When enemies adapt: the ongoing evolutionary battle between cereal crops and rust fungi

2025 Farrer Oration

27th November 2025

Presented by

Robert F. Park

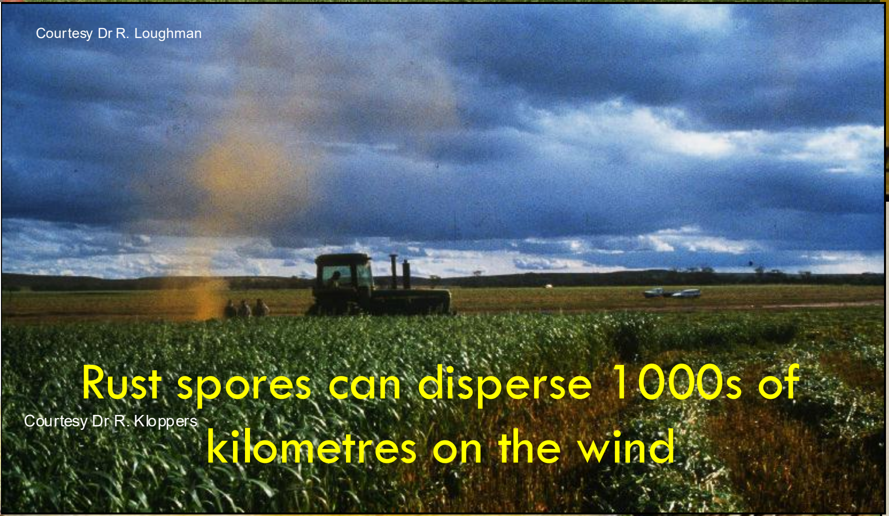
The Plant Breeding Institute

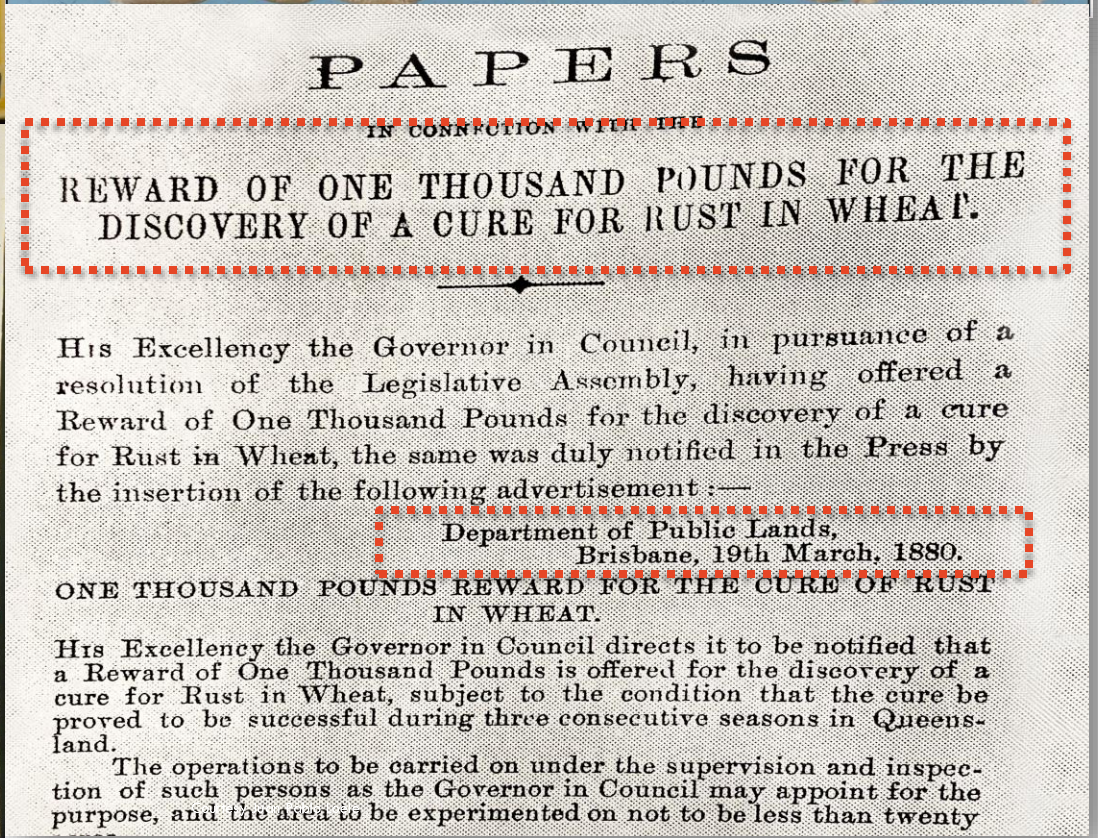
School of Life and Environmental Sciences

Sydney Institute of Agriculture

THE UNIVERSITY OF SYDNEY

Australian Cereal Rust Control Program





PAPERS

IN CONNECTION WITH THE

REWARD OF ONE THOUSAND POUNDS FOR THE DISCOVERY OF A CURE FOR RUST IN WHEAT.

His Excellency the Governor in Council, in pursuance of a resolution of the Legislative Assembly, having offered a Reward of One Thousand Pounds for the discovery of a cure for Rust in Wheat, the same was duly notified in the Press by the insertion of the following advertisement:—

Department of Public Lands,
Brisbane, 19th March, 1880.

ONE THOUSAND POUNDS REWARD FOR THE CURE OF RUST IN WHEAT.

His Excellency the Governor in Council directs it to be notified that a Reward of One Thousand Pounds is offered for the discovery of a cure for Rust in Wheat, subject to the condition that the cure be proved to be successful during three consecutive seasons in Queensland.

The operations to be carried on under the supervision and inspection of such persons as the Governor in Council may appoint for the purpose, and the area to be experimented on not to be less than twenty

Transactions of the Royal Society of SA, 1879

13

Red Rust:

ITS NATURE, APPROXIMATE CAUSES, AND PROBABLE CURE.

By Otto Tepper, F.L.S., London; Corresponding Member.

(Abridged.)

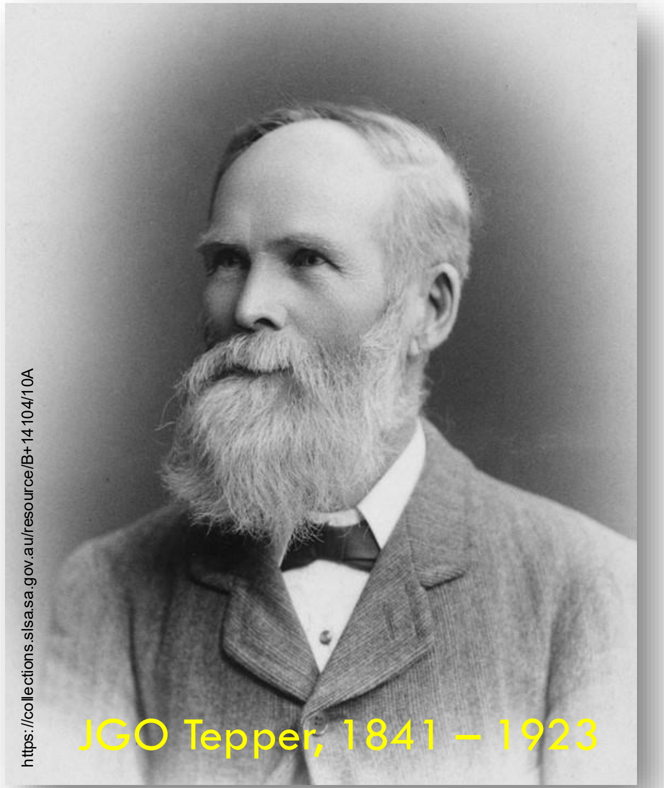
[Read November 1, 1879.]

The subject under consideration divides itself naturally into various questions, viz.:—

What is Red Red Rust, and how is it produced?

What laws govern its development, and the growth of its fostering plant?

respecting locality and situation. They seem to prove that the occurrence of the fungus does not depend either on the soil or local circumstances, but more likely upon—(*a*) Particular atmospheric conditions. (*b*) The structure of the wheat-plant. (*c*) The constitution of the soil (that is the soluble salts it contains); and suggest the direction in which the remedies lie.



https://collections.slsa.sa.gov.au/resource/B+14104/10A

JGO Tepper, 1841 – 1923

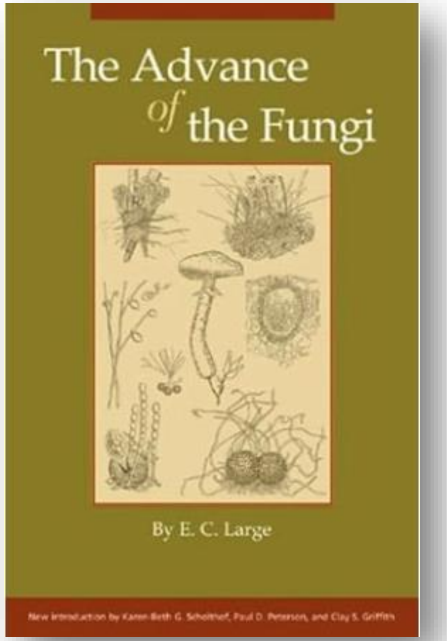
Seeking for a remedy in another direction, there *may* be discovered a substance which, when applied to the soil, or the seeds, and imbibed by the plants, will act adversely to the growth of fungoids, in the same way as bluestone (sulphate of copper) checks the "Dust Brand" (*Ustilago segetum*).

William Farrer, 1845 – 1906

-pioneered Australian wheat improvement by cross-breeding and selection

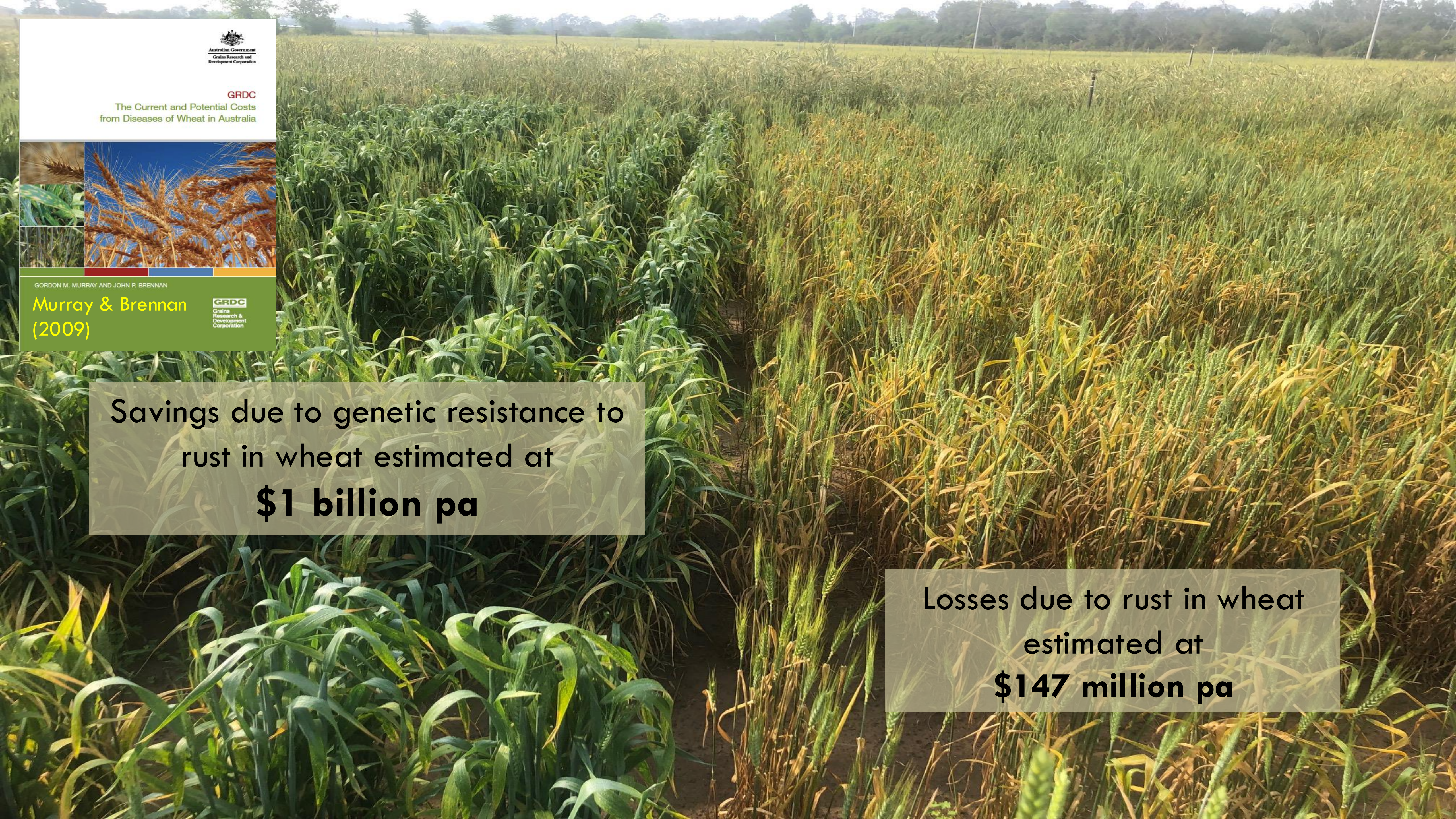
-introduced earliness from India and improved gluten strength from a North American introduction, Fife

-to improve yield, derivatives were further crossed to older Australian wheats



"The mighty rust investigations, soon to be world-wide, began in Australia with a series of rust in wheat conferences"

E.C. Large
The Advance of the Fungi



Murray & Brennan (2009)

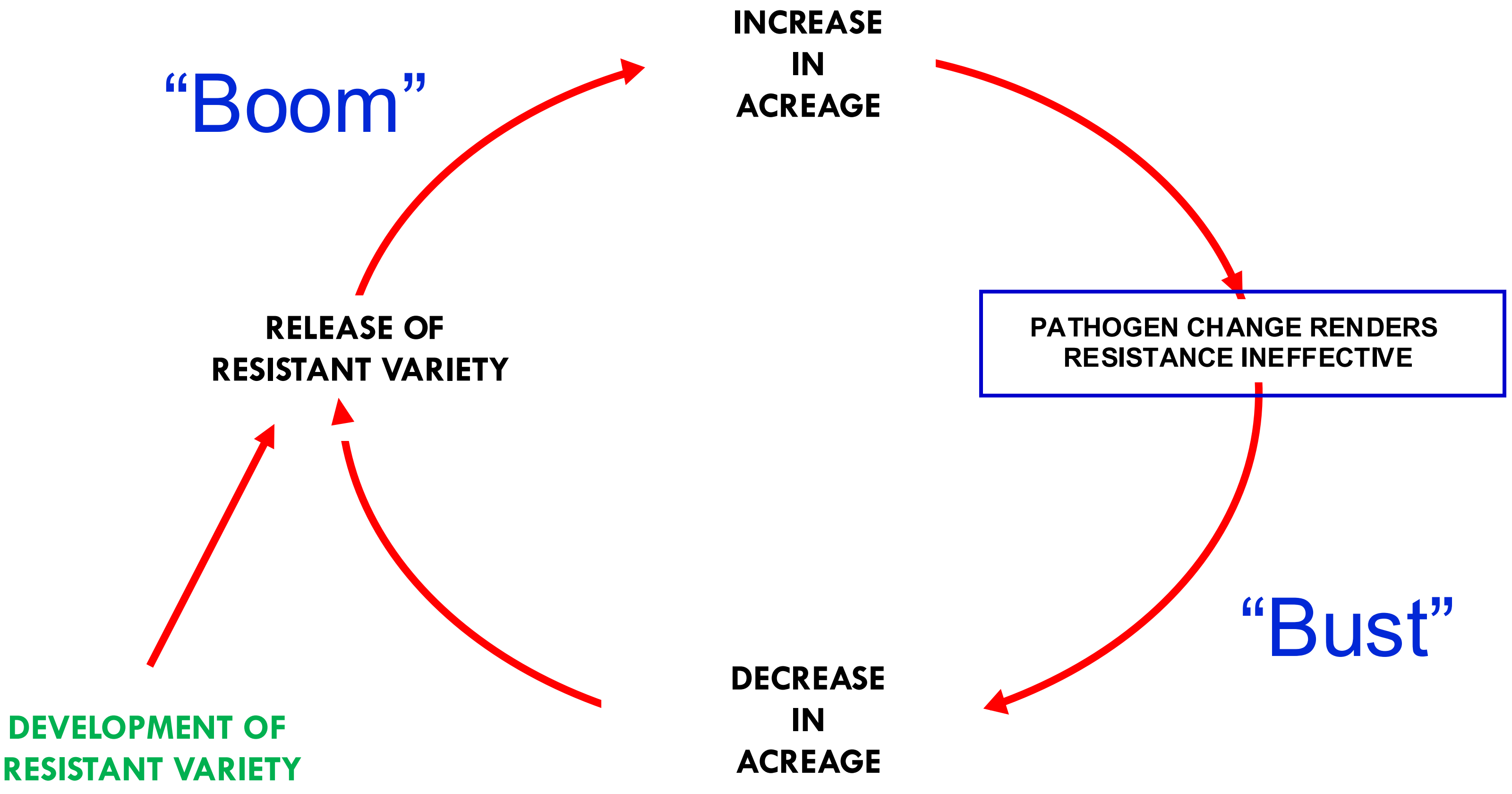
Savings due to genetic resistance to rust in wheat estimated at

$1 billion pa

Losses due to rust in wheat estimated at

$147 million pa

The pathogen adapts: "boom and bust"



<u>Pathogen change due to:</u>

1. exotic incursion
2. simple mutation
3. asexual hybridisation

Stem rust: 50,000 ha of wheat killed in Ethiopia
November 2014


The Economist | World politics | Business & finance | Economics | Science & technology | Culture

Wheat rust and world farming

Rust in the bread basket

A crop-killing fungus is spreading out of Africa towards the world's great wheat-growing areas

Jul 1st 2010 | From the print edition | Timekeeper | Like 232 | Tweet 23

IT IS sometimes called the "polio of agriculture": a terrifying but almost forgotten disease. Wheat rust is not just back after a 50-year absence, but spreading in new and scary forms. In some ways it is worse than child-crippling polio, still lingering in parts of Nigeria.

16 cereal rust diseases caused by 10 rust pathogens in Australia

Disease	Pathogen	Wheat	Barley	Oat	Rye	Triticale
Stem rust	*Puccinia graminis* f. sp. *tritici*	X	X		X	X
	Puccinia graminis f. sp. *avenae*			X		
	Puccinia graminis f. sp. *secalis*		X		X	
	Puccinia graminis "scabrum"		X		X	
Stripe rust	*Puccinia striiformis* f. sp. *tritici*	X				X
	Puccinia striiformis f. sp. *pseudo-hordei*		X			
Leaf rust	*Puccinia triticina*	X				
	Puccinia hordei		X			
	Puccinia secalina				X	
Crown rust	*Puccinia coronata* f. sp. *avenae*			X		

Story 1:
"Resistance or fungicides?"
Puccinia hordei

Mumta Chhetri, Will Cuddy, Yi Ding,
Robert Park, Xiaohui Yu

Fungicides in controlling foliar pathogens in broadacre crops

Fungicides first used to control cereal diseases in Australia in the early 1980s following the introduction of stripe rust

Most wheat and barley growers now use fungicides

Insensitivity (resistance) to fungicides evolved rapidly in a number of pathogens throughout the world, including Australia (e.g. wheat and barley powdery mildew pathogens)

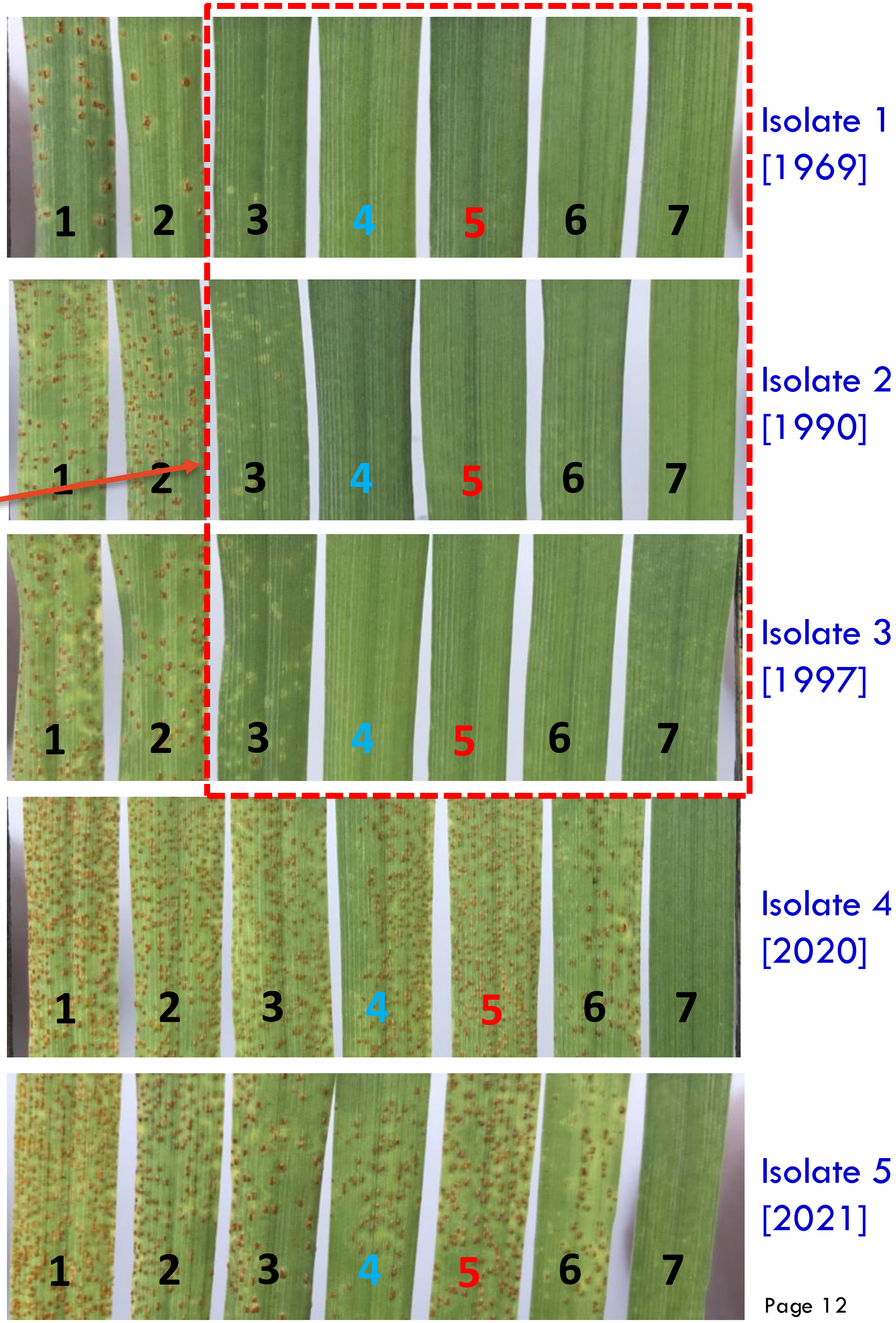
Cases of fungicide insensitivity in rusts **are rare**; several examples but none fully documented

We began looking at fungicide insensitivity in rusts in 2017

Insensitivity to tebuconazole in *Puccinia hordei*

Commercial application rates: 145mL/ha (low), 290mL/ha (high)
Applied 1 day before inoculating with rust:

Treatment
Water
~0.03x low field rate
~0.3x low field rate
~low field rate
~1.3x high field rate
~12x high field rate
~51x high field rate



<u>Also insensitive to:</u>
Triadimenol,
Epiconazole,
Propiconazole,
Prothioconazole

CYP51: a cytochrome P450 enzyme conserved in fungi

Azole fungicides inhibit the “CYP51” enzyme (essential for fungal cell membrane structure, function and integrity)

Changes in the *Cyp51* gene confer fungicide resistance (mutations, gene copy number)

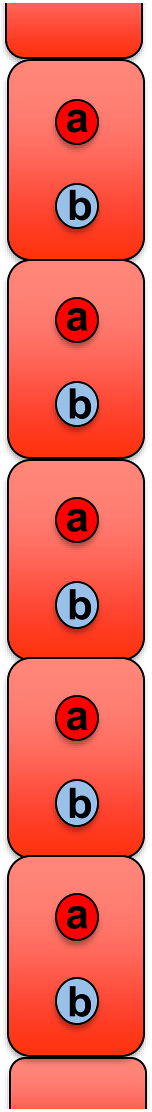
Resistance to azole fungicides due to CYP51 has been detected in many fungal pathogens - **but not in a rust**

Whole genome sequencing and assembly of two *P. hordei* isolates (Ph518, Ph560) with contrasting fungicide sensitivities

Cyp51 located to chromosome 9

Five identical copies of *Cyp51* in the azole insensitive Ph560, only two copies found in the azole sensitive Ph518

Chromosome 9 appears to be a compartmentalized, highly variable core chromosome - a genomic hotspot of plasticity, potentially harboring expansions/ gene family diversification relevant to adaptive processes in *P. hordei*



Morals to Story 1:

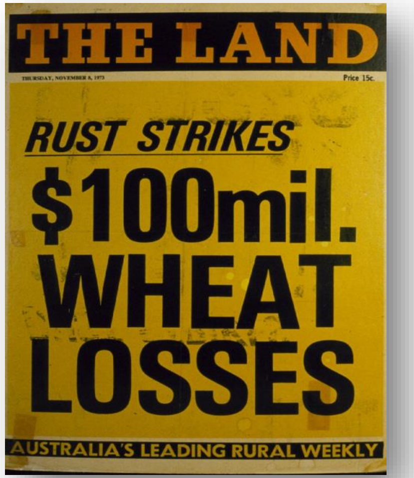
Rust evolution is complex, they have an uncanny ability to adapt to selection pressures imposed by agricultural practices – not just resistance, but fungicides too

The emergence of resistance to fungicides in many cereal fungal pathogens, including rust, is changing the economics of their use in broadacre crops

Fungicides are a support tool, they alone cannot be relied upon for disease control in cereal crops

Resistance remains the foundation of an integrated approach to rust control

Story 2:
"A tale of two rusts"



THE LAND

THURSDAY, NOVEMBER 8, 1973 Price 15c.

RUST STRIKES

$100mil. WHEAT LOSSES

AUSTRALIA'S LEADING RURAL WEEKLY

Puccinia graminis f. sp. tritici
Wheat stem rust

P. striiformis f. sp. tritici
Wheat stripe rust

THE LAND

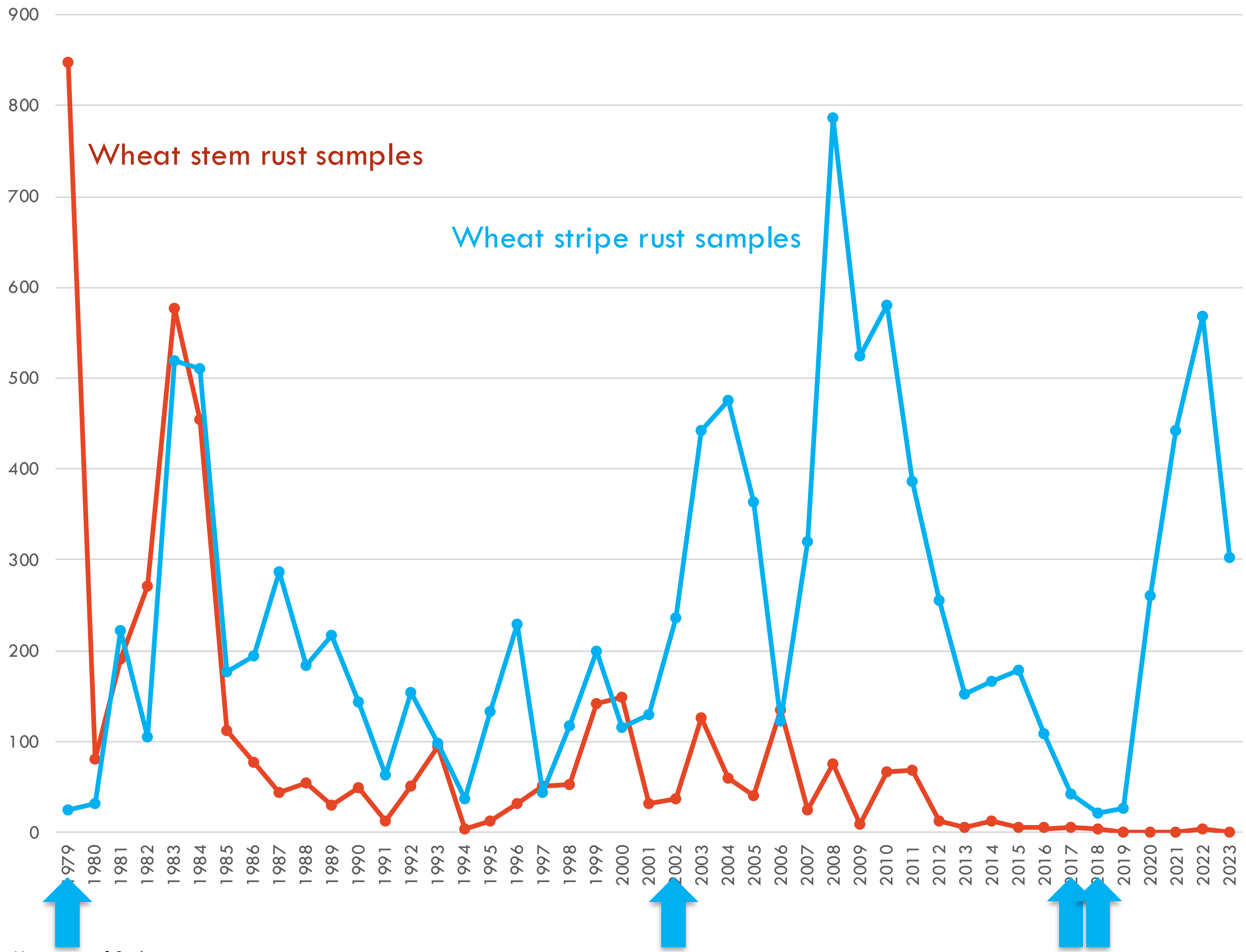
THURSDAY, SEPTEMBER 29, 1983 GENERAL Price 60c

STRIPE RUST: FARMERS 'PANIC'

PLUS REGIONAL EXTRA

AUSTRALIA'S LEADING RURAL WEEKLY

Number of rust samples received annually for pathotype analysis, 1979-2023



Stem rust

-incidence has declined dramatically, no samples from crops in 2019, 2020, 2021

Stripe rust

-first detected in Australia in 1979, #1 rust problem in cereals since

Why the difference?

Exotic incursions:

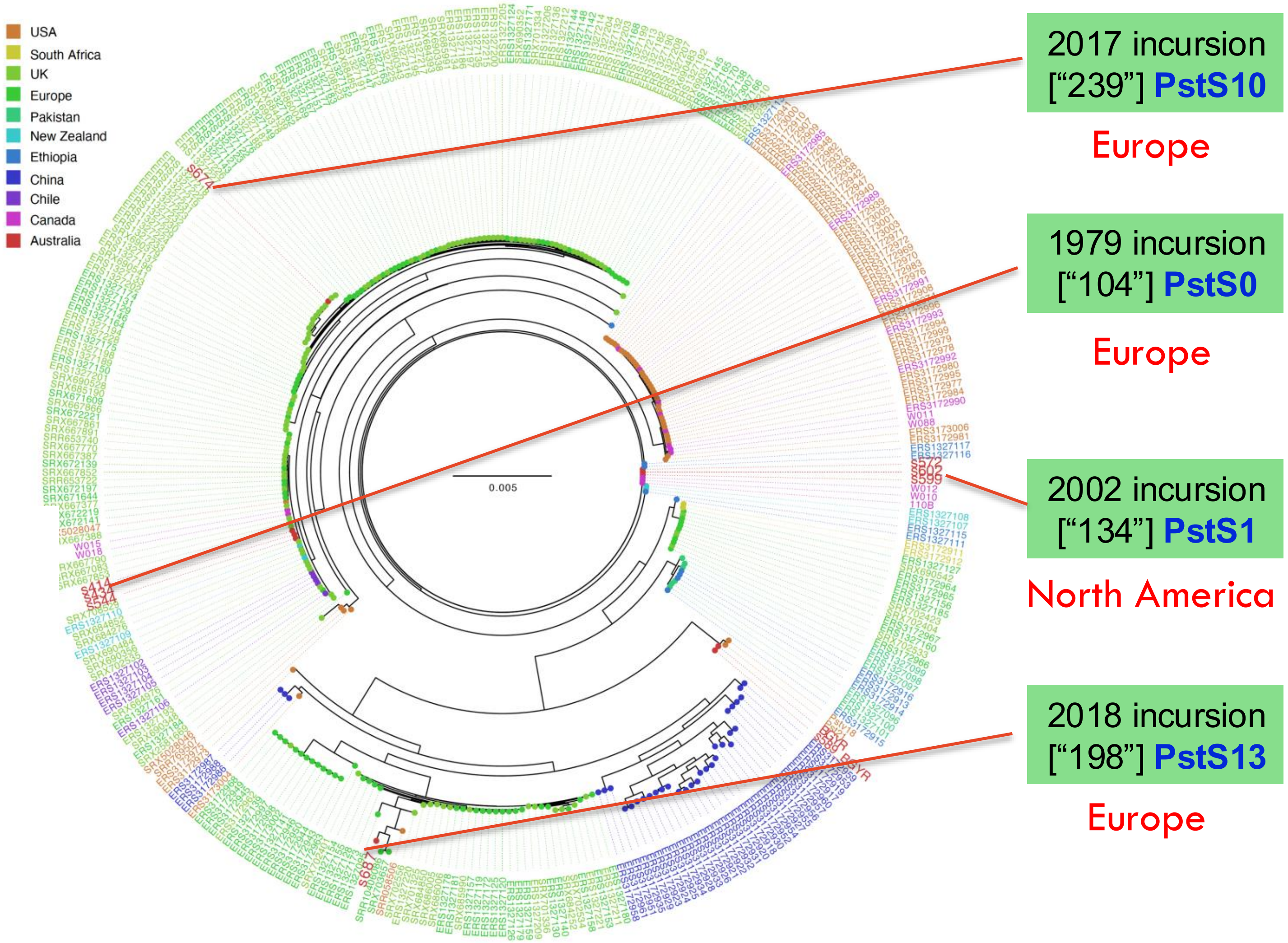
Stem rust, last incursion 1969

Stripe rust, incursions in 1979, 2002, 2017, 2018

Four exotic incursions of wheat stripe rust into Australia:

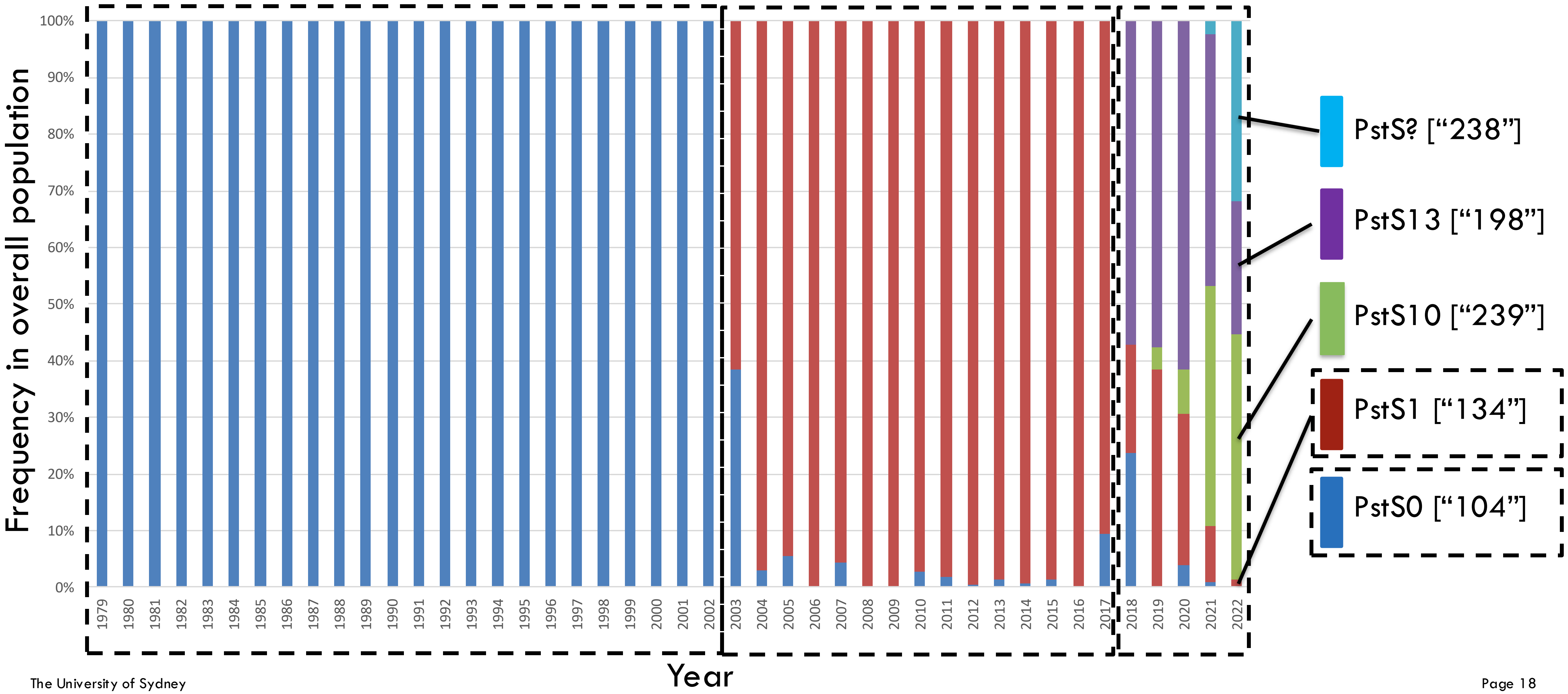
All have had huge economic impact

Increasing amounts of sequence data are allowing global tracking of rust strains

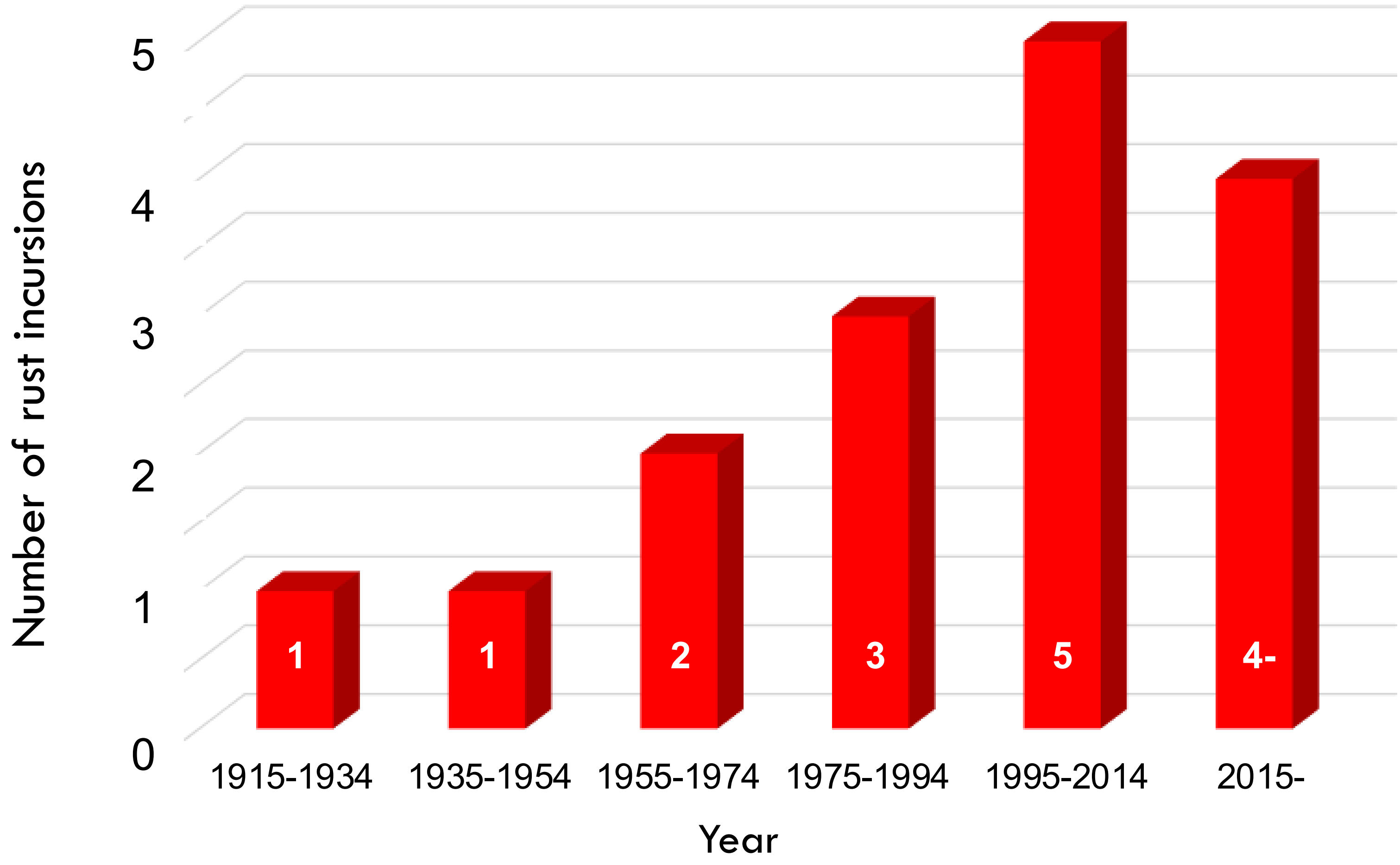


SNP phylogeny, 10 Australian + 315 non-Australian *P. striiformis* isolates

Frequencies of genetic lineages in Australian stripe rust populations, 1979-2022



The frequency of exotic rust incursions is increasing, eg wheat rusts:



Morals to Story 2:

Resistance breeding has been very successful in dealing with locally arising rust threats

Less successful in dealing with exotic incursions

“Winning battles but the war continues”

The frequency of incursions of exotic rust isolates has increased

International coordination is therefore crucial in controlling rusts

Story 3:
"Playing the long game"

Puccinia striiformis f. sp. pseudo-hordei

Will Cuddy
Mumta Chhetri
Yi Ding
Robert Park
Davinder Singh
Colin Wellings

Host specialization in the stripe rust pathogen *Puccinia striiformis*

Different forms ("formae speciales") of the stripe rust pathogen *Puccinia striiformis* infect cereals

Puccinia striiformis **formae specialis:**	**Disease name**	**Infectivity on:**			**In Australia?**
		Wheat	Barley	Barley grass	
f. sp. *tritici*	Wheat stripe rust [WYR]	High	Very low	High	Yes
f. sp. *hordei*	Barley stripe rust [BYR]	Very low	High	?	No
f. sp. *pseudo-hordei*	Barley grass stripe rust [BGYR]	Very low	Low	High	Yes

BGYR first detected in Australia in 1998

Weakly pathogenic on barley, but no major impact in agriculture

Whole genome sequencing showed it is distinct from *Psh* and *Pst*

Four exotic incursions of wheat stripe rust into Australia:


THE LAND
THURSDAY, SEPTEMBER 29, 1983 GENERAL Price 60c
STRIPE RUST: FARMERS 'PANIC'
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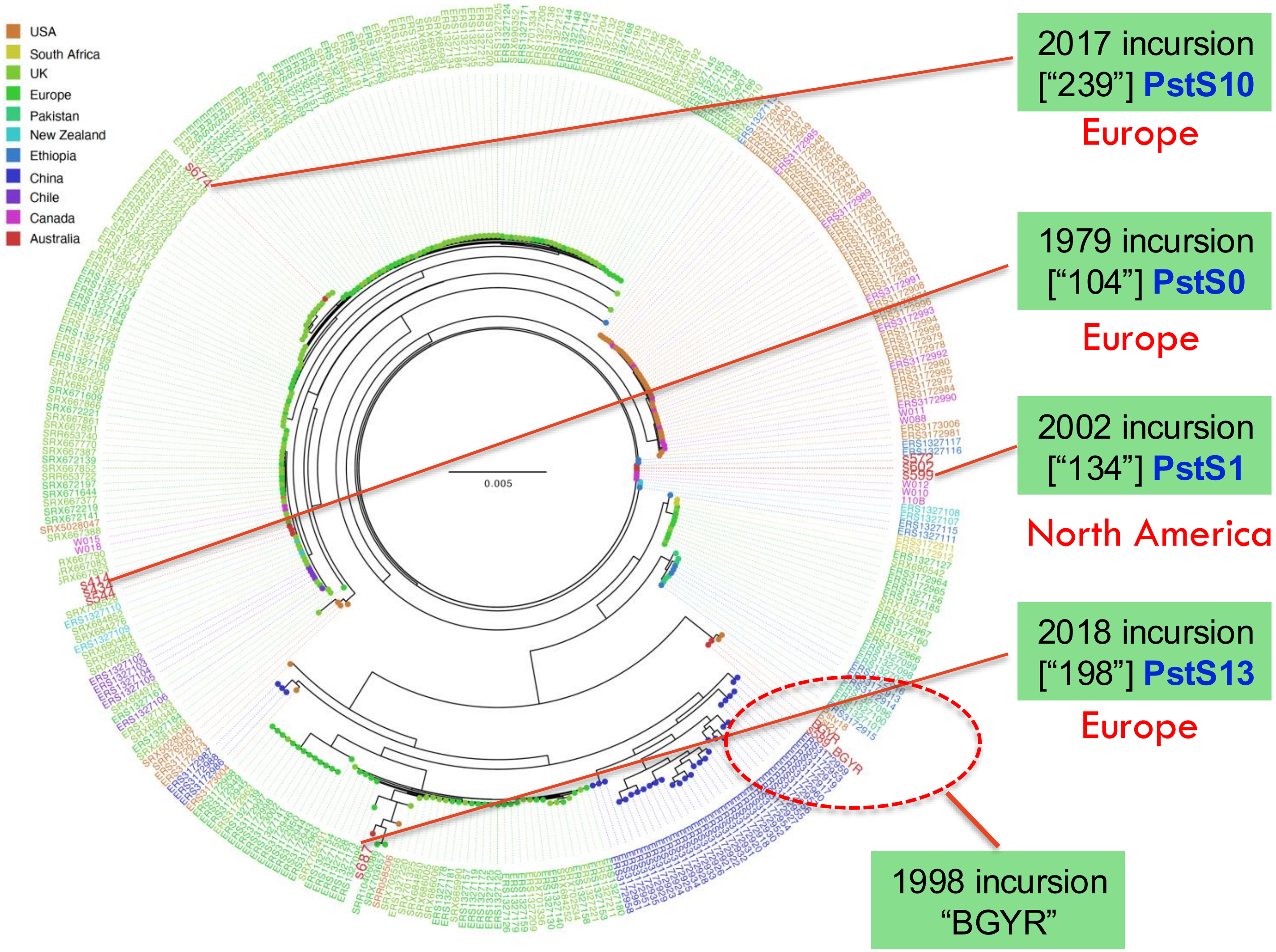


SNP phylogeny, 10 Australian + 315 non-Australian *P. striiformis* isolates


GRDC GROUNDCOVER

groundcover.grdc.com.au | Issue 154 | September – October 2021 | COMMENTARY / RUST 37

Reports of stripe rust in barley spark prompt response

By Professor Robert Park, Dr Yi Ding, Dr Davinder Singh and Dr Andrew Milgate

Early last year, we wrote about the threat posed to Australian barley growers by the exotic barley stripe/yellow rust pathogen (BYR). This pathogen causes significant problems in barley production in some parts of the world, but fortunately it is not present in Australia.

Although closely related to the wheat stripe rust pathogen (WYR), which is very common in Australia, BYR is specialised to barley and poses no threat to wheat.

Despite the absence of BYR in Australia, we receive occasional reports of stripe rust in barley crops. These reports require prompt action because they could mean that BYR has managed to find its way into Australia.

Such an incursion would be expected to impact significantly on barley production because many Australian barley varieties are highly susceptible to this pathogen. Resolving

greenhouse seedling assays both confirmed that the pathogen responsible was not BYR, but rather a stripe rust form different from BYR and WYR that researchers first detected in 1998.

Known colloquially as 'BGYR', this stripe rust form does not infect wheat and, while it can infect barley, all cultivars other than Skiff, Tantangara and Maritime have good levels of resistance to it.

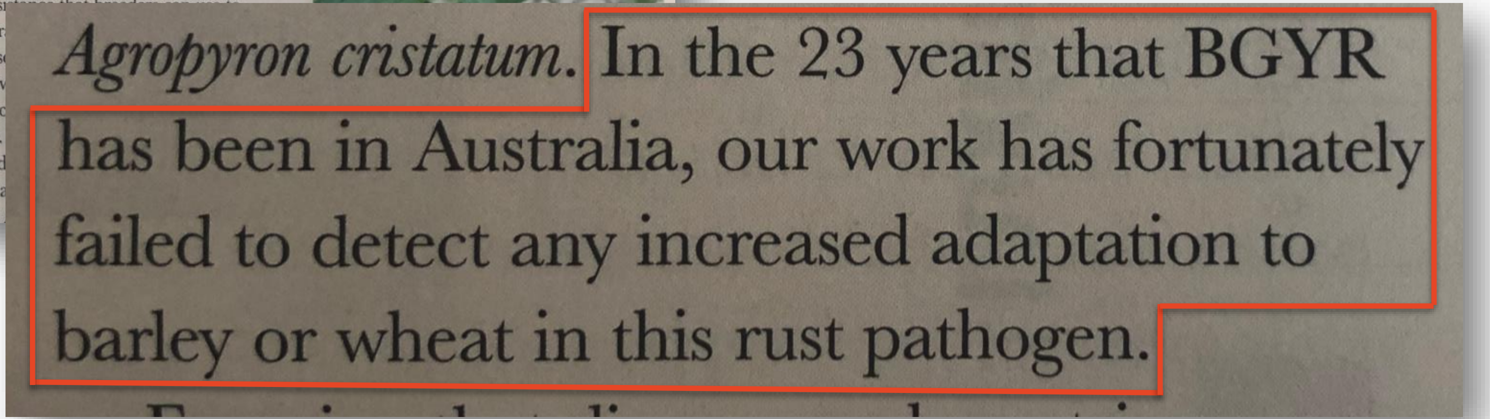
The name BGYR derives from 'barley grass stripe (yellow) rust', so named because it is very common on wild barley grass weed species such as *Hordeum glaucum* and *Hordeum leporinum*.

Using whole genome sequencing, we have been able to show that BGYR also occurs in North America, where it has been isolated from triticale and from the grass species *Agropyron cristatum*. In the 23 years that BGYR has been in Australia, our work has fortunately failed to detect any increased adaptation to

agronomists and other stakeholders, the Australian Cereal Rust Control Program monitors the occurrence and identity of rust pathogens in Australian cereal crops as an early warning scheme, to inform resistance breeding efforts and to enable rust risk management.

We have also been working with the International Maize and Wheat Improvement Center (CIMMYT) in Mexico to screen Australian barley varieties and breeding lines for response to BYR for about 20 years. This has provided an understanding of vulnerability to the disease and is enabling the development of markers linked to BYR resi… incorpor… disease s…

As alw… to inspec… diseases. collected… Australia… Sydney.

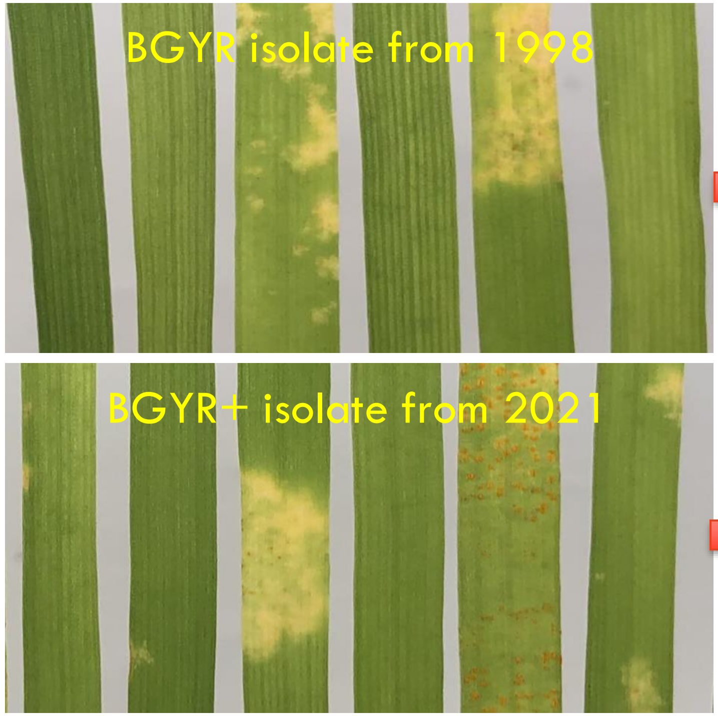

Agropyron cristatum. In the 23 years that BGYR has been in Australia, our work has fortunately failed to detect any increased adaptation to barley or wheat in this rust pathogen.

Article written: July 2021

Article published: Sept/Oct 2021

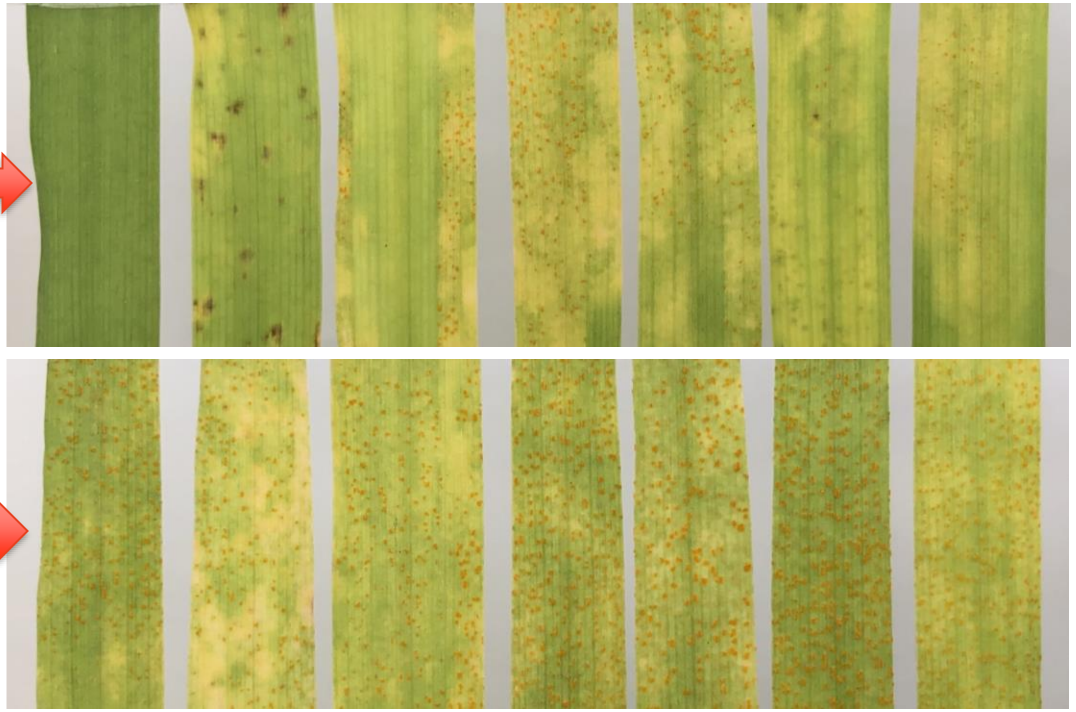
New BGYR variant ("BGYR+") discovered in a sample collected on 6th Aug 2021…

New variant of BGYR ("BGYR+") detected in 2021



Lee Kolben Avocet R Avocet S Morocco Breakwell

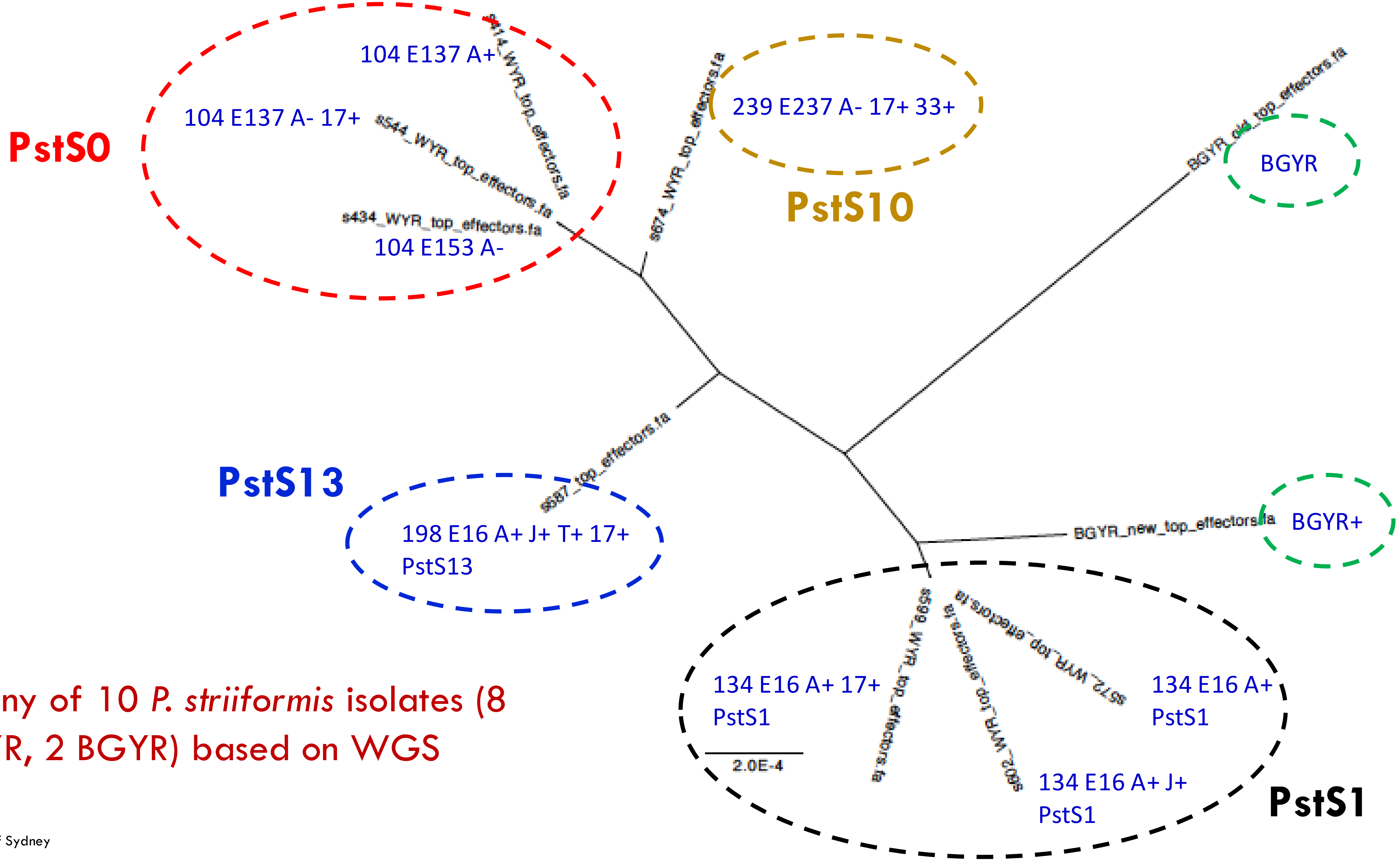
Response of 6 wheat differentials



Keel Ulandra Finniss Prior Empress Ketch Skiff

Response of 7 barley varieties

Research suggests 3-4 resistance genes in barley have been overcome by BGYR+



Phylogeny of 10 *P. striiformis* isolates (8 WYR, 2 BGYR) based on WGS

Morals to Story 3:

Don’t trust rust!

Integrating rust surveillance with resistance genetics is essential for optimal impact:

Timeline of impact:

2 Weeks

Monitor varietal resistance

Determine new varietal responses associated with pathogen change

Explain the genetic basis of changes in varietal response

Risk assessment

Provide new or relevant rust pathotypes for pre-breeding and research

Longer-term

Understand pathogenic and genetic variability

Wheat classification, Rust in Wheat Conference Melbourne 1896

Rust resistant
Ward's Prolific, Marshall's Number 3, Australian Wonder, Robin's Rust resistant

<u>For cooler districts:</u> Blount's Lambrigg, Pringle's Defiance, Tunnack, Smith's Nonpareil
<u>For cooler and moister districts:</u> Fife wheats such as Improved Fife and Hornblende

Rust Escaping
Allora Spring, Budd's Early, Early Poara, Canning Downs R.R., Early Baart

Prolific and Moderately Rust Resistant: Talavera, Leak's, White Lammas

Varietal response to rust

THE UNIVERSITY OF SYDNEY

Sydney Institute of Agriculture

Cereal Rust Report
Plant Breeding Institute

Rust resistance genotypes and expected rust responses of Australian cereal varieties

Cereal Rust Report 2023, Volume 20 Issue 3

15 September 2023

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Ph: 02 9351 8806, 0414 430 341

The rust responses for Australian cereal varieties provide growers and technica
informed rust control decisions. The varietal responses for wheat (common and du

Response	Description
R	highly resistant: occasional symptoms of infection including necrotic flecks; no sporulation
RMR	resistant: symptoms evident and usually with necrosis and chlorosis, limited sporulation, and affected leaf area up to 15%
MR	moderately resistant: evidence of sporulating areas on the leaf surface with some chlorosis and necrosis, and affected leaf area up to 30%
MRMS	intermediate: restricted sporulating areas with some chlorosis, and affected leaf area up to 50%
MS	moderately susceptible: freely sporulating lesions and affected leaf area up to 70%
MSS	moderately susceptible to susceptible: freely sporulating lesions with leaf area affected up to 90%
S	susceptible: abundant sporulation across the whole leaf surface; leaf area affected up to 100%; some chlorosis and necrosis evident
SVS	susceptible to very susceptible: abundant sporulation across the leaf surface; leaf area affected up to 100%; limited chlorosis
VS	highly susceptible: abundant sporulation across the whole leaf area with no evidence of chlorosis or necrosis; 100% leaf area affected

Stripe rust response of major eastern Australian wheat varieties 2021-22

Cultivar	2021 NVT	2022 NVT	Yr gene(s) ASR	Yr gene(s) APR
Beckom	MRMS	MRMS	*Yr7*, *Yr17*	*Yr18*, *Yr29*, ***YrAvS***
Calibre	MS	S *	*Yr4*, *Yr17*, ***Yr1A***	*Yr29*, ***YrAvS***
Coolah	MRMS	MSS *	*Yr3a*, ***Yr25***, *Yr33*	*Yr18*, *Yr29*
Coota	MS	S *	*Yr6*	*Yr29*, ***YrAvS***
LRPB Flanker	MR	MRMS *	*Yr7*, ***Yr1A***	*Yr18*
LRPB Hellfire	MR	MRMS *	*Yr7*	*Yr29*, ***YrAvS***
LRPB Lancer	RMR	RMR	*Yr6*, ***Yr1A***	*Yr18*
LRPB Mustang	RMR	MR *	*Yr7*, ***Yr1A***	*Yr18*
LRPB Spitfire	MR	MR (S)	*Yr7*	*Yr29*, ***YrAvS***
Scepter	MSS	MSS	*Yr17*, ***Yr25***	*Yr29*
Sunflex	RMR	MRMS *	*Yr7*, *Yr27*	*Yr29*
Sunmaster	MRMS	MRMS	*Yr17*, *Yr33*	Nil
Vixen	S	SVS *	*Yr7*	*Yr29*, ***YrAvS***

* change in response from previous National Variety Trial rating

Closing comments

100+ years of monitoring cereal rust pathogens has underpinned all control strategies: resistance gene discovery and characterisation, resistance breeding, post-release management of varieties

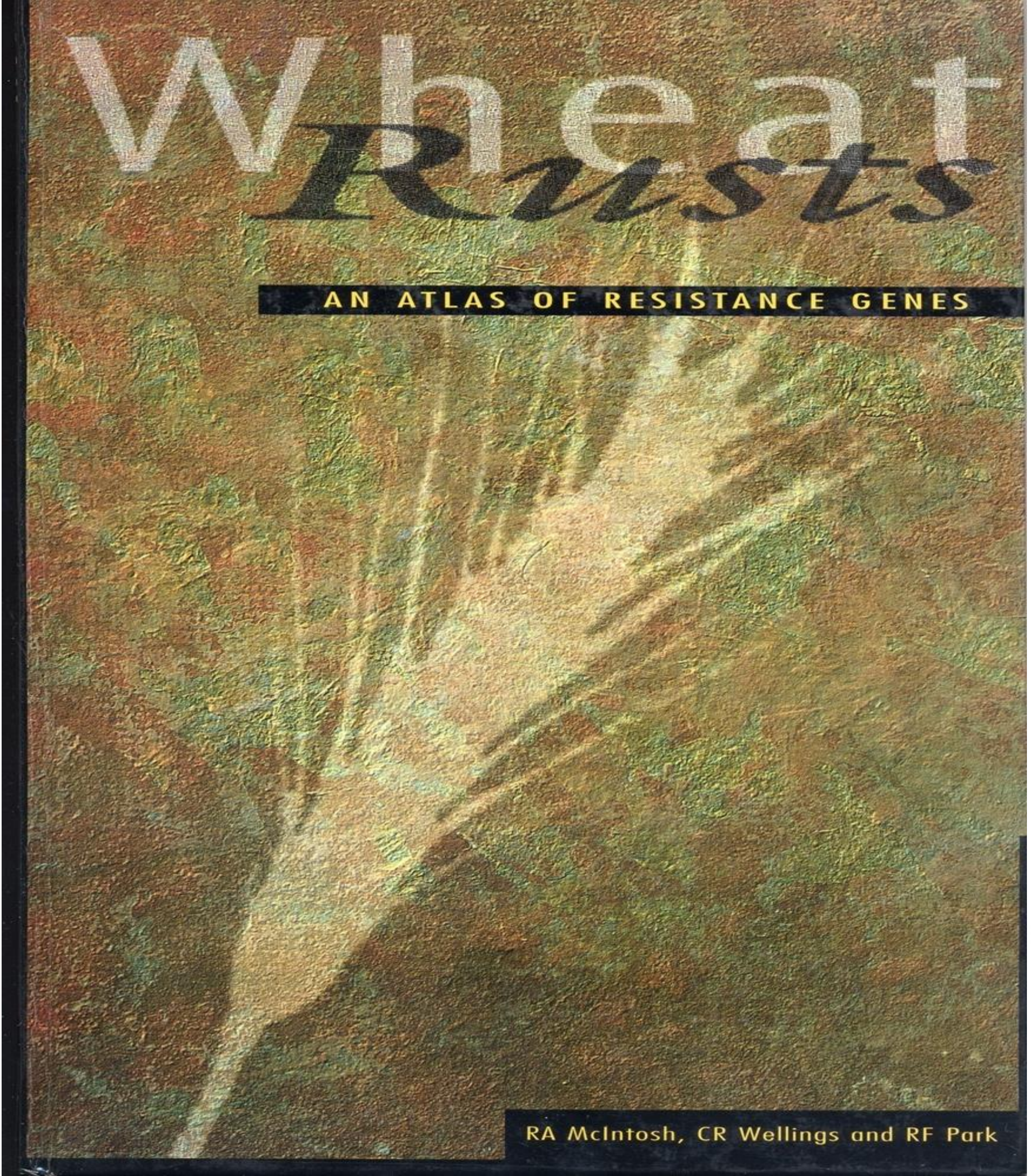
“Pathogenomics” is improving global surveillance of rusts and beginning to unravel the molecular basis of host: pathogen interactions, virulence and avirulence, and fungicide insensitivity

Pre-emptive resistance breeding has been very successful in winning “local” battles, but less successful in dealing with exotic incursions; the fight continues, new threats emerge, intercontinental rust movement has become more frequent

Rust evolution is complex, the role of ancillary hosts such as barley grass should never be ignored

“Pyramids” of diverse resistance genes are preferable to keep one step ahead of evolving rust pathogens

Must ensure continued translation of research outputs to the field to help all farmers


Wheat
Rusts
AN ATLAS OF RESISTANCE GENES
RA McIntosh, CR Wellings and RF Park


Volume 58 • Issue 6 • 2007
Australian Journal of
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Special Issue
Global Landscapes in Cereal Rust Control
THE LAND
RUST STRIKES
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