video/ZvsqA-NrcNY

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Pre-sow-assessment-of-crown-rot-risk-in-the-northern-region

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

14 http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/High-crown-rot-risk-barley-vs-wheat#sthash.1ifM6ySg.dpuf

15 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

16 S Simpfendorfer, M Gardner (2013) Crown rot: be aware of the balancing act or the fall may be harder! GRDC Update Papers 25 Feb. 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

Figure 4: Basal browning indicating crown rot infection.

Effect of sowing time

Earlier sowing within the recommended window of a given variety for a region generally brings the grain-fill period forward to the point where the probability of moisture stress during grain-fill is reduced. Earlier sowing may also increase the extent of root exploration at depth, which could provide greater access to deeper soil water later in the season, buffering against crown rot expression (Figure 5). This has been shown in previous research by NSW DPI across seasons to reduce yield loss from crown rot. [17]

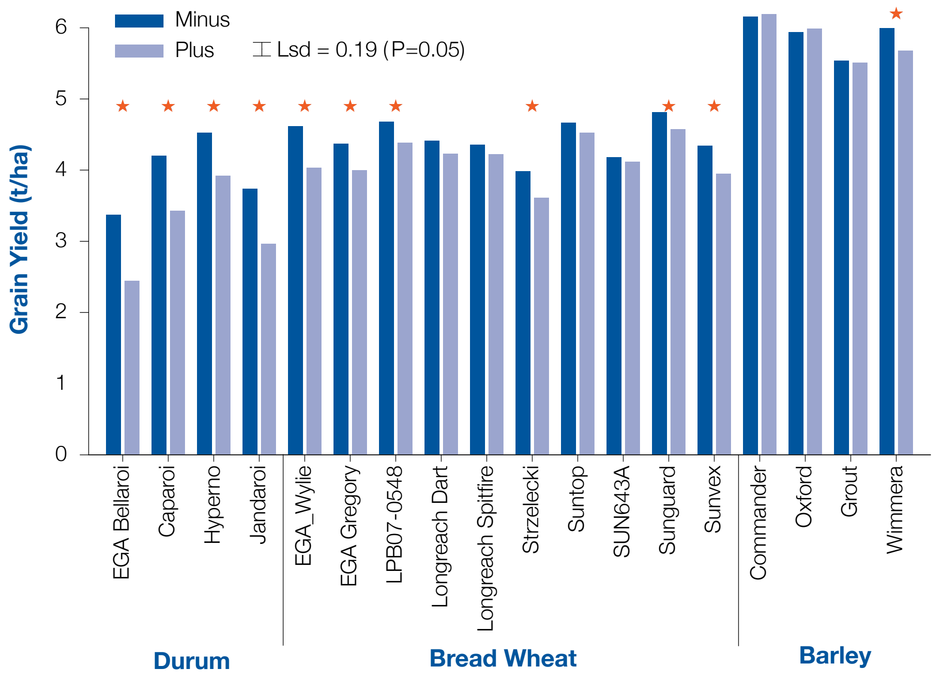

Figure 5: Effect of crown rot on the yield of 18 different varieties averaged across two sowing times at Walgett in 2012. Varieties designated with a star represent a significant yield loss from crown rot infection.

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

More information

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/468328/Northern-grains-region-trial-results-autumn-2013.pdf

http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-98-May-June-2012/Seedborne-Fusarium-tests-crown-rot-strategies

17 UNE grains course notes.

Crown rot phases

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

- Survival: The crown rot fungus survives as mycelium (cottony growth) inside winter cereal (wheat, barley, triticale and oats) and grass weed residues that it has infected. The crown rot fungus will survive as inoculum inside the stubble for as long as the stubble remains intact, which varies greatly with soil and weather conditions; decomposition is generally a very slow process.
- Infection: Given some level of soil moisture, the crown rot fungus grows out of stubble residues and infects new winter cereal plants through the coleoptile, sub-crown internode or crown tissue, which are all below the soil surface. The fungus can also infect plants above the ground right at the soil surface through the outer leaf sheathes. However, with all points of infection, direct contact with the previously infected residues is required, and infections can occur throughout the whole season given moisture. Hence, wet seasons (2010, 2011 and start of 2012) 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/temperature stress around flowering and through grain-fill. Expression is also affected by variety. Moisture stress is believed to trigger the crown rot fungus to proliferate in the base of infected tillers, restricting water movement from the roots through the stems, and producing whiteheads that contain either no grain or lightweight, shrivelled grain. The expression of whiteheads (Figure 6) in plants infected with crown rot (i.e. still have basal browning) is restricted in wet seasons and increases greatly with increasing moisture stress during grain-fill. [18]

More information

Monitoring fusarium crown rot populations in spring wheat residues using quantitative real-time polymerase chain reaction (AC Hogg *et al*. 2010): http://www.ncbi.nlm.nih.gov/pubmed/19968549#

Decomposition and chemical composition of cereal straw (BA Summerell, LW Burgess 1989): http://www.sciencedirect.com/science/article/pii/0038071789901296

Figure 6: 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.

[18] S Simpfendorfer, M Gardner (2013) Crown rot: be aware of the balancing act or the fall may be harder! GRDC Grains Update Papers 25 Feb. 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

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 mustard, canola or faba beans.
- Crown Analytical Services (CAS), Moree, offers a commercial stubble assessment service (see www.crownanalytical.com.au) and is an agent for PreDicta B soil testing, which is not currently calibrated for crown rot in the northern region but its application is being investigated. (Northern growers are advised to use Predicta B for nematode testing.)
- If growing cereals in crown rot-affected paddocks, select types with lower yield loss risk such as barley and some bread wheats. Avoid all durum varieties.
- Match nitrogen application to stored soil moisture and potential yield.
- Limit nitrogen application prior to and at sowing to avoid excessive early crop growth.
- Ensure zinc nutrition is adequate.
- Sow on the inter-row if possible when sowing cereal after cereal. [19]
- Current seed treatments do not offer any control.

More information

www.crownanalytical.com.au

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2009/09/ECONOMICS-OF-PHOSPHORUS-AND-ZINC-NUTRITION

Crop rotation

Growing non-host break crops remains an important tool for managing crown rot, as break crops allow time for decomposition of winter cereal residues that harbour the crown rot inoculum. Canopy density and rate of canopy closure can affect the rate of decomposition and these vary with different break crops (i.e. faba bean and canola). Crops that are sparser in nature, such as chickpea, 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 nematode (RLN). Table 4 lists suggested rotations under different levels of crown rot infection.

More information

http://www.regional.org.au/au/asa/2003/c/6/kirkegaard.htm

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

Table 4: Suggested rotations under varying crown rot conditions

LF, Long fallow; DC, double-crop. Faba bean, field pea, or canola/mustard can substitute for chickpea and other summer crops for sorghum

High (25% diseased plants)	Medium (11–24%)	Low (10%)
LF–sorghum–DC chickpea–wheat	Pre-plant burn–chickpea–wheat/barley	No limitation to crop choice. However, regular inclusion of break crops will prevent crown rot levels from rising
Chickpea–LF–sorghum–LF–wheat	Chickpea–pre-plant burn–wheat/barley	
DC Mungbean–LF–sorghum–DC chickpea–wheat/barley	LF–sorghum–wheat/barley	
LF–sorghum–LF–wheat/barley–chickpea	DC Summer crop–LF–wheat/barley	
3 Years lucerne provided it is kept grass-free		

Growing barley before wheat in paddocks with high crown rot inoculum is not an option as yield loss can result.

All current barley varieties are very susceptible and 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 moisture stress interactions with infection, which result in the production of whiteheads. [20]

Inter-row sowing

Northern Grower Alliance (NGA) research shows:

- Inter-row sowing will reduce the level of crown rot incidence and severity (measured as inoculum in residues, not as whitehead expression), on average, by ~50%.
- Inter-row sowing provides an increased disease management benefit under low disease conditions.
- Inter-row sowing resulted in a useful, but relatively modest, 5% increase in average yield compared with on-row sowing.
- Inter-row sowing is not a tool to enable back-to-back cereal production under moderate–high crown rot risk.
- Inter-row sowing will provide best benefit by incorporation into a crown rot disease management package based on sound crop rotation. [21]

Stubble burning

Burning removes the above-ground portion of crown rot inoculum but the fungus will still survive in infected crown tissue below-ground; 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 as 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.

More information

http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-70-September-October-2007/Crown-rot-Stubble-avoidance-lessens-crown-rot

http://www.nga.org.au/results-and-publications/browse/1/grdc-update-papers-diseases

http://www.nga.org.au/results-and-publications/browse/45/complete-summary

Videos

http://www.grdc.com.au/Media-Centre/GRDC-Gallery/Video/ZvsqA-NrcNY

Podcast

http://www.grdc.com.au/Media-Centre/GRDC-Podcasts/Northern-Weekly-Update/2013/10/17-North

More information

http://www.grdc.com.au/~/media/4CA071540A0F4E28AE0FF786D8BCB1DA.pdf

http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-107-NovDec-2013/Stubble-management-still-a-burning-question

[20] 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

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

Details on crown rot resistance or tolerance among barley varieties can be found in the annual *NSW Winter Crop Variety Sowing Guide*, and the National Variety Trials (NVT) website, www.nvtonline.com.au.

However, no barley varieties possess adequate field resistance. The *NSW Winter Crop Variety Sowing Guide* and www.nvtonline.com.au indicate which varieties of barley have been found particularly susceptible to crown rot. No barley varieties recommended for NSW are considered to have even moderate resistance to the fungus. Given the lack of resistance, rotation with chickpea or summer crops is currently the best method of controlling crown rot. [22]

In 2007–2009, NGA ran a series of trials across north-western NSW to assess the impact of crown rot on winter cereal yields (Figure 7); 2007 had a very hot, dry finish and the trials showed some significant yield losses from the addition of crown rot inoculum. The years 2008 and 2009 had milder springs and crown rot had less impact on yield.

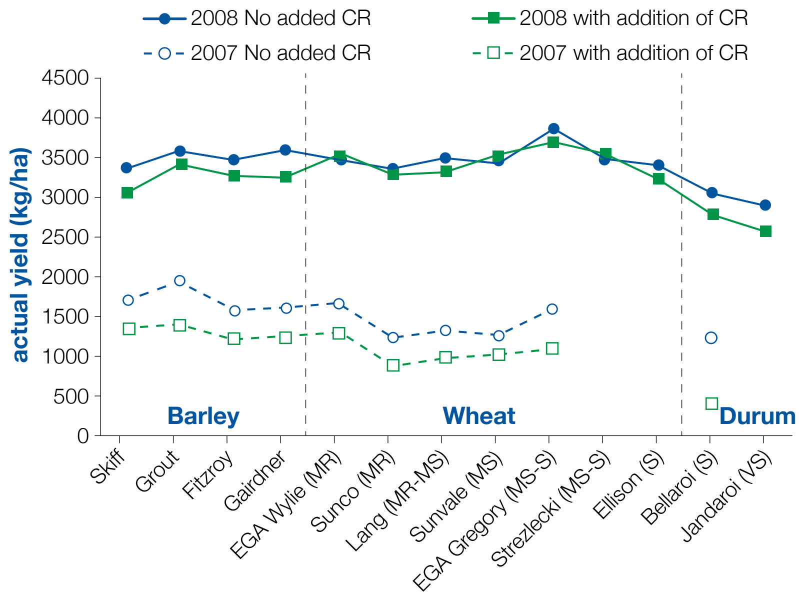

Figure 7: Percentage yield loss by crop 2007 and 2008.

Key findings:

- The level of crown rot yield loss was minimal in the 2008 trials. This highlights the impact of conditions late in the season in determining the level of yield loss due to crown rot.
- Yield loss in barley was similar to that in bread wheat.
- Despite the favourable finish, durum losses were still of concern and more than triple the average loss in barley.
- There was no clear pattern of yield loss difference within either the barley or wheat varieties under the lower crown rot yield loss conditions in 2008. [23]

9.4.2 Common root rot

Common root rot is a soil-borne fungal disease that attacks wheat, barley and triticale. 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 or wheat–barley sequences.

More information

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

http://www.grdc.com.au/Research-and-Development/National-Variety-Trials/Crop-Variety-Guides

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2008/06/The-Impact-of-crown-rot-on-winter-cereal-yields

https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2009/09/THE-IMPACT-OF-CROWN-ROT-ON-WINTER-CEREAL-YIELDS-YEAR-2

22 QDAF Diseases: http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/barley/diseases

23 GRDC (2009) The impact of crown rot on winter cereal yields—year 2. GRDC Update Papers 17 Sept. 2009, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2009/09/THE-IMPACT-OF-CROWN-ROT-ON-WINTER-CEREAL-YIELDS-YEAR-2

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

Common root rot symptoms:

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

More information

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

http://www.grdc.com.au/Research-and-Development/National-Variety-Trials/Crop-Variety-Guides

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

The disease may be controlled by planting partially resistant varieties or by crop rotation. Where the disease is severe, rotation to non-susceptible crops for at least 2 years is recommended. Summer crops such as sorghum, sunflower, or white French millet can be used for this purpose.

Common root rot can occur from tillering onwards but is most obvious after flowering. It shows no distinct paddock symptoms, although the crop may lack vigour and severe infections can lead to stunting of plants. It appears more prevalent in paddocks that are N-deficient. When N is not limiting, yield loss occurs through a reduction in tillering due to poor N-use efficiency. Affected plants are usually scattered through the crop. Common root rot is widespread through the grain belt and the disease is often found in association with crown rot. [24]

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Wheat-and-barley-disease-management-in-2011-Yellow-spot-and-head-diseases-in-wheat-Strategies-and-products-for-barley-leaf-rust

9.4.3 Botryosphaeria head blight (white grain disorder)

White grain was conspicuous in harvested samples of wheat in the 2010 season. This symptom is the result of infection with one of principally two fungal pathogens: *Fusarium graminearum* and *Botryosphaeria zeae*. Fusarium head blight or head scab is the disease that causes white grain and head blight from infection by *Fusarium* species. White grain or white grain disorder is the terminology currently used to describe the disease caused by *B. zeae*. It is proposed that this disease be known in future as Botryosphaeria head blight (BHB). [25]

9.4.4 Fusarium head blight

The extensive rain and warm conditions during flowering of the crop in 2010 resulted in the first widespread significant occurrence of FHB in wheat, durum and barley crops in southern Queensland. This caused significant downgrading of some crops. Until recently, FHB has been reported irregularly and in isolated areas of Australia's northern region. The most significant infections in the past occurred in durum crops on the Liverpool Plains in the late 1990s.

Fusarium head blight is a fungal disease that can occur on many grass species, including crop and weeds. Where it occurs in crops, it is most common in wheat, durum and barley. It is a frequent and widespread disease of major wheat-production areas of North America, Asia and Europe, where much research into its control has been ongoing for >20 years.

Fusarium head blight can cause significant yield losses and quality reductions. Major yield losses occur mainly from floret sterility. Additional yield and quality losses can occur when damaged and shrivelled lightweight grains are produced because of infection. Quality reductions may also occur from seed discoloration, varying from whitish grey, pink to brown. Fungal infection can sometimes be associated with the production of a toxin (mycotoxins).

24 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

25 G Platz (2011) Wheat and barley disease management in 2011. Yellow spot and head diseases in wheat. Strategies and products for barley leaf rust. GRDC Update Papers 19 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Wheat-and-barley-disease-management-in-2011-Yellow-spot-and-head-diseases-in-wheat-Strategies-and-products-for-barley-leaf-rust

If fungal toxins are produced in infected seed, the grain is often unacceptable for certain end uses and downgraded in the marketplace depending on the concentration of toxin present. Toxin levels and fungal infection cannot be accurately estimated from visual appearance. [26]

Symptoms

In barley, infected seed may show a bleached appearance or a browning or water-soaked appearance (Figure 8). Severely infected barley grain at harvest may show a pinkish discoloration in the sample, and although rare, salmon-orange spore masses of the fungus can be seen on the infected spikelet and glumes during prolonged wet weather. [27]

Figure 8: Infected barley heads and seed. (Photo: DAFF Qld)

Identity, survival and spread

Pathogen

Several species of *Fusarium* can cause FHB. The most common species causing FHB is *Fusarium graminearum*. This fungus can also cause stalk and cob rot of corn.

The crown rot fungus is a closely related species, *Fusarium pseudograminearum*. The crown rot fungus can occasionally affect heads but this is rare. The infections in Queensland during the 2010 season have been almost 100% *Fusarium graminearum*. [28]

For details of testing services, see *Section 1: Planning and paddock preparation*.

Survival and spread

The fungi persist and produce spores on previous crop residues of wheat, barley and corn (Photo 6*a*, *b*), although other grass weeds and crops can also be a source of inoculum. During moist weather, sexual spores are produced in microscopic, black, flask-shaped structures on old crop and weed debris on the soil surface.

[26] DAFF (2012) Fusarium head blight (FHB) or head scab. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/health-pests-diseases/a-z-significant/fusarium-head-blight

[27] DAFF (2012) Fusarium head blight (FHB) or head scab. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/health-pests-diseases/a-z-significant/fusarium-head-blight

[28] DAFF (2012) Fusarium head blight (FHB) or head scab. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/health-pests-diseases/a-z-significant/fusarium-head-blight

Figure 9: Persistent fungal spores from previous crops. (Photos: DAFF Qld)

The most favourable conditions for spore production and infection are 48–72 h of high humidity and temperatures of 23–29°C. Longer periods of high humidity can compensate for lower temperatures if optimum temperatures are not experienced. These conditions do not have to be continuous and spore production will still take place if 1 or 2 dry days punctuate the humid periods.

With continued high humidity, the spores are windblown or splashed onto the heads of cereal crops where they germinate in the humid conditions and infect the plant. If prolonged favourable conditions persist, asexual spores are produced on the head and they result in even more spores and secondary infections. Spores from within a crop are the major inoculum source, but spores blown from surrounding crops, sometimes long distances away, can also be a source of infection.

Wheat and durum crops are susceptible to infection from the flowering (pollination) period to hard dough stage of kernel development, but the flowering period is when most infection occurs. Spores landing on the extruded anthers at flowering grow into the developing kernels. The anthers are a major source of infection in wheat as they exude chemicals that attract the fungus.

Infection by spores landing on glumes or other parts of the head is also possible. Once a floret is infected, the fungus can grow into the rachis and then grow up and down in the rachis, infecting adjacent kernels. Infection of adjacent kernels can also occur through the fungus growing over the surface of the glume to an adjacent floret.

Barley flowers when the head is in the boot. Often the anthers are not extruded, so in barley, infection is most common after the head emerges from the leaf sheath and through penetration of the glume. Barley is resistant to growth in the rachis, but infection of adjacent kernels can occur with the fungus growing over the surface of the glume to an adjacent floret. Under favourable environmental conditions for the disease, infection can continue in barley until grain maturity. [29]

Management

Fusarium head blight is best managed by integrating multiple management strategies. Use of a single strategy often fails when the environment favours severe disease. Management strategies to reduce FHB should include a combination of as many of the following practices as possible.

A disease will develop into a serious epidemic when three important factors all occur at once. These are:

- a susceptible host
- adequate inoculum
- conducive weather conditions

As there is no demonstrated resistance in Australian cultivars and weather cannot be controlled, management of the disease should revolve around reducing inoculum. [30]

29 DAFF (2012) Fusarium head blight (FHB) or head scab. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/health-pests-diseases/a-z-significant/fusarium-head-blight

30 DAFF (2012) Fusarium head blight (FHB) or head scab. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/health-pests-diseases/a-z-significant/fusarium-head-blight

Resistance

All current varieties of wheat, barley and durum grown commercially in Australia are likely to be susceptible to FHB. Although some level of resistance does exist in germplasm around the world, resistance to FHB is a complex trait without simple inheritance. Even in countries where FHB occurs more extensively and frequently, after many years of breeding, commercial varieties have only moderate levels of resistance.

Durum is more susceptible to the disease than bread wheat and barley. Durum should be avoided in areas where there is likelihood of the disease developing. [31]

Seed treatment

There has been no evidence that the fungus can grow from infected seed up through the stem and into the developing head to produce head blight. However, infected seed can result in seedling blight and dead seedlings when the seed is planted.

No seed dressings are currently registered for control of seedling blight caused by the FHB pathogens. Research conducted by the Department of Industry and Investment in NSW in the 1990s showed that the most effective seed treatment to prevent seedling blight was thiram + carboxin. Tests are under way to determine the effectiveness of more modern fungicides as seed dressings.

If grain from an infected source is to be used as seed, it should be cleaned and only used if it has high germination and vigour. [32]

Tillage

Because the fungus survives on residue left on the soil surface, any tillage practices that bury, destroy or promote faster decomposition of residue from a host crop will reduce the potential inoculum for future host crops. Before removing or destroying residues, consideration should be given to any effect of these practices on ground cover, water infiltration and soil organic matter. [33]

Crop rotation

Crop rotation is effective in reducing FHB levels. Sowing a susceptible crop after 1 year or more of non-host crops will reduce inoculum levels. The greatest risk of FHB infection is when small grains are planted on last year's FHB-infected wheat, barley or corn.

Corn in a rotation is a significant risk, as *Fusarium graminearum*—the major cause of FHB—also attacks corn, causing stalk, root and cob rot, and the fungus can survive for more than one season in corn residue. Although it does not appear to exhibit any significant disease symptoms, sorghum can also host *Fusarium graminearum*, which may infect following winter cereal crops. However, the two major species of *Fusarium* that attack sorghum, *F. thapsinum* and *F. andiyazi*, are not pathogens of winter cereals.

The best rotational crops for reducing the inoculum level include any non-grass species (e.g. sunflower, cotton, soybean, chickpea, mungbean, faba bean, canola, field pea). [34]

Planting date

As infection requires moisture during flowering or head emergence, staggering the planting period or planting varieties with varying maturity should spread the risk in years where there are not continuous or repeated periods of high humidity. [35]

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31 DAFF (2012) Fusarium head blight (FHB) or head scab. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/health-pests-diseases/a-z-significant/fusarium-head-blight

32 DAFF (2012) Fusarium head blight (FHB) or head scab. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/health-pests-diseases/a-z-significant/fusarium-head-blight

33 DAFF (2012) Fusarium head blight (FHB) or head scab. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/health-pests-diseases/a-z-significant/fusarium-head-blight

34 DAFF (2012) Fusarium head blight (FHB) or head scab. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/health-pests-diseases/a-z-significant/fusarium-head-blight

35 DAFF (2012) Fusarium head blight (FHB) or head scab. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/health-pests-diseases/a-z-significant/fusarium-head-blight

More information

www.apvma.gov.au

Pathology Service: http://www.dpi.nsw.gov.au/aboutus/services/das/plant-pests-diseases

Fungicide

Currently, no fungicide sprays are registered in Queensland for control of FHB. However, fungicides have proven a useful tool in reducing infections in other countries; reductions in FHB severity of 50–60% can be achieved when the most effective fungicides are applied at early flowering for wheat and durum, and at early head emergence for barley. If conditions are favourable for FHB infection in coming seasons, emergency registration for chemicals should be able to be obtained prior to the crop flowering.

When applying fungicide to control FHB, the target is the vertical head rather than the more horizontal flag leaf. Modify application techniques for best effectiveness. Spray coverage and disease control for FHB is improved when the sprays are directed at a 30° angle from horizontal both forward and backward, or less optimally with single nozzles directed toward the grain head. Also, a higher water volume is recommended for good head coverage and ground application is more effective than aerial application. [36]

9.5 Leaf diseases

More information

[Leaf rust in barley and stripe rust in wheat - Impact on different varieties]()

9.5.1 Rusts

Leaf rust is Australia's most common and damaging rust disease in barley.

Although less common, stem rust has also caused problems in barley production. A form of stripe rust that is specialised to barley grass, known as barley grass stripe rust, can infect some barley cultivars, but the threat it poses is minor. True stripe rust of barley does not occur in Australia, so it is considered a serious exotic threat.

9.5.2 Leaf rust

Found in all barley-growing regions of Australia, leaf rust is prone to reaching epidemic levels, with outbreaks in recent years in Queensland.

In the early 1990s, the leaf rust pathogen developed the ability to overcome resistance in a range of barley cultivars carrying the gene *Rph12* (examples of these varieties include Gairdner⦶, Fitzgerald, Baudin⦶, Tallon and Lindwall). Since then, pathotypes with this virulence have appeared in all barley-growing regions across Australia. In early 2010, a new pathotype was detected that could overcome the resistance gene *Rph3* in the barley varieties Fairview⦶, Finniss⦶, Fitzroy⦶ Grange, Henley, Starmalt⦶, Oxford, Wimmera⦶ and Yarra.

This pathotype has been detected mainly in north-eastern Australia.

More information

http://www.grdc.com.au/GRDC-FS-AdultPlantResistance

http://www.grdc.com.au/GCS110

Research is under way to incorporate new sources of resistance to leaf rust into new Australian barley cultivars. This work has targeted more durable resistance sources that are effective at post-seedling growth stages, such as adult plant resistance. Several Australian barley cultivars already contain adult plant resistance provided by the *Rph20* gene. Examples of these barley varieties include Flagship⦶, Oxford, Shepherd⦶ and Westminster⦶.

9.5.3 Stripe rust

A common feature of the pathogens that cause cereal rust disease is the existence of forms that are specialised to a particular cereal crop species. Stripe rust, for example, has a form that is specific to wheat, and another form that is specific to barley. While the wheat form of stripe rust has been present in Australia since 1979, the barley form has not been recorded in this country. Recent GRDC-funded tests in Mexico have shown that Australian barley cultivars are generally susceptible to the barley form of stripe rust, which means this exotic disease poses a significant threat to the Australian barley industry.

Another form of stripe rust, first found in Australia in 1998, is specialised to wild barley grass. The origin of this pathogen is unknown, but it is thought to have been introduced

[36] DAFF (2012) Fusarium head blight (FHB) or head scab. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/health-pests-diseases/a-z-significant/fusarium-head-blight

to Australia. Although it can infect some Australian barley cultivars, notably Maritime ⦶, Skiff and Tantangara, the level of infection is usually low and there is no evidence of yield losses. However, plant breeders routinely screen germplasm to help avoid potential vulnerability to the disease.

9.5.4 Stem rust

Like stripe rust, there are different forms of stem rust that are specialised to the different cereal species. Barley crops can be affected by one of three specialised stem rust pathogens. These include the wheat stem rust pathogen, the rye stem rust pathogen, and a pathogen that is a hybrid between the wheat and rye stem rust forms. Where stem rust is found on barley, it is important to determine which of these three pathogens is responsible for the rust disease, to assess the threat it poses to nearby wheat crops. Wheat is not affected by the rye stem rust pathogen or the hybrid form.

Observations over many years have indicated that stem rust can be mostly controlled in barley. Avoiding sowing barley in spring and stem rust control in nearby wheat and rye crops can help reduce the risk of barley stem rust developing. [37]

Rusts have a number of features in common. They can infect only a limited number of specific host plants (mostly volunteer wheat, triticale and barley) and can only survive on green, growing plant tissue. Plants facilitating the survival of rust fungi (alternative hosts as show in Table 5 or volunteer cereals) through the summer are known as the 'green bridge'.

Table 5: Alternative hosts for cereal rusts [38]

Disease	Pathogen	Primary hosts	Alternate hosts	Symptoms
Leaf rust	*Puccinia triticina*	Bread and durum wheats, triticale	*Thalictrum, Anchusa, Isopyrum, Clematis*	Isolated uredinia on upper leaf surface and rarely on leaf sheaths
Leaf rust duri type	*Puccinia triticiduri*	Durum and bread wheats in traditional agriculture	*Anchusa italica*	Isolated uredinia on lower leaf surface; fast teliospore development
Stem rust	*Puccinia graminis* f. sp. *tritici*	Bread and durum wheats, barley, triticale	*Berberis vulgaris*	Isolated uredinia on upper and lower leaf surfaces, stem and spikes
Stripe rust	*Puccinia striiformis* f. sp. *tritici*	Bread and durum wheats, triticale, a few barley cultivars	Unknown	Systemic uredinia on leaves and spikes and rarely on leaf sheaths

More information

GRDC Fact Sheet: http://www.grdc.com.au/greenbridge factsheet

More information

www.nvtonline.com.au

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

Rust diseases occur throughout the cereal-growing northern region, frequently causing economic damage. In Queensland in recent times, stripe rust has been the most important of these diseases.

Rust fungi continually change, producing new pathotypes. These pathotypes are detected when disease is found on a previously resistant variety. Even if a resistant variety has been sown, the crop should be monitored for foliar diseases on a regular basis. See the University of Sydney's Plant Breeding Institute (PBI) site and publications for more information: http://sydney.edu.au/agriculture/documents/pbi/cereal_rust_report_2010_vol_8_1.pdf.

Monitoring should start no later than GS32, the second node stage on the main stem, and continue to at least GS39, the flag leaf stage. This is because the flag leaf and the two leaves below it are the main factories contributing to yield and quality. It is most important that these leaves are protected from diseases. [39]

[37] GRDC (2013) Barley rust diseases in focus. GRDC Ground Cover issue 105, July–Aug. 2013, http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-105-July-August-2013/Barley-rust-diseases-in-focus

[38] RP Singh, J Huerta-Espino, AP Roelfs. The wheat rusts. FAO, http://www.fao.org/docrep/006/y4011e/y4011e0g.htm

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

To keep up to date with rust incursions throughout the winter crop season, subscribe to the PBI '*Cereal rust report'* at: http://sydney.edu.au/agriculture/plant_breeding_institute/rust_alert.shtml

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

9.5.5 Key points to reduce the risk of rusts

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

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

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

Where more susceptible varieties are used, ensure that a suitable fungicide strategy is in place, with the right chemicals available at short notice. Fungicides are better at protecting than curing. Fungicide applications on badly infected crops provide poorer control and do not restore lost green leaf area. [40]

For more information, download the GRDC Fact Sheet '*Adult plant resistance'* from: http://www.grdc.com.au/GRDC-FS-AdultPlantResistance

40 GRDC (2012) Adult plant resistance. GRDC Fact Sheet Nov. 2012, http://www.grdc.com.au/GRDC-FS-AdultPlantResistance

9.6 Foliar diseases

Our farming systems maintain ample inoculum of foliar diseases. Reduced/minimum tillage has delivered substantial benefits in water and soil conservation but it has also ensured the survival and increase of stubble-borne diseases. Despite a sequence of dry years, conditions have been adequate for infection of crops by yellow spot and net blotches. While these diseases may not have reached epidemic proportions through the dry period, they are present at relatively high levels in most crop stubbles. [41]

The planting of resistant varieties and the use of in-crop fungicides can be used in combination with targeted management practices to minimise the effect of foliar diseases. Those most likely to affect barley in the northern growing region are net blotch, spot blotch and SFNB, as well as leaf rust and stem rust, and they can all cause significant yield and quality losses in barley crops. Powdery mildew can also be a problem (Table 6).

Growers should assess the disease risk of individual paddocks before sowing. Consider the recent history of a paddock, the incidence of diseases in recent barley crops and the amount of infected stubble in the target and neighbouring paddocks. Infective stubble can usually be recognised by the presence of small black 'pimples' on the straw.

Table 6: Barley foliar diseases (GS, growth stage; Zadoks)

http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/barley/diseases

Disease	Survival mode	Optimal conditions	Dispersal	GS when infected	Pot. yield loss (%)	Control options
Leaf rust	Living barley plants	15–22°C; free moisture (dews)	Airborne	20–90; tillering to maturity	30+	Prevent green bridge, resistant varieties, fungicides, timely sowing
Stem rust	Living wheat, barley, rye, or rough wheat grass	20–30°C, free moisture (dews)	Airborne	>40, booting to maturity	50+	Prevent green bridge, resistant varieties, fungicides, timely sowing
Net blotch	Stubble, seed, volunteer plants	15–25°C, free moisture	Limited airborne	10–90, emergence to maturity	50+	Crop rotation, stubble removal, treat seed, resistant varieties, foliar fungicides
Spot form net blotch	Stubble, volunteer plants	15–25°C, free moisture	Limited airborne	11–90, first leaf to maturity	30+	Crop rotation, stubble removal, resistant varieties, foliar fungicides
Spot blotch	Stubble, seed, soil	20–30°C, free moisture	Limited airborne	10–90, emergence to maturity	50+	Crop rotation, stubble removal, treat seed, resistant varieties, foliar fungicides
Powdery Mildew	Stubble, volunteer plants	15–22°C, high humidity (85-100%)	Airborne	11–90, first leaf to maturity	15	Treat seed, resistant varieties, foliar fungicides

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

More information

[Spot form of net blotch management in barley grown in the Mallee environment]

[Spot form of net blotch yield loss and management in barley using fungicides and resistance in Victoria]

Barley powdery mildew: A new pathotype of powdery mildew was detected in Queensland and NSW in 2014.

The new pathotype overcomes the MlLa resistance gene that many barley varieties carry. [42]

Nationwide surveys of powdery mildew of barley were conducted in 2010 and 2011. Those surveys identified a relatively simple population structure with apparently more virulences in the eastern states than in Western Australia. This was not surprising as there has been relatively little breeding for resistance to powdery mildew in Australian breeding programs so the disease has not been forced to develop new virulences to survive.

Within 12 months of these surveys, three previously undetected virulences (Va3, Va9, Va12) that were specific to resistance genes in Shepherd, Grout and Navigator respectively were isolated in the Northern Region. In 2014, virulence for the resistance gene MlLa was detected in northern NSW and Queensland. Varieties such as Commander, Compass and Hindmarsh are now more susceptible to the disease than previously.

Table 7: Comparison of seedling and adult responses of commercial barley varieties to established and new pathotypes of powdery mildew.

	Shepherd pathotype	Shepherd pathotype	New MlLa pathotype	New MlLa pathotype
Variety	**Seedling**	**Adult**	**Seedling**	**Adult**
Commander	MSS	MRMS	VS	S
Compass	MSS	MS	VS	S
Granger	R	R	R	R
Grout	R	R	R	R
Hindmarsh	MS	MSS	VS	SVS
La Trobe	MS	MSS	VS	S
Mackay	MRMS	RMR	VS	MR
Oxford	R	R	R	R
Shepherd	VS	MS	MR	R

Powdery mildew disease needs to be considered in context. In the Northern Region, powdery mildew is unlikely to cause losses in yield in excess of 10-15% in susceptible varieties. In crops with high yield potential, this can be significant and would justify fungicidal control. Despite having detected powdery mildew virulent on seedlings of Shepherd, Grout and Navigator the commercial impact to date has been minor.

Shepherd crops on the Darling Downs are commonly infected with powdery mildew; yet severe infections are rare. It is thought this is due to other minor resistances providing some protection. There are no reports that any commercial crops of Grout have suffered from significant infection of powdery mildew and the area sown to Navigator in the North is still very small.

A greater risk is posed by pathotypes that can attack varieties carrying the MlLa resistance gene. Commander and Compass are sown throughout the region and are considered susceptible to strains carrying virulence for this gene. Increasing levels of powdery mildew in either of these varieties would signal the need for the application of fungicide.[43]

Varietal resistance or tolerance

42 NSW DPI (2015) Winter crop variety sowing guide 2015: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2015.pdf

43 Managing barley and wheat diseases - priority issues and actions for 2015: http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Managing-barley-and-wheat-diseases-priority-issues-and-actions-for-2015#sthash.JfZ1SyD4.dpuf

Identification and deployment of disease-resistance genes are key objectives of Australian barley breeding programs. Several studies have explored the inheritance of resistance to net form of net blotch (NFNB). In most cases, one–three genes have been identified against different pathotypes of the fungus. In Canada and Egypt, one dominant gene for resistance was detected, whereas in Australia, Khan and Boyd (1969) identified two dominant resistance genes. More recently, numerous genes were identified in different barley lines from around the world. This work has identified several markers that are associated with resistance to NFNB. The chromosomal regions in which these markers are located will be focal points of further research and the validation and implementation of markers for routine selection in breeding programs. The markers located in these regions could also be used in pedigree-based association mapping studies using diverse barley genetic resources. A current study of barley genotypes using NFNB isolates from Western Australia, Queensland, and South Australia has detected more than six genes for resistance (Gupta *et al.* 2002). Having multiple markers linked to low disease response in each QTL (quantitative trait locus) region offers a good opportunity for plant breeders to use markers to select for resistance to NFNB. [44]

9.6.1 Damage caused in favourable conditions

Net blotch: Occurs in two forms. One (*Pyrenophora teres* f. *teres*) is the net type or net form (i.e. NTNB or NFNB), and the other is the spot form (i.e. SFNB (*P. teres* f. *maculata*). Likely to be a problem in wetter years and in stubble-retained situations, net blotch has become the most significant disease of barley in the region. High levels of NFNB or SFNB will kill leaves prematurely. One extended period of leaf wetness will result in more disease than the equivalent of several wet periods. [45]

Powdery mildew: Often present in susceptible varieties, *Blumeria graminis hordei* generally causes relatively small yield losses of <10%. Some seed treatments can give good early-season control of powdery mildew but these may also shorten coleoptile length and cause emergence problems. Resistant varieties are the best means of control.

Rusts: Leaf rust (*Puccinia hordei*) and stem rust (*Puccinia graminis tritici, secalis* and *tritici x secalis*) are more likely to occur in wetter years or higher rainfall areas. Traditionally, rusts are the major airborne diseases of barley in Queensland and both can cause significant yield loss and quality downgrading. Although sporadic in occurrence, leaf rust occurs in all barley-growing regions of Australia.

Leaf rust has reached epidemic levels at times, including recent outbreaks in southern parts of the Western Australian cereal belt. Some 12 years ago, the pathogen acquired the ability to overcome a resistance gene that is present in the cultivars Gairdner⦶, Fitzgerald⦶, Baudin⦶, Tallon and Lindwall⦶, and since then, this ability (virulence) of the pathogen has either spread to, or reappeared in, all barley-growing regions.

Leaf rust of barley is a biotroph, requiring living host material (green barley plants) to carry the disease from one season to the next. It too requires frequent wet periods but the disease multiplies most rapidly when dry days are followed by mild nights with heavy dews. Such conditions ensure the liberation, spread and subsequent infection by rust spores.

Stem rust tends to be a problem when inoculum levels are high due to epidemics in crops such as wheat and triticale.

Spot blotch: Spot blotch (*Cochliobolus sativus*) is favoured by warm wet conditions and is promoted by stubble retention. It can be seed-borne. Leaf symptoms are almost identical to SFNB. Spot blotch may also cause discoloration of grains. This disease

44 M. Cakir *et al*. (2003) Mapping and validation of the genes for resistance to *Pyrenophora teres* f. *teres* in barley. *Australian Journal of Agricultural Research* 54, 1369–1377, http://dx.doi.org/10.1071/AR02229

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

is more likely to be a problem in sub-coastal areas. Popular varieties are susceptible. Spot blotch can lead to severe crop losses in subtropical areas of northern NSW and Queensland, and localised barley yield losses greater than 30% have been reported. [46] The pathogen also causes common root rot, seedling blight and head blight in barley. It attacks many grass species including the cereals, wheat, rye and triticale.

9.6.2 Symptoms

Net blotch: Small brown blotches that elongate and form thin brown streaks along and across the leaf blade. This often forms a net-like pattern surrounded by yellowing. Severely affected leaves wither rapidly. Lesions can be restricted on less susceptible varieties.

Powdery mildew: Some varieties may appear susceptible at the seedling stage but develop resistance to mildew during elongation. Where this occurs, lower leaves of infected plants may take on a blotchy appearance, which can be confused with other blotches caused by other diseases. Where powdery mildew is responsible, fine mycelium is usually evident on the older leaves.

Spot blotch: Infection in seedlings starts as dark brown to black spots on leaf sheaths and progresses from lower to upper leaves during crop development. If infection occurs early in the crop cycle and conditions remain favourable for disease development, complete defoliation is possible, resulting in severe yield reductions. On susceptible adult plants, lesions are generally oblong with chlorotic margins. These often coalesce to kill large portions of the leaf, with severely infected leaves senescing prematurely.

For images and descriptions of foliar diseases, visit GRDC 'Wheat and barley leaf symptoms: The back pocket guide' at: http://www.grdc.com.au/uploads/documents/GRDC-Wheat-Barley-BPG-2011.pdf .

9.6.3 Management options

Timely application of a suitable fungicide is the last line of defence against foliar diseases which become evident during the growing season. However, seasonal conditions (particularly a damp spring) and inherent resistance in the variety can deplete the efficacy of an application.

When a cereal variety is truly resistant to a disease (rated R), there will be no response to a fungicide application, since the fungicide only protects an inherent yield potential that would have been expressed in the absence of disease. Before disease management is dismissed, it is important to make sure that the variety is resistant to all of the major diseases prevalent in that region.

For varieties with intermediate resistance to disease (rated MR to MS), the timing of a disease outbreak in the crop's lifecycle and the speed at which it develops will influence choice and timing of disease management. Earlier infections tend to be associated with greater disease susceptibility and need earlier intervention. Greater disease resistance delays the onset of a disease epidemic.

Some varieties will be more susceptible to early disease (seedling susceptibility) and then develop greater resistance at stem elongation, i.e. they have APR. With these varieties it is important to make sure that earlier sowing and/or increased disease early in the season does not destroy green leaf tissue on flag-1 and flag-2 (first leaf and second leaf below flag leaf, respectively) prior to the expression of APR. To find out more, go to: https://www.grdc.com.au/uploads/documents/GRDC_Fungicide.pdf

[46] J Bovill *et al.* (2010) Mapping spot blotch resistance genes in four barley populations. *Molecular Breeding 26*, 653–666, http://link.springer.com/article/10.1007%2Fs11032-010-9401-9#page-1

Table 8: Modes of action registered for control of foliar diseases in Australian cereals

Group	Active ingredient	Example product name	Foliar (F), seed (S). pr or-furrow (IF)
3 – DMI	Triadimefon	Triad®	F and IF
	Propiconazole	Tilt®	F
	Propiconazole + cyproconazole	Tilt® Xtra	F
	Tebuconazole	Folicur®	F and S
	Flutriafol	Impact®	F and IF
	Tebuconazole + flutriafol	Impact® Topguard	F
	Tebuconazole + prothioconazole	Prosaro®	F
	Epoxiconazole	Opus®	F
	Triadimenol	Baytan®	S
	Fluquinconazole	Jockey®	S
3 + 11	Azoxystrobin + cyproconazole	Amistar® Xtra	F
	(Strobilurins)	Opera®	F

Spot blotch: Repeated fungicide applications can be used to control spot blotch, but the use of resistant cultivars offers the most economically and environmentally sound means of control. Early fungicide application may yield benefits in controlling SFNB.

Net blotch: Growers are advised to avoid planting barley on barley where stubble is retained, as stubble-borne spores are the main source of infection for the new crop. NFNB may be seed-borne, and grain from heavily diseased crops should not be retained for planting.

Powdery mildew: Fungicides have traditionally worked well in controlling powdery mildew. However, a GRDC-funded project based in Western Australia has recently confirmed triazole resistance in powdery mildew in barley. This has had a devastating effect in Western Australia, causing losses estimated at $100 million. The resistance is associated with two mutations, one of which was detected in the northern region, and sends a warning to use fungicides responsibly.

For these reasons, barley growers should limit the use of tebuconazole (Folicur®, Impact® Topguard), flutriafol (e.g. Impact®), triadimefon (Triad®) or triadimenol (Baytan®) alone where powdery mildew is the target disease. Growers should instead consider rotating with fungicides from alternative modes of action (e.g. Amistar®Xtra, Opera®) and the remaining triazole fungicides (e.g. TILT®, TILT®Xtra, Prosaro®, Opus®). [47]

If inoculum pressure is particularly intense, fungicides that normally control rust can be seen to have little or no effect. This was thought to be the case with the fungicide propiconazole on leaf rust in barley, where a number of crops were sprayed three times and leaf rust continued to develop. This was contrary to previous experience. The leaf rust may also have become less sensitive to propiconazole, which has been widely used for control of foliar diseases for over a decade. Continued use of a chemical can result in selection for increased resistance to that chemical. Work is planned to investigate whether this has occurred.

Stem rust in barley can be largely prevented if stem rust is controlled in wheat and rye crops, and by avoiding spring sowings of barley. Barley crops can be affected by the wheat stem rust pathogen, the rye stem rust pathogen, or a third stem rust pathogen that is a hybrid between the wheat and rye stem rust forms. Where stem rust is found on barley, it is important to determine which of these three pathogens is responsible in order to assess any potential threat to nearby wheat crops (wheat is not affected by the rye stem rust pathogen or the hybrid form).

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Yellow-spot-in-wheat-leaf-rust-and-net-blotch-diseases-in-barley-lessons-from-2010-for-better-management-in-2011#sthash.YYMe148g.dpuf

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Spot-form-of-net-blotch-management-in-barley-grown-in-the-Mallee-environment

http://www.nga.org.au/results-and-publications/browse/11/spot-form-net-blotch-in-barley

[47] GRDC (2013) Cereal fungicides. Managing cereal fungicide use. Northern region. GRDC Fact Sheet May 2013, https://www.grdc.com.au/~/media/38E058BDF7014380907F794FDECD6345.pdf