SOUTHERN
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GRDC GROWNOTES™

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

TRITICALE

SECTION 9

DISEASES

GENERAL DISEASE-MANAGEMENT STRATEGIES | RUST | YELLOW LEAF SPOT (TAN SPOT) | TAKE-ALL | CROWN ROT | COMMON ROOT ROT | SMUT AND BUNT | RHIZOCTONIA BAREPATCH | ERGOT | SEPTORIA TRITICI BLOTCH | CEREAL FUNGICIDES | BARLEY YELLOW DWARF VIRUS | DISEASE FOLLOWING EXTREME WEATHER

Diseases

Key messages

- Triticale can be less susceptible to the common fungal diseases of cereals, which makes it suitable for use in rotations where stubble is retained.
- Some varieties have good resistance to stem, leaf and stripe rusts, mildew and *Septoria tritici* blotch as well as both resistance and tolerance to cereal cyst nematode (CCN).
- Soil testing is essential for diagnosing many cereal diseases.
- Keeping consistent paddock records and implemented crop rotations are some of the most important and simple strategies in fighting crop diseases.

In the early development stages of triticale in Australia, the crop was relatively free of disease compared with other winter cereals. As the crop expanded in the 1980s, a range of fungal and other diseases became more important and began to require active management. The main diseases have been the three rusts (leaf, stem and stripe rust), crown rot, Barley Yellow Dwarf Virus (BYDV), and nematodes. [1]

Many growers use triticale as a disease break in their rotations and value the benefits of triticale for its vigourous root growth. Triticale is considered resistant to Root-lesion nematodes and Cereal Cyst nematodes making it a useful crop rotation in managing these diseases. Other favoured characteristics of triticale are its resistances to BYDV, mildew and rusts, which may cause significant yield reductions in wheat, barley and oats. [2] Triticale is tolerant to rusts, *Septoria tritici*, smuts, bunt, powdery mildew, take-all, root rots, Wheat mosaic virus and Barley stripe mosaic virus. [3] Triticale has vastly superior tolerance over wheat to *Septoria tritici* blotch. [4]

Table 1 shows the reaction to diseases by different varieties of triticale grown in the southern region. [5]

1 RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Rethowan, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, http://www.apri.com.au/1A-102_Final_Research_Report_.pdf

2 KV Cooper, RS Jessop, NL Darvey (2004) Triticale in Australia. In M Mergoum, H Gómez-Macpherson (eds), Triticale improvement and production. FAO Plant Production and Protection Paper No. 179. Food and Agriculture Organisation, ftp://ftp.fao.org/docrep/fao/009/y5553e/y5553e02.pdf

3 Varughese, Pfeiffer and Pena (1996) in Mergoum, M., & Macpherson, H. G. (2004). Triticale improvement and production (No. 179). Food & Agriculture Org. ftp://ftp.fao.org/docrep/fao/009/y5553e/y5553e02.pdf

4 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW DPI, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf. See also GRDC. Field Peas: The Ute Guide. App. GRDC, https://grdc.com.au/Resources/Apps

5 Agriculture Victoria (2016) Triticale [download]. In Victorian winter crop summary. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary

Table 1: *Triticale variety agronomic guide and disease reaction.*

Variety	Maturity	Height	Head colour	Stem rust	Stripe rust	Leaf rust	Yellow leaf spot	*Septoria tritici*	CCN resistance	*Pratylenchus neglectus* resistance	*P. thornei* resistance
Astuteⓓ	M	M–T	W	RMR	RMR#	RMR	MRMS	–	R	RMR	MS
Berkshireⓓ	E–M	T	W	R	MRMS#	R	MR	RMR	–	MR	MS
Bisonⓓ	M	T	W	RMR	R#	RMR	MR	MR	R	MR	RMR
Canobolasⓓ	E–M	M–T	W	R	MRMS#	RMR	MR	RMR	–	MR	MSS
Chopperⓓ	E	S–M	W	MR	MRMS#	R	MR	RMR	R	MRMS	MSS
Endeavourⓓ	L		W	R	RMR#	R	MR	R	–	MR	SVS
Fusionⓓ	M	M–T	W	R	RMR#	R	MRMS	R	R	RMR	MS
Goanna	E–M	T	W	R	RMR#	R	MR	R	R	MRMS	SVS
KM10	E–M			R	R#	MRMS	MRMS	MR	–	MR	MSp
Rufus	M	T	W	R	MRMS#	R	MR	RMR	R	MSS	MSS
Tahara	M	T	W	R	MRMS#	R	MR	RMR	R	MR	S
Tobrukⓓ	M–L	–	W	R	MR#	R	MR	R	–	MR	SVS
Tuckerbox	M	T	W	MR	MR#	R	MR	RMR	–	MRMS	S
Yowie	M	M–T	W	R	MR#	R	MR	RMR	R	MR	MSS

Maturity: E = early, M = mid-season, L = late, VL = very late
Height: M = medium, T = tall
Colour: W = white, Br = brown
Disease resistance order from best to worst: R > RMR > MR > MRMS > MS > MSS > S > SVS > VS
p = provisional ratings—treat with caution. R = resistant, M = moderately, S = susceptible, V = very.
Varieties marked may be more susceptible if alternative strains are present.

Source: Agriculture Victoria

9.1 General disease-management strategies

Key points:

- Use resistant or partially resistant varieties.
- Use disease-free seed.
- Use fungicidal seed treatments to kill fungi carried on the seed coat or in the seed.
- Have a planned in-crop fungicide regime.
- Conduct soil testing to determine the severity of potential disease infestations. This can be used as a tool to determine what crop is grown in what paddock the following year.
- Send plant or stubble samples away for analysis to determine the pathogen or strain you are dealing with or the severity of the disease.
- Keep the farm free of weeds, which may carry over some diseases. This includes cereals over summer that may act as a green bridge.
- Rotate crops. [6]
- Stay up to date with local disease guides: Cereal disease guide 2016–SA and Cereal disease guide 2016–Vic.

Cereal root disease management in the Southern region

Cereal root diseases can have serious impacts on grain yield if they are not adequately controlled. The key to preventing root diseases is to identify paddocks at risk by inspecting the roots of previous cereal crops or taking a PreDicta B soil test before sowing. Knowledge of the potential root diseases in a paddock enables the most appropriate control strategies to be implemented prior to and/or at

6 DAF Qld (2015) Wheat:diseases, physiological disorders and frost. DAF Qld, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/diseases

sowing. Management must be implemented prior to sowing as there are no in-crop management options available for the control of root diseases, compared with many foliar diseases. [7] To protect the paddock environment and maximise yields:

- Minimise losses associated with root diseases by inspecting plant roots in the previous crop or using a PreDicta B soil test prior to sowing to identify at-risk paddocks.
- Crown rot can an major disease if inoculum levels are high from the previous season. Reduce risk by rotating to non-cereal crops
- In paddocks with high numbers of root-lesion nematodes (RLNs), yield losses can be minimised by selecting partially tolerant cultivars and avoiding late sowing. Resistant cultivars can reduce nematode densities and therefore reduce losses in subsequent intolerant crops.
- Cereal cyst nematode is a very damaging nematode if numbers are allowed to increase by growing susceptible cereals.
- Rhizoctonia root rot will likely be a low risk if there is a wet summer with multiple rainfall events, provided summer weeds are controlled.
- Take-all will be a low risk if there is a dry spring, limiting inoculum build up.

9.1.1 Tools for diagnosing cereal diseases

Crop Disease Au app

ANDROID APP ON Google play | Available on the App Store

The app Crop Disease Au, developed by the National Variety Trials, allows the user to quickly:

- Identify crop diseases.
- Compare disease-resistance ratings for cereal, pulse and oilseed varieties.
- Potentially, facilitate the early detection of exotic crop diseases.

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

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

The precursor for this app was the Victorian Department of Economic Development, Jobs, Transport and Resources (DEDJTR) Crop Disease app developed by a team of grains pathologists. Crop Disease Au functions similarly to the old app, but provides information for all Australian grain-growing regions.

MyCrop

ANDROID APP ON Google play | Available on the App Store | Web-based

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

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

7 G Hollaway, J Fanning, F Henry, A McKay (2015) Cereal root disease management in Victoria. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Cereal-root-disease-management-in-Victoria

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

CropPro

Web-based

The online tool CropPro, developed by DEDJTR and GRDC, has diagnostic and economic features that allow growers to efficiently identify and manage constraints to both crop productivity and profitability. The core functions of CropPro are to:

- Diagnose the cause of wheat and canola crop problems.
- Support risk analysis.
- Provide evidence-based information for management of crop constraints.

It combines paddock and crop symptoms in one resource, enabling users to work through a simple process of elimination. CropPro also has an economic feature allowing growers to compare return-on-investment outcomes for different management options and an Agronomist Toolkit that includes an extensive list of resources, online decision-support tools and apps.

Through CropPro, the Field Crop Diseases Manual is available online. The manual provides an all-in-one resource for disease identification, biology and management information for cereal, pulse and oilseed crops.

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

MORE INFORMATION

Field Crop Diseases Manual online

MyCrop

GRDC, Cereal root and crown diseases: Back pocket guide

9.2 Rust

In Australia, there are three rust diseases of triticale and wheat:

- stripe rust
- stem rust
- leaf rust

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

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

Rusts have a number of features in common. They can only infect a limited number of specific host plants (mostly volunteer triticale, wheat and barley) and can only survive on green, growing plant tissue. Biotrophic pathogens (including stem rust, stripe rust and leaf rust) require a living plant host and, since they cannot survive on soil, seed or dead tissue, need a 'green bridge', grassy weeds or overlapping crops to persist. Plants that facilitate the survival of rust fungi through the summer are known as the 'green bridge'. [8]

Stripe rust reached epidemic levels in eastern Australia during 2009, resulting in widespread fungicidal spraying. Given favourable conditions rust can cause large losses in susceptible varieties. However, growers have shown that by planning to manage this disease they can effectively minimise its effects.

The University of Sydney's 2016 Cereal Rust Report warns growers to monitor crops carefully. Reports on wheat leaf rust, barley leaf rust and wheat stripe rust in the

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

MORE INFORMATION

The Rust Bust

Cereal rust situation, September 2016

eastern states suggest that these diseases are starting to gain momentum in crops. Recent weather conditions across large areas of the cereal-growing regions are likely to favour rust development. Monitoring of crops for all cereal rusts is advised and samples of all rusts observed in cereal crops should be submitted for pathotype analysis to the Australian Cereal Rust Survey. [9]

The Rust Bust is an initiative of the Australian Cereal Rust Control Program (ACRCP) Consultative Committee, with support from the GRDC. The Rust Bust aims to raise awareness of wheat rust-management strategies that reduces risk of disease outbreak.

9.2.1 Varietal resistance or tolerance

Some triticale varieties have good resistance to stem, leaf and stripe rusts (Tables 2 and 3). [10]

Table 2: *Triticale variety Rust disease susceptibility ratings.*

Variety	Stem rust	Stripe rust	Leaf rust
Astute⚲	RMR	RMR#	RMR
Berkshire⚲	R	MRMS#	R
Bison⚲	RMR	R#	RMR
Canobolas⚲	R	MRMS#	RMR
Chopper⚲	MR	MRMS#	R
Endeavour⚲	R	RMR#	R
Fusion⚲	R	RMR#	R
Goanna	R	RMR#	R
KM10	R	R#	MRMS
Rufus	R	MRMS#	R
Tahara	R	MRMS#	R
Tobruk⚲	R	MR#	R
Tuckerbox	MR	MR#	R
Yowie	R	MR#	R

Maturity: E = early, M = mid-season, L = late, VL = very late
Height: M = medium, T = tall
Colour: W = white, Br = brown
Disease resistance order from best to worst: R > RMR > MR > MRMS > MS > MSS > S > SVS > VS
p = provisional ratings—treat with caution. R = resistant, M = moderately, S = susceptible, V = very.
Varieties marked may be more susceptible if alternative strains are present

Source: Agriculture Victoria

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

10 Agriculture Victoria (2016) Triticale [download]. In Victorian winter crop summary. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary

Table 3: *Resistance ratings of triticale to specific stripe rust pathotypes.*

Variety	Stripe Tobrukⓓ Pathotype	Stripe YR17-27 Pathotype
Breakwell▲	SVS	MR
Endeavourⓓ	RMR	RMR
Yukuri	RMR	RMR
Crackerjack▲	MS°	RMR
Tobrukⓓ▲	MSS°	MR
Canobolasⓓ▲	MSS	MRMS
Chopperⓓ▲	MSS	MRMS
Berkshireⓓ▲	MS	MRMS
Bogongⓓ▲	MS	MRMS
Rufus▲	MS	MRMS
Tahara▲	MS	MRMS
Fusionⓓ	MR•	RMR
Yowie§	MRMS, MS•	MR
Tuckerbox	MRMS	MR
Goanna§	MRMS	RMR
Hawkeyeⓓ	MR, MSS•	MR,MS•
Jaywickⓓ	MR, MRMS•	RMR, MS•
Cartwheel	-	R
Astuteⓓ§	-	RMR
Bisonⓓ§	-	R
KM10§	-	R

VS = Very susceptible, SVS = Susceptible to very susceptible, S = Susceptible, MSS = Moderately susceptible to susceptible, MS = Moderately susceptible, MRMS = Moderately resistant to moderately susceptible, MR = Moderately resistant, RMR = Resistant to moderately resistant, R = Resistant.

§ Limited data available on Astuteⓓ, Bisonⓓ, Goanna, KM10 and Yowie in NSW.

▲ Outclassed.

• Mixed population, some plants are more susceptible to stripe rust.

° Susceptible to head infection.

Source: Rust Bust.

9.2.2 Symptoms

Table 4 outlines the symptoms of common diseases of cereals. [11]

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

Table 4: *Diagnosing leaf diseases in wheat.*

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

Source: DAF Qld

9.2.3 Stripe rust

Stripe rust has become more damaging in recent years owing to new races arriving in eastern Australia.

Stripe rust is caused by the fungus *Puccinia striiformis*. It is easily distinguished from other wheat rusts by the yellow-orange spores, which produce small, closely packed pustules that develop into stripes along the length of the leaf veins. The spores occur on the upper surface of the leaves, the leaf sheaths, awns and inside of the glumes (Photo 1). [12]

Photo 1: *Stripe rust in a cereal plant.*

Source: DAF Qld

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

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

There are several fungicides recommended for the control of stripe rust. Fungicides can be incorporated with the fertiliser or applied as seed dressings to delay the onset

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

of disease. Later on, if the if the main leaves (the flag, flag 1, -2 and -3 leaves) leaves require protection, recommended foliar fungicides can be applied for the control of stripe rust.

See the APVMA website for up-to-date fungicide registrations.

Stripe rust in southern Australia

There have been two introductions of stripe rust into Australia. They probably came in on clothing. The first arrived in Victoria in 1979, and it rapidly spread across eastern Australia. It mutated, and a number of pathotypes (also known as races or strains) developed, enabling the rust to attack more varieties over time. Even though it became widespread in eastern Australia, it did not move to Western Australia.

The second introduction occurred in Western Australia in 2002. By 2003, this pathotype was in eastern Australia. This one, known as the WA pathotype, quickly became dominant in eastern Australia. It has undergone several mutations in eastern Australia, and there are now many pathotypes of stripe rust that are common in southern Australia. The resistance ratings provided in disease guides often represent the most important of the pathotypes. [13]

The Plant Breeding Institute at the University of Sydney received samples in 2016 of stripe rust in Victoria: a sample off Derrimut from Nullawil, and a sample off Scepter from Rupanyup. Stripe rust has also been reported by Dr Hugh Wallwork around the Northern Yorke Peninsula in South Australia, but no samples have yet been received to confirm its presence. [14]

Severe symptom development on TobrukⒹ triticale was reported in November 2009. Experiments confirmed that isolates collected from TobrukⒹ were capable of causing more severe infection on TobrukⒹ in adult plants compared to the 'Jackie' pathotype in greenhouse tests. This lead to the naming of a new pathogenic variation caused by the 'TobrukⒹ' pathotype, which was responsible for the poor performance of TobrukⒹ in 2009. Photo 2 shows the contrast in infection types between the 'Jackie' and 'TobrukⒹ' pathotypes on TobrukⒹ and EndeavourⒹ triticale.

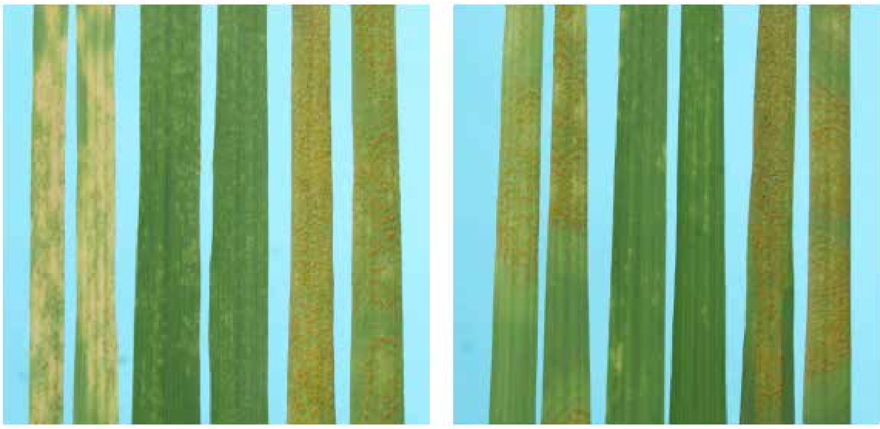


Photo 2: *Paired leaves of triticale cultivars TobrukⒹ and EndeavourⒹ compared to the susceptible Jackie, inoculated with the 'Jackie' pathotype (left) and 'TobrukⒹ' pathotype (right).*

Source: Cereal Rust Report, 2010.

Managing stripe rust

Avoid growing highly susceptible varieties: replace susceptible varieties with a moderately or highly resistant variety. Growers should check to ensure their current variety has adequate field resistance to both the Jackie and TobrukⒹ pathotypes of

MORE INFORMATION

Stripe rust

VIDEOS

WATCH: GCTV1: Cereal rust

13 G Holloway (2016) Stripe rust of wheat. Note AG1167. Revised, Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/stripe-rust-of-wheat

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

stripe rust (See Table 3 in section above) or consider using foliar fungicides to control the disease in the crop if required.

There are now options available to treat seed to provide seedling protection against the disease. [15] Seed treatment should be considered for controlling seedling stripe rust in susceptible varieties, especially those sown early for grazing. [16]

Newer varieties generally have improved stripe-rust resistance. Varieties with at least an MR–MS (moderately resistant–moderately susceptible) should be used. Usually changing to a more resistant variety also gives a yield advantage. For example, changing from Jackie to Endeavour⦻ makes good sense. Endeavour⦻ offers a 15% yield increase over Jackie, has excellent dry-matter production for early grazing, and is resistant to all current strains of stripe rust.

Seek local advice on managing stripe rust in triticale. Remember that just because a variety is rust resistant does not mean it will be completely free of stripe rust.

Under very high disease pressure, isolated leaves of resistant varieties can be infected. This does not automatically mean the resistance has broken down or that the crop needs spraying. [17] In these cases rust samples should be sent to:
Australian Cereal Rust Survey
Plant Breeding Institute
Private Bag 4011
Narellan, NSW 2567

9.2.4 Stem rust (black rust)

Triticale is thought to have good resistance against stem rust. [18] All the present commercial varieties have been screened for the current races of stem rust and they have adequate levels of resistance, although if new races arrive varieties will require screening for them as the levels of resistance to new races are unknown. [19]

Stem rust is caused by the fungus *Puccinia graminis* f. sp. *tritici*. Stem rust will infect all cereals. It produces reddish-brown spore masses in oval, elongated or spindle-shaped pustules on the stems and leaves. Unlike leaf rust, pustules erupt through both sides of the leaves (Photo 3). [20] Ruptured pustules release masses of stem rust spores, which are disseminated by wind and other carriers.

Photo 3: *Stem rust in a cereal plant.*

Source: DAF Qld

15 Agriculture Victoria (2012) Growing triticale. Note AG0497. Revised. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale

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

17 Waratah Seed Company (2010) Triticale: planting guide. Waratah Seed Company, http://www.porkcrc.com.au/1A-102_Triticale_Guide_Final_Fact_Sheets.pdf

18 Adhikari, K. N., & McIntosh, R. A. (1998). Inheritance of wheat stem rust resistance in triticale. Plant breeding, 117(6), 505–513.

19 Jessop RS, Fittler M. (2009). Triticale production Manual—an aid to improved triticale production and utilisation. http://www.apri.com.au/1A-102_Final_Research_Report_.pdf

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

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

Some cereal varieties have reasonable resistance to stem rust (rating 5 or higher). However, in the past, stem rust has had the ability to cause significant economic damage (50–100% of yield). This has happened when conditions are conducive for the disease and susceptible varieties are grown, or a new pathotype has developed which has overcome a variety's resistance.

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

Foliar fungicides to control stem rust are presented in Tables 4 and 5 in section: Managing cereal rusts.

Stem rust in southern Australia

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

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

Following the exceptionally wet January of 2011 there was a large amount of inoculum carryover that resulted in widespread stem rust in southern Australia during 2011. Despite this, the widespread use of chemicals helped minimise losses from this disease. [21]

9.2.5 Leaf rust (brown rust)

The current commercial triticale varieties have good resistance to leaf rust and newer varieties should maintain this attribute. [22]

Leaf rust is caused by the fungus *Puccinia triticinia* (previously called *Puccinia recondite* f. sp. *tritici*). The disease can infect triticale, rye and wheat. It produces reddish-orange spores which occur in small, 1.5 mm, circular to oval-shaped pustules. These are found on the top surface of the leaves, distinguishing leaf rust from stem rust (Photo 4). [23]

MORE INFORMATION

Stem rust

VIDEOS

WATCH: GCTV5: Green bridge control for less stem rust

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

22 Jessop RS, Fittler M. (2009). Triticale production Manual—an aid to improved triticale production and utilisation, http://www.apri.com.au/1A-102_Final_Research_Report_.pdf

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

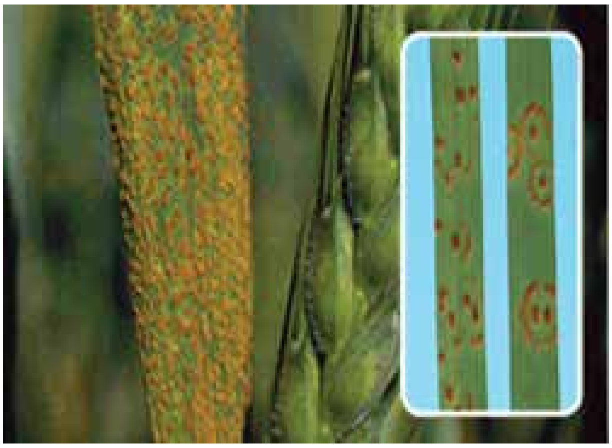


Photo 4: *Leaf rust in wheat.*

Source: DAF Qld

In most parts of southern Australia leaf rust is effectively controlled with resistant varieties, but it can cause problems in areas where susceptible varieties are grown. Cereal varieties mostly have reasonable resistance (rating of MR–MS,5 or higher).

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

See the APVMA website for up-to-date fungicide registrations.

The Plant Breeding Institute at the University of Sydney received samples of leaf rust in 2016 from all wheat-growing states except Tasmania (Figure 1). One was from Lismore in Victoria, and samples from South Australia have been received from Port Neill off the variety Mace, and off other wheats from Paskeville and Roseworthy in late August and early September. [24]

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

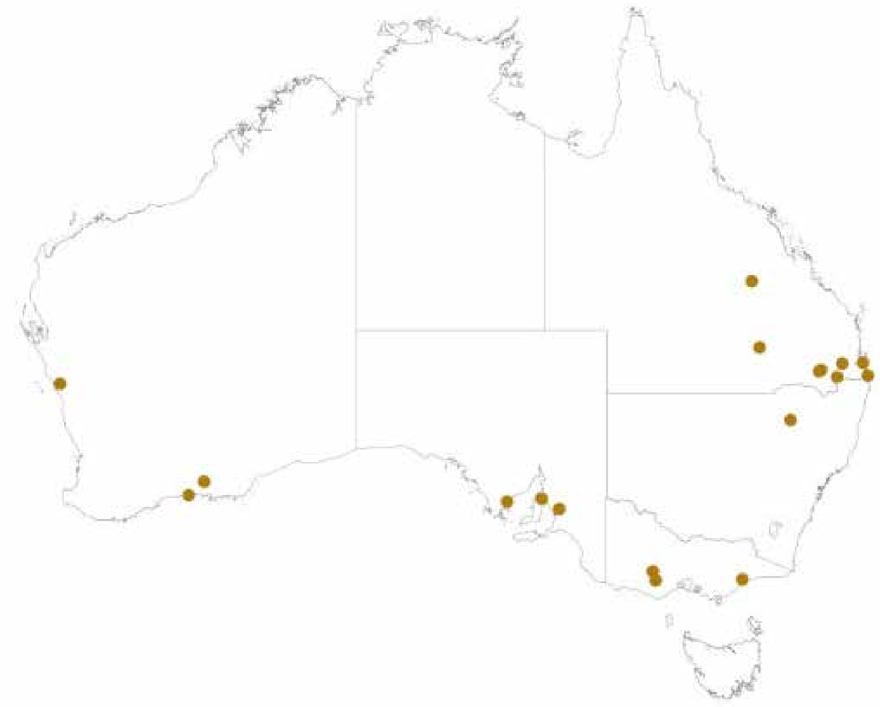


Figure 1: *Reported detections of leaf rust in 2016.*

Source: University of Sydney

MORE INFORMATION

Leaf rust

CSIRO, Cereal rusts

The Rust Bust

How to manage rust, SA

9.2.6 Managing cereal rust

Rust diseases of cereals can be eliminated or 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.

Rust fungi change continuously, producing new pathotypes. These are detected when disease is found on a previously resistant variety. Even if a resistant variety has been sown, the crop should be monitored on a regular basis, starting no later than growth stage 31 (first node detectable) and continue to at least growth stage 49 (first awns visible). This is because the main leaves (the flag, flag-1, flag-2 and flag-3 leaves) are the main factories contributing to yield and quality. It is very important that these leaves are protected from any diseases. [25] However, the importance of maintaining these leaves completely disease free diminishes as crops are grown into the more arid, lower yielding and higher spring temperature finishing regions. [26]

See the APVMA website for up-to-date fungicide registrations.

IN FOCUS

Breeding cereals for rust resistance in Australia

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

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

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

WATCH: GCTV Extension files: Rust sampling

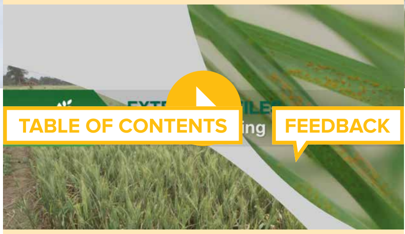
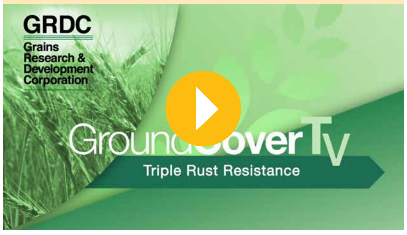


TABLE OF CONTENTS
FEEDBACK

WATCH: GCTV18: Adult plant resistance—fungicide

WATCH: GCTV9: Cereal rust—adult plant resistance

WATCH: GCTV18: Triple rust resistance



The Australian Cereal Rust Control Program conducts annual pathogenicity surveys for all cereal rust pathogens, undertakes genetic research to identify and characterise new sources of resistance, and provides a germplasm screening and enhancement service to all Australian cereal-breeding groups. These three activities are interdependent and are closely integrated, with particular emphasis on linking pathology and genetics to develop more resistant varieties. Recent changes in the wheat rust pathogens, including the development of virulences for the Yr17, Lr24, Lr37 and Sr38 resistance genes, and the introduction of a new pathotype of the wheat stripe rust pathogen, have provided new and significant challenges for wheat rust resistance breeding. Similar challenges exist in breeding barley and oats for rust resistance. In future, as more markers linked to durable rust resistance sources become available, it is likely that the use of marker-assisted selection will become more common-place in rust resistance breeding. [27]

9.3 Yellow leaf spot (tan spot)

Yellow leaf spot, also known as tan spot, has become a widespread and important disease of cereals in southern Australia (Photo 5). It has been supported by stubble retention, intense wheat production in the rotation and wide spread cultivation of susceptible varieties. [28]

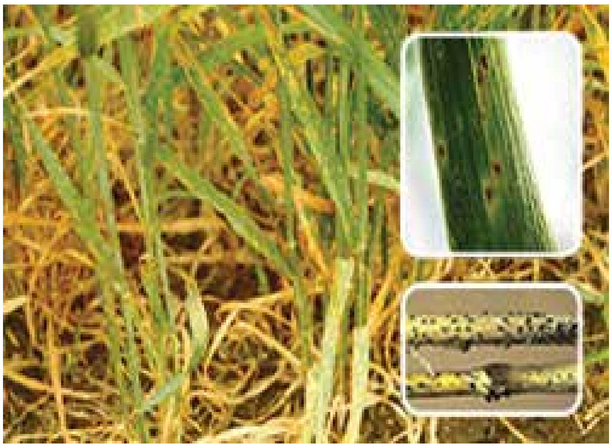


Photo 5: *Yellow leaf spot in cereal crop.*

Source: DAF Qld

VIDEOS

WATCH: GCTV2: Yellow or tan spot

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

As the crop develops, masses of a second type of spore (conidia) are produced on old lesions and dead tissues. Conidia result in rapid development of the epidemic within a crop and spread of the disease to other crops and areas. Again, wet conditions are necessary for spore production and infection. Strong winds are needed to spread the disease any great distance. [29]

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

28 G Holloway (2014) Yellow leaf spot of wheat. Note AG1114. Revised. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/yellow-leaf-spot-of-wheat

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

9.3.1 Varietal resistance

Most triticale cultivars have moderate resistance to yellow leaf spot (Table 5). [30] However, it can still carryover the disease into following years. [31]

Table 5: *Triticale variety disease guide for yellow leaf spot.*

Variety	Yellow leaf spot
Astute⑴	MRMS
Berkshire⑴	MR
Bison⑴:	MR
Canobolas⑴:	MR
Chopper⑴	MR
Endeavour⑴	MR
Fusion⑴	MRMS
Goanna	MR
KM10	MRMS
Rufus	MR
Tahara	MR
Tobruk⑴	MR
Tuckerbox	MR
Yowie	MR

Maturity: E = early, M = mid-season, L = late, VL = very late
Height: M = medium, T = tall
Colour: W = white, Br = brown
Disease resistance order from best to worst: R > RMR > MR > MRMS > MS > MSS > S > SVS > VS
p = provisional ratings—treat with caution, R = resistant, M = moderately, S = susceptible, V = very
Varieties marked may be more susceptible if alternative strains are present

Source: Agriculture Victoria

9.3.2 Damage caused by yellow leaf spot

Yellow leaf spot is most often observed in seedlings, but when conditions are suitable it can progress up the plant where it causes significant yield loss. [32] Grain yield can be reduced and losses of around 10% may occur in triticale under suitable conditions (e.g. high humidity after GS39). Only in extreme pressure situations would losses be greater than this in triticale in the southern region and unlikely to be greater than 20%. Pink grain with reduced value can result under severe yellow leaf spot epidemics.

9.3.3 Symptoms

Yellow leaf spot is characterised by tan-brown flecks turn into yellow-brown oval-shaped spots or lesions surrounded by yellow margins. They may expand to 10–12 mm in diameter. Large lesions coalesce, and develop dark brown centres or cause the tips of leaves to die. Spots develop on both sides of leaves (Photos 6 and 7). Severe yellow leaf spot may result in short, spindly plants with reduced tillering and root development. Where conditions are favourable to the disease, plants may be fully defoliated soon after flowering. [33]

30 Agriculture Victoria (2016) Triticale [download]. In Victorian winter crop summary. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary

31 Birchip Cropping Group (2004) Triticale agronomy 2004. Online Farm Trials, http://www.farmtrials.com.au/trial/13801

32 G Holloway (2014) Yellow leaf spot of wheat. Note AG1114. Revised. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/yellow-leaf-spot-of-wheat

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

Photo 6: *Yellow leaf spot in triticale.*

Source: Thomas County Ag

Photo 7: *Yellow leaf spot lesions may coalesce, causing the tip of the leaf to die.*

Source: Thomas County Ag

9.3.4 Conditions favouring development

Yellow leaf spot is likely to develop in wet years in fields where cereal residues remain on the soil surface. Temperatures of 15–28°C, with up to 12 hours of leaf wetness, are optimal condition for infection. [34]

34 GRDC (2011) Management to reduce the risk of yellow leaf spot. Factsheet. GRDC, https://grdc.com.au/Resources/Factsheets/2011/08/Yellow-Leaf-Spot-Fact-Sheet

9.3.5 Management of disease

The impact of the disease can be reduced by:

- Planting partially resistant varieties.
- Rotating with resistant crops such as barley, oats or chickpeas.
- Incorporating the stubble into the soil.
- Grazing or burning the stubble late in the fallow period.

Incorporation or burning of stubble is not recommended unless infestation levels are very high. The correct identification of the yellow leaf spot fungus in infected stubble should be carried out before the stubble is removed. Varieties partially resistant to yellow leaf spot offer the only long-term solution and should be considered for planting where yellow leaf spot could be a problem. [35]

MORE INFORMATION

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

Minimising the risk of yellow leaf spot

- Avoid sowing cereal-on-cereal.
- If you are going to sow cereal-on-cereal consider a late (autumn) stubble burn, and/or select a wheat variety with some level of resistance to yellow leaf spot (however, consider tolerance/resistance to other diseases as well). Triticale-on-wheat may be a reasonable option as triticale has better resistance and early vigour, potentially allowing it to establish before infection.
- Primary management decisions for yellow leaf spot need to be made prior to and/or at sowing. Fungicides are a poor last resort for controlling yellow leaf spot as they have reduced efficacy. [36]

In-crop fungicides and timing

Yellow leaf spot is difficult to control with fungicide.

Fungicides used against yellow leaf spot in Australia include:

- propiconazole
- tebuconazole
- azoxystrobin + cyproconazole
- propiconazole + cyproconazole

Identifying the disease and applying early control, before disease spreads up the plant, is crucial. (Table 6).

Table 6: *Rate of fungicide (product formulation) recommended as foliar sprays for the control of yellow leaf spot in cereals.*

Diseases	Foliar fungicides							
	Epoxi-conazole (125 g/L)	Flutriafol (250 g/L)	Propi-conazole (250 g/L)	Triadimefon (125 g/L)	Tebu-conazole (430 g/L)	Prothio-conazole (210 g/L) + Tebu-conazole (210 g/L)	Azoxy-strobin (200 g/L) + Cypro-conazole (80 g/L)	Propi-conazole (250 g/L) + Cypro-conazole (80 g/L)
Yellow leaf spot (tan spot)			250–500 mL/ha		145 or 290 mL/ha	150–300 mL/ha	400 or 800 mL/ha	250–500 mL/ha
Withholding periods	6 weeks for grazing and harvest	7 weeks for grazing and harvest	4 weeks for harvest, 7 days for grazing	4 weeks for grazing and harvest	5 weeks for harvest, 14 days for grazing	5 weeks for harvest, 14 days for grazing	6 weeks for harvest, 21 days for grazing	6 weeks for harvest, 21 days for grazing

Source: DAFF.

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

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

MORE INFORMATION

Management to reduce the risk of yellow leaf spot: Southern region

Yellow leaf spot: Is it worth spraying?

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

Information on fungicide effectiveness has been gathered from irrigated field trials and does not confirm the economic viability of such applications during the extreme pressure of large-scale epidemics. [37]

See the APVMA website for up-to-date fungicide registrations.

9.3.6 Integrated disease management of rusts and yellow leaf spot

Key points:

- Destroy volunteer plants by March, as they can provide a green bridge for rust carryover.
- Community efforts are required to eradicate volunteers from roadsides, railway lines, bridges, paddocks and around silos.
- Crop rotation is very important in the case of yellow leaf spot.
- Growing resistant varieties is an economical and environmentally friendly way of disease reduction.
- Seed or fertiliser treatment can control stripe rust up to four weeks after sowing, and suppress it thereafter.
- During the growing season active crop monitoring is very important for an early detection of diseases.
- Correct disease identification is very important; you can consult the department's fact sheets, charts, website and experts.
- When deciding if a fungicide spray is needed, consider crop stage and potential yield loss.
- Select a recommended and cost-effective fungicide.
- For effective coverage, the use of the right spray equipment and nozzles is very important.
- Read the label, wear protective gear, be safe to yourself and environment.
- Avoid repeated use of fungicides with the same active ingredient in the same season.
- Always check for withholding periods before grazing and harvesting a crop applied with any fungicide.
- If you suspect any severe disease outbreak, especially on resistant varieties, please inform your agronomist or local DPI.

Rust diseases occur throughout the cereal growing southern regions, frequently causing economic damage. Wherever possible, sow resistant varieties rated MR (Moderately Resistant) and above.

See the APVMA website for up-to-date fungicide registrations.

9.4 Take-all

Key points:

- Take-all (*G. Graminis*) is a fungal disease of the roots of cereals.
- Like cereal rye, triticale has good resistance to take-all, [38] and it is slightly less susceptible to take-all than wheat. Early sowing increases the risk. [39]

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

38 H Wallwork (1989) Screening for resistance to take-all in wheat, triticale and wheat-triticale hybrid lines. Euphytica, 40 (1–2), 103–109.

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

- In early field experiments conducted over six years with a wide range of take-all disease severities, triticale was intermediate in resistance to take-all, between wheat (susceptible) and rye (resistant). [40]
- Though triticale is less susceptible to take-all than wheat, it can still carryover the disease into following years. [41]
- Grass-free pastures and break crops minimise *G. graminis* survival, e.g. pulses and canola.
- Monitor rainfall patterns (when and how much?), and adjust sowing times where possible.
- Control weeds during late summer and early autumn.
- Ammonium based nitrogenous fertilisers decrease take-all incidence through improved crop nutrition.
- In severe take-all outbreaks, grass free cropping may be a management strategy.

Take-all is a soil-borne disease of cereal crops and grasses and is most severe on crops in southern Australia, particularly in the higher-rainfall areas. The disease is caused by two variations of the fungus *Gaeumannomyces graminis*: *G. graminis* var. *tritici* (Ggt) and *G. graminis* var. *avenae* (Gga). [42]

9.4.1 Symptoms

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

The appearance of whiteheads later in the season is another indicator of a take-all (although frost and micronutrient deficiencies can also cause whiteheads), with severe infections causing the crop to hay-off early. Infected plants will produce pinched grain, with severe infections yielding little harvestable seed in the head (hence take-all) and in some cases infected areas may not be worth harvesting. [43]

What to look for in the paddock

- Patches (up to several metres in diameter and with indistinct and irregular edges) of white-coloured tillers and heads containing shrivelled or no grain (Photo 8). [44]
- Affected plants can be individuals scattered among healthy plants or entire populations of plants over a large area.

40 TW Hollins, PR Scott, RS Gregory (1986).The relative resistance of wheat, rye and triticale to take- all caused by *Gaeumannomyces graminis*. Plant Pathology, 35 (1), 93–100.

41 Birchip Cropping Group (2004) Triticale agronomy 2004. Online Farm Trials, http://www.farmtrials.com.au/trial/13801

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

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

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

Photo 8: *Patches with irregular edges of white coloured tillers and heads containing shrivelled or no grain.*

Source: DAFWA

What to look for in the plant

- First obvious aboveground signs of infection are seen after flowering, with the development of whiteheads.
- Roots of affected plants are blackened and brittle, and break easily. They are black to the core, not just on outer surface (Photo 9).

Photo 9: *Roots of affected plants are blackened, brittle, break easily, and are black to the core (left). Severely affected plants can have blackened crowns and lower stems (right).*

Source: DAFWA

9.4.2 Conditions favouring development

Gaeumannomyces graminis survives the Australian summer in the residue of the previous season's grass host (Figure 2). [45] The arrival of cooler temperatures and rainfall in the autumn encourages the fungus into action, and it is in this period that it infects the roots of the emerging crop. Higher rainfall in winter is likely to increase take-all disease pressure. While lower soil moisture will decrease the chance of a severe outbreak of take-all, plants that are already infected will find it difficult to cope due to water stress.

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

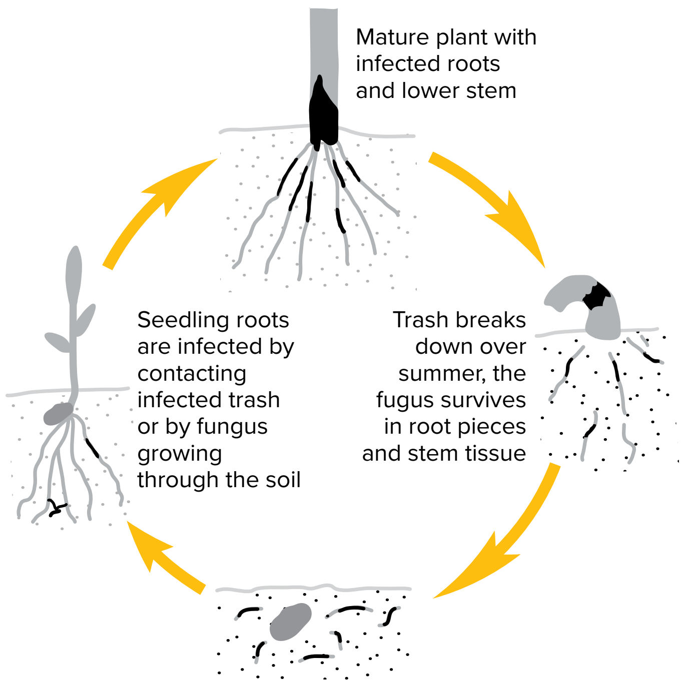


Figure 2: *Common life cycle of the take-all fungus (adapted from MacNish, 2005).*

Source: Soilquality.org

Hosts

All annual grasses can be infected by *G. graminis*, although some species are more susceptible than others. While wheat, barley and triticale are the most susceptible crops to take-all, barley grass is also an effective host to the disease. Brome grass, silver grass and ryegrass are all viable host species for take-all, too. Oats is one of the only cereal crop to offer resistance, although evidence of *G. graminis* strains capable of causing yield loss have been reported in areas where continual oat cropping occurs. The non-cereal crops (e.g. lupins, canola and clover) do not host take-all. [46]

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

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

9.4.3 Managing take-all

Key points:

- By far the most effective method of reducing take-all is to remove grasses in the year before the cereal crop with a grass-free pasture or break crop.
- Seed, fertiliser or in-furrow applied fungicides are registered for take-all control.
- Acidifying fertilisers can slightly reduce disease severity; conversely, the severity of take-all may increase following liming.
- Control volunteer grasses and cereals.
- Delay sowing following the opening rains by implementing a short chemical fallow. [47]

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

Fungicides, applied as either fertiliser or seed treatments, are registered for use against take-all, but are generally only economically viable where severe outbreaks have occurred. Registered fungicides provide useful protection in paddocks with low to medium disease risk. In many cases it is more practical to sow non-cereal crops or pasture to reduce take-all carryover.

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

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

9.5 Crown rot

Key points:

- *Fusarium* species are responsible for causing two distinctly different diseases in winter cereal crops: crown rot and Fusarium head blight.
- Triticale is susceptible to crown rot. [48]
- Crown rot survives on infected stubble, from where it is passed onto the following crop.
- Use non-host crops (i.e. pulses, oilseeds and broadleaf pasture species) in rotation sequences to reduce inoculum levels.
- Control grass-weed hosts to reduce opportunities for *Fusarium* spp. to survive fallow or non-host rotations.
- Sow varieties with partial resistance or improved tolerance where available.

Information concerning the resistances of triticale varieties to *Fusarium* diseases is very limited. For crown rot (*Fusarium psuedograminearum)* most research has been completed in wheat, but data from 2007 included one triticale (Everest). Inoculation with the crown-rot fungus caused the greatest reduction in yield in durum wheat

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

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

(average of 58%) with less but similar reduction in five wheat varieties (25%) and one triticale (23%). Within the wheat varieties the reductions were in a 10% range and it is likely that a similar position would occur within triticale varieties. This emphasises the importance of crop rotational strategy, e.g. the use of disease break crops such as canola and mustard, within the cropping system. [49]

There are two types of disease caused by *Fusarium* species that affect cereal crops, Fusarium head blight (FHB) and crown rot.

Crown rot is very damaging disease in the Northern cropping region, but is less prevalent in the Southern region. A survey of 957 wheat crops during the period 1997 to 2009 estimated annual losses from crown rot to be approximately 2-3% with crop losses inversely correlated to growing season rainfall. Field experiments showed yield loss in wheat ranged from 0-51% and was related to spring rainfall and inoculum levels prior to sowing. less than 5%, with sporadic loss. [50]

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

While all winter cereals host the crown rot fungus, the amount of yield loss due to infection varies with cereal type. The approximate order of increasing yield loss is cereal rye, oats, barley, bread wheat, triticale and durum wheat. [51]

Both FHB and crown rot become apparent after flowering, however the conditions that encourage them are different: Fusarium head blight requires prolonged wet weather during flowering and grainfill, and crown rot expresses as whiteheads following periods of moisture and/or heat stress. Crown rot is sometimes first seen in patches or in wheel tracks, but is often not obvious until after heading. Then it becomes obvious with the appearance of dead heads that contain shrivelled or no grain are called whiteheads, although it is important to note that yield loss can occur even without the formation of whiteheads.

9.5.1 Update on the latest research

Key points:

- Managing the impact of crown rot on yield and quality means managing the balance between inoculum levels and the amount of soil water.
- Although most management strategies tend to focus solely on combating inoculum levels, sometimes to the detriment of soil-water levels, it is more important to maintain good levels of soil water so that triticale is not temperature or water stressed during grainfill.
- For crown rot, cultivation, even shallow cultivation, distributes infected residue more evenly across paddocks and into the infection zones below the ground for crown rot. This is not good!
- Some of the newer wheat varieties appear promising in that they provide improved tolerance to crown rot.
- PreDicta B is a good tool for identifying the level of risk for crown rot (and other soil-borne pathogens) prior to sowing. However, it requires a dedicated sampling strategy and is not a simple add-on to a soil nutrition test.

Crown rot is a significant disease of winter cereals. Infection is characterised by a light honey-brown to dark brown discolouration of the base of infected tillers, and the crown rot-induced production of whiteheads that causes major yield loss is related to the presence of the fungus and moisture stress post-flowering. It is critical that growers understand that there are three distinct and separate phases of crown

49 RS Jessop, M Fittler (2009) Appendix 1. Triticale production manual: an aid to improved triticale production and utilisation. In J Roake, R Rethowan, R Jessop, M Fittler, Improved triticale production through breeding and agronomy. Pork CRC, http://www.apri.com.au/1A-102_Final_Research_Report_.pdf

50 G Holloway. (2007). GRDC Final reports: DAV00062 – Victorian cereal pathology support with emphasis on crown rot management. http://finalreports.grdc.com.au/DAV00062

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

rot, namely survival, infection and expression. Management strategies are different for each phase.

Survival—the crown-rot fungus survives as mycelium (cottony growth) inside winter cereal and grass-weed residues, which it has infected. The fungus will survive as inoculum inside the stubble for as long as the plant material remains intact, which varies greatly with soil and weather conditions as decomposition is a very slow process.

Infection—given some level of soil moisture, the crown-rot fungus grows out of stubble residues and infects new winter cereal plants through the coleoptile, sub-crown internode or crown tissue, which are all below the soil surface. The fungus can also infect plants on the soil surface through the outer leaf sheaths. However, whatever the points of infection, direct contact with the previously infected residues is required. Infections can occur throughout the whole season, given the necessary moisture. Hence, wet seasons favour increased infection events by the crown-rot fungus, especially when combined with the production of greater stubble loads, which significantly build up inoculum levels.

Expression—yield loss is related to moisture and temperature stress around flowering and through grainfill. This stress is believed to trigger the crown rot fungus to proliferate in the base of infected tillers, restricting water movement from the roots through the stems, and producing whiteheads. The expression of whiteheads in plants infected with crown rot (i.e. they will still have basal browning) is restricted in wet seasons and increases greatly with increasing moisture and temperature stress during grainfill. Focus attention to crops around trees in a paddock or along tree lines. Even in good years, whiteheads associated with crown-rot infection are likely to be seen around trees. This is due to the extra competition for water. [52]

9.5.2 Damage caused by crown rot

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

Photo 10: *Scattered whiteheads in a cereal paddock.*

Source: DAFWA

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

9.5.3 Symptoms of crown rot

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

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

- Brown tiller bases, often extending up 2–4 nodes (Photo 11). [53] This is the most reliable indicator of crown rot, with browning often becoming more pronounced from mid to late grainfilling through to harvest.
- Whitehead formation, particularly in seasons with a wet start and dry finish (Photo 12). These are usually scattered throughout the crop, and do not appear in distinct patches. These may first appear in wheel tracks where crop-available moisture is more limited.
- A cottony fungal growth that may be found around the inside of tillers, and a pinkish fungal growth that may form on the lower nodes, especially during moist weather (Photo 13).
- Pinched grain at harvest. [54]

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

Source: DAFWA

53 DAFWA (2016) Diagnosing crown rot of cereals. DAFWA, https://www.agric.wa.gov.au/mycrop/diagnosing-crown-rot-cereals

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

Photo 12: *Scattered single tillers and whiteheads.*

Source: DAFWA

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

Source: DAFWA

9.5.4 Symptoms of Fusarium head blight

Fusarium head blight (FHB) is an infection of the head rather than root or crown as with crown. In wheat, FHB appears as premature bleaching of spikelets within a head. Frequently only part of the head (usually the upper half) is affected (Photo 14). [55] Salmon pink to orange spore masses (sporodochia) at the bases of infected spikelets can also be apparent during prolonged warm, humid weather. Infected wheat grains have a chalky white appearance and are usually shrivelled and lightweight; they may sometimes have pink staining, too. In barley, infected spikelets have a brown or water-soaked appearance, rather than bleaching, and the grains have an orange or black encrustation on their surfaces.

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

Photo 14: *FHB results in heads that are partly or fully bleached.*

Source: DAFWA

9.5.5 Conditions favouring development

Crown rot

The effects of crown rot on yield tend to be most severe when there are good crop conditions in the first part of the season followed by a dry finish. This is because the moist conditions at the beginning of the season enable the fungus to grow from infected stubble to an adjacent seedling, while the dry conditions during flowering and grainfilling cause moisture stress, allowing rapid growth of the pathogen within the plant. A wet finish to the season can reduce the damage caused by crown rot, but will not prevent yield loss in all cases. [56]

Cultivation can also have a huge impact. Crown rot is a stubble-borne disease and for a plant to become infected it must come into contact with inoculum from previous winter cereal crops. So by cultivating soil, growers are actually helping to spread the crown rot inoculum to next year's crop. The best thing a grower can do with infected stubble is leave it alone. [57]

Interaction with root-lesion nematodes

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

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

57 T Dixon (2013) Balancing crown rot and nematodes in wheat. Ground Cover. No. 104, May–June 2013. GRDC, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-104-May-June-2013/Balancing-crown-rot-and-nematodes-in-wheat

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

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

FHB

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

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

9.5.6 Management

Key points:

- Rotate crops—this is the most important management tool. A grass-free break from winter cereals is the best way to lower crown-rot inoculum levels.
- Test—a pre-sowing PreDicta B soil test will identify paddocks at risk of crown rot.
- Sow winter cereals into paddocks where the risk is lowest.
- Choose more resistant crop varieties, but variety choice needs to be combined with effective management.
- Observe—check plants for browning at the base of infected tillers as this is the most reliable indicator of crown rot. Don't rely solely on whiteheads as an indicator (Figure 3).
- Keep crown rot inoculum at low levels is the most effective way to reduce yield loss from this disease. [58]

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

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

Source: GRDC

Crown rot may be controlled through planting more resistant varieties and by using crop rotation. If the disease is severe, rotation to a non-susceptible crop for at least two and preferably three years is recommended. A winter crop such as chickpea, oats or any summer crop may be used as a disease-free rotation crop. [59]

There is no treatment available in controlling FHB, only preventative measures. Avoid multiple winter cereal crops, which can promote the disease once it is established. Do not sow winter cereals into summer crop paddocks until all summer residues have broken down. Additionally, avoid sowing winter cereals adjacent to those paddocks. [60]

Crop rotation

The most effective way to reduce crown rot inoculum is to include non-susceptible crops in the rotation sequence. The crown rot fungus can survive for two to three years in stubble and soil. Growing a non-host crop for at least two seasons is recommended to reduce inoculum levels. This allows time for decomposition of winter cereal residues that host the crown rot fungus. Stubble decomposition varies with the type of break crop grown: canopy density and rate of the canopy closure as well as row spacing, the amount of soil water they use and seasonal rainfall.

Because crown rot survives from one season to the next on infected stubble, the use of break crops can give stubble a chance to decompose and thus reduce soil

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

60 DAFWA. (2015). Diagnosing Fusarium head blight in cereals. https://agric.wa.gov.au/n/2138

inoculum levels. The use of break crops with dense canopies, such as canola, can be particularly effective, as these help to maintain a moist soil surface, which further promotes the breakdown of cereal residues.

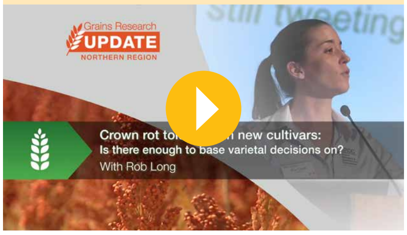
The number or break crops required to sufficiently reduce crown rot levels will vary, depending on rainfall in the break year. In dry years, when residue breakdown is slower, a two-year break crop may be required to reduce crown rot to acceptable levels. In wetter seasons, a one-year break may be sufficient.

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

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

VIDEOS

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



Variety selection

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

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

NSW DPI trials at 23 sites in 2013–14 indicate that susceptibility can represent a yield benefit of around 0.50 t/ha in the presence of high levels of crown rot infection. However, variety choice is NOT a solution to crown rot with even the best variety still suffering up to 40% yield loss from crown rot under high infection levels and a dry/hot seasonal finish. [61]

MORE INFORMATION

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

Understanding crown rot underpins effective management, southern and western regions

Crop management

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

- Reducing moisture stress in plants through good fallow management and avoiding excessively high sowing rates.
- Matching nitrogen fertiliser inputs to available soil water to avoid excessive early crop growth.
- Ensuring good crop nutrition. Zinc nutrition can be particularly important as the expression of whiteheads can be more severe in zinc-deficient crops.

Cultivation

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

- Survival—stubble decomposition is a microbial process driven by temperature and moisture. Cultivating stubble in theory increases the rate of decomposition as it reduces particle size of stubble, buries the particles in the soil where microbial activity is greater and the soil environment maintains more optimal moisture and temperature conditions compared to the soil surface or above ground. However, cultivation also dries out the soil in the cultivation layer, which immediately slows down decomposition. Decomposition of cereal stubbles is

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

a very slow process that requires adequate moisture for an extended period of time to occur completely. One summer fallow, even if extremely wet and stubble has been cultivated, is *not* long enough!

- Infection—the cultivation of winter cereal stubble harbouring the crown-rot fungus breaks the inoculum into smaller pieces and spreads them more evenly through the cultivation layer across the paddock. Consequently, the fungus is given a much greater chance of coming into contact with seedlings when the next winter cereal crop germinates and starts to grow. In a no-till system the crown-rot fungus becomes confined to the previous cereal rows and is more reliant on infection through the outer leaf sheaths at the soil surface, thus greatly reducing infection. Cultivation or harrowing negates the option of inter-row sowing as a crown rot management strategy.
- Expression—extensive research has shown that cultivation dries out the soil to the depth of cultivation and reduces the water infiltration rate due to the loss of structure (e.g. macropores). The lack of cereal stubble cover can also increase soil evaporation. With poorer infiltration and higher evaporation, fallow efficiency is reduced for cultivated systems compared to a no-till stubble retention system. Greater moisture availability has the potential to provide buffering against the expression of crown rot late in the season.

Stubble burning

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

Reducing water loss

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

Grass-weed management

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

Sowing time

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

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

Row placement

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

Soil type

The soil type does not directly affect the survival or infection phases of crown rot. However, the water-holding capacity of each soil type does affect the expression of crown rot by the degree to which it buffers triticale plants against moisture stress late in the season. Hence, yield loss can be worse on red soils than black soils due to the generally lower water-holding capacity of red soils. On top of this, other sub-soil constraints, e.g. sodicity, salinity or shallower soil depth, can also reduce the level of plant-available water, which can increase the expression of crown rot. [62]

Soil testing

In addition to visual symptoms, the DNA-based soil test PreDicta B can be used to assess the level of crown rot in the paddock. Soil samples that include plant residues should be tested early in late summer to allow results to be returned before seeding. This test is particularly useful when sowing susceptible varieties, and for assessing the risk after a non-cereal crop. [63]

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

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

PreDicta B samples are processed weekly from February to mid-May (prior to crops being sown) to assist with planning the cropping program. The test is not intended for in-crop diagnosis. That is best achieved by sending samples of affected plants to your local plant pathology laboratory. In order to get an accurate result, it is important to follow the PreDicta B sampling protocol (Photo 15). [64]

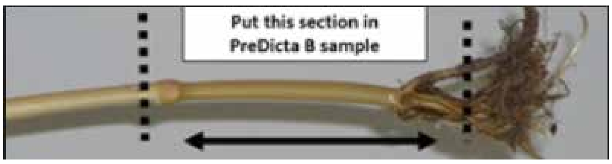


Photo 15: *It is important to follow the PreDicta B sampling protocol precisely.*

Source: GRDC.

MORE INFORMATION

PreDicta B

VIDEOS

WATCH: GRDC, Grains research updates: Improving PreDicta B

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

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

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

9.6 Common root rot

Common root rot (*Bipolaris* spp.) is a soil-borne fungal disease which attacks cereals. It survives from one season to the next through fungal spores that remain in the cultivated layer of the soil. The disease increases in severity with continuous cereal sequences. The symptoms of common root rot are:

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

9.6.1 Damage caused by disease

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

9.6.2 Symptoms

What to look for in the paddock

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

What to look for in the plant

- Browning of roots and sub-crown internode (the piece of stem emerging from the seed to the crown) (Photo 16). [65]
- Blackening of sub-crown internode in extreme cases.

Photo 16: *Blackening of sub-crown internode in an extreme case of common root rot.*

Source: DAFWA

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

9.6.3 Conditions favouring development

- The disease can occur from tillering onwards, but is most obvious after flowering.
- There are no distinct paddock symptoms, although the crop may lack vigour.
- Severe infections can lead to stunting of plants.
- Common root rot appears to be 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.
- The disease is widespread through the grain belt, and is often found in association with crown rot.
- The fungus that causes common root rot survives on the roots of grasses and as dormant spores in the soil. It can build up to damaging levels in continuous wheat rotations [66]

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

9.6.4 Management

The disease may be controlled by planting the more resistant varieties and using crop rotation. Where the disease is severe, rotation to non-susceptible crops for at least two years is recommended. [67] It is important to:

- Reduce levels of the fungus in your paddocks by rotating with crops such as field peas, faba beans and canola.
- Keep susceptible crops and pasture grass-free.
- Sow more resistant wheat or barley varieties.
- If moisture permits, reduce sowing depth to limit the length of the sub-crown internode (SCI).
- Ensure adequate nutrition, especially of phosphorus, which reduces severity.
- Reconsider stubble burning, as it does not decrease spore levels in the soil. [68]

9.7 Smut and bunt

Triticale is not usually prone to infection from smuts and bunt. However, it is good insurance for better yields to apply a seed dressing to the grain when it is being graded. [69]

9.7.1 Bunt or stinking smut

Bunt or stinking smut (*Tilletia* spp.) affects mature triticale, durum and wheat ears. A mass of black fungal spores replaces the interior of a grain with what is known as a bunt ball. Compared with healthy plants, infected plants are shorter and have darker green ears and gaping glumes (Photo 17). [70] Bunt is usually only noticed at harvest when bunt balls and fragments are seen in the grain. It is important to manage this disease, as AWB will not accept grain deliveries with traces of bunt balls.

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

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

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

69 Agriculture Victoria. (2012). Growing Triticale. http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale

70 DAFWA (2016) Smut and bunt diseases of cereal: biology, identification and management. DAFWA, https://www.agric.wa.gov.au/autumn/smut-and-bunt-diseases-cereal-biology-identification-and-management?page=0,1

Photo 17: *Common bunt in cereal head showing glumes containing bunt balls.*

Source: DAFWA

The spores germinate with the seed when it is planted, and infect the young seedling. The fungus then grows inside the developing wheat plant, finally replacing each normal grain with a mass of spores. If a bunt ball is crushed, a putrid, fishy odour is released. Spores released during harvest will contaminate sound grain.

Managing bunt

- All seed should be treated with a fungicidal seed dressing which will control bunt.
- Grain from a crop with bunt should not be used for seed. [71]

Seed treatments are extremely effective in controlling bunt. However, seed treatments need to be applied every year, and a good coverage of grain is essential to prevent infection.

Following a bunt infection clean seed should be obtained. All machinery that handled infected grain should be thoroughly cleaned and wheat should not be sown back into an infected paddock for several years. [72]

9.7.2 Loose smut

Triticale is susceptible to loose smut, though it does not usually occur to a degree where control is warranted. [73]

Loose smut is a fungal disease that becomes evident at head emergence. A loose, powdery mass of fungal spores is formed in the head; these spores are readily blown away leaving a bare, ragged stalk (Photo 18). [74]

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

72 G Holloway, F Henry. (2007). Bunts and smuts of cereals. Agriculture Victoria. http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/bunts-and-smuts-of-cereals

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

74 DAFWA (2016) Smut and bunt diseases of cereal: biology, identification and management. DAFWA, https://www.agric.wa.gov.au/autumn/smut-and-bunt-diseases-cereal-biology-identification-and-management?page=0,1

Photo 18: *Close-up view of barley heads affected with loose smut.*

Source: DAFWA

If the spores settle on healthy flowers, they may germinate and infect the embryo of the developing seed. When this seed is planted, the smut grows inside the plant until flowering, when the disease appears. Because loose smut is carried inside the seed, systemic seed dressings are needed to control it. These are more expensive than the others and should be used only when a high incidence of loose smut is expected. [75]

Managing smut

The disease is controlled by pickling seed with a systemic fungicide which penetrates the developing seedling to kill the internal infection. Seed-dressing fungicides for cereals differ in their efficacy for smut management with trial research demonstrating that some seed dressings can reduce the incidence of loose smut in heavily infected seed to nearly zero. The correct application of seed dressings is critical to ensuring adequate prevention and control. [76]

9.8 Rhizoctonia barepatch

- The presence of *Rhizoctonia* fungal disease is most evident as bare patches in a young crop. Close inspection of infected seedlings shows brown discolouration or rotting of the roots and evidence of 'spear tips'.
- In cereals, oats are most tolerant, followed by triticale, wheat and then barley, which is the most intolerant. [77]
- Adequate nutrition during crop emergence gives the crop a better chance of getting ahead of the disease.
- Fast-growing roots will push past the infected topsoil before *Rhizoctonia* infects the root tip.
- Poor weed management prior to seeding allows *Rhizoctonia solani* to 'prime' itself for infection of the upcoming crop.

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

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

77 GRDC (2008) What is Rhizoctonia bare patch? Factsheet. GRDC, https://grdc.com.au/uploads/documents/grdc_fs_rhizo.pdf

- In severe paddock infections cultivation following late summer–early autumn rains can help to reduce infection by the fungus.

Rhizoctonia barepatch is a fungal disease caused by *Rhizoctonia solani* (Kuhn). It affects a wide range of crops and has become more prevalent in light soils in recent years following the introduction of minimum-tillage practices. The traditional practice of tilling prior to planting encouraged the breakdown of the fungus in the soil before seedlings emerged. Minimum tillage decreases the rate of organic-matter breakdown, thereby providing a habitat for *Rhizoctonia solani* over summer. The disease affects most major crops to varying degrees, with barley being most susceptible and oat crops are least susceptible. Bare patch and root rot of cereals, and damping off and hypocotyl rot of oilseeds and legumes are all caused by different strains of *R. solani*. [78]

MORE INFORMATION

Karoonda break crops trails: soil biology and rhizoctonia disease

9.8.1 Symptoms

The characteristic symptom of Rhizoctonia barepatch is clearly defined bare patches in the crop (Photo 19). [79] The reason these patches are clearly defined relates to the susceptibility of young seedlings, and the placement of the fungus within the soil profile. *Rhizoctonia solani* tends to reside in the upper layers of soil, but not in the surface, and only infects seedlings through the root tip soon after germination. Older plants have a more developed root epidermis that does not allow the penetration of fungal hyphae into the root. For this reason, once the crop is fully established, plants have either perished due to seedling infection or are reasonably healthy. Some yield loss may be associated with plants on the margins of the bare patch. Roots of a plant infected with *R. solani* will typically be shorter and have a brown 'spear tip' where they have rotted. Plants within a patch remain stunted with stiff, rolled leaves and can be darker green than those outside the patch. [80]

VIDEOS

WATCH: Over the Fence: Improving soil health helps fight against Rhizoctonia

What to look for in the paddock

- Severely stunted plants occur in patches with a distinct edge between diseased and healthy plants.
- Patches vary in size from less than half a metre to several metres in diameter.
- Patches of uneven growth occur from mid-winter when seminal roots have established (Photo 19).

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

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

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

Photo 19: *Patches vary in size from less than a metre to several metres in diameter. Patches have a distinct edge.*

Source: DAFWA

What to look for in the plant

- Affected plants are stunted with stiff, rolled leaves and are sometimes darker green than healthy plants (Photo 20).
- Roots of affected plants are short with characteristic pinched ends called 'spear tips' (Photo 21).

Photo 20: *Affected plants are stunted with stiff, rolled leaves which are sometimes darker than those of healthy plants.*

Source: DAFWA

VIDEOS

WATCH: How to diagnose Rhizoctonia root rot

Photo 21: *Roots of affected plants are short with characteristic pinched ends or 'spear tips'.*

Source: DAFWA

9.8.2 Conditions favouring development

Rhizoctonia solani survives best in organic matter just below the surface of undisturbed soil. The fungus benefits from summer rainfall by infecting and multiplying in weeds, and has a limited ability to survive on the residue of previous seasons crops. The break of season initiates the development of the fungus in soil, where it lies primed to infect germinating seeds. Infection by the pathogen is encouraged by factors that restrict root growth, such as low soil fertility and sulfonylurea herbicides. If there is a delay between the season break and seeding, it is imperative that weeds are controlled to minimise proliferation of the fungus. Good nitrogen nutrition helps to minimise the effects of the disease; bare patches are smaller and less severe.

In general, Rhizoctonia barepatch is most likely to be a severe problem where the plant is under stress from factors other than the disease, for example, low rainfall or poor nutrition.

Factors affecting Rhizoctonia

There are certain soil conditions that favour *Rhizoctonia* development during and after seeding.

Soil nutrition

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

Soil disturbance

Rhizoctonia is sensitive to cultivation, with cultivation after rain and before sowing most effective at reducing infection. Disturbing the soil prevents the fungus from 'priming' itself for infection of the emerging crop.

Soil moisture

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

Weeds

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

Herbicides

Sulfonylurea herbicides , both residual and recently applied, can sometimes worsen *Rhizoctonia*, and this is attributed to minor herbicidal effects on the crop. [81] Ensure soil Zinc levels are adequate or apply foliar zinc to help alleviate Group B herbicide effects.

9.8.3 Managing *Rhizoctonia*

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

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

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

Currently there are no resistant crop varieties, but there are a number of products on the market with claims for Rhizoctonia barepatch control. Consult your local adviser for specific information.

In areas where the disease is known or suspected it is best practice to clean knife points once the seeding is complete, to eliminate movement of the fungus from one paddock to the next. In general, maintaining adequate nutrition (especially nitrogen) during crop establishment is the best way to reduce the impact from *R. solani* infection. [82]

MORE INFORMATION

Management to minimise Rhizoctonia disease in cereals

9.9 Ergot

Triticale, like rye, is susceptible to ergot, a fungal disease, caused by *Claviceps purpurea*, that can ruin a year's crop. Careful crop rotation, the use of a clean seedbed, and diligent maintenance of field edges will minimise this chance, but triticale intended for human or animal consumption should be tested for toxins.

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

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

Ergot can make grain less palatable to livestock, as well as causing serious health problems. [83]

Ergot is relatively rare in Australian grains, however it is considered a constant threat as it contains toxic chemicals (alkaloids) that are very harmful to both animals and humans. For this reason, Ergot in grain could prove quite damaging to grain trade. [84]

9.9.1 Damage caused by disease

Ergot bodies contain alkaloid chemicals that can cause lameness, gangrene of the extremities and nervous convulsions (staggers) that can lead to death in both humans and other animals. Symptoms begin to occur after long periods of low level ingestion as toxins accumulate in the body. Yields of crops affected by ergot are generally not much diminished yield losses, but economic losses can be quite severe, because grain tendered by growers is likely to be rejected at receival. [85]

Gangrenous ergotism of humans and cattle

In humans, gangrenous ergotism causes blockages of circulation to the extremities resulting first in tingling and then in gangrene in the fingers and toes, as well as vomiting, diarrhoea, and ulceration of the mouth. It is a dry form of gangrene, and limbs may fall off.

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

Convulsive ergotism

Symptoms are similar to those of gangrenous ergotism, and are followed by painful spasms of the limbs, epilepsy-like convulsions and delirium in humans. Cattle become excitable and run with a swaying, uncoordinated gait. [86]

9.9.2 Symptoms

What to look for in the plant

Characteristically ergot pieces have a purple–black surface with a white to grey interior (Photo 22). They are usually horn-like in shape and replace one or more grains in the heads of cereals and grasses. These ergot bodies can be up to four times larger than normal grain.

- Hard, dry purple–black fungal bodies (ergots) that replace the grain in the seed head.
- Yellow droplets of sugary slime in infected heads during flowering. [87]

83 UVM Extension Crops and Soils Team (2011) Triticale. University of Vermont, http://northerngraingrowers.org/wp-content/uploads/TRITICALE.pdf

84 AWB (n.d.) Ergot. Factsheet. AWB, https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT_factsheet.pdf

85 AWB (n.d.) Ergot. Factsheet. AWB, https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT_factsheet.pdf

86 HerbiGuide (n.d.) Rye. HerbiGuide, http://www.herbiguide.com.au/Descriptions/hg_Rye.htm

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

Photo 22: *Ergot bodies in cereal grain head.*

Photo: C Wolinsky

What to look for in stock

Producers are encouraged to keep an eye on animals that may have eaten ergot-infected grain, especially in hot or sunny weather (Photo 23). Signs of ergot poisoning include animals seeking shade, being reluctant to move, and panting and distress following any exercise. Animals may also drool, have an increased respiratory rate, and reduced feed intake. [88]

Photo 23: *Producers need to be aware that even a small amount of ergot in grain can cause serious illness to their stock.*

Photo: Michael Raine

9.9.3 Conditions favouring development

Key points:

- Ergots survive in the soil for up to one year, producing spores that infect plants during flowering.
- Infection is more likely when there is cool wet weather at flowering.

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

- It is spread by rain splash or by insects attracted to the sugary droplets.
- High levels of grass-weed contamination can increase ergot infection in cereals, or ergots produced in grasses can contaminate grain samples. [89]

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

Crops are generally perceived to be at greatest risk when grass weed populations are high. Infected grasses usually produce slender ergots and in some cases can be fully responsible for the contamination of grain samples. [90]

Ongoing periods of spring and summer rain can increase occurrence of ergots in ryegrass; therefore, ergots in crops are more likely to develop in years of above-average rain when ryegrass is flowering. [91]

9.9.4 Management of disease

Key points:

- Give contaminated paddocks a one-year break without cereals or grasses.
- Manage grass-weed contamination in crops.
- Clean seed. [92]

For grain that is contaminated, grain-cleaning equipment can be used to remove the majority of ergot bodies (Photo 24). However, the grower will need to determine whether this is economically viable.

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

90 AWB (n.d.) Ergot. Factsheet. AWB, https://www.awb.com.au/NR/rdonlyres/BFA96F0A-1967-4B8D-8B6C-631A00F15478/0/ERGOT_factsheet.pdf

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

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

Photo 24: *Ergot-contaminated seed.*

Source: DAFWA

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

During planting, clean seed must be used, as there are currently no effective treatments against ergot. For growers using conventional tillage, ergot pieces need to be buried to a minimum depth of 4 cm. This prevents the fruiting bodies that are produced by the ergot from reaching the soil surface and releasing spores. This may have an effect on the usual sowing operations and guidance should be sought.

Finally, to eliminate the development of host reservoirs, growers may be able to mow or spray grass pastures to prevent flowering. [93]

Control of grasses within cereal crops will help prevent cross-infection. This is best achieved by preventing seedset in the season before cropping, by clear fallowing, hard grazing or hay cutting, together with the use of selective herbicides. [94]

The only practical control is to sow clean, year-old seed on land that hasn't grown cereal rye for at least a year. Mowing roadside and headland grass prior to seedset will reduce or eliminate this major source of ergot re-infestation. [95]

Strategies to reduce the risk of ergot infection:

- Use ergot-free seed if possible.

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

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

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

- Rotate with crops resistant to ergot, such as flax, canola and legumes.
- As the source of ergot infection is often the grass in headlands or ditches, mowing this grass before flowering or seedset will greatly reduce or eliminate the chances of ergot infection.
- Ergots germinate at or near the soil surface. To prevent them from germinating, work the field to a depth greater than 4-5 cm to bury the ergot bodies.
- Seed at a uniform depth as shallow as possible for adequate moisture to obtain a uniform early emergence.
- Separate the seed collected from the first few combine rounds to prevent contamination of the entire lot, as most of the ergot infested grain will likely be concentrated in this region. [96]

Marketing options

Stockfeed intended for feedlot cattle has been limited to 0.1% ergot sclerotia (dormant, or vegetative, stage of ergot bodies) by weight since 2004.

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

Although there is a 0.3% sclerote contamination limit for grain intended for livestock, some end-users will not accept ergot-contaminated grain at all. Grower pigs, chickens and laying hens are more tolerant of the alkaloids in sclerotia, and are a potential market for grain that contains 0.3% sclerotia. Grain with levels higher than the animal-feed limit can be mixed with clean grain to reduce the sclerote levels. Fortunately, the incidence of ergot contamination of bulk grain has been very low in the last decade. [97]

9.10 *Septoria tritici* blotch

Triticale has vastly superior tolerance over wheat to *Septoria tritici* blotch (Table 9). [98]

Septoria tritici blotch (STB) is an important stubble-borne foliar disease of cereals in southern Australia. This disease has increased in importance in the high-rainfall cropping regions in recent years, even though it has been well controlled in Victoria for the last 30 years through the use of partially resistant varieties. The increase in STB in the high-rainfall zone has been favoured by stubble retention, intensive wheat production, susceptible cultivars and favourable disease conditions.

When susceptible and very susceptible varieties are grown, *Septoria tritici* blotch is likely to cause annual average losses of up to 20%, with much higher losses possible in individual crops.

9.10.1 Symptoms

The fungus causes pale grey to dark brown blotches on the leaves, and to a lesser extent stems and heads. The diagnostic feature of *Septoria tritici* blotch is the presence of black fruiting bodies (pycnidia) within the blotches (Photo 25). [99] These tiny black spots give the blotches a characteristic speckled appearance. When the disease is severe, entire leaves may be affected by disease lesions (Photo 26).

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

97 DAF Qld (2010) Ergot-affected and mouldy sorghum. DAF Qld, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/disease-management/ergot-affected-and-mouldy-sorghum

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

99 G Hollaway (2014) Septoria tritici blotch of wheat. Note AG1336. Revised. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/septoria-tritici-blotch-of-wheat

In the absence of the black fruiting bodies, which are visible to the naked eye, similar blotching symptoms may be caused by yellow leaf spot or nutritional disorders such as aluminium toxicity or zinc deficiency.

The only other disease that has black fruiting bodies within the blotches is *Septoria nodorum* blotch, but this disease is rare in Victoria.

Photo 25: *The presence of black fruiting bodies within the blotches is a diagnostic feature of Septoria tritici blotch.*

Source: Agriculture Victoria

Photo 26: *Septoria tritici blotch can cause complete death of leaves.*

Source: Agriculture Victoria

9.10.2 Varietal resistance or tolerance

Table 7 lists the resistance of different varieties to Septoria tritici blotch. [100]

Table 7: *Triticale variety resistance ratings to Septoria tritici blotch.*

Variety	*Septoria tritici*
Astute⊕	–
Berkshire⊕	RMR
Bison⊕	MR
Canobolas⊕	RMR
Chopper⊕	RMR
Endeavour⊕	R
Fusion⊕	R
Goanna	R
KM10	MR
Rufus	RMR
Tahara	RMR
Tobruk⊕	R
Tuckerbox	RMR
Yowie	RMR

Maturity: E = early, M = mid-season, L = late, VL = very late
Height: M = medium, T = tall
Colour: W = white, Br = brown
Disease resistance order from best to worst: R > RMR > MR > MRMS > MS > MSS > S > SVS > VS
p = provisional ratings––treat with caution. R = resistant, M = moderately, S = susceptible, V = very.
Varieties marked may be more susceptible if alternative strains are present

Source: Agriculture Victoria

9.10.3 Conditions favouring development

Septoria tritici blotch, also called Septoria leaf spot or speckled leaf blotch of wheat is caused by the fungus *Mycosphaerella graminicola* (asexual stage *Zymoseptoria tritici*, synonym *Septoria tritici*).

Septoria tritici blotch survives from one season to the next on stubble. Following rain or heavy dew in late autumn and early winter, wind-borne spores (ascospores) are released from fruiting bodies (perithecia) embedded in the stubble of previously infected plants. The spores can be spread over large distances.

Early ascospore infections cause blotches on the leaves. Within these blotches a second type of fruiting body, pycnidia, are produced. Asexual spores ooze from pycnidia when the leaf surface is wet and spores are dispersed by rain splash to other leaves where they cause new infections. This phase of disease development depends on the rain splash of spores; therefore, *Septoria tritici* blotch will be most severe in seasons with above-average spring rainfall. A combination of wind and rain provides the most favourable conditions for spread of this disease within crops.

9.10.4 Management

An integrated approach that incorporates variety selection, cultural practices, crop rotation and fungicides is the most effective way to manage *Septoria tritici* blotch.

100 Agriculture Victoria (2016) Triticale [download]. In Victorian winter crop summary. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/victorian-winter-crop-summary

Variety selection

The majority of commercially grown varieties now have partial resistance (i.e. they are moderately susceptible) to *Septoria tritici* blotch. This resistance has to date been durable, and sufficient to effectively control this disease in Victoria.

It is important to avoid very susceptible varieties as they will build up inoculum levels. This will cause yield loss in that variety, and in adjacent moderately susceptible wheat crops. For information on the resistance status of varieties consult the current Victorian Cereal Disease Guide.

Cultural practices

Following an outbreak of *Septoria tritici* blotch do not sow wheat into infected stubble and avoid early sowing as a high number of ascospores are released early in the season. If this is not possible, destroying stubble by grazing or cultivation will reduce the number of spores available to infect the new season's crop. Such practices will have more effect if undertaken on a district basis. This practice is not, however, practicable in light soil areas where stubble must be kept to prevent erosion.

Crop rotations

Crop rotations are important to ensure wheat is not sown into paddocks with high levels of stubble-borne inoculum. A one-year rotation out of wheat is generally effective to provide disease break. However, the fungus may survive for over 18 months on stubble during very dry seasons.

Fungicides

Some seed-applied fungicides can suppress early infection and should be used in areas where *Septoria tritici* blotch is known to occur. Effective foliar fungicide sprays are available if necessary. However, it is important to correctly identify *Septoria tritici* blotch before spraying with a fungicide as nutritional disorders such as aluminium toxicity or zinc deficiency can be confused with *Septoria tritici* blotch.

In high-risk areas, the timing of fungicides will be important to achieve adequate disease control. In early sown susceptible varieties, a fungicide application at growth stage 31–32 may be required to suppress the disease and protect emerging leaves. Once the flag leaf has fully emerged, at GS39, another fungicide application may be required to protect the upper canopy.

Since STB is prone to developing resistance to fungicides, and resistance has been detected in Australia, it is important that fungicide strategies to reduce the likelihood of resistance developing are adopted.

Fungicide resistance

Increasing resistance of *Zymoseptoria tritici* to some triazole (Group 3) fungicides was recently detected in Victoria by Dr Andrew Milgate, of the NSW Department of Primary Industries. Two mutations of *Septoria tritici* blotch giving resistance to triazole fungicides were identified. These mutations reduce the effectiveness of fungicides, rather than making them completely ineffective. However, continued use of triazole fungicides will put further selection pressure on the pathogen, and potentially new mutations will be selected.

Fungicides with reduced effectiveness against *Septoria tritici* blotch include triadimefon, triadimenol, tebuconazole, propiconazole and epoxiconazole. Epoxiconazole is not registered for control of *Septoria tritici* blotch in Australia.

Dr Milgate found that resistance may not be causing reduced spray efficacy at present, but a strategy to prolong fungicide effectiveness will prolong the life of this fungicide group. [101]

101 A Milgate. (2014). Septoria fungicide resistance detected. Ground Cover Issue 110- Cereal foliar fungal diseases. https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS110/Septoria-fungicide-resistance-detected

Managing fungicide resistance

There are a number of methods thought to reduce the selection rate for further mutations.

The first method is to alternate different triazoles, as not all triazole fungicides are affected equally by mutations of the *Septoria tritici* blotch fungus. This means not using the same traizole fungicide more than once in a crop, if multiple sprays are required during the season.

The second is to used fungicides that combine triazoles, such as Tilt Xtra® (propiconazole and cyproconazole) or Impact Topguard® (tebuconazole and flutriafol), which are registered for use on *Septoria tritici* blotch.

The third is to use fungicides with different modes of action. However, in Australia there is a limited choice in this regard. Products that combine a strobilurin (Group 11) fungicide with a triazole fungicide may reduce the risk of resistance development. Custodia® (tebuconazole and azoxystrobin) is registered for *Septoria tritici* blotch in Australia.

Strobilurins on their own are considered to be at high risk of developing resistance due to their single site mode of action. In the United Kingdom, resistance to strobilurins is so widespread in *Septoria tritici* blotch populations they are no longer effective, even in mixtures. Resistance of *Septoria tritici* blotch to strobilurins has been recently detected in New Zealand, too. While not yet registered in Australia, SDHI (Group 7) carboxamide fungicides mixed with triazole (Group 3) fungicides are being used in New Zealand and the United Kingdom to manage *Septoria tritici* blotch.

When using fungicides, it is important that growers always follow label guidelines and ensure maximum residue limits are adhered to.

Biosecurity

As resistant mutations of the *Septoria tritici* blotch fungus have been identified in other countries, including New Zealand, the United Kingdom and mainland Europe, it will be important to not accidentally introduce these resistant mutations into Australia after travelling overseas.

The risk of introducing exotic diseases or new mutations of a pathogen into Australia can be minimised by having a biosecurity hygiene plan, and implementing it following overseas travel.

Basic biosecurity hygiene includes washing clothes and cleaning footwear before returning to Australia. If high risk areas have been visited, consider leaving clothing and footwear behind. Remind family members, employees or others travelling to also take these precautions. [102]

MORE INFORMATION

Septoria tritici blotch, southern region

9.11 Cereal fungicides

All of the diseases addressed so far are caused by different fungi. Fungal disease is a major disease threat to all Australian crops, and keeping paddocks (and farms) healthy and disease loads low requires thoughtful management.

- Fungicides are only one component of a good management strategy.
- Correct identification of the cause of plant symptoms is essential, and an understanding of the growth and spread of any pathogen will assist in any decision making.
- Cultivar resistance is the best protection against fungal diseases. Ideally, when suitable varieties are available, opt for moderately resistant (MR) to resistant (R) varieties in disease-prone environments.
- Disease control using fungicides is an economic decision. Does the yield potential justify the return on investment in applying the fungicide?

102 G Hollaway (2014) Septoria tritici blotch of wheat. Note AG1336. Revised. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/septoria-tritici-blotch-of-wheat

- If growing susceptible varieties have the right chemicals on hand.
- For cereal rusts and mildew, remove the green bridge between crops to prevent rusts from over-seasoning.
- Monitor crops throughout the season.
- Spray if disease threatens key plant parts (flag to flag-2) of varieties that are moderately susceptible (MS) or susceptible (S). Note that if the disease has already reached this part of the plant it is too late to control the disease. Effective fungicide management relies on good identification and early control. Management should be pre-emptive if environmental conditions are suitable for disease growth and if a variety is susceptible.
- Fungicides do not increase yield; they protect yield potential and cannot retrieve lost yield if applied after infection is established.
- Fungicide resistance is a major emerging issue. Do not use tebuconazole-based products; e.g. on barley if there is any chance of powdery mildew occurring, and select varieties that are resistant to powdery mildew (Table 8). [103]

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

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

Source: R Oliver, Curtin University. In GRDC

VIDEOS

WATCH: GCTV9: Banding fungicide in cereals

9.11.1 Fungicide stewardship

There have been a number of pathogens, including *Septoria tritici* blotch, which have recently developed a level of fungicide insensitivity or resistance in Australia. The occurrence of these highlights the important role all growers play in fungicide resistance.

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

1. Remove the source of infection:

- For many pathogens, stubble is the source of the infection each year. By removing stubble before sowing, there is a substantial reduction of pathogen population size.

103 GRDC (2013) Managing cereal fungicide use, southern region. Factsheet. GRDC, https://grdc.com.au/Resources/Factsheets/2013/05/Cereal-fungicides

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

2. Variety choice:

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

3. Fungicide choice and use:

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

The timing of application in the disease epidemic is critical to getting the most out of these products. [104]

MORE INFORMATION

GRDC, Cereal fungicides

9.12 Barley yellow dwarf virus

The yellow dwarf diseases of cereals have now been divided into two groups: Barley yellow dwarf virus (BYDV) and Cereal yellow dwarf virus (CYDV). They are the most important virus diseases of cereals worldwide. They have a wide host range which includes wheat, barley, oats, triticale and over 150 non-commercial grass species.

The virus is usually spread by aphids from infected grasses to crops. Wet summers and autumns promote growth of host grasses and build up of aphid vectors, resulting in early crop infection, severe symptoms and yield losses. Yellow dwarf viruses (YDVs) tend to be more serious in the high-rainfall cropping regions in southern Australia, but can occur in all cropping regions. The virus is best controlled by monitoring and spraying for aphids early in the season.

Economic importance

Work in 1984 estimated yield losses caused by BYDV in Victoria to be 2%, with up to 20% in individual crops. Trial data has shown that yield losses of 9–79% can occur when plants are infected early in the growing season (before the end of tillering) and losses of 6–9% may occur when plants are infected late (after tillering). [105]

9.12.1 Symptoms

After infection, symptoms take at least three weeks to appear. They usually appear as patches of yellow or red stunted plants. The symptoms first appear where aphids have landed. Flying aphids may infect individuals or groups of plants dotted throughout the crop. If the aphids colonise the crop, rings or patches develop which increase in size with time (Photo 27). [106] If crawling aphids move into the crop from adjoining pastures or crops then symptoms will appear along the fence line first.

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

105 Agriculture Victoria (2011) Barley yellow dwarf virus. Note AG1113. Revised. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus

106 DAFWA (2015) Managing barley yellow dwarf virus and cereal yellow dwarf virus in cereals. DAFWA, https://www.agric.wa.gov.au/barley/managing-barley-yellow-dwarf-virus-and-cereal-yellow-dwarf-virus-cereals?page=0,1

Photo 27: *Patches where aphids have landed and transmitted the virus.*

Source: DAFWA

YDV symptoms can be variable and can differ with host species, cultivar and time of infection. Sometimes, infection of cereals may occur without visible symptoms. Distinct symptoms usually occur on cereals although many infected grasses are symptomless. [107]

Infected wheat plants develop a slight to severe yellowing or pale striping between veins (interveinal chlorosis) in young leaves (Photo 28). Leaf tips can also die (necrosis). Reddening of the leaf tips (particularly of the flag leaf) can often be seen and is the most characteristic symptom of virus infection in wheat. If a sensitive variety is infected before tillering, the plant is usually stunted, has fewer tillers and more sterile ones. Grain matures early, yield is greatly reduced and grain is shrivelled. Effects are milder with a late infection. [108]

107 Agriculture Victoria (2011) Barley yellow dwarf virus. Note AG1113. Revised. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus

108 DAFWA (2015) Managing barley yellow dwarf virus and cereal yellow dwarf virus in cereals. DAFWA, https://www.agric.wa.gov.au/barley/managing-barley-yellow-dwarf-virus-and-cereal-yellow-dwarf-virus-cereals

Photo 28: *Barley yellow dwarf virus infection of a cereal plant.*

Source: DAFWA

9.12.2 Conditions favouring development

Because the YDVs have a such wide host range in the grass family (Poaceae), they survive between cropping seasons in volunteer cereals, annual and perennial pasture grasses, and wild grasses. In Victoria, perennial ryegrass is the main reservoir of YDVs in the high-rainfall areas. The virus and vectors can survive in small pockets of surviving grass even in the low-rainfall areas. The aphid vectors of the viruses tend to build up in autumn and spring on the grasses, and then move into cereal crops where they often develop colonies. High rainfall areas have a greater build-up of the grasses, virus and vectors.

There are at least six serotypes of the YDVs which are spread predominantly by different aphid vectors. The distribution and relative importance of the different types are largely dictated by the abundance of the aphid vector species. If samples are being tested, tests should include serotype PAV, MAV, RMV for (BYDV) and RPV for (CYDV).

The most common vectors found in Victoria are the oat aphid (*Rhopalosiphum padi*), the corn aphid (*R. maidis*), the English grain aphid (*Sitobian miscanthi*) and the rose-grain aphid (*Metopolophium dirhodum*). The viruses are not transmitted by any other insects and are not transmittable through seed, soil or sap. The aphids need to feed on an infected plant for at least 15 minutes, which is followed by a latent period of 12 hours, before the virus will transmit to a healthy plant. Aphids remain infected for the rest of their life.

See Section 7: Insect control for more information on aphids.

YDV outbreaks are likely to be worse in years when wet, cool summers allow larger than normal numbers of aphids and alternate hosts to survive summer, followed by a mild winter which favours the build up of aphid numbers. Early sown crops or long season crops sown in high rainfall areas are particularly vulnerable to this disease. [109]

9.12.3 Management

Where it is not possible to grow resistant varieties, YDV can be reduced by controlling aphid activity in crops, especially early in the season to prevent the spread of the disease, and or delayed sowing to avoid the main aphid flights in the autumn.

109 Agriculture Victoria (2011) Barley yellow dwarf virus. Note AG1113. Revised. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus

Later sowing will reduce the incidence of YDV, but this needs to be weighed up against possible yield reduction from delayed sowing.

Resistant varieties, when available, are the preferred option for management. There are a number of oat and a couple of wheat and barley varieties with varying levels of resistance.

Chemical treatments

It is vital to prevent spread of the virus by aphids during the first 8–10 weeks after crop emergence by using insecticides. In situations where aphids are likely to be a problem in the first few weeks after sowing, a seed treatment containing imidacloprid could be used for protection. This action requires a follow-up pyrethroid spray. [110]

Foliar sprays can be used soon after crop emergence if aphids are easily found. There are a number of products registered for control of aphids in cereals. The active ingredient pirimicarb only effects aphids, and will have less effect on any beneficial insects present at the time of spraying. Synthetic pyrethroids are also registered for use on aphids in cereals, but will have a detrimental effect on many beneficial insects. You will need to discuss with your agronomist the insecticide best suited to your situation. [111] If using pyrethroids, the first spray is three weeks after emergence (or at the 2-leaf stage if aphids easily found), and the second at seven weeks after emergence.

MORE INFORMATION

Barley Yellow dwarf virus, southern region

Crop diseases after drought

9.13 Disease following extreme weather

9.13.1 Cereal disease after drought

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

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

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

Weeds that harbour diseases are harder to kill.

Soil water and nitrogen may be unbalanced and these are likely to impact on diseases. [112]

9.13.2 Cereal disease after flood

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

The legacy of the floods and excess rain include the transport of inoculum (e.g. of crown rot, nematodes, leaf spots through movement of infected stubble and soil) (Photo 29), development of sexual stages (e.g. in leaf spots, head blights), survival of

110 DAFWA. (2015). Managing Barley yellow dwarf virus and cereal yellow dwarf virus in cereals. https://www.agric.wa.gov.au/barley/managing-barley-yellow-dwarf-virus-and-cereal-yellow-dwarf-virus-cereals

111 Agriculture Victoria (2011) Barley yellow dwarf virus. Note AG1113. Revised. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/barley-yellow-dwarf-virus

112 G Murray, T Hind-Lanoiselet, K Moore, S Simpfendorfer, J Edwards (2006) Crop diseases after drought. Primefacts. No. 408. NSW DPI, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/123718/crop-diseases-after-drought.pdf

volunteers (unharvested material and self-sown plants in double-crop situations), and weather-damaged seed. [113]

Photo 29: *Yellow leaf spot-infected stubble following flood.*

Photo: Rachel Bowman, Seedbed Media

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