Annual Results Report

2023

Validation and extension of management strategies for wheat powdery mildew

Project code:	TRE2204-001RTX
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REPORT SENSITIVITY

Does the report have any of the following sensitivities?

Intended for journal publication	YES ☐ NO ☒
Results are incomplete	YES ☒ NO ☐
Commercial/IP concerns	YES ☐ NO ☒
Embargo date	YES ☐ NO ☒ If Yes, Date: <Choose date>

KEY MESSAGES

List the key messages of the report.

- At the Bute and Malinong sites, currently registered products from fungicide groups 3, 7 and 11 did not provide high levels of powdery mildew, consistent with previous findings from SAGIT project TC120.
- Products from alternative modes of action (e.g. group 13) have provided high levels of mildew control but were ineffective at controlling other pathogens such as stripe rust. Mixtures with alternative mode of action for control of other pathogens would need to be explored to deploy these actives in a commercial setting to control all pathogens.
- The later application of fungicide treatments at GS55-59 at Port Neill provided incomplete powdery mildew control as the disease was already well established in the canopy. However, treatment differences were observed in head infection, with higher levels of head infection related to lower grain yield.
- The frequency of the G143A mutation, which confers strobilurin resistance, varied greatly between some regions in 2022. The Eyre Peninsula SA had very low levels of the mutation present, whilst the Mallee SA and Upper South East SA had low-moderate levels and the Victorian samples had high levels of the mutation on average.
- Low level varietal resistance, i.e. MSS is enough to significantly reduce WPM infection, compared with highly susceptible SVS varieties.

BACKGROUND

- Why do the trials?

Wheat powdery mildew (Blumeria graminis f. sp. tritici) is a sporadic disease that can cause up to 25% yield loss in conducive conditions. In the Southern region, wheat powdery mildew (WPM) has been increasing in incidence and severity in recent years and was particularly prevalent in areas of the Yorke Peninsula, Lower North, Eyre Peninsula and South-east of South Australia and the North-east of Victoria in 2021. However, in the 2022 growing season, high incidences of wheat powdery mildew spread to other areas across the Southern region.

Shifts in fungicide sensitivity and resistance to both Group 3 (DMI) and Group 11 (QoI) fungicides, which reduce the efficacy of these products when applied in-crop, have been detected in WPM in the Southern Region. The alternative fungicide mode of action, Group 7 (SDHI), has limited registered products for WPM. Resistance management strategies are necessary to prevent loss or reduced efficacy of the fungicide options available to manage this disease.

This project and trials continue the work initiated from the SAGIT project TC120 “management of fungicide resistant wheat powdery mildew”.

METHODS

How was the trial/experiment conducted? Avoiding overly technical language, describe the way the project has approached the task.

In 2022 the project had three main field components:

1. Field trials investigating best management of wheat powdery mildew

Small plot trials were established in 2022 at Bute, Katamatite, Pt Neill and Malinong. These included sown trials at Bute and Katamatite, whereas trials at Malinong and Pt Neill were established in farmer's crops. The trials include:

- Pre-em fungicide – Bute
- Post em fungicide product – Bute
- DMI fungicide combinations – Bute
- Wheat varietal resistance interaction with fungicide – Bute
- Fungicide application timing – Katamatite
- Post em fungicide product – Katamatite
- Post em fungicide product, given low efficacy of earlier fungicide application – Malinong
- Post em fungicide product for WPM control in the head, given low efficacy of earlier fungicide application – Pt Neill

Assessments during the year have consisted of

- Canopy score for mildew infection
- Counts of mildew pustules for individual leaves and stem
- Head score for mildew infection
- Sampling individual treatments for resistance mutation frequency
- Scoring treatments for other incidental diseases including stripe rust, leaf rust and blotches (Wirrega blotch and Septoria)

All trials were harvested and grain quality assessed.

2. Surveying grower paddocks to determine frequency of mutations conferring reduced sensitivity or resistance to DMI and QoI fungicides.

Samples of wheat powdery mildew have been collected from 145 paddocks across the Eyre Peninsula, Mallee, Upper SE and Mid North regions of SA and the NE and SW Vic as part of the paddock survey for mutation frequency. Mildew samples were collected using a Nucleic Acid Preservation (NAP) buffer for DNA extraction, with three samples collected from each paddock. A smaller subset of paddocks also had samples collected in Benzi agar tubes for live culturing. Samples were tested and analysed by the Centre for Crop and Disease Management (CCDM) for group 3 and group 11 fungicide resistance mutations.

3. Understanding the cause of spatial variability in mildew incidence related to soil type. Collecting samples from for nutrient analysis.

A subset of 15 paddocks from 145 were sampled for nutrient analysis. Two samples were collected from each paddock, one from a sandy soil type with high mildew incidence and one sample from a heavier textured soil with lower mildew incidence. Two metres of crop were collected from each location, by randomly placing a 0.5m ruler at four locations and cutting the adjacent row at ground level. Crop stage ranged from GS59-79. Samples were dried in an oven and weighed for dry matter, then subsampled and submitted to APAL for nutrient analysis.

LOCATION

Where field trials have been conducted, provide the following location details in the table below: latitude and longitude, or nearest town. (Add additional rows as required.)

Site #	Latitude (decimal degrees)	Longitude (decimal degrees)	Nearest town
Trial Site #1	33.8740330	138.0779790	Bute
Trial Site #2	-36.0325337	145.6575972	Katamatite
Trial Site #3	-34.1475240	136.3002313	Port Neill
Trial Site #4	-35.499325	139.508146	Malinong

If the research results are applicable to a specific GRDC region/s (e.g. North/South/West) or GRDC agro-ecological zone/s, indicate which in the table below:

Research	Benefiting GRDC region (select up to three)	Benefitting GRDC agro-ecological zone	
Validation and extension of management strategies for wheat powdery mildew	Choose an item. Southern Region Choose an item.	☐ Qld Central ☐ NSW NE/Qld SE ☒ NSW Vic Slopes ☐ Tas Grain ☒ SA Midnorth-Lower Yorke Eyre ☐ WA Northern ☐ WA Eastern ☐ WA Mallee	☐ NSW Central ☐ NSW NW/Qld SW ☒ Vic High Rainfall ☒ SA Vic Mallee ☒ SA Vic Bordertown-Wimmera ☐ WA Central ☐ WA Sandplain

RESULTS

What happened? Provide a description of the results from the work so far and some interpretation of what these mean in terms of farm practice or modified approaches to the underlying issue when interpreted for on-farm use. This can include graphs and photos.

Bute post em fungicide product trial

The powdery mildew infection at the Bute trial site did not occur until later winter. The disease was mostly contained to the lower canopy but moved up the canopy onto upper leaves and the head in spring. However, powdery mildew levels were not high. Other diseases, in particular stripe rust, had a significant impact on some treatments and may have confound some of the results obtained at Bute. Products that do not control stripe rust suffered high levels of infection and reduced green leaf area compared with other products that provided good control of stripe rust. As a result, the Opus treatment became a “rust control” but, also had a minimal effect on powdery mildew. The lowest label rate of Opus was used at 250 mL/ha at the GS39 timing only in an attempt to establish a new control treatment if needed (Table 1). Assessment of both stripe rust and blotch (both Wirrega blotch and Septoria) were made to account for treatment effects on these diseases (data not presented). This allowed for interactions with mildew infection to be understood and to collect efficacy data on non-target pathogens.

This trial received two applications of the listed fungicides (Table 1) at GS31 and GS41. The results show high levels of powdery mildew control with currently registered products was not achievable at this site. The best mildew control with registered products was from the group 3 + 11 mixes of DMI and azoxystrobin. The frequency of the resistance mutation G143A at this site was low at 1.2% in the untreated control (Table 4). It was therefore expected some control of wheat powdery mildew would occur from Group 11 fungicides.

In contrast, products recognised as mildewicides such as Legend and Talendo provided high levels of control (Table 1). Both of these products contain alternative modes of action from fungicide group 13.

Table 1. Wheat powdery mildew pustule counts and canopy score assess on 28 September 2022 at Bute, SA. The canopy scores range from 0-6 and represent the amount of powdery mildew present in the lower canopy (higher score = higher presence of powdery mildew). Pustule count data has been log10 transformed and was analysed using ASREML. The canopy score data was not transformed and was analysed by ANOVA.

Product	Rate (ml or g/ha)	Log10 1+ F-1 pustules	Log10 1+ F-2 pustules	Log10 1+ F-3 pustules	Log10 1+ Total pustules	Canopy score
Nil	0	0.29 a	0.51 a	0.56 a	1.03 a	3.00 a
[a]Tebuconazole430	290	0.11 bcde	0.29 abcdef	0.24 cdefg	0.77 abcd	2.75 a
[b]Opus®	500	0.15 b	0.49 ab	0.34 abcdef	0.87 abc	2.63 ab
Propiconazole	230	0.12 bcd	0.34 abcde	0.28 bcdefg	0.82 abc	2.38 abc
[c]Proviso 250EC®	250	0.02 def	0.28 bcdef	0.49 abc	0.76 abcde	2.25 abcd
Prosaro®	300	0.01 def	0.14 defghi	0.39 abcd	0.60 cdef	2.13 abcd
[d]Mirador625®	200	0.03 cdef	0.27 bcdef	0.36 abcde	0.59 cdef	2.25 abcd
Veritas Opti®	630	0.09 bcdef	0.24 cdefgh	0.32 abcdef	0.51 defg	1.75 bcde
Amistar Xtra®	800	0.03 cdef	0.23 cdefgh	0.16 defg	0.49 defg	1.50 cde
Tazer Xpert®	2000	0.11 bcde	0.13 defghi	0.11 efg	0.42 fgh	1.38 def
Maxentis®	600	0.04 bcdef	0.16 defghi	0.08 efg	0.36 fghi	1.63 cde
Opus® (GS39 only)	250	0.14 bc	0.35 abcd	0.56 ab	0.93 ab	2.63 ab
Aviator Xpro®	500	0.05 bcdef	0.42 abc	0.34 abcdef	0.72 bcde	1.75 bcde
[f]Talendo®	500	0.03 def	0.09 fghi	0.23 cdefg	0.46 efg	0.00 g
[e]Legend®	200	0.00 f	0.02 i	0.02 g	0.02 j	0.50 fg
Pr (>F)		<0.001	<0.001	<0.001	<0.001	<0.001
LSD (0.05)		0.11	0.22	0.28	0.30	0.88

[a]Tebuconazole applied alone is not registered for the control of wheat powdery mildew. It has been applied standalone in this trial for research and demonstration purposes.

[b]Opus (Epoxiconazole 125) label rate for powdery mildew is 250mL/ha, 500mL/ha is maximum label rate for wheat for control of leaf rust, stripe rust and Septoria nodorum blotch. It has been applied standalone in this trial for research and demonstration purposes.

[c]Proviso (prothioconazole) is not registered in wheat when applied stand alone. It has been applied standalone in this trial for research and demonstration purposes.

[d]Azoxystrobin (Mirador® 625) is registered in wheat only when mixed with a DMI mix partner. It has been applied standalone in this trial for research and demonstration purposes.

[e]Legend applied under APVMA permit PER93197. Permit expiry date 31 July 2024. Always check the APVMA website for permit status prior to use.

[f]Talendo is available for use under PER93216. Permit expiry date 31 July 2024. Always check the APVMA website for permit status prior to use.

Malinong product trial

The trial area was sprayed at the beginning of August with 500 mL/ha of Opus125. However, the powdery mildew infection was still active after this application of fungicide, providing inadequate control. The trial was established on the 31 August with fungicide treatments applied and the crop growth stage was GS41.

This trial was also infected with stripe rust, which infected the upper canopy and heads of the plants. Therefore, the grain yield (data not presented) was not representative of powdery mildew infection alone. This may also have interacted with some of the powdery mildew pustules, as both diseases need active green leaf area to infect.

The group 3 + 11 mixtures of DMI and azoxystrobin were the best of the registered products at the time for providing some level of control on the flag leaf. The mildewicide Legend did not provide any significant control of powdery mildew on the flag leaf. This was not consistent with observations at Bute where this product provided high levels of control.

The standalone DMI fungicides and group 3 + 11 fungicide mixes did not provide any powdery mildew control on the head compared to the control treatment. Prosaro and the three-way DMI mixture did provide some level of control on the head, indicating that some mildew control may be achievable by increasing the DMI fungicide load. Similarly, the mildewicide Legend provided high levels of head control.

Table 2. Powdery mildew pustule counts, canopy score and head score for powdery mildew (6 October, 2022). The canopy score ranges from 0-6 and represents the amount of powdery mildew present in the lower canopy, with a higher score representing higher presence of powdery mildew. All data has been log10 transformed and was analysed using ANOVA.

Products	Rate	log10 1+Flag pustules	log10 1+F-1 pustules	Canopy score	Head score
Nil	0	0.81 ab	1.13 ab	2.92 ab	4.07 ab
[a]Tebuconazole430	290	0.66 abc	1.16 ab	2.50 abc	3.65 abcd
[b]Opus125®	500	0.63 abcd	1.16 ab	2.75 ab	3.63 abcd
[c]Proviso 250EC®	250	0.25 def	0.90 b	2.92 ab	4.18 a
Prosaro®	300	0.58 abcde	1.13 ab	2.13 bcd	2.69 cdef
[b]Opus® + [a]Tebuconazole430 + [c]Proviso®	500 + 290 + 250	0.43 bcdef	0.40 c	2.08 bcd	2.58 def
[d]Mirador625®	200	0.42 bcdef	1.07 ab	3.08 ab	2.83 cdef
Veritas Opti®	340	0.69 abc	1.41 a	3.00 ab	3.60 abcd
Amistar Xtra®	800	0.16 f	0.94 b	2.00 bcd	3.07 abcdef
TazerXpert®	2000	0.32 cdef	1.16 ab	3.25 a	3.75 abcd
Maxentis®	600	0.41 cdef	1.06 ab	2.42 abcd	2.85 bcdef
Aviator Xpro®	500	0.39 cdef	0.96 b	2.50 abc	3.47 abcde
Elatus Ace®	500	0.41 cdef	1.06 ab	2.92 ab	3.83 abc
[e]Legend	200	0.48 abcdef	1.16 ab	2.25 abcd	2.07 f
	Pr(>F)	0.016	<0.001	0.0276	0.033
	LSD 0.05	0.40	0.37	1.09	1.23

[a]Tebuconazole applied alone is not registered for the control of wheat powdery mildew. It has been applied standalone in this trial for research and demonstration purposes.

[b]Opus (Epoxiconazole 125) label rate for powdery mildew is 250mL/ha, 500mL/ha is maximum label rate for wheat for control of leaf rust, stripe rust and Septoria nodorum blotch. It has been applied standalone in this trial for research and demonstration purposes.

[c]Proviso (prothioconazole) is not registered in wheat when applied stand alone. It has been applied standalone in this trial for research and demonstration purposes.

[d]Azoxystrobin (Mirador® 625) is registered in wheat only when mixed with a DMI mix partner. It has been applied standalone in this trial for research and demonstration purposes.

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Port Neill product trial

The trial area was sprayed with Prosaro at 300 mL/ha approximately three weeks before the application of the fungicide treatments in the trial, which occurred on the 5 September at GS55-59. When the fungicide treatments were applied all leaves had emerged and head emergence ranged from 50-100% emerged. The intention was to see if a head spray would provide adequate control on the wheat heads.

The first head score on the 30 September showed that the standalone DMI fungicides were providing some level of powdery mildew control on the head (Table 3). In comparisons the group 3 + 11 fungicides were providing slightly higher levels of control (Table 3). Mirador, which contains azoxystrobin as the active ingredient, provided head control at similar levels to the group 3 + 11 fungicides. Thus, the group 11 strobilurin component was providing some control of powdery mildew, which is consistent with the resistance testing (Table 4), which shows a low level of the G143A mutation was present at this site.

The second head score on the 3 November showed the standalone DMI fungicides were no longer any different to the control (Table 3). This highlights that once the control period of the fungicide ended the powdery mildew was able to infect the head. The group 3 + 11 products and Mirador were still providing some level of control (Table 3).

The relationship between WPM head infection and grain yield ($R^2 = 0.47$) indicates when the head score was less than 4 there was little difference in grain yield but declined when the head score exceeded 4, where the untreated control yielded 3.2 t/ha (Figure 1). A head score of 4 indicates approximately 40% of the head has mildew growth. It is likely another disease was also resulting in yield loss as the mildewicide Legend did not yield as well as expected in regard to the head score. This particular mildewicide is not effective at controlling other common wheat diseases such as rusts and blotches.

Table 3. Powdery mildew pustule counts and head scores for the Port Neill product trial. Pustule count data has been log10 transformed and analysed using ANOVA.

Product	Rate	log10 1+Flag pustules	log10 1+Total pustules	Head score	Head score
		30 September			3 November
Nil		0.39 a	1.13 abcdef	4.5 a	5.2 a
[a]Tebuconazole430	290	0.15 de	0.96 def	3.2 bc	4.7 ab
[b]Opus125®	500	0.37 ab	1.21 abcd	3.7 ab	4.6 ab
[c]Proviso 250EC®	250	0.36 abc	1.36 a	2.8 bcde	4.4 abc
Prosaro®	300	0.25 abcde	0.87 f	2.1 cdef	3.0 efg
[b]Opus® + [a]Tebuconazole430 + [c]Proviso®	500 + 290 + 250	0.26 abcd	1.11 abcdef	2.8 bcde	3.5 def
[d]Mirador625®	200	0.39 a	1.33 a	1.9 def	3.3 def
Veritas Opti®	340	0.34 abcd	1.17 abcde	3.0 bcde	3.4 def
Amistar Xtra®	400	0.16 cde	0.92 ef	2.2 cdef	2.8 fgh
Amistar Xtra®	800	0.22 abcde	0.98 cdef	2.2 cdef	2.4 gh
TazerXpert®	2000	0.38 a	1.23 abcd	1.8 ef	3.1 efg
Maxentis®	300	0.34 abcd	1.10 abcdef	3.0 bcd	3.4 def
Maxentis®	600	0.17 bcde	0.95 def	1.9 def	2.9 efgh
Aviator Xpro®	500	0.40 a	1.25 abc	2.4 cde	4.1 bcd
[e]Legend	200	0.29 abcd	1.00 bcdef	1.9 def	3.1 efg
	Pr(>F)	0.033	0.029	0.005	<0.001
	LSD(0.05)	0.195	0.29	1.22	0.85

[a]Tebuconazole applied alone is not registered for the control of wheat powdery mildew. It has been applied standalone in this trial for research and demonstration purposes.

[b]Opus (Epoxiconazole 125) label rate for powdery mildew is 250mL/ha, 500mL/ha is maximum label rate for wheat for control of leaf rust, stripe rust and Septoria nodorum blotch. It has been applied standalone in this trial for research and demonstration purposes.

[c]Proviso (prothioconazole) is not registered in wheat when applied stand alone. It has been applied standalone in this trial for research and demonstration purposes.

[d]Azoxystrobin (Mirador® 625) is registered in wheat only when mixed with a DMI mix partner. It has been applied standalone in this trial for research and demonstration purposes.

[e]Legend applied under APVMA permit PER93197. Permit expiry date 31 July 2024. Always check the APVMA website for permit status prior to use.

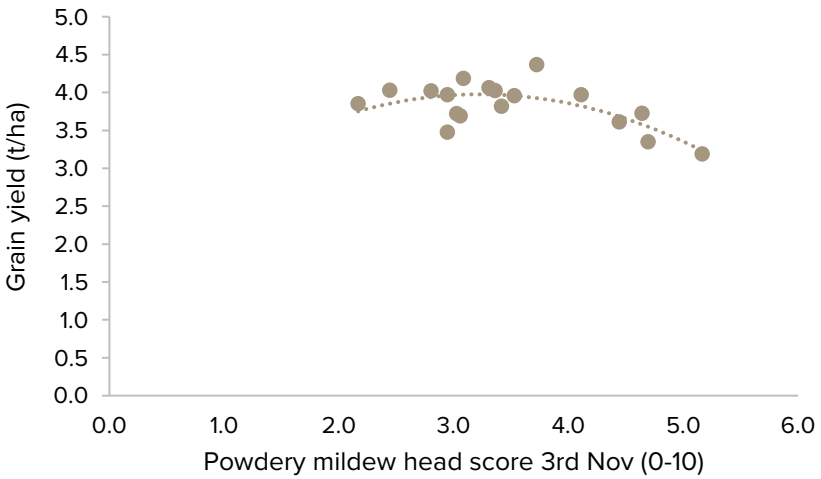

Figure 1. Wheat powdery mildew head score in Vixen wheat at Port Neill on Nov 3rd and grain yield response ($Y = -0.1987x^2 + 1.2825x + 1.906$, $R^2 = 0.47$).

Katamatite product trial

This trial was infected by powdery mildew, stripe rust and septoria. Therefore, the grain yield (data not presented) was not representative of powdery mildew infection alone. The stripe rust and septoria may have also interacted with some of the powdery mildew pustules, as these diseases need active green leaf area to infect.

At the first assessment GS57 (head almost fully emerged) powdery mildew infection on the flag leaf and flag-1 was low (<0.5%). There was no difference in powdery mildew severity for any of the products trialled at this timing.

Later in the season the GS75 (mid grain fill) assessment of disease severity showed powdery mildew infection across the trial was variable. Many products had similar or more pustules on the head compared to the control (Table 4). This indicates the group 3 (DMI) alone or in combination with group 7 (SDHI) or group 11 (Qol) fungicides were not providing any powdery mildew control on the head compared to the control. Similarly, the mildewcide Legend had pustule numbers similar to the control.

Data from the disease incidence scores at the same timing (GS75) showed Legend (20%) was the only treatments with reduced incidence of powdery mildew compared to the control (75%). All other products had powdery mildew incidence scores ranging from 48 – 88% (Table 4).

Table 4. Powdery mildew leaf area infection (11/10/22), pustule count and disease incidence (7/11/22) for fungicide products trialled at Katamatite, Vic 2022.

Product	Rate	% Leaf Area Infection GS57		No. of Pustules GS75	Disease incidence % GS75	Grain yield
		Flag	Flag-1	Head	Head	(t/ha)
Nil		0.0	0.0	2.7 d-g	75 abc	1.81 h
[a]Tebuconazole430	290	0.2	0.1	6.4 bcd	80 ab	2.64 ef
[b]Epoxiconazole800	78	0.3	0.2	8.0 ab	88 a	3.08 cde
[c]Proviso 250EC®	250	0.0	0.1	4.5 b-g	65 abc	3.09 cd
Prosaro®	300	0.1	0.1	3.0 c-g	60 abc	3.69 b
[a]Teb + [b]Epoxy800 + [c]Proviso®	290 + 78 + 250	0.2	0.5	4.4 b-g	70 abc	4.28 a
[d]Mirador®	200	0.1	0.1	5.3 b-f	78 ab	2.57 fg
Veritas®	630	0.2	0.1	7.5 ab	85 ab	2.99 def
Amistar Xtra®	800	0.0	0.1	10.6 a	85 ab	3.32 bcd
TazerXpert®	2000	0.0	0.1	6.9 abc	78 ab	3.39 bcd
Maxentis®	600	0.1	0.1	5.8 b-e	73 abc	3.7 b
Aviator Xpro®	500	0.1	0.1	5.2 b-f	85 ab	3.49 bc
Elatus Ace®	500	0.3	0.6	8.5 ab	87 a	3.35 bcd
[e]Legend®	200	0.0	0.0	0.5 g	20 e	2.17 gh
	LSD	ns	ns	4.2	28	0.44
	P val	0.342	0.557	<0.01	<0.01	<0.01

[a]Tebuconazole applied alone is not registered for the control of wheat powdery mildew. It has been applied standalone in this trial for research and demonstration purposes.

[b]Epoxiconazole 800 formulation is not registered for control of powdery mildew. It has been applied in this trial for research and demonstration purposes.

[c]Proviso (prothioconazole) is not registered in wheat when applied stand alone. It has been applied standalone in this trial for research and demonstration purposes.

[d]Azoxystrobin (Mirador® 625) is registered in wheat only when mixed with a DMI mix partner. It has been applied standalone in this trial for research and demonstration purposes.

[e]Legend applied under APVMA permit PER93197. Permit expiry date 31 July 2024. Always check the APVMA website for permit status prior to use.

Katamatite fungicide timing trial

As above this trial was also infected by powdery mildew and stripe rust. The level of stripe rust infection ranged from 10-70% leaf area for the flag and flag-1 at GS65. The grain yield data has not been presented as it is not representative of powdery mildew infection alone.

At GS65 powdery mildew (and strip rust) were assessed on the head, flag leaf and F-1. None of the plant parts showed any difference in powdery mildew pustule number compared to the control (Table 5). The average pustule number for all Prosaro applications was 7.0 on the head, 1.7 on the flag leaf and 2.6 on the F-1 leaf. The results show the dual active DMI (group 3) Prosaro was not providing any powdery mildew control as a single application of 300 ml/ha at GS31, GS33 and GS39.

The double application of 300 ml/ha at GS31 and GS39 was also not able to reduce powdery mildew compared to the control.

Table 5. Powdery mildew infection assessed as number of pustules at GS65 (21/10/2022) for fungicide timing trial at Karamatite, Vic 2022.

Treatment	Powdery Mildew (No. of Pustules) at GS65		
	Head	Flag leaf	Flag-1
Unsprayed Control	5.6	0.6	0.4
Prosaro® 300ml/ha @ GS31	4.5	2.2	2.4
Prosaro® 300 ml/ha @ GS33	10.8	2.5	4.8
Prosaro® 300 ml/ha @ GS39	7.1	1.4	1.3
Prosaro® 300 ml/ha @ GS31 + 300 ml/ha @ GS39	6.8	1.7	4.3
LSD P=0.05	ns	ns	ns
P val	0.32	0.52	0.17

Bute variety x fungicide trial

The benefit of varietal resistance in limiting WPM build up is clear in untreated plots, where WPM pustule number typically follow the variety resistance rating (Figure 2). This is consistent with findings in both 2020 and 2021 (Trengove et al 2021, Trengove et al 2022). In the Bute region, Calibre has performed better than its S rating in both 2022 and 2021 (Trengove at al 2022), being more closely aligned with Mace (MSS) and Grenade CL Plus (MS) in those seasons, respectively. WPM is a highly variable pathogen, and this deviation from expected performance based on resistance rating may reflect the local pathotype that is present. Brumby all but eliminated WPM development, highlighting its R status (Figure 2). Brumby's high level of resistance is derived from a major gene and supported by alternate minor genes that confer a lower level of resistance. Due to the high genetic variability in WPM, pathotypes may already exist that can overcome this major gene resistance and have virulence on this variety, where virulence will then depend on the performance of the minor genes. This was observed in a small isolated hot spot in Brumby in 2021 in a WPM variety trial at Bute, SA (Trengove et al 2022). Therefore, Brumby is expected to provide excellent resistance when first grown in a region. However, there is a risk it will be overcome by more virulent pathotypes if they are selected across a wide area on a repeated basis. The timeframe over which this may occur will depend on the frequency and regional extent of virulent pathotypes in the WPM population, and the area of varietal selection. This makes rotating varieties an important strategy in managing WPM.

In a SVS variety like Chief CL a robust fungicide program like strategy 2 was required to reduce WPM levels significantly, but still had more WPM than Grenade CL (MS) with no fungicide treatment. Untreated plots were severely affected by stripe rust and leaf rust late in the season, being the main influence on yield in those plots (data not shown). With the nil plots excluded due to stripe rust, within variety, there was no grain yield difference between fungicide programs, except for the variety Chief CL (Figure 3). WPM continued to develop late in the season in Chief CL resulting in a

0.67t/ha difference between Strategy 2 and complete WPM control. Responses of similar magnitude were recorded in SVS varieties in 2020 and 2021 to WPM control (Trengove et al 2021, Trengove et al 2022).

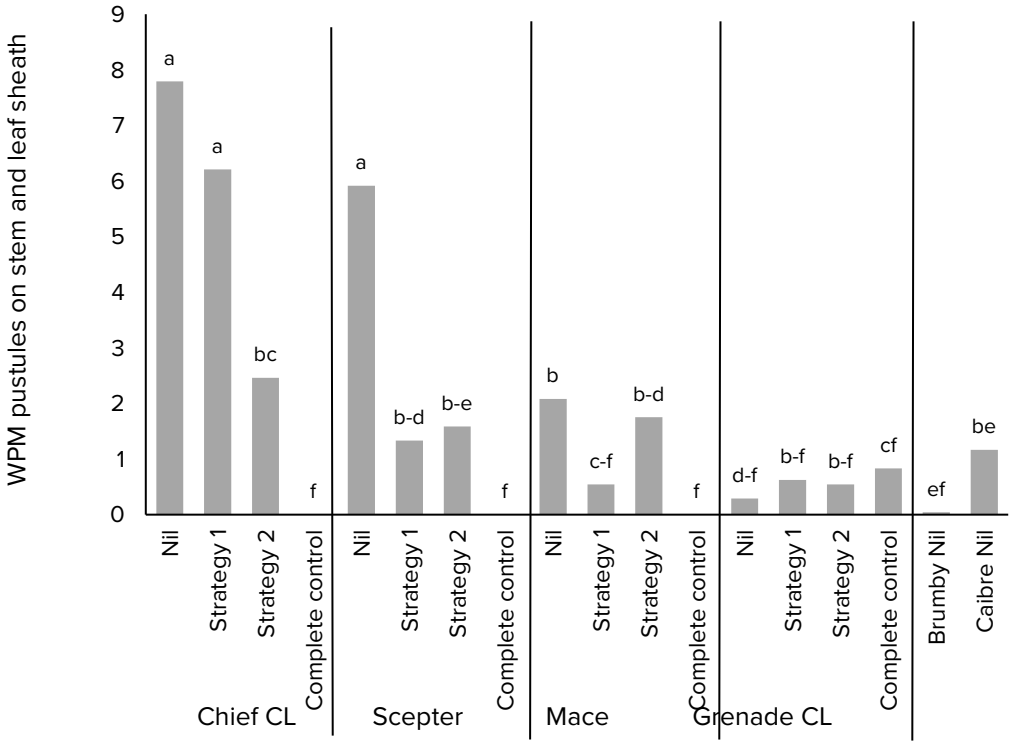

Figure 2. Variety by fungicide trial at Bute 2022. WPM pustules on the stem and leaf sheath assessed 27/9/2022 (Pr(>F) = <0.001).

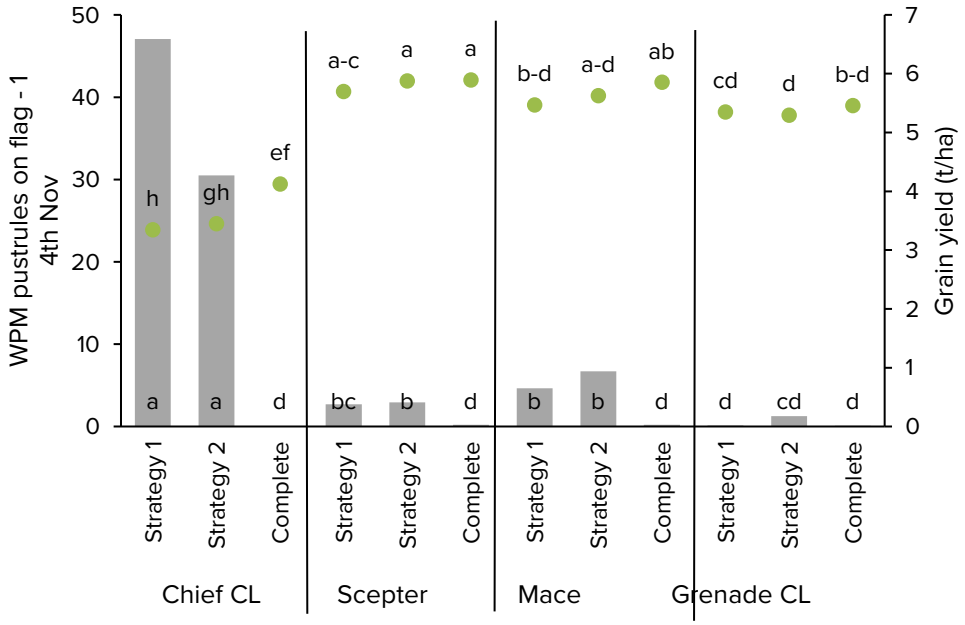

Figure 3. Variety by fungicide trial at Bute 2022. WPM pustules on the Flag minus 1, assessed 4/11/2022 (Pr(>F) = <0.001) and final grain yield (Pr(>F) = <0.001).

Bute DMI loading trial

When QoI group 11 fungicides are rendered ineffective due to resistance, and control from SDHI group 7 fungicides is typically low, the DMI group 3 fungicides have been the remaining fungicidal control option, albeit at reduced levels due to reduced sensitivity. A trial at Bute investigated the effect of applying DMI actives at full label rates, standalone or in two-way and three-way mixes, to try and optimise control. Active ingredients included tebuconazole, epoxiconazole and prothioconazole. Results indicate that increasing the load of DMI by applying active ingredients in combination provided better control than applying the actives as standalone treatments (Figure 4).

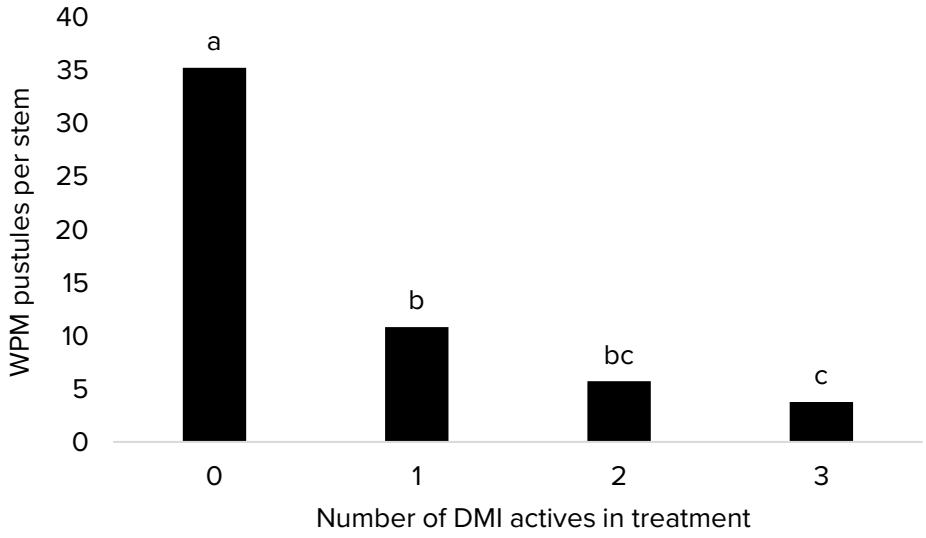

Figure 4. Total WPM pustule number assessed on the Flag minus 1, 2 and 3 and the lower stem on 29/9/2022 for Chief CL treated with group 3 DMI fungicide combinations.

Product trial resistance testing

Resistance samples were collected and tested for the frequency of the G143A mutation within the powdery mildew population. Samples were collected after the fungicide treatments had been applied in order to see any shift in the frequency as a result of the fungicide applications.

At two sites, Bute and Port Neill, the application of azoxystrobin alone resulted in a significant increase of the G143A mutation (Table 6). Therefore, the application at these sites selected for resistant populations of powdery mildew carrying this G143A mutation. The application of standalone DMI fungicides also increased the frequency of the mutation, despite the population not being exposed to a strobilurin fungicide.

At Katamatite, the standalone application of azoxystrobin did not increase the frequency of the mutation compared to the untreated control. However, the application of products containing azoxystrobin plus a DMI fungicide named Tazer Xpert and Veritas did increase the frequency of the G143A mutation compared to the untreated control. Tebuconazole applied alone also increased the

frequency of the G143A mutation. However, the mechanism of selection for this mutation is not yet understood for DMI fungicides.

Data presented here and from SAGIT project TC120 (Trengove et al 2022) indicates that where initial G143A mutation frequency is low (< 5%), such as sites Bute 2020, Bute 2022, Malinong and Port Neill, the response to selection with fungicide containing azoxystrobin is a small increase in frequency, with treated plots typically finishing with < 10% mutation frequency. However, where initial frequency is moderate (~20%), such as Bute 2021 and Katamatite, the response to selection with fungicide containing azoxystrobin is a larger increase in frequency, with treated plots typically finishing with ~50% mutation frequency. The speed of change increases with higher starting mutation frequency given continued selection pressure.

Table 6. Frequency (%) of G143A mutation, conferring resistance to QoI (strobilurin, group 11) fungicides, in response to fungicide treatments for fungicide product trials located in Bute, Katamatite, Malinong and Port Neill in 2022.

Treatment	**Bute**		**Katamatite**		**Malinong**	**Port Neill**	
Nil	1.2	c	24	c	4.2	2.0	b
[b]Epoxiconazole (3)	4.9	b	38	bc	6.8	2.2	b
[d]Azoxystrobin (11)	9.2	a	45	bc	10.6	4.1	a
Tazer Xpert (3 + 11)	5.8	ab	70	ab	12.3	1.6	b
[a]Tebuconazole (3)			53	ab			
Veritas (3 + 11)			79	a			
[c]Prothioconazole (3)	2.4	bc					
Maxentis (3 + 11)	5.3	b					
Aviator Xpro (3 + 7)	3.1	bc					
Pr (>F)	0.002		0.022		0.107	0.011	

[a]Tebuconazole applied alone is not registered for the control of wheat powdery mildew. It has been applied standalone in this trial for research and demonstration purposes.
[b]Epoxiconazole 800 formulation is not registered for control of powdery mildew. It has been applied in this trial for research and demonstration purposes.
[c]Proviso (prothioconazole) is not registered in wheat when applied stand alone. It has been applied standalone in this trial for research and demonstration purposes.
[d]Azoxystrobin (Mirador® 625) is registered in wheat only when mixed with a DMI mix partner. It has been applied standalone in this trial for research and demonstration purposes.

Powdery mildew regional surveys

Across the EP, Mallee, Upper SE regions of SA and from regions across Vic 145 samples of mildew were collected for resistance testing. Some paddock samples were not able to undergo successful DNA extraction. However, the majority were successful with 136 samples successfully processed.

In general, there is a regional difference for the frequency of the G143A mutation with the frequency increasing from west to east (Figure 5, Figure 6). The frequency is also increasing overtime within regions, demonstrated in regions that have been sampled twice over time.

For the regions sampled in 2022, Vic has the highest mutation frequency with a median of 68.2%, followed by the Upper SE, Mallee and the EP has the lowest with a median of 0.72%. Interestingly, only three paddocks from the 136 had nil mutation detected. This indicates that the mutation is present in nearly all paddocks across these regions and it would be expected that the use of fungicides containing a strobilurin will further select for populations with this mutation. However, in the short term, areas such as the EP may still obtain some useful efficacy on wheat powdery mildew from the strobilurins.

With a median of 68.2% mutation frequency in Vic, it is expected that the mutation will be nearing close to 100% in the near future with continued strobilurin use. Therefore, it will be important that fungicides with different modes of action that are able to control powdery mildew become available for broadacre use.

Fungicide use in regions such as the Mallee is typically low, and cheaper Group 3 DMI fungicides tend to be used when required with very little use of Group 11 strobilurin fungicides. Given this, it is interesting to note the presence of the G143A mutation in this region, especially given wheat powdery mildew is rarely identified as an issue in the Mallee. It may provide some insight into the geographical spread of wheat powdery mildew over time, the hypothesis being that the source of the G143A mutation is not from local selection, but from spore movement from other regions where the mutation is already present. In this case, it is hypothesised that spore movement from Vic in the east where the mutation is in high frequency to the west is advancing the spread of resistance in that direction.

Testing for the Y136F mutation, the gateway mutation conferring reduced sensitivity to the Group 3 DMI fungicides, showed the mutation had high frequency everywhere, with all tests reporting mutation frequency > 90%, with mean > 99%. Given the saturation of this mutation, it is not providing much insight into the likely performance of the Group 3 DMI fungicides, other than they are likely compromised in all regions. More work is required to understand what other mutations are involved in conferring reduced sensitivity to these fungicides and the resistance mechanisms associated with those mutations to better understand how the DMI fungicides are best used going forward.

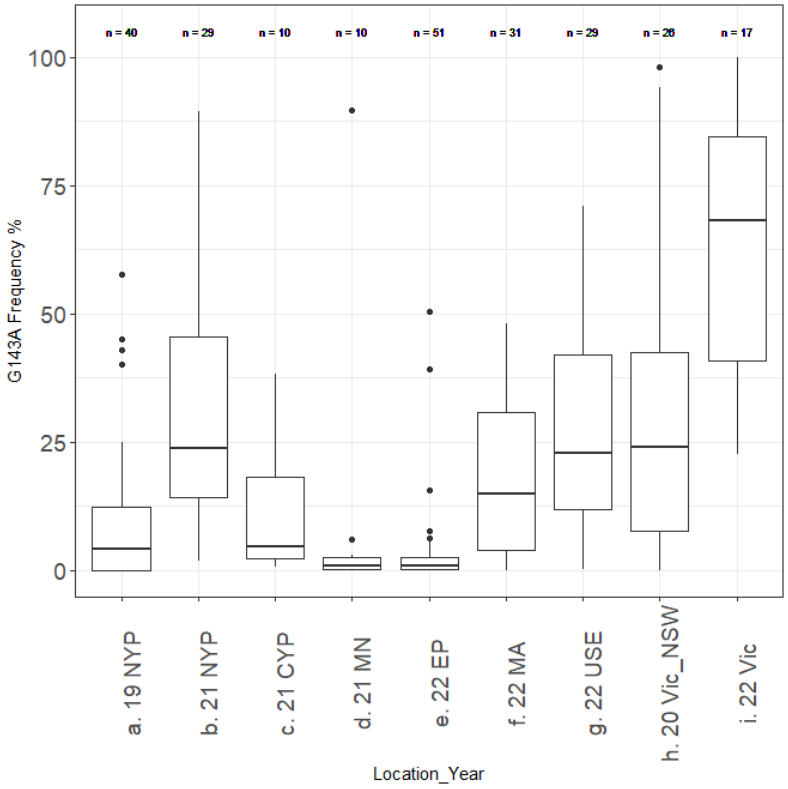

Figure 5. Frequency (%) of G143A mutation, conferring resistance to QoI (strobilurin, group 11) fungicides, for the regional paddock samples from years 2019, 2020, 2021 and 2022. NYP = Northern Yorke Peninsula SA, CYP = Central Yorke Peninsula SA, MN = Mid North SA, EP = Eyre Peninsula SA, MA = Mallee SA, USE = Upper South East SA, Vic = NE & SW Victoria.

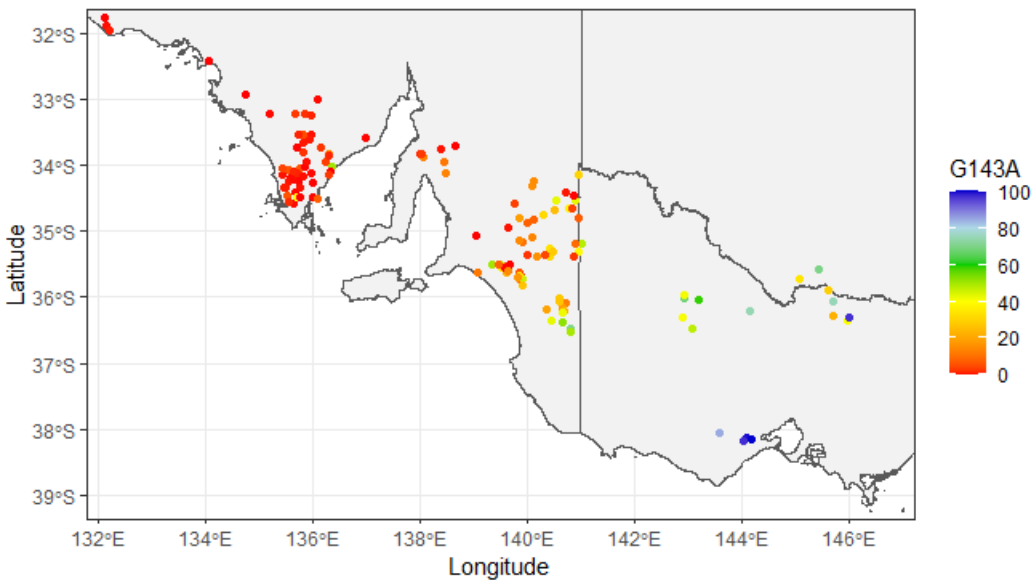

Figure 6. Frequency (%) of G143A mutation, conferring resistance to QoI (strobilurin, group 11) fungicides, for 145 samples from south eastern Australia collected in Spring, 2022.

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