Office Use Only	
Project Code	
Project Type	

FINAL REPORT 2022

Applicants must read the *SAGIT Project Funding Guidelines* prior to completing this form. These guidelines can be downloaded from www.sagit.com.au

Final reports must be submitted by email to admin@sagit.com.au as a Microsoft Word document in the format shown **within two months** after the completion of the Project Term.

PROJECT CODE	TC120
PROJECT TITLE	(10 words maximum)
Management of fungicide resistant wheat powdery mildew	

PROJECT DURATION *These dates **must** be the same as those stated in the Funding Agreement.*	
Project start date	**1/04/2020**
Project end date	**30/06/2022**

PROJECT SUPERVISOR CONTACT DETAILS *(responsible for the overall project)*		
Title:	**First Name:**	**Surname:**
Mr	Sam	Trengove
Organisation:	**Trengove Consulting Trust**	

ADMINISTRATION CONTACT DETAILS *(responsible for all administrative matters relating to project)*		
Title:	**First Name:**	**Surname:**
Mr	Sam	Trengove
Organisation:	**Trengove Consulting Trust**	

PROJECT REPORT: *Please provide a clear description for each of the following:*

Executive Summary (200 words maximum)

A few paragraphs covering what was discovered, written in a manner that is easily understood and relevant to SA growers. A number of key dot points should be included which can be used in SAGIT communication programs.

In 2019 wheat powdery mildew with reduced sensitivity to group 3 fungicides and resistance to group 11 fungicides was identified on the Yorke Peninsula. A survey in 2021 as part of this project has confirmed that the level of resistance or reduced sensitivity has increased over the last three years highlighting the importance of the issue.

Despite the presence of pathotypes with reduced sensitivity to group 3 fungicides and resistance to group 11 fungicides, these modes of action remain the dominant fungicides in use in the area. The trial program has highlighted that these fungicides are still able to provide useful control and identified differences in efficacy between the individual group 3 DMI fungicides. It was thought that new generation group 7 SDHI fungicides would fill in the gap when the other groups become less effective. However, trials have shown that the SDHI component does not provide useful additional control above that of the DMI mix partner in the commercial products.

Four alternative modes of action assessed in the fungicide product trials showed superior levels of control compared with currently registered products. These require further development to achieve registration in wheat in Australia.

Varietal resistance was shown to significantly reduce powdery mildew incidence and has much greater effect on mildew than registered group 3, 7 and 11 fungicides. For example, changing from a SVS variety to MSS reduced mildew incidence more than two applications of registered fungicide. However, the dominant wheats grown currently are typically rated SVS, with few elite yielding varieties with better resistance ratings.

Pre-emergent fungicides reduced mildew incidence early in the season in 2020, when mildew was developing early in the season, with flutriafol the most effective product. They did not have any effect in 2021, when mildew development did not occur until late stem elongation.

Project objectives

A concise statement of the aims of the project in outcome terms should be provided.

Considering the development of fungicide resistance in Wheat Powdery Mildew (Blumeria graminis f.sp) in the northern YP region, the aim of this project is to improve management of these resistant pathotypes. This will be achieved through a multi-faceted trials program assessing best management practice including fungicide products, application timing and varietal resistance interactions. Results will be delivered to growers to increase grower adoption of best practice management.

Overall Performance

A concise statement indicating the extent to which the project objectives were achieved, a list of personnel who participated in the Research Project including co-operators, and any difficulties encountered and the reasons for these difficulties.

The trial program was able to successfully demonstrate the benefits of varietal resistance, pre-emergent fungicide application and identify the most suitable post emergent fungicide products for control of wheat powdery mildew with fungicide resistance to strobilurin’s and reduced sensitivity to DMI’s. Trial sites were established successfully near Bute in both 2020 and 2021, with sufficient disease pressure to assess treatment effects. A survey of 50 wheat paddocks across the YP and Mid North containing mildew was completed successfully in Sept 2021, providing data on the frequency of mutations conferring reduced sensitivity to group 3 and resistance to group 11 fungicides.

The project has generated significant interest from industry with results being presented at many events including the GRDC advisor updates in 2021 and 2022 and GRDC grower updates. GRDC has since provided additional funding for two years of trials and extension of results generated in the SAGIT funded program.

Personnel who participated in the project –
Trengove Consulting - Sam Trengove, Stuart Sherriff, Jordan Bruce, Joe Simpson, Nathan Jones, Kurt Ollwitz
CCDM – Fran Lopez Ruiz, Kejal Dodhia
SARDI – Tara Garrard, Hugh Wallwork
Survey participants including agronomists and growers from the Mid North and Yorke Peninsula

COVID 19 restricted Fran Lopez Ruiz and another member from CCDM to travel from Perth to SA.

Low disease levels in 2021 due to weather conditions meant that yield responses to disease control were limited.

KEY PERFORMANCE INDICATORS (KPI)

*Please indicate whether KPIs were achieved. The KPIs **must** be the same as those stated in the Application for Funding and a brief explanation provided as to how they were achieved or why they were not achieved.*

KPI	Achieved	If not achieved, please state reason.
Identify trial site location and confirm presence of fungicide resistant Wheat Powdery Mildew. Confirm trial protocols	Yes ☒ No ☐	
Establish 5 replicated plot trials including- 1. Variety (3-4 with differing resistance status) x fungicide treatment (3-4) = 9-16 treatments 2. Post em fungicide efficacy trial, single timing = approx. 10-12 treatments 3. In furrow fungicide and seed treatment efficacy trial x +/- post em fungicide = approx. 10-14 treatments 4. Fungicide timing trial, 1 or 2 (anticipated) high efficacy products applied a. GS14 b. GS31 c. GS49 d. GS14 + GS31 e. GS14 + GS49 f. GS31 + GS49 g. GS14 + GS31 + GS49 h. Nil Best bet product by timing trials, testing combinations of products used in sequence, incl seed treatments = approx. 10 treatments	Yes ☒ No ☐	
Complete in season fungicide treatments and monitoring- • early season assessments of crop establishment, • post emergent fungicide treatments,	Yes ☒ No ☐	

• disease assessments trial harvest and quality		
Trial data analysis and reporting	Yes ☒ No ☐	
Establish 5 replicated plot trials including- 1. Variety (3-4 with differing resistance status) x fungicide treatment (3-4) = 9-16 treatments 2. Post em fungicide efficacy trial, single timing = approx. 10-12 treatments 3. In furrow fungicide and seed treatment efficacy trial x +/- post em fungicide = approx. 10-14 treatments 4. Fungicide timing trial, 1 or 2 (anticipated) high efficacy products applied a. GS14 b. GS31 c. GS49 d. GS14 + GS31 e. GS14 + GS49 f. GS31 + GS49 g. GS14 + GS31 + GS49 h. Nil 5. Best bet product by timing trials, testing combinations of products used in sequence, incl seed treatments = approx. 10 treatments	Yes ☒ No ☐	
Complete in season fungicide treatments and monitoring- • early season assessments of crop establishment, • post emergent fungicide treatments, • disease assessments trial harvest and quality	Yes ☒ No ☐	
Collect 40 samples from YP and 10 from Mid North and Adelaide plains of WPM and submit to CCDM for assessment of disease resistance.	Yes ☒ No ☐	
Collation of all trial results, resistance results and reporting	Yes ☒ No ☐	

TECHNICAL INFORMATION (Not to exceed **three** pages)

Provide sufficient data and short clear statements of outcomes.

Varietal resistance to wheat powdery mildew

Wheat varietal resistance is an important part of powdery mildew management. A total of seven varieties were included in this trial in 2020 and 2021 with a range of resistance levels to determine the benefit of varietal resistance and its interaction with fungicide use. The varieties included Grenade CL Plus^A (MS, 2021), Kord CL Plus^A (MS, 2020), Mace^A (MSS), Scepter^A (SVS) and Chief CL Plus^A (SVS). Scepter^A and Chief CL Plus^A were both chosen as they have commonly been grown in the area and field observations indicate that Chief CL Plus^A may be more susceptible than Scepter^A, despite both being rated SVS. Two new lines, Calibre^A (RAC2721) rated S and Brumby^A (IGW6683) with provisional rating of R were also included in 2021, although no fungicide treatments were applied to these two varieties. This was to test their ratings against the WPM population at this site and known commercial cultivars.

Variety responses to powdery mildew were similar in 2020 and 2021 although infection was generally more severe in 2020. Powdery mildew build-up occurred late in the 2021 winter, however, varietal resistance played an important role in the level of infection in the crop canopy (Figure 2). For the four main varieties, improving the rating from SVS (Chief CL Plus[A]) to MS (Grenade CL Plus[A]) reduced the number of pustules on the leaf flag -1 (F -1) by 96%. Calibre[A] incurred less WPM infection than expected given its resistance rating, with results at this site placing it between the MS and R varieties, rather than its current S rating. However, WPM has large genetic diversity, with many different pathotypes likely to be encountered across the cropping regions, meaning that varietal resistances can perform differently depending on which pathotype is present. In accordance with its R rating, Brumby[A] performed well at resisting WPM infection. No WPM infection was recorded on this variety at all, except in one small 4m^2 hotspot in the 3rd replicate of the trial. In this hotspot infection was observed with average canopy score of 1.5, but no infection on the F -1 on September 22. Tara Garrard and Hugh Wallwork (SARDI) collected a sample of this isolate for culturing and testing in the glasshouse, with their results indicating that where this pathotype is dominant Brumby is likely to perform more like an SVS, rather than R. This example highlights the scale of genetic diversity that can be encountered in the field.

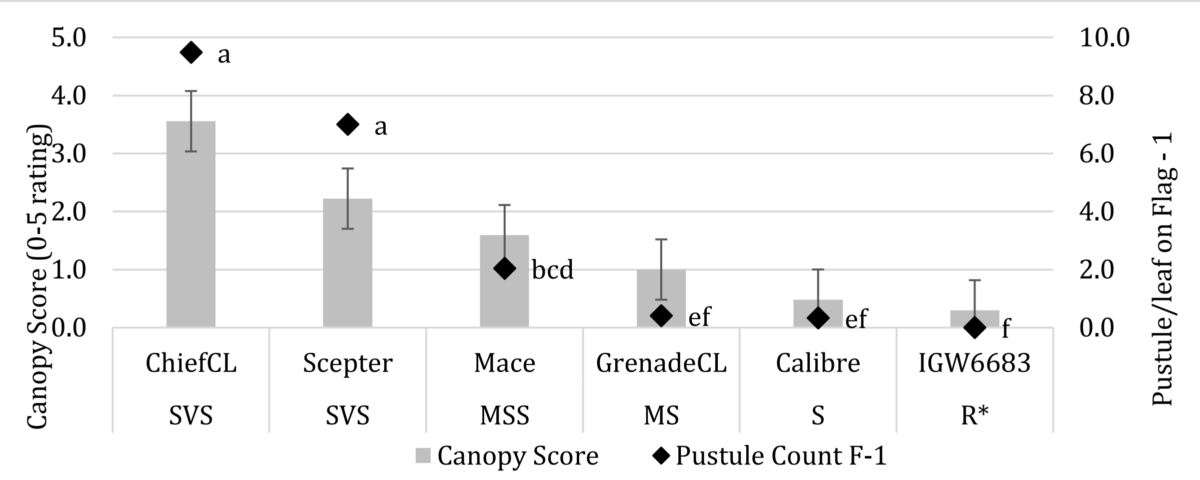

Figure 2. Powdery mildew canopy score (0 = no powdery mildew, 5 = severe infection) and pustule count on F-1 (number of pustules on the leaf flag – 1) for the nil fungicide treatments in the variety * fungicide trial at Bute 22/9/2021. Letters denote significant differences between pustule count (Pr(>F) = <0.001) and error bars show LSD 0.05 for canopy score.

Varietal resistance has a significant effect on fungicide performance and their importance. In the variety Chief CL Plus[A], which was shown to have the highest level of susceptibility to WPM, a one spray strategy (Amistar Xtra 800mL/ha applied at GS39) did not significantly reduce the canopy score and the district practice treatment (Epoxiconazole125 500mL/ha# applied at GS32 followed by Amistar Xtra 800mL/ha applied at GS39) reduced the infection score to 1.9 (low-moderate) (Figure 3). Scepter[A] was less susceptible to this WPM population, with the single spray strategy reducing the canopy score of infection from 2.2 (low-moderate) to 1.3 (low). This was equivalent to the district practice treatment. In comparison, the variety tested with the best currently available resistance, Grenade CL Plus[A], had a lower canopy score in the nil fungicide treatment than the other varieties that were treated with a two-fungicide strategy, as did Calibre[A] and Brumby[A].
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The level of powdery mildew in the canopy was lower than the previous year, but some effect on grain yield was still apparent (Figure 4). Grain yields for Chief CL Plus[A], Scepter[A] and Mace[A] increased by 0.6-0.7 t/ha (11-13%) through the application of fungicide whereas in the more resistant variety Grenade CL Plus[A] there was no yield response. In 2020 the yield response in Chief CL Plus[A] was also 0.7t/ha (17%), but at a lower yielding site this was a larger relative increase.

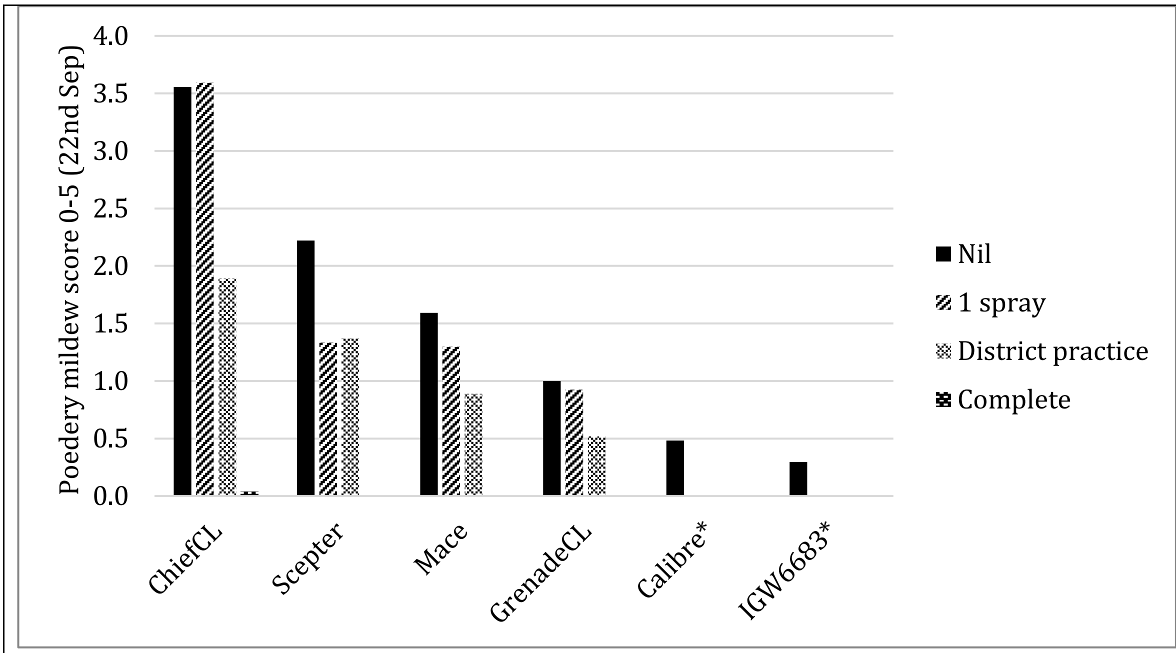

Figure 3. Powdery mildew canopy score (0 = no powdery mildew, 5 = severe infection) in the variety * fungicide trial at Bute 22/9/2021 (Pr(>F) = 0.001, LSD 0.05 = 0.2). Nil = no fungicide, 1 spray = Amistar Xtra 800mL/ha applied at GS39, District practice = Epoxiconaxole125 500mL/ha# applied at GS32 + Amistar Xtra 800mL/ha applied at GS39, Complete = complete control. *Calibre and IGW6683 only received Nil treatment.

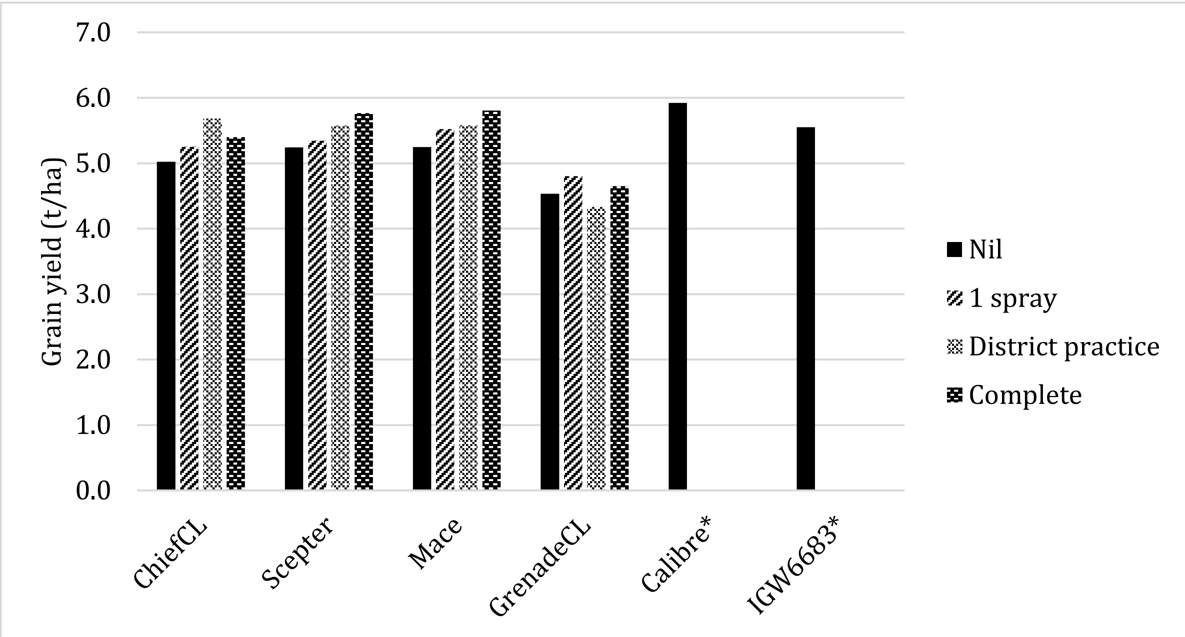

Figure 4. Grain yield (t/ha) for the variety * fungicide trial at Bute 2021 (Pr(>F) = 0.001, LSD 0.05 = 0.51). Nil = no fungicide, 1 spray = Amistar Xtra 800mL/ha applied at GS39, District practice = Epoxiconaxole125 500mL/ha# applied at GS32 followed by Amistar Xtra 800mL/ha applied at GS39, Complete = complete control. *Calibre and IGW6683 only received Nil treatment.

Wheat powdery mildew fungicide resistance and post-emergent fungicide performance

Wheat powdery mildew fungicide resistance was confirmed on the northern Yorke Peninsula (NYP) in 2019. The frequency of the gateway mutation at Cyp51, which is used as a resistance marker due to its association with the presence of other mutations conferring reduced sensitivity to the Group 3 DMI fungicides, ranged from 2.2 to 99.5%. The group 11 (QoI) resistance mutation was as high as 57.5% in one paddock, but more than half of tested paddocks had no QoI resistance mutation (Table 1). A second survey was conducted in 2021 and the geographical spread of mutations associated with fungicide resistance on the central Yorke Peninsula (CYP), NYP and the mid north (MN) was assessed (Figure 5). For the NYP, CYP and MN the average level of the QoI resistance mutation was 32.6, 11.9 and 10.2% respectively, with a large range in frequencies in each of the areas (Table

1). It shows that there has been a significant increase in the frequency of this mutation on the NYP since the first survey in 2019. All paddocks tested in this region now record at least a low level of the resistance mutation, and the median has increased from 0 to 19%. This is consistent with QoI resistance development in other pathogens, where once resistant individuals have been selected, resistance development occurs quickly with ongoing QoI fungicide selection pressure. The analysis of the NYP samples revealed a higher frequency of the resistance mutation compared with nearby regions, and this is consistent with anecdotal observations from agronomists, where WPM control has been more difficult in this region. Frequencies of the QoI resistance mutation in 2021 on the CYP and MN is more comparable with the levels on the NYP in 2019. These results demonstrate where the CYP and MN might be in two years' time, with ongoing QoI fungicide use. There is a large amount of variability within each region, as shown by the range from minimum to maximum between paddocks, this may be explained by fungicide applications an fungicide history within individual paddocks.

Table 1. Average, median, minimum and maximum frequency of the G143A mutation in the wheat powdery mildew strobilurin (QoI) target Cytb tested using ddPCR for the samples collected from paddocks across the central Yorke Peninsula (CYP), northern Yorke Peninsula (NYP) and the mid north of SA (MN).

Area	# of samples	Average frequency (%)	Median Frequency (%)	Minimum frequency (%)	Maximum frequency (%)
NYP 2019	17	13	0	0.0	57.5
NYP 2021	30	32.6	19.2	1.7	89.5
CYP 2021	11	11.9	4.6	0.6	38.3
MN 2021	10	10.2	0.8	0.0	89.7

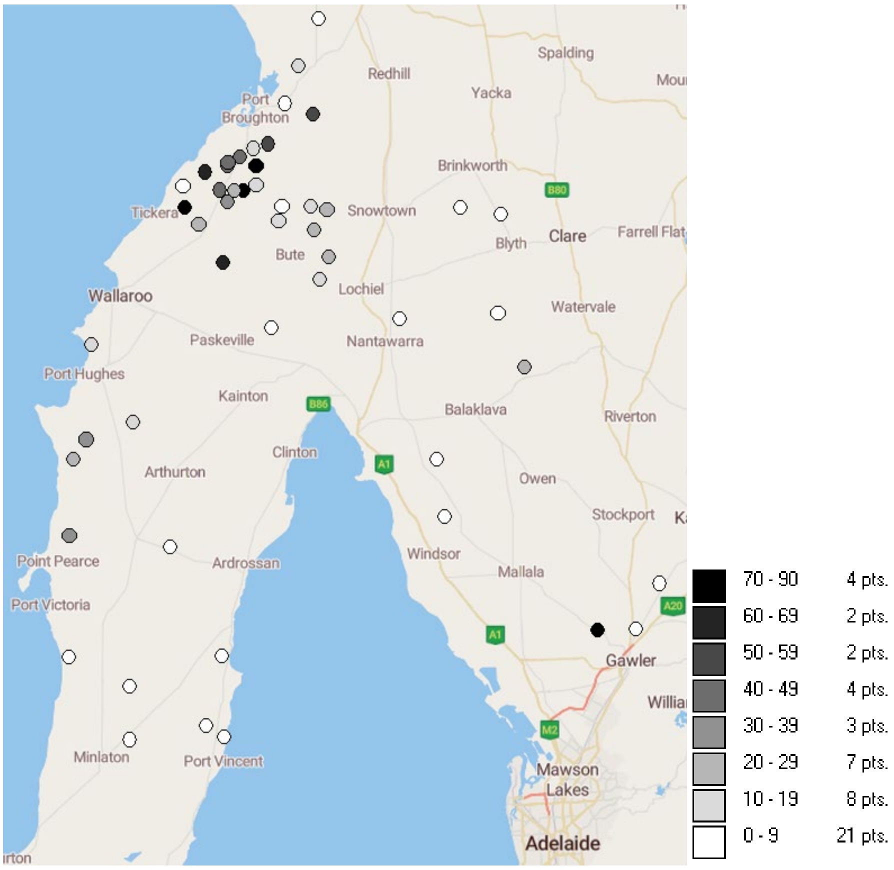

Figure 5. Sample locations and frequency of the G143A mutation in the wheat powdery mildew strobilurin (QoI) target Cytb tested using ddPCR for the samples collected for paddocks across the central Yorke Peninsula, northern Yorke Peninsula and the mid north of SA in 2021, number of points in the legend show number of paddocks sampled in that range.

At the 2020 trial site SE of Bute there was a low level of the QoI resistance mutation, in the untreated control with 0.5% frequency. The application of Tazer Xpert, containing QoI fungicide azoxystrobin increased the frequency of the resistance mutation to 9.2% (data not shown). However, the effect of QoI application was inconsistent at this site in 2020, with other QoI treatments having no effect on increasing resistance frequency. In contrast, at the 2021 trial site north of Bute, the untreated had 19% QoI resistance frequency (Figure 6). The application of any fungicide treatment containing a group 11 QoI increased the resistance mutation frequency significantly, to an average of 48.5%. As expected, the application of group 3 DMI and group 7 SDHI fungicides did not affect the frequency of the QoI resistance mutation.

At the 2021 trial site, the application of fungicide did not have any impact on the frequency of the gateway mutation at the DMI target Cyp51. The frequency averaged across four selected treatments, including untreated, was 87%. In comparison the average frequency at the 2020 trial site was 70%. However, due to the limitation with this target, it is not possible to say which of these samples had isolates which may have caused any field failures, as only the gateway mutation is detected, not the mutation(s) actually conferring resistance.

The presence of fungicide resistance and reduced sensitivity has a significant impact on fungicide performance. In 2020, the group 3 fungicides ranged in performance from 15 – 73% control of WPM on the leaf, F-1 (Figure 7). The straight group 11 active ingredient, azoxystrobin, produced 64% control and the group 3 + 11 mixtures ranged from 73 – 84% control. By contrast, the relative performance of these fungicides tended to be poorer in 2021, particularly for the straight azoxystrobin treatment and treatments containing azoxystrobin as a mix partner. The straight group 3 DMI control ranged from 0 – 62%, and control from the group 3 + 11 mixtures ranged 41 – 67%. Control from the straight azoxystrobin treatment was only 15% in 2021. The general decline in performance from treatments containing the group 11 azoxystrobin can be attributed, at least partly, to the increasing frequency of the QoI resistance mutation at this trial site. It is likely that the ongoing use of this fungicide group will continue to increase the resistance frequency in the future.

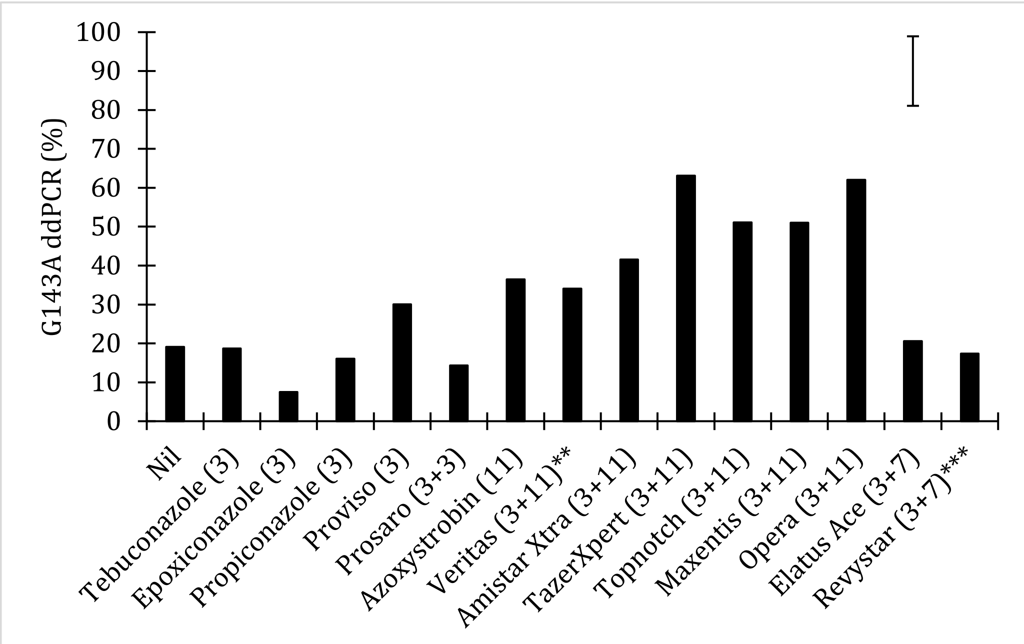

Figure 6. Frequency of the G143A mutation in the wheat powdery mildew Cytb (strobilurin resistance) for a subset of samples collected from the 2021 fungicide product trial using the NAP buffer method. Bar shows LSD 0.05.

** Veritas is not currently registered for the control of Powdery Mildew in wheat. It has been included at the maximum label rate for other wheat foliar disease control.

*** Revystar is not currently commercially available, registration is pending

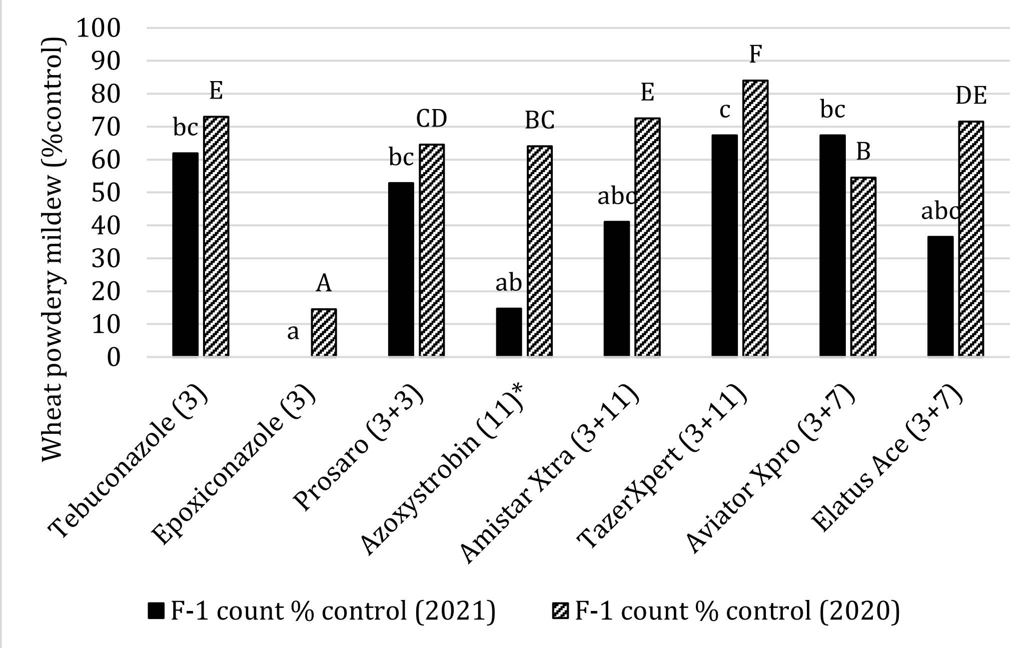

Figure 7. Flag-1 pustule percent control for the post emergent product trial in years 2020 and 2021 at Bute. Statistics performed using log10(1+count) transformation, lower and upper letters represent significant differences for the 2021 and 2020 data, respectively.

Fungicide resistant mutations in WPM are widespread in SA, it is therefore important to make assessments of individual fungicides in context of the resistance status at the site. However, it is also important to consider that powdery mildew is a population, and the population can shift with use of different fungicides.

At this site in 2021, of the group 3 fungicides, epoxiconazole had the poorest efficacy, not being significantly better than the untreated control for pustule number on the leaf, flag -1 (F -1) (Figure 8). This is a similar result to 2020. Of the other group 3 fungicides, tebuconazole, propiconazole, and Proviso (prothioconazole) performed similarly to each other, reducing the canopy score to an average of 2.0. The fungicide Prosaro, contains a full label rate of prothioconazole and half rate of tebuconazole, the effect of this is additive with Prosaro producing the best control of the straight group 3 treatments, with a canopy score of 0.9, although this difference did not occur in the F -1 pustule number (Figure 8).

Of the group 3 + 11 mixtures, Veritas, Amistar Xtra, Tazer Xpert, Topnotch and Opera all performed similarly with an average canopy score of 2.1, which is no better than the straight group 3 DMI performance. Opera contains the group 11 fungicide pyraclostrobin applied at 85g ai /ha at full label rate. Veritas delivers 76 gai/ha azoxystrobin when applied at 1 L/ha. The other three have azoxystrobin applied between 120 and 160g ai/ha at full label rate. This indicates that pyraclostrobin is performing in a similar manner to azoxystrobin. The fungicide Maxentis (prothioconazole + azoxystrobin) had the greatest efficacy in terms of canopy score, but it is not clear why this occurred as prothioconazole did not perform better than the other group 3 fungicides.

The next generation of fungicides registered for use in Australian wheat are the group 7 (SDHI) active ingredients, these are typically co-formulated with a group 3 DMI. In both years, 2020 and 2021, these fungicides performed in a similar manner to the straight group 3 fungicides. In both years a straight group 7 active ingredient (not registered) was included in the trials and performed poorly, i.e., fluxapyroxad (Figure 8). This indicates that the group 3 mix partner in these new fungicides is providing the control of powdery mildew and further development of group 3 reduced sensitivity will reduce the efficacy of these products also.

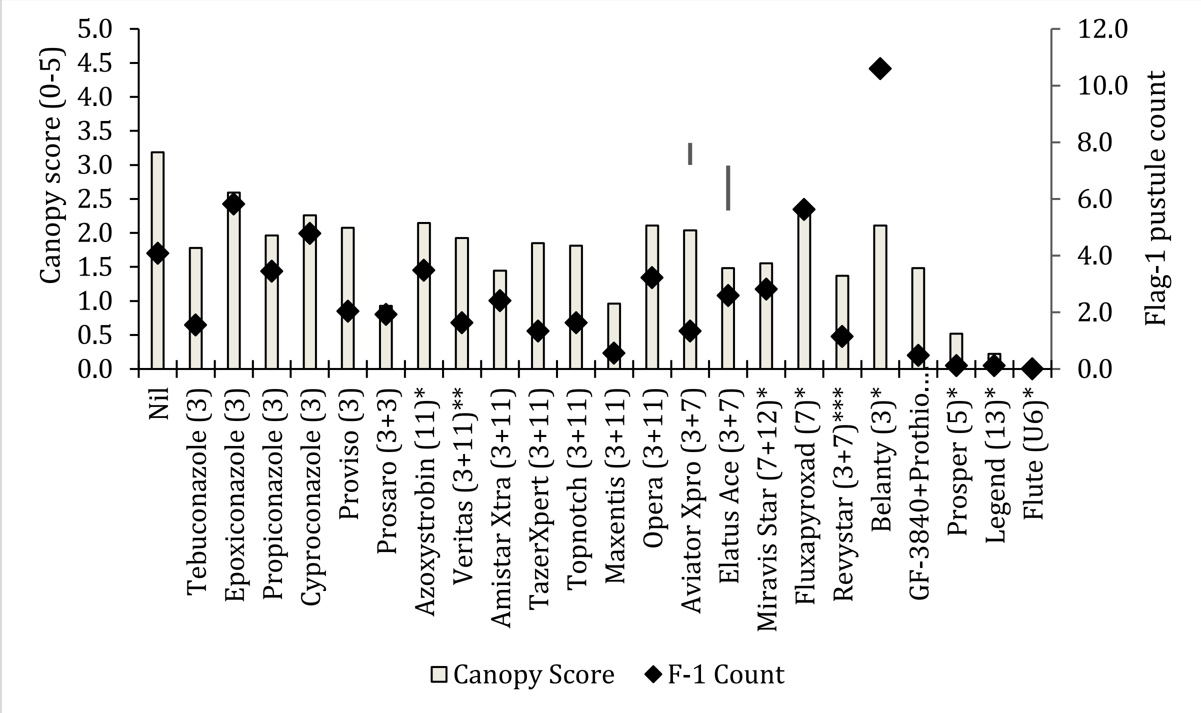

Figure 8. Canopy score and F-1 pustule count for the post-emergent fungicide trial at Bute 2021 assessed on Sept 22. Pr(>F) = <0.001 for both and LSD (0.05) = 0.3 (left) and 1.6 (right) for the canopy score and F-1 pustule count, respectively.

* These products and active ingredients (not registered) were included for research purposes in the post-emergent fungicide trial to evaluate the individual fungicide group performance.

** Veritas is not currently registered for the control of Powdery Mildew in wheat. It has been included at the maximum label rate for other wheat foliar disease control.

*** These products are not currently commercially available, registration is pending.

Fungicide active ingredients from six alternative mode of action groups were also tested in 2020 and a subset of these were included again in 2021. These were from group 5, 12, 13, M5, U6 and U8, with actives from groups 5, 13 U6 and U8 showing high levels of mildew control. The performance of the mildewcides provided a step change in mildew control compared with currently registered products, demonstrated in 2021 by Flute, Legend and Prosper (Figure 8).

A fungicide sequencing trial was included in both years, assessing whether the order during the growing season that different fungicide groups are deployed is important, including pre and post-emergent use patterns. In short, the sequence of fungicide use of registered group 3, 7 and 11 fungicides did not have a significant effect on mildew development. However, where the sequence included a group 5, 13 or U6 fungicide, mildew levels were significantly lower.

Fungicide timing

The importance of fungicide timing was assessed in both seasons with fungicide (Elatus Ace in 2020, Amistar Xtra in 2021) applied at GS14, 32, 39 and 65 and combinations of these timings. The best strategy for fungicide timing was not clear cut and may depend on season. In 2020 mildew was observed developing early in the season with first pustules observed at GS14 when first timings were applied. Early assessments at GS45 indicate that two sprays at GS14 and 32 were necessary to minimise mildew infection at that time, compared with a single spray at either timing (Table 2). Two spray treatments tended to have less mildew on the F-2 at GS65 however, treatments that combined applications at GS14 and 45 had the highest yields. By contrast, in 2021 mildew development did not occur until later in stem elongation. As a result, the GS14 application provided no mildew control benefit as it was too early (Table 3). The GS39 application was the most effective at reducing mildew infection on F-1, but the two-application strategy at GS32 and GS39 was the most effective at reducing infection throughout the canopy. No yield responses were observed in 2021 (data not shown).

Table 2: powdery mildew and grain yield response to Elatus Ace applied at 500ml/ha at four growth stage combinations in Scepter wheat, 2020.

Timing	Total stem pustule number (GS45, 13/8/2020)		F-2 Pustule number (GS65, 11/9/2020)		Grain yield (t/ha)	
Nil	46	a	10	a	3.74	c
14	25	b	11	a	3.78	c
32	25	b	9	b	3.89	c
45			17	a	3.99	bc
14 + 32	17	c	5	b	3.96	bc
14 + 45			12	a	4.28	a
32 + 45			6	b	3.92	bc
32 + 65			5	b	3.92	bc
14 + 32 + 45			5	b	4.19	ab
14 + 32 + 45 + 65			6	b	4.20	ab
Pr(>F)	*<0.001*		*<0.001*		*0.010*	
LSD (0.05)					*0.28*	

Table 3: powdery mildew assessment at GS65 (29/9/2021) in response to Amistar Xtra applied at 800ml/ha at four growth stage combinations in Chief CL Plus wheat, 2021.

Timing (Zadoks GS)	PM Canopy score		Flag-1 pustule count	F-1 transformed Log10 (1+Count)	
Nil	4.0	a	35	1.47	a
14	4.0	a	35	1.36	ab
32	2.8	b	15	1.04	cde
39	3.3	ab	10	0.82	def
14 + 32	2.8	b	21	1.20	abc
14 + 39	3.0	b	7	0.63	f
32 + 39	1.7	c	8	0.71	f
32 + 65	3.2	b	17	1.11	bcd
14 + 32 + 39	1.7	c	8	0.64	f
14 + 32 + 39 + 65	1.0	c	7	0.74	ef
Pr(>F)	<0.001		-	<0.001	
LSD (0.05)	0.8			0.30	

A trial assessing fungicide rate and spray water volume were conducted in 2021, but treatment differences were not significant.

GRDC update papers for 2021 and 2022 are attached as appendices for further detail.

CONCLUSIONS REACHED &/OR DISCOVERIES MADE (Not to exceed one page)

Please provide concise statement of any conclusions reached &/or discoveries made.

Key findings from the field survey of resistance mutations within the WPM population include

- Wheat powdery mildew resistance mutation frequency increased from 2019 to 2021. On the northern YP QoI resistance mutation increased from median frequency of 4% in 2019 to 19% in 2021.
- Group 11 QoI resistance mutation has been detected at lower levels in the central Yorke Peninsula and Mid North regions in 2021 compared with northern YP. Therefore, the northern YP is currently a hotspot for QoI resistance development for regions surveyed to date.
- Mutation at Cyp51 F136 is a gateway mutation that infers reduced sensitivity to the group 3 DMI fungicides is likely to be present. In 2021 all regions surveyed had high (>98%) median frequency of the gateway mutation, increasing from 2019 where the median mutation frequency was 59% and 38% in the northern YP and Mid North, respectively.

Key findings from the fungicide efficacy product trials include

- All registered fungicides in wheat in Australia are derived from three fungicide groups, group 3 DMI, group 7 SDHI and group 11 QoI. With resistance and reduced sensitivity to group 11 and group 3 developing in many paddocks, and poor wheat powdery mildew efficacy from group 7 fungicides, there are no registered fungicides that provide high levels of control.
- In the fungicide product trial in 2021, the application of group 11 QoI fungicides increased the frequency of resistance mutation from 19% in the untreated control to an average of 48.5% across group 11 QoI treatments. This highlights the rapid increase in resistance and decline in efficacy expected with repeated use of this mode of action. In 2020 where the site had low (0.5%) mutation frequency, the effect of group 11 QoI treatments had limited effect on mutation frequency.
- The presence of group 11 resistance mutations in 2021 meant that the performance of group 3 + 11 fungicide mixtures was generally not any better than the straight group 3 (DMI triazole) fungicides, whereas in 2020 the group 11 fungicides did improve control where resistance was lower.
- Group 7 SDHI post emergent fungicides had low efficacy against powdery mildew in both seasons and rely heavily on the DMI mix partner for powdery mildew control.
- High frequency of the Cyp51 F136 mutation has commonly been encountered at trial sites, yet the group 3 DMI fungicides are currently providing the best fungicidal control, albeit incomplete control. The loss of sensitivity to the group 3 DMI fungicides typically occurs more slowly than the group 11 QoI. Therefore, the group 3 DMI fungicides are likely to provide an incomplete but predictable level of control.
- Alternative mode of action fungicides did provide high levels of powdery mildew control in both seasons. These fungicides do not currently have registration in wheat in Australia. Products such as Flute (cyflufenamid, group U6), Vivando (metrafenone, group U8), Legend (quinoxyfen, group 13) and Prosper (spiroxamine, group 5) provided high levels of control.
- Pre-emergent fungicides reduced powdery mildew infection early in 2020, when infection occurred early in the growing season (GS14). They had no effect in 2021 when mildew development occurred later in the growing season (GS39). Flutriafol was the most efficacious product in this scenario. Despite having limited effect post emergent, the SDHI product Systiva applied as a seed dressing also provided some mildew control in 2020.

Key findings from the variety trial include

- Varietal resistance plays an important role in managing wheat powdery mildew. Varieties rated MS had less powdery mildew infection in the untreated than Chief CL Plus[A] and Scepter[A] (SVS) treated with commercial fungicide strategy.

- Fungicide application to Chief CL Plus[A] increased grain yield by 0.7-0.8 t/ha (13-17%) in both seasons, whereas in the MS varieties there was no yield response to fungicide.
- New varieties Calibre (AGT) and Brumby (IGW6683, Intergrain) showed improved resistance to powdery mildew than other varieties tested. However, in one small 4m^2 hotspot infection was observed in Brumby. SARDI follow up testing indicates that where this pathotype is dominant Brumby is likely to perform more like an SVS, rather than R. This example highlights the scale of genetic diversity that can be encountered in the field, and the challenges in managing wheat powdery mildew.

INTELLECTUAL PROPERTY

Please provide concise statement of any intellectual property generated and potential for commercialisation.

Nil

APPLICATION / COMMUNICATION OF RESULTS

A concise statement describing activities undertaken to communicate the results of the project to the grains industry. This should include:

- *Main findings of the project in a dot point form suitable for use in communications to farmers;*
- *A statement of potential industry impact*
- *Publications and extension articles delivered as part of the project; and,*
- *Suggested path to market for the results including barriers to adoption.*

Note that SAGIT may directly extend information from Final reports to growers. If applicable, attach a list of published material.

Fungicide resistance in wheat powdery mildew is present in SA and increasing, reducing the options available for powdery mildew control where it occurs. Varietal resistance is effective at reducing mildew infection, however most adapted main season wheats in SA have poor resistance to powdery mildew, many rated as SVS. These varieties dominate plantings in SA at present and are estimated to account for > 80% of SA wheat planting, with Scepter being the most widely grown accounting for over 60% of plantings.

Applying results from this project to the northern YP it is estimated that 40% of the region is planted to wheat, equating to 48,000ha grown in the region, where 20% is estimated to be sandy soils where powdery mildew is more prevalent, or 9,600ha. With approx. 80% of the area sown to SVS varieties, that is 7,680ha susceptible to high levels of mildew infection. Results from this project have shown that losses of 0.7t/ha are common for these varieties in these scenarios with no fungicide, that is approx. 5,400t at a value of $2.16M. In the 2021 trial in Scepter, a single spray fungicide ($18/ha) and two spray fungicide ($45/ha) still incurred a 0.5t/ha and 0.2t/ha yield loss, respectively. So, despite a minimum of $864,000 invested in a single fungicide application across the whole wheat crop in the region, these prone areas are still incurring a loss of 3,840t, valued at $1.54M. These estimates are considered conservative given that mildew severity observed in some commercial crops has exceeded the levels observed in trials in this project, particularly in 2021. In 2022 mildew has been observed statewide and on soil types not typically considered to be high risk, therefore these potential loss estimates increase substantially when a larger region of the state is considered.

Results have been communicated via a range of channels over the course of the project, including

- GRDC advisor updates Adelaide, 2021 and livestream 2022
- NSS crop walks 2020 and 2021 – approx. 50 attendees each visit
- GRDC southern panel tour 14/9/2021 – approx. 12 attendees
- Presentation to the SA Independent consultants' group
- Articles included in NSS and AIR EP annual results books in 2021 and 2022
- AIR EP crop walk presentation September 2022
- Personal communication with industry representatives of most fungicide suppliers including Ag Nova, Adama, Bayer, BASF, Corteva, Nufarm and Syngenta.

- Data communicated to GRDC chemical regulation manager to assist in identifying opportunities for emergency permits for fungicide actives.
- Articles included in Trengove Consulting newsletter and personal communication with clients
- Several posts on Twitter throughout the growing season have shared visual responses observed at trials in real time.

Additional paths to market may include articles in industry publications such as Ground Cover and industry pod casts. Challenges to adoption include

- availability of suitably adapted wheat varieties with reliable powdery mildew resistance.
- Inability to mix and rotate fungicides, given limited modes of action, advanced stage of resistance development and poor efficacy from group 7 fungicides

POSSIBLE FUTURE WORK

Provide possible future directions for the research arising from the project including potential for further work and partnerships.

Work on fungicide resistant wheat powdery mildew is continuing through a GRDC funded project 'Validation and extension of management strategies for wheat powdery mildew'. This is a two-year project (2022-23) that will

- Expand the field trial work to include sites on the Yorke and Eyre Peninsula, Upper SE and NE Vic. These trials continue to assess best management of powdery mildew in the context of evolving fungicide resistance. It includes assessing fungicide active ingredients, best combinations of DMI fungicide active ingredients, varietal resistance, fungicide application timing and the benefits of a head wash fungicide strategy.
- Expand the survey of commercial paddocks for resistance mutation frequency, including. 157 paddocks from EP, Upper SE, SA Mallee and Vic have been sampled in 2022. The Yorke Peninsula will be sampled again in 2023 to follow on from the 2021 survey.
- Investigate the cause of spatial variability in powdery mildew incidence, following the observation that it is more prevalent in crops growing on sandy soils. Investigations will include assessing the link between crop nutrition and mildew incidence and the effect of microclimate (temp, humidity, leaf wetness) experienced in each location on mildew development.
- Continue to extend results, via field day visits to trial sites, presentation at GRDC update events and a fact sheet.

There is scope for registration of fungicide active ingredients with good activity on wheat powdery mildew that are not currently available to Australian growers to be pursued. This has potential to significantly expand the options for fungicide mode of action, which is currently limited to group 3, 7 and 11. Communication and advocacy to chemical companies and potential registrants is ongoing.