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Project Code	
Project Type	

SAGIT

FINAL REPORT 2023

PROJECT CODE	S/UA1021
PROJECT TITLE	
Characterising the optimal flowering period for the Murray Plains	

PROJECT DURATION						
Project start date	**1/04/2021**					
Project end date	**30/06/2023**					
SAGIT Funding	2021/22		2022/2023		2023/2024	

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PROJECT REPORT:

Executive Summary

Across 2021 and 2022, the combination of crop modelling software Agricultural Production Systems sIMulator (APSIM), and replicated variety x time of sowing field trials were conducted to define and validate flowering windows of the Murray Plains. Flowering time data, seasonal weather conditions, soil types and locations were used in addition to historic climatic data through APSIM. The use of long-term climatic data and seasonal data across 2021 and 2022 produced the following conclusions:

- Barley had consistently higher yields across flowering dates, and it was found to be more important for the wheat to flower on time due to frost/heat/drought stress than barley.
- Modelling suggested that the optimal flowering period (OFP) for wheat at Palmer was between the 27th August and 11th September, based on the past 50 years of climatic data.
- Current elite spring wheat phenology types have a range of optimal sowing dates that start from the first week of April (Denison) and extend all the way until Mid-May (Vixen).
- Rockstar (mid-slow spring) and Denison (slow spring) wheat had the most stable yields across germination dates and wheat varieties.
- Compass (very quick spring) was the most consistent barley for high grain yield across germination dates and seasons.
- In an above average season for rainfall, new winter barley varieties performed well in the Low Rainfall Zone (LRZ) as well the new winter wheat line Mowhawk (LPB19-14343).

Project objectives

The main objectives for the project were:

- To characterise the optimal flowering period (OFP) for wheat and barley in the Murray Plains region.
- Enable Murray Plains growers to better match sowing time and variety development speed to their optimal flowering period.
- Determine the potential for sowing early slower maturing cereal varieties in the Murray Plains region.

Overall Performance

The main objective of the project was to characterise the OFP for the Murray Plains region which was successfully done for wheat through both APSIM simulations and field validated data. Soil testing was used to validate soil types at trial sites to accurately run APSIM to generate a model of the OFP based on 50 years of climatic data. This modelled OFP was then validated using field trials across seasons to identify sowing dates for diverse phenology types. The development of a barley OFP was found to be more challenging due to APSIM not being able to simulate flowering time reliably compared to the field derived data. More work is being done on this validation which is the main focus in the new project (UAD 02222R). The benefit of this new project is that the field data across multiple seasons can be used to develop an OFP if the modelling is found to continue to not be representative of the actual flowering that occurs in the field.

The second objective was well complemented by the fact that the project had a simulation and field component to allow growers direct access to the data being developed. This combination has produced both accurate and validated outputs, as well as aided in extending these results to growers and sparked questions at crop walks. Growers seeing frost damage and low biomass, for example at the trial site from early sowing with the wrong phenology type, helped them understand the influence of both sowing time and variety development speeds. Discussions with individual growers have also demonstrated the change in mindset for when sowing should be completed and the urgency/importance of ensuring the timing of seeding is right.
The final objective of investigating the potential for longer season varieties has been clearly demonstrated with the lack of early sowing opportunities over the two seasons. Dry starts delayed germination of grower crops until May both seasons, with no April sowing opportunities. This was overcome in the trial work by using supplementary irrigation, which created its own issues in 2022

with animal pressure since the trial had the only green shoots in the district. Large cages were placed on early sown plots for the start of the season to prevent any damage. However, some important results were still produced from early sowing in the project, with varieties like Rockstar proving their versatility and yield stability across a range of sowing dates. The benefit of running barley and wheat in the same trial also demonstrated what species perform better across sowing dates, with barley yields generally more stable from April sowing dates compared to wheat.

The personnel involved with the project and developed outputs included: Mr Brendan Kupke, Ms Melissa McCallum, Dr Rhiannon Schilling, Dr Courtney Peirce from SARDI. The Murray Plains farmers group were co-operators as well as host growers Steen and Deanna Paech, and Adrian and May Bormann.

KEY PERFORMANCE INDICATORS (KPI)

KPI	Achieved	If not achieved, please state reason.
Trial sown at Palmer for both times of sowing	Yes ☒ No ☐	
In season measurements, plots harvested, and data analysis completed	Yes ☒ No ☐	
Trial sown at Palmer for both times of sowing	Yes ☒ No ☐	
Preliminary modelling of OFPs completed	Yes ☒ No ☐	
In season measurements, plots harvested, and data analysis completed	Yes ☒ No ☐	
OFP defined and validated with optimal sowing times for varieties and species	Yes ☒ No ☐	Barley model developed and tested but requires further validation
Final report submitted to SAGIT	Yes ☒ No ☐	

TECHNICAL INFORMATION

APSIM wheat simulations and field validated data for Murray Plains OFP

APSIM was used to develop an OFP using climatic data from the past 30, 50 and 70 years (Figure 1a). Demonstrated in Figure 1a, the OFP has been starting earlier and ending earlier in recent years, with later flowering causing significantly lower yields over the past 30 years in comparison to the last 70 years. The main driver of this was a combination of late season heat stress, and more significantly less spring rainfall in the LRZ. The number of years of climatic data used was subjective, however we have selected the last 50 years which was the most common amongst other authors and ensures that only temperatures post 1957 were used (improvement in temperature measurements post 1957).

When comparing the simulations to all the field data across phenology types, there was some similarity, especially from the 2021 season. In 2021, peak grain yield in the field was associated with flowering in early September, which was right in the middle of the simulated OFP in 2021 (Figure 1b). However, in 2022, which was a season with decile 9 growing season rainfall (decile 10 in spring), the optimal flowering date was a whole month later (3rd October) due to water being non-limiting, unlike an *'average'* season. This highlights the limitation of OFPs which are based on a large number of growing seasons, and do not necessarily represent single seasons very well, especially with extreme weather. However, there did seem to be a peak in yield when flowering on the 22nd August (Figure 1b), before yields declined again into late August and early September flowering, due to the average autumn and winter rainfall. It was only once the decile 10 spring rainfall finally occurred where moisture was non-limiting, that late flowering into October saw a substantial yield improvement and peak. Additionally, the diversity of phenology types and elite lines created a variation in actual yield potential, which was demonstrated by the relative variation in yield at any given flowering time (Figure 1b).

Figure 1a *Figure 1b*

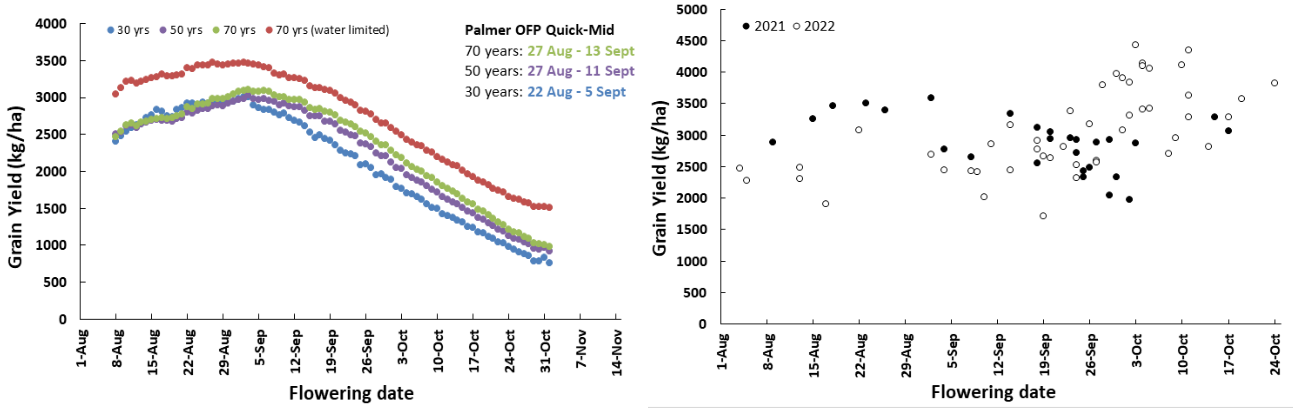

*Figure 1 **(a)** A simulation of the optimal flowering period (OFP) for a quick-mid wheat variety Mace at Palmer in the Murray Plains. The red dots show the water limited maximum potential yield using the past 70 years of climate data. The green, purple and blue dots represent the frost, heat and drought 15 day running mean yield over the past 70, 50 and 30 years respectively. **(b)** A comparison of the relative wheat grain yield of every variety and their respective flowering dates in the field trial for 2021 and 2022.*

Developing a barley OFP for the Murray Plains

The development of a simulated OFP for barley in the Murray Plains was challenging, with APSIM not correctly simulating flowering date for common barley phenology types such as Compass. Early sowing in APSIM of Compass created much earlier flowering than field derived data (in-excess of 2 weeks earlier from early April sowing). This created an OFP which started in early August and finished around the middle of August (not shown). Further validation and simulations are required to validate this which will be conducted in 2023 as part of project UAD 02222R. The 2021 growing season data in Figure 2, showed some tendency for relatively earlier flowering in comparison to the wheat (Figure 1b). Peak yield was associated with flowering in the middle of August with a decline in yield already occurring in late August and onwards. In 2022, the pattern was similar to the wheat, where later flowering in September and October had the highest yields, with the peak in late September, slightly earlier than the wheat. Even with less diversity for phenology in Australian varieties in comparison to wheat, the barley performed well across flowering dates.

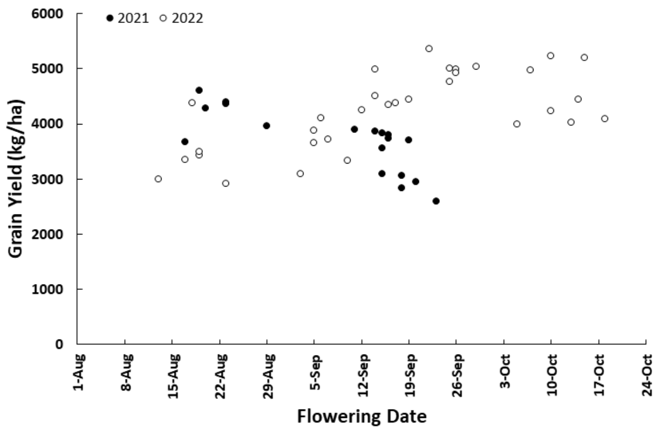

Figure 2 A comparison of the relative barley grain yield of every variety and their respective flowering dates in the field trial for 2021 and 2022.

Optimal sowing dates for different wheat phenology types

Combining the field data from both seasons and the simulated OFP for the Murray Plains, allowed for the development of optimal sowing times for different wheat spring types. Sowing and flowering dates were plotted for quick to slow spring wheat types in Figures 3 a-d for both the 2021 and 2022 seasons from the field. By using the flowering date associated with peak grain yield from APSIM and slope of the trendline from the field data, the optimal sowing date range for the two seasons was produced. Depending on development speed, earliest sowing date to achieve optimal flowering started on the 2nd April until the 14th May. These could also be extended to a *'less optimal range'* if the target flowering date was at the start of the OFP (27th

August) or end (11th September). However, by using the method for the flowering date to achieve maximum simulated yield, it allows for variation between relative growing season temperatures, which could cause even earlier or later flowering that could push the flowering date outside the OFP. Hence, targeting flowering dates at either end of the optimal range risks flowering occurring outside the optimal period, particularly in seasons that vary in temperature from average conditions. The two seasons used were defined as having close to average temperatures in 2021 and cooler than average in 2022.

Figure 3a

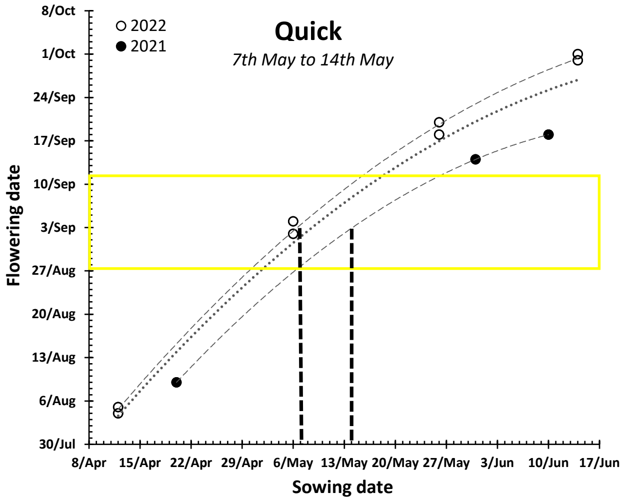

Figure 3b

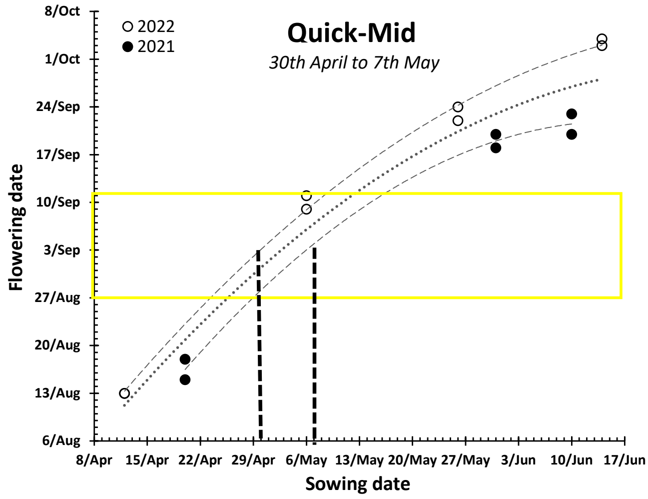

Figure 3c

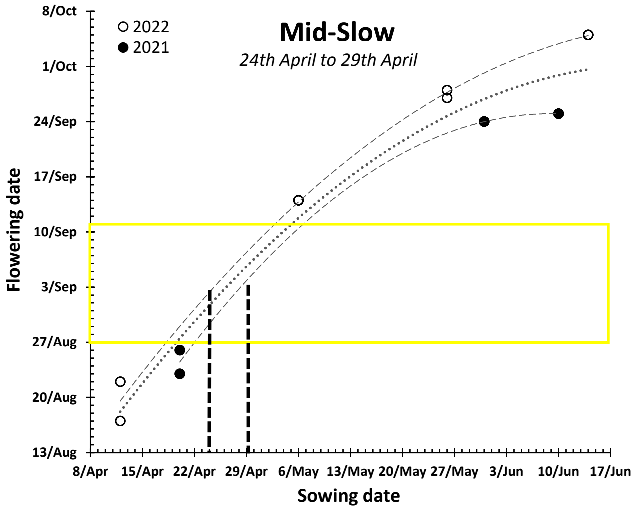

Figure 3d

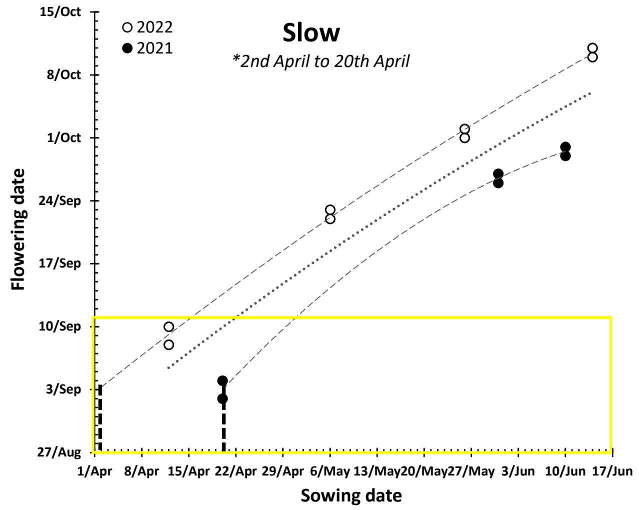

*Figure 3 The optimal sowing dates for (**a**) quick (Vixen/Anvil CL Plus), (**b**) quick-mid (Ballista/Calibre/Scepter), (**c**) mid-slow (Rockstar/Sheriff CL Plus) and (**d**) slow (Denison/Valiant CL Plus) spring wheat phenology types. Developed from field derived flowering and sowing dates from the 2021 and 2022 growing seasons in the Murray Plains. The yellow box depicts the OFP as simulated in APSIM, and the vertical black dotted lines the sowing dates required to flower at the simulated peak yield on the 3rd of September. The dashed line of best fit depicts the average for the 2021 and 2022 seasons individually, while the dotted line of best fit is the combined average for both seasons. * The line of best fit is extrapolated past earliest flowering points on graph to predict optimal seasonal sowing date so interpret start of OFP date with caution.*

High yielding wheat and barley varieties across germinations dates in the Murray Plains

Across seasons, Denison and Rockstar wheat, and Compass barley have demonstrated their ability to produce both high and stable yields across a range of sowing dates (Table 1 a/b). When yields were averaged across sowing dates for 2021 and 2022, these varieties had the highest average yields (t/ha) and were consistent across each sowing date. This highlights one of the reasons why Murray Plains growers continue to persist with Compass as their main barley variety due to this consistency in yield. However, newer variety Commodus CL did also demonstrate ability to match Compass for yield and stability but with the added flexibility of having the Clearfield technology. Interestingly, additions for the 2022 season, French winter barley types Newton and Pixel, as well as Cyclops, had high yields in a growing season that was well above average rainfall. Denison and Rockstar are both not grown in the Murray Plains, mainly due to being slower developing varieties in comparison to the current benchmark

Scepter, which also showed a high yielding ability in the low rainfall zone. This data demonstrates that having seed of one of these varieties on hand would allow for flexibility in terms of having April sowing potential and maintaining yield stability into May from later germination dates.

*Table 1 The mean grain yield for each variety of wheat **(a)** and barley **(b)**, as well as 2022 **(c)**, **(d)** respectively across sowing dates. Sowing dates that make up mean grain yield for 2021 include: 20th April, 31st May, 10th June; and for 2022: 12th April, 6th May, 26th May, 14th June.*

Table 1a

Site mean	Yield (t/ha) across Germination Date			
yield: **2.88 t/ha**	20-Apr	31-May	10-Jun	Combined
Vixen	2.88	3.34	2.55	**2.92**
Ballista	3.26	3.12	2.94	**3.11**
Scepter	3.46	3.05	2.95	**3.15**
Rockstar	3.51	2.93	2.43	**2.96**
Sheriff CL Plus	3.39	2.72	2.33	**2.81**
Denison	3.59	2.88	2.93	**3.13**
Valiant CL Plus	2.77	2.49	2.34	**2.53**
Longsword	2.65	2.04	1.97	**2.22**
DS Bennett	2.87	3.29	3.07	**3.08**
TOS mean yield	**3.15**	**2.87**	**2.61**	
p-value	<0.001			
LSD ($p \le 0.05$)	0.366			

Table 1b

Site mean	Yield (t/ha) across Germination Date			
yield: **3.6 t/ha**	20-Apr	31-May	10-Jun	Combined
Beast	4.47	3.97	3.65	**4.03**
Compass	4.61	3.98	3.38	**3.99**
Commodus CL	4.32	4.02	3.14	**3.83**
Spartacus CL	3.71	3.45	2.81	**3.32**
Maximus CL	4	3.54	2.82	**3.45**
RGT Planet	3.93	2.6	2.48	**3.00**
TOS mean yield	**4.17**	**3.59**	**3.05**	
p-value	0.017			
LSD ($p \le 0.05$)	0.486			

Table 1c

Site mean	Yield (t/ha) across Germination Date				
yield: **3.07 t/ha**	12-Apr	6-May	26-May	14-Jun	Combined
Anvil CL Plus	2.47	2.69	2.91	3.97	**3.01**
Vixen	2.28	2.45	2.64	3.90	**2.82**
Calibre	2.31	2.42	2.81	4.44	**2.99**
Scepter	2.49	2.86	2.52	4.10	**2.99**
Rockstar	3.08	3.16	3.80	4.06	**3.52**
Sheriff CL Plus	1.90	2.45	2.57	3.42	**2.59**
Denison	2.43	3.39	3.84	4.11	**3.44**
Valiant CL Plus	2.02	2.67	3.08	3.63	**2.85**
Longsword	1.71	2.59	3.41	3.29	**2.75**
Mowhawk	2.78	3.18	4.14	4.34	**3.61**
Illabo	2.33	3.31	2.95	3.28	**2.97**
DS Bennett	2.71	2.82	3.58	3.82	**3.23**
TOS mean yield	**2.38**	**2.83**	**3.19**	**3.86**	
p-value	0.013				
LSD ($p \le 0.05$)	0.663				

Table 1d

Site mean	Yield (t/ha) across Germination Date				
yield: **4.24 t/ha**	12-Apr	6-May	26-May	14-Jun	Combined
Beast	3.00	3.09	4.24	5.36	**3.92**
Compass	3.44	3.65	4.51	4.99	**4.15**
Commodus CL	3.35	3.72	4.37	5.01	**4.11**
Cyclops	4.37	4.11	4.99	4.77	**4.56**
Maximus CL	3.49	3.88	4.35	4.93	**4.16**
RGT Planet	2.91	3.33	4.45	5.04	**3.93**
Pixel	4.00	4.98	5.23	5.20	**4.85**
Newton	4.23	4.02	4.44	4.09	**4.19**
TOS mean yield	**3.60**	**3.85**	**4.58**	**4.92**	
p-value	<0.001				
LSD ($p \le 0.05$)	0.6626				

Suitability of longer season wheat varieties with early sowing in the Murray Plains

In both seasons of field trials, there was no early sowing (April) opportunity that would enable reliable germination and establishment. This demonstrates that April germination in the Murray Plains under the rain shadow of the Mt Lofty ranges is rare and that keeping a long season variety may not be a viable or a realistic option. However, through 10mm of supplementary irrigation to replicate an April rainfall event, there were some grain yield responses as demonstrated in Table 2. With Scepter being the current benchmark variety and most popular, slower developing varieties Rockstar and Denison had improvements in grain yield across April germination dates. However, this improvement was not substantial on average, with only a 0.32t/ha and 0.03t/ha yield benefit respectively on Scepter from an April germination date. Interestingly, no winter phenology type was able to out-yield Rockstar a mid-slow spring type. This demonstrates that although winter types have a strong vernalisation hold, which allows for much earlier sowing, slower spring types like Rockstar and Denison are higher yielding from April germination dates than the winter types. However, new winter genetics coming though breeding programs, namely Mowhawk which was added to the trial in 2022, could start to push the winter yield barrier in the low rainfall zone (Table 1a and Table 2).

Table 2 The mean grain yield and flowering dates for slower wheat phenology types across early times of sowing for the 2021 and 2022 seasons in comparison to the most popular wheat variety in the region Scepter.

	2021		2022		combined
	20th April Germination		12th April Germination		
	t/ha	Flowering date	t/ha	Flowering date	t/ha
Scepter (control)	*3.46*	*18-Aug (0)*	*2.49*	*13-Aug (0)*	***2.98***
Sheriff CL Plus	3.39	26-Aug (+8)	1.9	17-Aug (+4)	**2.65**
Rockstar	3.51	23-Aug (+5)	3.08	22-Aug (+9)	**3.30**
Denison	3.59	2-Sep (+15)	2.43	8-Sep (+26)	**3.01**
Valiant CL Plus	2.77	4-Sep (+17)	2.02	10-Sep (+28)	**2.40**
Longsword	2.65	8-Sep (+21)	1.71	19-Sep (+37)	**2.18**
DS Bennett	2.87	3-Oct (+46)	2.71	8-Oct (+56)	**2.79**
Mowhawk	-	-	2.78	18-Sep (+36)	-
Illabo	-	-	2.33	24-Sep (+42)	-

CONCLUSIONS REACHED &/OR DISCOVERIES MADE

This project was able to combine both crop modelling through APSIM, and field trial data to develop and validate the OFP for the Murray Plains. This combination proved important to ensure that the modelling was reliable as highlighted in the barley simulations. The limitation of APSIM not accurately simulating early sown barley will require further work to optimise and further field trial data can be used to help develop this.

The wheat OFP for the Murray Plains in this project based on the past 50 years of climatic data was the 27th August to the 11th September. This was validated through the 2021 growing season and partially during 2022. The rainfall extremities of the 2022 season, highlighted the main downfall of the OFP idea where individual seasons (especially extreme seasons) are not necessarily well represented. Further research into predicted El Nino/La Nina seasons could provide useful in helping growers strategically adjust their time of sowing/variety selection to limit or maximise financial outcomes in these seasons respectively.

The addition of French origin winter barley lines in 2022 helped broaden the range in development and time to flowering. In a decile 9 growing season in the low rainfall zone, they both performed well from early sowing. However, drought stress was evident in late winter and further seasons are required to determine if they could be a reliable option to growers.

The slower spring wheat type seem to have the advantage over winter types in the Murray Plains with April germination dates. Rockstar was highest yielding across both seasons from April germination with Denison also performing well. Mowhawk (quick winter) was a new variety added for the 2022 season that did perform quite well and has potential to improve the winter wheat yield potential in the LRZ in general.

Within the current elite spring wheat types available to SA growers, a wide range of sowing dates can be used to still flower within the OFP. Denison, a slow spring type can be sown in early April, all the way to Vixen a quick spring which can be sown optimally until the middle of May in the Murray Plains.

INTELLECTUAL PROPERTY

The project has not created IP with all outputs/industry reports available to growers. No potential for commercialisation.

APPLICATION / COMMUNICATION OF RESULTS

Main findings for the project include:

- Modelling suggests that the optimal flowering period (OFP) for wheat at Palmer is between the 27th August and 11th September, based on the past 50 years of climatic data.
- Current elite spring wheat phenology types have a range of optimal sowing dates that start from the first week of April (Denison) through to Mid-May (Vixen) in the Murray Plains.
- Across two seasons, Rockstar (mid-slow spring) wheat had the most stable yields across germination dates and wheat varieties.
- In an above average season for rainfall, new winter barley varieties performed well in the LRZ as well the new winter wheat line Mowhawk (LPB19-14343).

The key industry impact for the project was the production of locally relevant information and knowledge transfer to growers and agronomists in the Murray Plains region and wider. Research in other areas has shown the benefits of early sowing but growers often don't have the genetics or the knowledge of to implement it on farm. With larger GRDC projects on these topics going to the eastern mallee and mid north, there has been a knowledge gap for the Murray Plains region. This project has helped bridge the gap by providing practical examples of the different phenology types available to growers and their yield potential in the low rainfall zone. This has given both growers and agronomists the latest locally relevant information for their region as well as help with variety selection and selection of sowing time.

The direct comparison of slower spring and winter phenology types for early sowing has demonstrated their relative yield potential and stability across germination dates. With the slow spring phenology types outyielding winter types, this may create practice change for growers and agronomists. It's demonstrated that having one of these varieties on farm will provide flexibility as an early sowing option in April, but also later if required or conditions are not favorable for early sowing. Demonstrating how drought tolerant they are during late Autumn hot and dry spells in both seasons will help with promoting early sowing.

The project had numerous extension opportunities with various audiences conducted by Brendan Kupke including:

- Aug 2021
  – MPF Committee tour of 2021 trial site
- Sept 2021
  – MPF field day at trial with approximately 40 growers/advisors.
- Feb 2022
  – MPF research update attended by 35 members during higher covid restrictions.
- July 2022
  – Dodgshun Medlin agronomist visit
- Aug 2022
  – MPF winter field day at trial with approximately 30 growers/advisors.
- Sept 2022
  – MPF spring field day at trial with approximately 40 growers/advisors.
  – Dodgshun Medlin agronomist and clients walk through (approximately 20 growers and advisors)
- Jan 2023
  – SARDI Agronomy program online research update (approximately 20 researchers)
- Mar 2023
  – Elders Murray Bridge client trial update day (approximately 40 growers/advisors)

– MPF research update day

A number of written outputs were developed and published through different avenues which included:

- 2021 Murray Plains Farmers update paper
- 2021 Crop Science Society South Australia report
- 2022 Industry report for Murray Plains farmers, agronomists and plant breeders
- Data from 2022 grain yields published in Longreach Plant Breeders tech-pack for the release of Mowhawk

The integrity of only having two seasons of field data is a limitation to adoption as it does not represent enough diverse seasons (especially a warm growing season in this case). The new project UAD 02222R will help with increasing adoption and validity of results by having another season of field data. Despite this, the developmental information and simulations have already proven useful for local agronomists who have been asking for reports and have participated in discussions at crop walks.

Having access to industry reports will help with adoption and for growers to confirm the validity of the modelling by comparing their own crops with the optimal sowing date curves developed in the project. This will continue to be useful for growers across future seasons with the developmental data collected.

POSSIBLE FUTURE WORK

The main benefit to the project was the combination of crop modelling and field trial work to validate the modelling. This helped growers understand how models are developed but also provided a great extension opportunity through practical demonstrations at field trials. A similarly designed project could be set up in other regions of SA that have not had local research done in the area of crop phenology, OFP and time of sowing.

The optimal time to flower in 2022 was nearly a month later than normal in a decile 9 rainfall growing season. This led to the question of how does a grower prepare for seasons like this when they are most likely to have the highest gross margins? Further research needs to be done with the concept of the OFP to include other factors such as gross margins in high rainfall seasons in particular, La Nina or alternatively dry El Nino seasons. This would allow growers to be more adaptive across seasons and to ensure that they don’t limit their yield potential in seasons when water is not as limiting.

The current project UAD 02222R also builds on the outputs from this project to further fine tune practical outcomes for growers. It has a focus on barley flowering time and simulations to better fine tune when the OFP is for barley, which is not widely well modelled yet. It also has a focus on the other components of grain yield including biomass production and plant numbers by drones. Looking at other components of grain yield will help build the whole picture, as matching crop development to the environment is only one part of the yield equation. Additionally, developing protocols to do this via drone technology will enable this research to be faster, easier and more accurate by measuring whole plots instead of smaller quadrat samples.