Wheat rust developments - new stripe rust pathotypes with implications for wheat (common and durum) and triticale; pathotypes of leaf rust and virulence for resistance gene Lr24

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Take home messages

- The structure of stripe rust populations in eastern Australia has become more complex in recent years, particularly as a consequence of two further exotic rust incursions. This has had important implications for varietal response to stripe rust, not only in common wheat but also in durum wheat and triticale
- There have now been four documented incursions of stripe rust since it was first detected in Australia in 1979. Three of these originated from Europe (1979, 2017 and 2018) and one from North America (2002). This continues the trend that has emerged over the past 100 years of increasing frequency of exotic incursions, presumably associated with increased international movement of people and inadvertent transport of rust spores on contaminated clothing
- Exotic wheat rust incursions have cost the industry hundreds of millions of dollars. The critical importance of thoroughly laundering clothing and personal effects after interstate or overseas travel cannot be emphasised enough
- Stripe rust in particular is likely to be important during 2021 especially where summer rain supports inoculum carry over. 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
- The variability of rusts and their rapid spread across the Australian continent reinforces the importance of regular and nationally coordinated monitoring of these pathogens. As always, growers and other stakeholders are encouraged to monitor crops closely for rust over the break and in the 2021 season, and to forward freshly collected samples wrapped in paper only, to the Australian Cereal Rust Survey, at University of Sydney, Australian Rust Survey, Reply Paid 88076, Narellan NSW 2567.

Background

Developing new high yielding wheat varieties with in-built genetic resistance to rust diseases has been estimated to save the Australian grains industry some $1.1 billion per year. The resistance of varieties can, however, change due to the occurrence of a new pathotype (aka strain/race).

An important part of keeping one step ahead of the ever-changing fungal rust pathogens has been to monitor the pathotypes that occur in Australia, and to determine their impact on current and yet to be released varieties. This work has been conducted at the University of Sydney for the past 100 years, currently as a core component of the Australian Cereal Rust Control Program (ACRCP). It has been particularly successful in minimising the impact of new rust pathotypes that arise locally, via for example random mutation. In contrast, periodic incursions of wheat rust isolates from outside Australia have made resistance breeding more challenging.

While stem rust and leaf rust of wheat have been present in Australia since at least the first attempts to grow wheat, stripe rust was not detected until 1979 when it is believed it was inadvertently brought here from Europe on contaminated clothing or the like. A second stripe rust incursion was detected in 2002, into WA. In this case, the presumed origin of the new 'WA' ('134') pathotype group was North America.

Rust pathotypes and varietal resistance

Rust pathotypes are variants within a rust pathogen species that differ in ability to infect wheat varieties. They are similar to strains of viruses that infect people, except that differences in the animal and plant immune systems mean that they interact with their hosts differently:

- A person that is susceptible to a new virus strain **can** develop resistance
- A plant that is susceptible to a new rust pathotype **cannot** develop resistance

Our long-term monitoring of wheat rust populations in Australia have shown clearly that new pathotypes arise either via mutation (most commonly), exotic incursion (infrequent), or asexual hybridisation (rare).

Rust pathotypes are identified by applying rust from a field-collected sample to a set of indicator lines carrying different resistance genes. While this basic approach has not changed much in 100 years, rust pathotype identification has improved dramatically as our understanding of the genetic basis of resistance to these pathogens has improved. A landmark in this change was the publication in 1995 of a comprehensive atlas of rust resistance genes in wheat, by Professors McIntosh, Park, and Wellings, with support from the Australian Centre for International Agricultural Research. The book has become an international standard for wheat rust pathogen and rust resistance gene identification and was recently made freely available for download by funds provided by the Bill and Melinda Gates Foundation (see useful resources).

Wheat stripe rust

Wheat stripe rust pt. 239 E237 A- 17+ 33+

This stripe rust pathotype was first detected in rust samples collected from Victoria in November 2017. Although it was not detected in 2018 and only a single isolate was identified in 2019 (from Victoria), 15 isolates were recovered in the 2020 season from widespread locations throughout NSW.

Using DNA sequencing, we were able to determine that this pathotype belongs to a family of stripe rust pathotypes known as the PstS10 group. This is the most common group of wheat stripe rust pathotypes in Europe at present, strongly implicating this region as the origin of this pathotype.

Impact:

The main varieties that have increased vulnerability to this pathotype include Coolahⓓ, LRPB Flankerⓓ, Axeⓓ, B53ⓓ, Buchananⓓ, Cobaltⓓ, EGA Gregoryⓓ, Forrestⓓ, Gauntletⓓ, Grenade CL Plusⓓ, Mitchⓓ, Steel, Trojanⓓ, Vikingⓓ and Zenⓓ.

Wheat stripe rust pt. 198 E16 A+ J+ T+ 17+

This stripe rust pathotype was first detected near Wagga Wagga in late-August 2018 and was subsequently isolated from Victoria and Tasmania that year. In 2019, it was isolated from throughout eastern Australia, where it was the most common pathotype of the wheat stripe rust pathogen. In 2020 it was once again the dominant stripe rust pathotype in eastern Australia (67% of all isolates processed), being isolated from all eastern mainland states.

DNA sequencing has identified that this pathotype belongs to the PstS13 group. Like the PstS10 group, the PstS13 group is also common in Europe at present where it is principally associated with triticale. It has caused total crop failure in organically grown triticale there and was responsible for severe stripe rust epidemics on durum and bread wheat in Italy in 2017. Significantly, this pathotype was introduced into South America around 2016, where it caused severe stripe rust epidemics on over 3 million hectares of wheat in Argentina in the 2016/17 and 2017/18 cropping seasons. Many growers there applied fungicides but were unable to control the disease and suffered significant economic losses. Yield losses of between 53 and 70% were recorded in the seven most susceptible varieties being grown.

Impact:

Common wheat: Unlike pathotypes within the 'WA' ('134') group, pt. 198 E16 A+J+ T+ 17+ cannot overcome the resistance gene *Yr25*. Detailed comparative tests have shown the likely occurrence of this resistance gene in the Australian wheat cultivars Cosmickⓓ, Derrimutⓓ, DS Pascalⓓ, Hydraⓓ, LRPB Flankerⓓ, LRPB Spitfireⓓ, Sunprimeⓓ, and Wallupⓓ. These results show that fortunately, some of the wheat varieties currently grown in Australia are more resistant to the 198 pathotype than they are to the older '134' group pathotypes. The results also account for associations between specific wheat varieties and either the '134' group of pathotypes or pathotype 198 E16 A+ J+ T+ 17+ that have emerged in processing stripe rust samples submitted for pathotype analysis in 2020. We are continuing genetic analyses to locate the specific rust resistance gene(s) involved.

Data collected from the field during 2019 by NSW DPI, AgVic and the University of Sydney indicate that pathotype "198" poses an increased threat to several wheat varieties (e.g. DS Bennettⓓ and LPB Trojanⓓ and to a lesser extent Devilⓓ, Illaboⓓ, DS Darwinⓓ, Emu Rockⓓ and Hatchet CL Plusⓓ).

Durum wheat: As reported in our Cereal Rust Update Volume 17 Issue 2, several durum varieties (e.g. DBA Artemisⓓ, DBA Bindaroiⓓ, DBA Lillaroiⓓ, DBA Spesⓓ, DBA Vittaroiⓓ and EGA Bellaroiⓓ) are more susceptible to pathotype 198 E16 A+ J+ T+ 17+. While our initial tests implicated the resistance of the foreign wheat variety Suwon92/Omar in this, further testing suggests that pathotype 198 E16 A+ J+ T+ 17+ likely overcomes an as yet uncharacterised seedling resistance gene in these durum wheat cultivars. Further genetic studies are underway to characterize the resistance that has been rendered ineffective in these durums by the 198 pathotype.

Triticale*:* One of the intriguing features of evolution in the wheat stripe rust pathogen in eastern Australia over the past 18 years or so has been the acquisition of virulence for several resistance genes in triticale. Pathotypes within the '134' group have virulence for three stripe rust resistance genes that occur in triticale, all of which are on the rye genome: *Yr9*, *YrJackie*, *YrTobruk*. While virulence for *Yr9* existed in the pathotype that entered Australia in 2002 (i.e. pt. 134 E16 A+), local mutations gave rise to virulence for *YrJackie* (first detected in 2007) and *YrTobruk* (first detected in 2010). This adaptation to triticale was a significant contributing factor in the damaging stripe rust epidemics experienced in eastern Australia from 2008 through 2011, as it allowed very early epidemic onset due to stripe rust build up in early sown triticale crops and later movement into main season wheat crops.

Coincidentally, pathotype 198 E16 A+ J+ T+ 17+ is also virulent for these three resistance genes in triticale. Detailed seedling tests in our greenhouse system have indicated that this pathotype is also virulent for a fourth stripe rust resistance in triticale, which is carried by the varieties Astuteⓓ, Berkshire, Bisonⓓ, and Joeyⓓ. Consequently, these four varieties are now more vulnerable to stripe rust infection.

Barley*:* Pathotype 198 E16 A+ J+ T+ 17+ differs from the '134' group of pathotypes in being virulent for one or more major (seedling) genes conferring stripe rust resistance in barley. Varieties that carry the resistance overcome by pathotype '198' include: Brindabella, Clipper, Ketch, Maritime, Prior, RGT Planetⓓ, Shepherdⓓ, and Tantangara. Despite this, we found no evidence of pt. 198 E 16 A+ J+

T+ 17+ on barley crops in eastern Australia in 2020, so it would appear that all current barley varieties have very good levels of resistance to this pathotype and that it poses no threat at this stage to the barley industry.

Several samples of stripe rust from barley crops were received in 2020; all were immediately genotyped using diagnostic SSR markers upon receipt and pathogenicity tested in the greenhouse, and all proved to be the Barley Grass Stripe Rust (BGYR) pathogen. There is circumstantial evidence that the BGYR pathogen may now have increased virulence on barley grass, and that its more common occurrence in barley crops in 2020 is a function of increased inoculum load. We are conducting tests at present to try to verify this.

Wheat leaf rust

Crop losses due to leaf rust of wheat tend to be lower than those caused by stem rust and stripe rust, but it is considered by many to be the most damaging wheat rust disease on a world-wide basis because it can develop under a broader range of environmental conditions and hence is more common and has a larger geographical footprint. As has been documented for stripe rust of wheat, there have been two incursions of exotic leaf rust isolates in recent years.

Wheat leaf rust pt. 104-1,3,4,6,7,8,10,12 +Lr37

This was first detected in August 2014 at Glenroy South Australia and is regarded as having an exotic origin. Significantly, it was shown to be virulent for the resistance genes *Lr27*+*Lr31*, rendering the cultivars Axe, Corack, Emu Rock, Grenade, Mace, SQP Revenue, Wallup and Wyalkatchem more susceptible to leaf rust.

This new '2014' rust took only 13 months to spread to all Australian wheat growing states. By the end of 2014, it represented half of the wheat leaf rust isolates identified nationally, and while it was again the dominant pathotype isolated in 2015 (54%) and 2016 (60%), it then declined in frequency due to the rapid increase and spread of yet another new pathotype (pt. 104-1,3,4,5,7,9,10,12 +Lr37), first detected in June 2016 in a sample collected from a crop of Mace at Port Neill South Australia. Like the '2014' pathotype, this pathotype is now present in all Australian wheat growing states, and it has been the most common pathotype in all regions. Varietal response to leaf rust has not changed due to this pathotype, but its rapid increase in frequency across all wheat growing regions suggests that it is more aggressive and as such may have greater epidemic potential.

The origin of the '2016' pathotype is not clear, but it appears likely to have arisen locally – possibly via asexual hybridisation. If this proves to be the case, it will be only the second documented example in the world, of a new pathotype of the wheat leaf rust pathogen arising in this way.

Wheat leaf rust pt. 93-3,4,7,10,12

This pathotype was first detected on Illabo wheat from Tootool in southern NSW in October 2020. It was subsequently isolated from several other locations in NSW. It is very similar to, and clearly related to, an existing one that was first detected in 2005, but differs from it in being unable to overcome the resistance genes *Lr2a* and *Lr20*. It is considered to be of exotic origin; an identical one was identified in New Zealand in 2014-15.

Based on the virulence/avirulence of the new pathotype, it is not expected to pose any additional threat to current wheat varieties. Having said that, it is not possible to assess the full risk of the new pathotype to the wheat industry until detailed comparative greenhouse and field tests are conducted. We plan to undertake these in the 2021 field cycle at the Plant Breeding Institute at Cobbitty.

Virulence for the resistance gene Lr24

The leaf rust resistance gene *Lr24* has been used extensively in Australia. It was first deployed in 1983 in the cultivar Torres, and since then more than 60 wheat cultivars have been released with this gene (e.g. Chief CL Plus, LRPB Gazelle, Sunguard, and Supreme).

The first detection of virulence for *Lr24* was in 2000, 17 years after it was first deployed. Virulence for *Lr24* only occurs in eastern Australia. However, unlike virulence for the stripe rust resistance gene *Yr17*, virulence for *Lr24* has not become dominant in eastern Australia. It was nonetheless detected in nine samples of leaf rust collected from wheat crops in NSW from Forbes, Grafton, Narrabri, and Wongarbon in 2020. This means that in many situations, varieties with the resistance gene *Lr24* should remain resistant, unless the pathotypes virulent for this gene increase in frequency. Keeping a watching brief on where *Lr24* virulent pathotypes occur, and their frequency, is important to ensure growers of varieties with this gene minimise their risk of losses due to leaf rust.

An added bonus of growing varieties with the resistance gene *Lr24* is that they also carry the stem rust gene *Sr24* – the two genes are genetically linked. Gene *Sr24* remains completely effective in protecting against stem rust in Australia, despite pathotypes with virulence being detected elsewhere (e.g. USA, South Africa, Kenya, Ethiopia).

Concluding comments

The confirmation of two further incursions of the wheat stripe rust pathogen brings to four the number documented since this disease was first detected in Australia in 1979. The evidence available implicates Europe as the source of three of these incursions (1979, 2017 and 2018) and North America as the source of the other one (2002). In addition to the two exotic incursions of the wheat leaf rust pathogen detected in 2014 and 2020, this continues the trend that has emerged from our long-term pathogenicity surveys of cereal rusts of an increasing frequency of exotic incursions with time, presumably associated with increased international movement of people and inadvertent transport of rust spores on contaminated clothing. Exotic wheat rust incursions have cost the industry hundreds of millions of dollars. The importance of thoroughly laundering clothing and personal effects after interstate or overseas travel cannot be emphasised enough.

Stripe rust was very common in wheat crops in eastern Australia during the 2020 season, and there were many situations in which fungicides were used to control the disease. This was principally due to the occurrence of pathotype 198 E16 A+ J+ T+ 17+. The amount of stripe rust that developed was, however, nowhere near that caused by the same pathotype in Argentina in 2016/17 and 2017/18. The value of existing stripe rust resistance in Australian wheat varieties in minimizing yield losses due to this pathotype in particular is even more apparent when one considers just how favourable the 2020 cropping season was for stripe rust. The much lower impact of pathotype 198 in Australia compared to its impact in Argentina and Europe is a clear endorsement of the value of genetic resistance in controlling rust diseases in cereals, and of the efforts of all stakeholders in using genetics as the foundation of rust control here in Australia.

The latest responses of Australian wheat and triticale cultivars to the pathotypes reported here, based on detailed greenhouse and field testing, are provided in our Cereal Rust Report (Volume 17 Issue 3), which can be downloaded from our website. Updated refined responses will also be provided in early 2021 based on results from the National Variety Trials 2020 cycle.

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The national rust pathotype surveillance program involves active participation by many people including state-based regional cereal pathologists, scientists in Universities and in the private sector, grain growers, and their important contribution is gratefully acknowledged.

Useful resources

Current Cereal Disease Guides, for example:

http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-disease-guide

Cereal seed treatment guide, 2020:

https://www.pir.sa.gov.au/__data/assets/pdf_file/0005/237920/Cereal_Seed_Treatments_2021.pdf

University of Sydney Cereal Rust Reports and mapping of rust pathotype distribution:

https://www.sydney.edu.au/science/our-research/research-areas/life-and-environmental-sciences/cereal-rust-research/rust-reports.html

McIntosh RA, Wellings CR, Park RF (1995). Wheat Rusts: An Atlas of Resistance Genes. (https://www.globalrust.org/sites/default/files/wheat_rust_atlas_full.pdf).

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