New cereal rusts in Western Australia and implications for management

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GRDC codes

US00067: The Australian Cereal Rust Control Program: towards 2019 and a century of monitoring cereal rust pathogens in Australia
US00064: The Australian Cereal Rust Control Program: National breeding support

Take home messages

- Rust pathogens spread freely and rapidly through the Australasian region. While this is predominantly in a west-to east direction, recent years have seen two examples of east-to-west transport.
- Monitor for the presence of the green bridge, and if present, make sure it is destroyed at least 4 weeks before crops are sown, either by heavy grazing or herbicides.
- Warm, moist autumn conditions favour the development of leaf rust.
- Monitor crops of vulnerable varieties for leaf rust in 2016 and send samples for pathotype analysis to the Australian Rust Survey. This service is free to all, and is funded by the grower levy paid to the Grains Research and Development Corporation.
- The identification of rust pathotypes involves greenhouse tests in which seedlings of indicator varieties are infected, and takes about 3 weeks. These tests are increasingly being supplemented with DNA-tests that are much quicker (less than 48 hours). The DNA tests provide useful basic information but are nowhere near powerful enough to identify pathotypes.
- Genetic resistance to rust in wheat and barley delivers significant benefit to Australian grain growers, estimated at $1.1 billion annually, and remains the basis of rust control especially in wheat.
- Minimum disease standards remain important for industry-wide benefit from genetic resistance.

The rust diseases of cereals in Australia

Australian winter cereal crops are infected by 10 different rust pathogens (**Table 1**). New pathotypes of two of these, the wheat leaf rust pathogen *P. triticina*, and the barley leaf rust pathogen *P. hordei*, were detected in WA in 2013 and 2015.

What is a rust pathotype?

Many people who have an interest in cereal diseases would have heard the term "pathotype" (pt., aka "races" or "strains"). Pathotypes are variants within a pathogen that differ in their ability to overcome rust resistance genes in cultivars. A good recent example of this concerns stripe rust and the wheat cultivar Mace(). Like many current wheat varieties grown in WA, Mace() carries the stripe rust resistance gene *Yr17*, a gene that is expressed at all growth stages (often referred to as seedling resistance genes, major resistance genes, all stage resistance genes). While Mace() is resistant to the "WA stripe rust pathotype", first detected in 2002, the resistance provided by *Yr17* was overcome in eastern Australia by a new pathotype, 134 E16 A+ Yr17+, first detected in 2006. To date, the latter Mace-virulent pathotype has not been detected in WA. For this reason Mace() is regarded as susceptible to stripe rust in eastern Australia, and resistant to stripe rust in WA.

Nine pathotypes of wheat leaf rust have been detected in WA since 1990, some of which were detected rarely, others of which have become common and have reached epidemic levels (**Table 2**).

Table 1. The rust diseases and causal pathogens of winter cereals in Australia

Crop	Disease	Pathogen
Wheat and triticale	Stripe rust	*Puccinia striiformis* f. sp. *tritici*
	Stem rust	*Puccinia graminis* f. sp. *tritici*
	Leaf rust	*Puccinia triticina*
Barley[a]	Stem rust	*Puccinia graminis*[b]
	Leaf rust	*Puccinia hordei*
Oat	Stem rust	*Puccinia graminis* f. sp. *avenae*
	Crown rust	*Puccinia coronata* f. sp. *avenae*
Cereal rye	Stem rust	*Puccinia graminis* f. sp. *secalis*
	Leaf rust	*Puccinia recondita* f. sp. *secalis*

[a] A form of stripe rust (*Puccinia striiformis* f. sp. *pseudohordei*), known locally as Barley Grass Stripe Rust, is common on wild barley grass in eastern Australia and can cause low levels of stripe rust on some barley cultivars.

[b] Barley can be infected by up to 3 different forms of the stem rust pathogen *Puccinia graminis* – *P. graminis* f. sp. *tritici*, *P. graminis* f. sp. *secalis*, and a hybrid between these two forms, known locally as the "scabrum rust". Determining which form is present can be important: a barley crop heavily infected with *P. graminis* f. sp. *tritici* could threaten nearby wheat crops; one infected by either of the other two forms would not.

Rust pathotype surveillance

The existence of rust pathotypes was first shown in the early 1900s in the USA. Not long after, Australian annual rust surveys were initiated at the University of Sydney, and continue to this day at the University's Plant Breeding Institute (PBI). The identification of rust pathotypes at the PBI is a free service that is open to anyone who would like to submit a sample for analysis. Directions on how to do so are provided at the end of this paper.

The identification of pathotypes involves infecting seedlings of a set of cereal varieties, each carrying a different known rust resistance gene, with a field collected sample of rust. The ability or inability of the rust isolate to infect each variety allows the pathotype or pathotypes present to be identified. These tests take about 3 to 4 weeks to complete, and if a new pathotype is suspected, often a longer time is needed to confirm this. The pathotype identification work at PBI is increasingly being supplemented by DNA profiling, which is comparatively quicker and may only take several days. However, while providing important information and a means by which exotic rust incursions can be

recognised rapidly, as yet, DNA profiling is nowhere near powerful enough to identify individual pathotypes.

The long-term studies of pathogenic variability of rust pathogens conducted at PBI have clearly established that Australia and New Zealand comprise a single rust epidemiological unit, within which rusts migrate freely and rapidly. This is why a nationally coordinated approach to the genetic control of cereal rusts (i.e. the Australian Cereal Rust Control Program) is fundamental to success.

The annual surveys of rust variability carried out at PBI have and continue to form the basis of all genetic based rust control efforts. They monitor the effectiveness of rust resistance genes in commercial cultivars; determine the implications of new endemic and exotic rust pathotypes in the rust responses of current cereal cultivars; facilitate the discovery and introduction of new resistance genes into locally adapted germplasm; and allow pre-emptive resistance breeding.

Table 2. Wheat leaf rust pathotypes detected in WA since 1990

Year of detection	Pathotype	Comments
1990	104-1,(2),3,(6),(7),11	Was common, less so now
1990	104-1,2,3,5,(6),(7),11	Rare
1993	122-1,2,3,(6),(7),11	Rare
1996	104-1,2,3,4,(6),(7),11	Rare
1998	104-1,2,3,(6),(7),11	Was common, less so now
2002	104-1,(2),3,(6),(7),11 +Lr37	Common (less since 2013 incursion)
2002	104-1,2,3,5,(6),(7),11	Rare
2013	76-1,3,5,7,9,10,12 +Lr37	New, introduced, becoming widespread
2015	104-1,3,4,6,7,8,10,12 +Lr37	New, introduced, likely to become dominant eventually

Recent changes in the wheat leaf rust pathogen in WA

Pathotype 76-1,3,5,7,9,10,12 +Lr37

Reports of unusually high levels of leaf rust in WA on wheat varieties including Wyalkatchem and Cobra were made by growers, agronomists and DAFWA staff in September 2013. Leaf rust samples from 5 widely separated locations (Borden, Esperance, Gibson, Northampton, Southern Cross) were sent to PBI and found to comprise *P. triticina* pt. 76-1,3,5,7,9,10,12 +Lr37. This pathotype was first detected in eastern Australia in 2011 and had not previously been reported in WA. It represents the first occurrence of virulence for the resistance genes *Lr13*, *Lr17a*, *Lr17b*, and *Lr26* in the west.

Pathotype 76-1,3,5,7,9,10,12 +Lr37 is considered to have arisen in eastern Australia via mutation from a "parental" pt. 76-3,5,7,9,10 +Lr37, which was first detected in Australia in Victoria in July 2006 and is regarded as an exotic incursion.

Pathotype 104-1,3,4,6,7,8,10,12 +Lr37

Pathotype 104-1,3,4,6,7,8,10,12 +Lr37 was first detected in South Australia in August 2014, and has since spread throughout much of the eastern Australian wheat belt. This pathotype is also considered to be an exotic incursion into Australia, based on its unique virulence profile and DNA fingerprint. In late September 2015, it was subsequently identified in samples of leaf rusted wheat collected from four separate locations in the northern region of the WA wheat belt.

Cereal rust migration within Australia

The movement of cereal rust inoculum from WA to eastern Australia has been documented many times over the past 90+ years, and is presumed to occur on prevailing winds. In contrast, movement from east to west is much less frequent. While 6 such examples of west-to-east movement of cereal rusts have been documented since 1990, the current detection is only the third example of east to west movement during that time, all being the wheat leaf rust pathogen *P. triticina*: in 1991, an

isolate of pt. 104-1,2,3,(6),(7),11 was first found at Salmon Gums in 1990; in 2013, pt. 76-1,3,5,7,9,10,12 +Lr37 at Esperance; in 2015, pt. 104-1,3,4,6,7,8,10,12 +Lr37 at Carnamah/ Yuna.

Just how these rust pathotypes moved to WA from eastern Australia is not known. Rust spores remain viable for up to 2 weeks under ambient conditions, and they adhere readily to clothing. It is therefore possible that they were spread on contaminated clothing. Normal laundering of clothing will kill rust spores, and all people who travel are strongly encouraged to ensure clothing is thoroughly cleaned before entering a new agricultural region.

Impact of the two new leaf rust pathotypes on wheat cultivars

The detection of pt. 76-1,3,5,7,9,10,12 +Lr37 in WA in 2013 represented the first occurrence of virulence for the resistance genes *Lr13*, *Lr17a*, *Lr17b*, and *Lr26* in the west. Pathotype 104-1,3,4,6,7,8,10,12 +Lr37, detected in 2015, poses much the same threat but in addition carries virulence for the resistance genes *Lr27+Lr31*, and the adult plant resistance (APR) gene *Lr12*. Because of this, the latter pathotype represents the greater threat of the two. With this in mind, the impact of pt. 104-1,3,4,6,7,8,10,12 +Lr37 on the wheat varieties most commonly grown in WA is shown in **Table 3**.

Table 3. Leaf rust genotypes and responses to leaf rust of wheat varieties commonly grown in WA

Change in response to leaf rust with new pathotypes?	Name	Resistance gene(s)	Leaf rust response
No	Arrino	*Lr3a*	MS
No	Bremer(l)	*Lr24, Lr37*	MR
No	Harper(l)	*Lr1, Lr37, +*	MRMS
No	Magenta(l)	*Lr1, Lr24*	R
No	Stiletto	Nil	SVS
No	Supreme(l)	*Lr24, Lr37*	RMR
No	Westonia	*Lr1, Lr23*	MS
No	Yitpi(l)	Nil	MSS
Yes	Bonnie Rock(l)	*Lr13*	MS
Yes	Calingiri	*Lr3a, Lr13*	MS
Yes	Cobra(l)	*Lr3a, Lr27+Lr31*	MR
Yes	Corack(l)	*Lr3a, Lr13*	S
Yes	Emu Rock(l)	*Lr13*	S
Yes	Justica CL Plus(l)	*Lr1, Lr13, Lr37*	MS
Yes	Mace(l)	*Lr13, Lr20*, Lr37, Lr27+Lr31*	MS
Yes	Scout(l)	*Lr1, Lr13, Lr37*	MS
Yes	Trojan(l)	*Lr27+Lr31*	MRMS
Yes	Wyalkatchem(l)	*Lr3a, Lr13, Lr20, Lr46**	S

Of the 18 varieties for which information is available, the leaf rust responses of 8 are not expected to change. The remaining 10 carry resistance genes either singly or in combination that prior to the detection of the two new pathotypes would have provided some protection against leaf rust. While all of these varieties are now more susceptible to leaf rust, it is very fortunate that all except Corack and Emu Rock(l) carry a level of residual resistance due to the presence of uncharacterised adult plant resistance. Growers of these varieties are nonetheless advised to monitor crops for the presence of leaf rust.

The leaf rust responses of the newer varieties Hydra(l), Impress CL Plus(l), and Zen(l) are currently not known.

If any rust is found on any cereal crop, it can be sent to the Australian Rust Survey (see below), where it will be analysed and the sender will be notified of the results. This is a free service, and its success in establishing the distribution and occurrence of known rust pathotypes, and in detecting new rust pathotypes, depends entirely on the collection and submission of samples.

Recent changes in the barley leaf rust pathogen in WA

A new pathotype of the barley leaf rust pathogen *Puccinia hordei* was detected in WA in 2013 from samples collected in the Southern region from September (Boxwood Hill, Chillinup, Esperance, Kamballup, South Stirling). The new pathotype, 5457P-, is a single-step mutational derivative of an existing pathotype, 5453P-, with added virulence for resistance gene *Rph3*. This was the first detection of virulence for *Rph3* in WA, and the third pathotype of *P. hordei* recorded in Australia with virulence for this gene.

The new pathotype is very similar to one detected in northern NSW in late 2008 (pt. 5457P+), but differs in being avirulent for resistance gene *Rph19*. Because of this similarity, it is expected that the new pathotype will not alter the response of barley cultivars in eastern Australia, should it migrate to that region.

Impact of the new barley leaf rust pathotype on barley varieties

The leaf rust responses of most of barley varieties grown in WA have not changed due to this pathotype (**Table 4**). The concern was that it may have reduced leaf rust resistance in varieties known to carry resistance gene *Rph3*, *viz*. Oxford(), Granger(), Bass() and Compass(). Fortunately, 2 of these varieties (Granger(), Oxford()) also carry the APR gene *Rph20*, and they remain resistant. Bass() is also considered to carry *Rph20* in addition to *Rph3*, but its response appears to have shifted more towards susceptibility and it is now rated as being Moderately Susceptible (**Table 4**).

Pathotype surveys and rust control

To have maximum impact in disease control, surveys of pathogenic variability in rust pathogens must be closely integrated with the development and management of new wheat cultivars. Where this has been practiced, surveys have provided both information and pathogen isolates that have underpinned rust control efforts, from gene discovery to post-release management of resistance resources. Information generated by pathotype surveys has been used to devise breeding strategies, inform selection of the most relevant isolates for use in screening and breeding, define the distribution of virulence and virulence combinations, allow predictions of the effectiveness/ineffectiveness of resistance genes, and issue advance warning to growers by identifying new pathotypes that overcome the resistance of cultivars before they reach levels likely to cause significant economic damage.

Maintaining and improving current levels of rust control

It has been estimated that 50% of the cost of plant improvement involves breeding to maintain current yield and quality levels to meet the challenges of degrading growing environments and evolving pathotypes of major pathogens ("maintenance breeding"). Protecting the *ca*. $1 billion savings to the Australian wheat industry from resistance breeding and reducing the current impact of rust diseases will only be possible if resistance remains a priority in breeding programs, and if the wheat industry as a whole continues to support genetic approaches to rust control.

Table 4. Leaf rust genotypes and responses to leaf rust of barley varieties commonly grown in WA

Change in response to leaf rust with new pathotype?	Name	Resistance gene(s)		Leaf rust response
		All stage (seedling)	APR	
No	Baudin(b)	*Rph12*	Nil	SVS
No	Buloke(b)	Nil	Nil	S
No	Gairdner	*Rph12*	*Rph23*	S
No	Vlamingh(b)	*Rph9.am*	Nil	SVS
No	Hindmarsh(b)	*Rph9.am*	Nil	MSS
No	Flinders(b)	*Rph12+*	*Rph20*	MRMS
No	La Trobe(b)	*Rph9.am*	Nil	MSS
No	Skipper(b)	Nil	Nil	S
No	Dash(b)	*Rph12+*	*Rph20*	RMR
No	Fathom(b)	*Rph12*	*Rph20*	MSS
No	Fleet(b)	*Rph?*	*Rph20*	MRMS
No	Litmus(b)	Nil	Nil	S
No	Lockyer(b)	Nil	Nil	S
No	Mundah(b)	*Rph2*	Nil	S
No	Oxford(b)	*Rph3*	*Rph20*	RMR
No	Roe(b)	*Rph2*	*Rph20*	SVS
No	Yagan	*Rph4*	Nil	S
No	Commander(b)	*Rph2, Rph19*	Nil	MSS
No	Granger(b)	*Rph3+*	*Rph20*	MR
No	Scope CL(b)	Nil	Nil	S
No	Hamelin(b)	*Rph9.am*	Nil	S
No	Stirling	*Rph9.am*	Nil	SVS
Yes	Compass(b)	*Rph3*	Nil	MRMS
Yes	Bass(b)	*Rph3*	*Rph20*	MS

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(b) Varieties with this symbol them are protected under the Plant Breeders Rights Act 1994.

How to prepare and send a rust sample for pathotype analysis

A detailed description on how to prepare rust samples for dispatch can be downloaded using the following web link:

http://sydney.edu.au/agriculture/documents/pbi/cereal_rust_report_2013_vol_11_3.pdf

The better the sample you send, the faster it can be processed and the more likely it is that your sample will work. Poor sample material (only a few leaves with low infection or samples that are not fresh) often requires an extra step in the diagnostic process, in which the rust has to be multiplied on a susceptible variety to produce enough inoculum for a seedling assay. Poor material is also more likely to have lower spore germination and is more likely to fail.

Good sample material will have sufficient rust to allow inoculation straight onto a differential set. In the case of leaf rust and stripe rust, such a sample would be a 10 cm length of leaf that was completely covered by rust pustules. In the case of stem rust, this would be a 10 cm length of 100% infected flag leaf sheath or 5 x 10cm peduncles with 100% infection. Wherever possible, collect enough leaf or stem material to make the required sample size. For example, 10 leaves each with 10% stripe rust infection, 3 leaves with 30% infection. See Figure 1 for examples of good sample sizes. It is important that the sample material is actively sporulating. When you wipe over a leaf or stem with a clean white cloth, you should see yellow, brown or black dust-like smearing. Please collect material while the leaves and stems are dry.

To help keep the sample as fresh as possible fold leaves infected with stripe rust or leaf rust in half from top to bottom so the rust is on the inside. Place folded leaves or stems into paper envelopes (never use **ANY** plastic packaging). If you are sending multiple types of rust samples at once (stripe, leaf and stem) please place each in a separate paper envelope. With every sample that is sent, please fill out the dispatch form that can be downloaded from:

http://sydney.edu.au/agriculture/plant_breeding_institute/cereal_rust/reports_forms.shtml#df

Alternatively, you can contact the ACRCP Annual Cereal Rust Survey and we will send you Reply Paid envelopes with the dispatch information required printed on the outside. Please include the cereal variety whenever it is known and geo-referencing that is as accurate as possible, preferably with latitude and longitude in decimal degrees. Knowing the variety helps us to monitor for new pathotypes more effectively. Precise geo-referencing helps to improve our mapping and epidemiological modelling.

Post your samples to the Survey as soon as possible. A sample that has been sitting on the dashboard of your vehicle for a week is likely to fail!

Send samples to:

The University of Sydney
Australian Rust Survey
Reply Paid 88076
NARELLAN NSW 2567

Remember, the better the sample you send and the more information you provide on the dispatch form, the faster we can provide you with an answer and better serve the Australian grains industry.