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ADULT PLANT RESISTANCE FACT SHEET

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ADULT PLANT RESISTANCE

Adult plant resistance is a useful trait to consider in variety selection, especially for rust resistance. Understanding how it works can make fungicide application decisions easier.

KEY POINTS

- **Adult plant resistance (APR)** to cereal fungal diseases provides protection in a crop's post-seedling stages (typically between tillering and booting, GS20-GS49).
- **Seedling resistance, by comparison,** is effective at all growth stages.
- **APR** can complement a fungicide strategy by protecting, from rust, those parts of the plant most responsible for yield.
- When selecting a variety, ensure that varieties rated MRMS (the minimum disease resistance standard) or better are chosen. In high-risk regions, varieties rated MR or better are recommended.
- Where more susceptible varieties are used, ensure a suitable fungicide strategy is in place and with the right chemicals available at short notice.
- Fungicides are better at protecting than curing. Fungicide applications on badly infected crops provide poorer control and do not restore lost green leaf area.

PHOTO: COLIN WELLINGS

Leaf rust symptoms on an adult plant leaf. Adult plant resistance genes Yr18-Lr34 behave as a single gene, which has provided durable protection against leaf rust. It has proved useful in Australian wheat varieties and is an important component in current resistance breeding programs.

What is Adult Plant Resistance?

Adult plant resistance (**APR**) is resistance to fungal diseases – particularly rusts – in cereal varieties in the post-seedling stage of crop development.

The expression of APR varies. It can be as early as tillering or late in the crop's development. Cooler seasons can delay the resistance trait being expressed.

As APR expression may be influenced by temperature and other factors, it is advisable to have a fungicide control strategy ready.

How does it work?

APR is provided by one or more 'minor' genes which are effective after the seedling growth stages (typically between tillering and booting, GS20-GS49) – hence the term Adult Plant Resistance.

Minor genes are genes of individual 'minor effect', so on their own may not protect a plant from rust attack. But if two or three minor genes are combined, the effect is cumulative and the variety can consequently show high levels of adult plant resistance.

However, many crop varieties with APR can still be susceptible to rust at the seedling stage.

Protection at the seedling stage is provided by 'major' or seedling resistance genes, which have much larger effect and often provide complete resistance at all growth stages. For this reason, seedling resistance would be better termed all-stage resistance.

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'Major' genes are comparatively easy to select for in breeding programs.

However, while breeders can produce varieties that are largely protected, this resistance is usually governed by a single gene in the plant.

This makes it vulnerable to any change in the rust pathogen. When a single gene protects the plant, the rust pathogen has to mutate only once to overcome that gene.

APR becomes effective at a particular wheat growth stage. Depending on the variety and the inoculum load, this can range from early in the crop's development, at tillering (GS20), through to full head emergence (GS59).

The expression of APR can also vary from season to season depending on environmental conditions and the cultivar.

Some genes are more temperature-sensitive; their effectiveness improving as temperatures rise.

On the other hand, if conditions remain cool into a long grain-fill period, disease pressure may also extend late into the cropping cycle, because the cool weather is holding back the expression of some APR genes.

What is a pathotype?

A pathotype (strain, race, biotype) is a variation of a rust pathogen that has particular features that enable it to overcome resistance and cause disease.

The wheat stem rust pathogen, for example, comprises many pathotypes that differ in their abilities to overcome the 57 stem rust resistance genes that have been characterised in wheat to date.

Strengthening a variety's resistance

If seedling resistance is based on multiple genes, it is less vulnerable to pathogen change. A recent example is in the wheat variety Livingston, which carries seedling resistances Yr17 and Yr27 and the APR gene Yr18. When the stripe rust pathogen developed a mutant pathotype virulent for Yr17 in 2006, the remaining two genes continued to provide good levels of resistance for Livingston. A new pathotype with virulence for Yr27 in 2008 was likewise unable to cause a problem commercially for Livingston because the other genes remained effective. A third pathotype, with combined virulence for both Yr17 and Yr27, was detected in 2010 and this caused Livingston's stripe rust response to move from R (resistant) to MR-MS (moderately resistant to moderately susceptible). However, Livingston did not become completely susceptible to this new pathotype as it still has the APR gene Yr18 (and possibly other APR genes) that continue to provide a level of protection.

Fungicide strategies

Chemical control at sowing

This includes:

- fungicide seed dressings;
- fungicide applied on fertiliser; and
- liquid in-furrow application at sowing.

The advantage of these treatments is that they can provide protection for extended periods.

PHOTO: ROBERT PARK

Stem rust on barley may be caused by either wheat stem rust, rye stem rust or a hybrid between these two forms of stem rust. The latter two will not infect wheat but if the pathogen turns out to be wheat stem rust, then that particular barley crop represents a direct threat to neighbouring wheat fields.

If a variety is vulnerable, such 'at-sowing' treatments could prove to be a cost-effective defense.

If a particular variety only has APR, it may be susceptible in early growth stages (prior to GS20). A treatment applied at seeding may effectively cover that period of vulnerability.

If a variety is vulnerable right through the season, then chemical control at seeding will provide initial protection but a further in-crop foliar fungicide application may be required.

Depending on which treatment is applied, protection can be effective from eight weeks up to flag leaf emergence (GS39).

Because the fungicide is effectively diluted as plants grow, treatments will be less effective as growth at the top of the plant increases.

Foliar fungicides

Foliar fungicides can be effective, but all current fungicides generally are intended to stop new infections rather than cure existing infections.

The principal aim of fungicides is to protect those parts of the plant that contribute most to grain yield – which in the case of wheat is mainly the top three leaves (Flag leaf, Flag-1 and Flag-2 leaves).

This is best achieved by applying fungicides early to prevent the spread of early epidemics. Fungicides can be applied conveniently, such as in a tank mix with a herbicide.

Growers may decide to do this as a form of insurance for the crop.

Alternatively, an application may be delayed until rust is detected in a crop or in other crops in the district.

Early applications, when adopted widely, help protect all crops in that region. This should reduce the need for later applications by all growers. This is particularly the case where varieties have a suitable level of APR.

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TABLE 1 Adult Plant Resistance (APR) disease response of Australian bread wheat varieties to leaf, stem and stripe rust 2012 disease response.

Variety	Rust Response				
	Leaf Rust		Stem Rust	Stripe Rust	
	Eastern states	WA		WA pathotype	Yr17-27 pathotype
AGT Katana[◊]	MS	MS	MSS	MRMS	MRMS
Amarok	R	R	S	R	MRMS
Annuello[◊]	RMR	RMR	RMR	MSS	MSS
Arrino	MS	MS	SVS	S	S
Axe[◊]	MR	MR	MRMS	RMR	RMR
Babbler[◊]	MS	R	RMR	MSS	MSS
Barnham	MRMS	MRMS	MRMS	RMR	MSS
Baxter[◊]	MR	MR	R, MS[C]	MSS	MSS
Beaufort[◊]	R	R	SVS	R	RMR
Binnu[◊]	MRMS	MRMS	S	R	MS
Bolac[◊]	MS	MR	MR	RMR	RMR
Bowerbird	R	R	MS	S	S
Bowie	MS	MS	S	RMR	S
Braewood[◊]	R	R	MR	R	MRMS
Bullaring[◊]	MS	R	RMR	MRMS	MRMS[C,D]
Bumper	R	R	MSS	MS	MS
Calingiri	MS	MS	S	S	S
Carinya	MRMS	R	RMR	R	MRMS
Carnamah	MS	MS	MRMS	S	S
Catalina[◊]	R	R	RMR	MS	MS
Chara[◊]	MS	R	MRMS	MSS	MSS
Clearfield JNZ	MRMS	R	MR	MSS	MSS
Clearfield STL	SVS	SVS	MRMS	S	S
Cobra	MR	MR	RMR	S	S
Corack[◊]	MSS	RMR	MR	MS	MS
Correll[◊]	MSS	MSS	MR	MRMS	MRMS
Crusader[◊]	R	R	RMR	R	MS
Cunningham	MRMS	R	RMR	MS	MS
Currawong	RMR	RMR	RMR	MRMS	MRMS
Dakota[◊]	MRMS	MRMS	MR	MRMS[D]	MRMS[D]
Derrimut[◊]	R	R	MR	R	MSS
Diamondbird	R	R	MRMS	MS	MS
Drysdale[◊]	MS	MS	MR	MS	MS
EGA Bonnie Rock[◊]	RMR	MR	MS	VS	VS
EGA Bounty[◊]	R	R	MR	MR	MR
EGA Burke[◊]	R	R	MR	MS	MS
EGA Eaglehawk[◊]	R	R	RMR	R	MRMS
EGA Gregory[◊]	RMR	RMR	MR	MR[C,D]	MR[C,D]
EGA Hume[◊]	R	R	MR	MRMS	MRMS
EGA Kidman[◊]	R	R	MR	MRMS[D]	MRMS[D]
EGA Stampede[◊]	R	R	RMR	MR	MR
EGA Wedgetail[◊]	MS	MS	MRMS	MRMS[D]	MRMS[D]
EGA Wentworth[◊]	MR	MR	RMR	MS	MS
EGA Willis	R	R	RMR	MRMS[D]	MRMS[D]
EGA Wylie[◊]	R	R	R	MS	MS
EGA2248	MRMS	MS	MRMS	MSS	MSS
Ellison[◊]	R	R	MR	R	MS
Elmore CL Plus[◊]	RMR	RMR	RMR	MRMS	MRMS
Emu Rock	S	R	MRMS	MRMS	MRMS
Endure[◊]	MRMS	RMR	MR	RMR	SVS
Envoy[◊]	R	R	MRMS	R	SVS
Espada[◊]	R	R	R	R	MRMS
Estoc[◊]	MRMS	MRMS	RMR	MRMS	MRMS
Fang[◊]	R	MR	R-MS[E]	R	MSS
Forrest	MRMS	MR	R	RMR	RMR
Fortune	MRMS	MR	MS	MS	MS
Frame	MS	MSS	MS	MS	MS
Frelon	R	R	SVS	R	R
Gauntlet	MR	MR	RMR	RMR	MRMS
GBA Hunter[◊]	MS[C]	MS[C]	RMR	RMR	MRMS[D]
GBA Ruby[◊]	MRMS	MR	MS	RMR	MSS
GBA Sapphire[◊]	MRMS	R	RMR	MS	MS
Giles[◊]	R	R	RMR	MS	MS
Gladius[◊]	MS	MS	MR	R	MRMS[D]
Guardian[◊]	MRMS	R	RMR	MS	MS
H45[◊]	R	R	MS	VS	VS
H46	R	R	MRMS	MR	VS
Hartog	MR	R	MR	MS	MS
Hornet	R	R	MSS	R	MS

Variety	Rust Response				
	Leaf Rust		Stem Rust	Stripe Rust	
	Eastern states	WA		WA pathotype	Yr17-27 pathotype
Impala	S	S	RMR	MR	MR
Impose CL Plus	RMR	RMR	RMR	RMR	VS
Janz	MRMS	RMR	RMR	MS	MS
Justica CL Plus[D]	MSS	MSS	MR	RMR	MRMS
Kellalac	S	S	MSS	MRMS	MRMS
Kennedy[D]	MRMS	MRMS	MR	MS	MS
King Rock[D]	MRMS	R	MS	RMR	VS
Kord CL Plus[D]	MS	MRMS	MR	RMR	MRMS
Kunjin	MSS	MS	MR	MS	MS
Lang	MRMS	R	R	MS	MS
Leichhardt	R	R	MR	MS	MS
Lincoln[D]	R	R	MR	RMR	RMR
Livingston[D]	R	R	MRMS	R	MRMS
Mace[D]	MR	MR	MR	R	SVS
Mackellar[D]	S[C]	R	MRMS	RMR	RMR
Magenta[D]	MS	R	RMR	MS	MS
Mansfield[D]	MS	RMR	SVS	RMR	RMR
Merinda[D]	R	R	RMR	RMR	MRMS
Naparoo[D]	R	R	RMR	R	R
Orion[D]	R	R	MR	RMR	MSS
Peake[D]	MR	MR	MR	MRMS[D]	MRMS[D]
Petrie[D]	MR	MR	RMR	MS	MS
Preston	R	MR	SVS	RMR	RMR
Pugsley[D]	MSS	SVS	S	R	S
QAL 3362	MS	-	MRMS	MS	MS
QAL Bis	R	R	RMR	RMR	SVS
QAL 2000[D]	R	R	RMR	R	VS
Rosella	MRMS	MR	MRMS	MRMS	MRMS
Rudd[D]	R	R	S	R	R
Sabel CL Plus[D]	MSS	MRMS	MR	RMR	MSS
Scout[D]	R	R	MR	RMR	MS
Sentinel[D]	R	R	RMR	RMR	RMR
Snipe	MS	MS	MR	MS	MS
Spitfire[D]	MS	MS	MR	MR	MR
SQP Revenue	R	R	R	R	R
Strzelecki[D]	R	R	MRMS	MR	MR
Sunbri	MRMS	MR	R	R	MR
Sunco	MR	MR	R	MRMS	MRMS
Sunguard[D]	RMR	RMR	R	MR	MR
Sunlin	MRMS	MR	MRMS	MR	MRMS
Sunstate	R	R	MR	R	MSS
Sunvale	MRMS	RMR	R	R	MR[D]
Sunvex[D]	R	R	R	R	MR
Sunzell	R	R	MR	RMR	MS[D]
Tammarin Rock[D]	MR	MRMS	MSS	MSS	MS[S]
Tennant[D]	MSS	RMR	RMR	RMR	RMR
Ventura	R	R	RMR	R	MSS
Waagen	MS	MR	MS	RMR	S
Wallup[D]	MS	RMR	RMR	MRMS	MRMS
Westonia	MS	MS	SVS	VS	VS
Whistler	MRMS	MRMS	MR	MSS	MSS
Wyalkatchem[D]	MS	RMR	MS[B]	S[B]	S
Wylah[D]	MS	RMR	MR	MS	MS
Yandanooka[D]	RMR	RMR	MS	S	S
Yenda[D]	R	R	R	R	S
Yitpi[D]	MSS	MSS	S	MRMS	MRMS
Young[D]	R	R	MRMS, R[C]	RMR	MS
Zippy[D]	MRMS	MR	MRMS	MSS[D]	MSS[D]

[A] – leaf rust responses are against pathotypes virulent for Lr13, Lr24 and Lr37 in eastern states. WA responses reflect pathotypes avirulent for Lr24 and/or Lr13
[B] – Wyalkatchem in WA: MR-MS to stem rust pathotypes avirulent for Sr15; MS to stripe rust
[C] – indicates a mixed (heterogeneous) response to the disease or for the presence of a resistance gene
[D] – these varieties may show high levels of stripe rust if disease onset is early and may benefit from fungicide protection
[E] – indicates a range in response
- – response unknown

VARIETIES CARRYING APR

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 per cent.

MR – moderately resistant: evidence of sporulating areas on the leaf surface with some chlorosis and necrosis, and affected leaf area up to 30 per cent.

MRMS – intermediate: restricted sporulating areas with some chlorosis, and affected leaf area up to 50 per cent.

MS – moderately susceptible: freely sporulating lesions and affected leaf area up to 70 per cent.

VARIETIES NOT CARRYING EFFECTIVE APR

MSS – moderately susceptible to susceptible: freely sporulating lesions with leaf area affected up to 90 per cent.

S – susceptible: abundant sporulation across the whole leaf surface; leaf area affected up to 100 per cent; some chlorosis and necrosis evident.

SVS – Susceptible to very susceptible: abundant sporulation across the leaf surface ; leaf area affected up to 100 per cent; limited chlorosis.

VS – highly susceptible: abundant sporulation across the whole leaf area with no evidence of chlorosis or necrosis; 100 per cent leaf area affected.

SOURCE: SYDNEY UNIVERSITY PLANT BREEDING INSTITUTE; SYDNEY.EDU.AU/AGRICULTURE/DOCUMENTS/PBI/CEREAL_RUST_REPORT_2012_VOL_10_1.PDF

TABLE 2 Seedling and adult plant resistance.

Zadoks growth stages	GS00-GS09	GS10-GS19	GS20-GS29	GS30-GS39	GS40-GS49	GS50-GS59	GS60-GS69	GS70-GS79	GS80-GS89	GS90-GS99
Development phase	Germination	Seedling growth	Tillering	Stem elongation	Booting	Ear emergence	Flowering	Milk	Dough	Ripening
Adult plant resistance: Often switches on around tillering to node formation. Can be earlier or later, depending on the gene(s) involved. Level of protection can vary with environment and inoculum load										
Seedling resistance	Resistant	Resistant	Resistant	Resistant	Resistant	Resistant	Resistant	Resistant	Resistant	Resistant
Adult plant resistance	Susceptible	Susceptible	Susceptible	+/- Resistant	Resistant	Resistant	Resistant	Resistant	Resistant	Resistant
Adult plant resistance	Susceptible	Susceptible	Susceptible	Susceptible	+/- Resistant	Resistant	Resistant	Resistant	Resistant	Resistant
Adult plant resistance	Susceptible	Susceptible	Susceptible	Susceptible	Susceptible	+/- Resistant	Resistant	Resistant	Resistant	Resistant

SOURCE: THE UNIVERSITY OF SYDNEY

Where effective seeding treatments or early spray applications are more sporadically applied, and susceptible varieties are grown, later treatments may be needed to protect the important top three leaves in wheat.

In varieties susceptible to stripe rust, an application at GS32 (second node), when the Flag-2 leaf is fully emerged and/or an application at GS39 when the flag leaf is fully emerged, minimises stripe rust development and maximises yield.

For stem rust management, later spray timings (post GS39) may provide an economic return in susceptible varieties.

In cultivars expressing APR at the MRMS level or better, there may be no need, in most grain growing regions, to apply later fungicides to protect the top two leaves.

In long-season districts with severe rust pressure, varieties may need an MR level of APR resistance to avoid the need for these later sprays.

A final factor to consider is that some varieties are more susceptible to head infection than others and this may be independent of resistance levels in the leaves.

Since fungicides are not effective at controlling head infection, late sprays to control all infection on the top leaves may be advisable when the risk of infection is high. This would reduce the number of spores available to infect the heads in the crop canopy.

The main factors to consider when deciding to apply foliar fungicides are:

- rust carryover (green bridge);
- the variety resistance rating;
- the level of infection present in the canopy;
- the growth stage of the plant;
- weather conditions to date;
- weather forecast for the coming weeks;
- yield potential; and
- cost of fungicide and application.

Variety choice

Variety choice is the first place to start when planning a cropping management program, and APR should be one of the factors taken into consideration.

A grower confident in their resources, experience and time available to manage a potential rust outbreak may accept the risk and choose a high-yielding variety that is moderately susceptible (MS) or susceptible (S) to rust.

However, in a mixed farming situation, where other enterprises require attention there may not be time to monitor crops closely. In this case, a resistant (R) or moderately resistant (MR) variety or a pre-planned fungicide strategy is recommended.

Very susceptible (VS) varieties should be avoided. They result in significantly increased spore production even compared to susceptible (S) varieties. This greatly increases the risk of damaging epidemics.

Mutations in the pathogen population that

PHOTO: COLIN WELLINGS

Dew forming on canopy leaves provides ideal conditions for a fungal infection.

lead to the development of new pathotypes is a 'numbers game'. The more spores released into the environment, the higher the probability that one will have a mutation that could create a new rust pathotype.

The widespread cultivation of very susceptible varieties places even greater pressure on currently effective resistance genes.

Resistance Ratings

Resistance ratings tables are revised and issued annually by the Australian Cereal Rust Control Program (ACRCP). The ACRCP group monitors rust populations to maintain awareness of pathotype distribution and to detect and report new and emerging pathotypes. Refer to the Cereal Rust Report under Useful Resources.

FREQUENTLY ASKED QUESTIONS

What is adult plant resistance?

Adult plant resistance (APR) is a resistance to fungal diseases (usually referring to cereal rusts, but also exists for some other diseases). Its protection covers the post-seedling stage of crop development.

The timing and effectiveness of APR varies from gene to gene, and variety to variety, and can also be temperature-sensitive – expression delayed by cool weather.

It is usually, but not always, conferred by multiple minor resistance genes.

How does APR differ from seedling resistance?

Seedling resistance maintains effective resistance to rusts throughout all growth stages of the plant.

By comparison, plants with APR may be vulnerable to infection in the early growth stages.

Seedling resistance is usually conferred by one or only a few major resistance genes.

APR is more often based on several minor resistance genes.

What is meant by disease expression?

More disease expression means more symptoms present on the leaves in the paddock. It can take the form of striping, spores and general evidence of disease.

If a major resistance gene or a combination of minor genes is providing effective protection you may not see any symptoms of rust development.

How does temperature affect APR?

Some resistance genes are more temperature-sensitive. Once temperatures start to rise, the resistance becomes more effective. If conditions stay cool, some genes may remain unexpressed for longer and disease may become more evident. In this case, a foliar fungicide application may need to be considered.

Are there resistance ratings tables available?

Resistance ratings tables (such as pages 3 to 4) are revised and issued annually by the Australian Cereal Rust Control Program and regional pathologists, and are based on data assembled through a consultative national meeting. The ACRCP conducts a national rust monitoring program to inform growers of seasonal rust outbreaks and to detect the presence of new pathotypes. Refer to the Cereal Rust Report under Useful Resources.

USEFUL RESOURCES

The Rust Bust
www.rustbust.com.au
For information on:
- The Australian Cereal Rust Control Program
- Cereal rust reports
- Fact Sheets
- Variety selection
- Rust Bust check list

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