Office Use Only

Project Code	
Project Type	

FINAL REPORT 2019

PROJECT CODE	:	S518

PROJECT TITLE
Drivers of Flowering Time in Durum

PROJECT DURATION

Project Start date	1 April 2018					
Project End date	30 June 2019					
SAGIT Funding Request	2018/19		2019/20		2020/21	

PROJECT SUPERVISOR CONTACT DETAILS

Title:	**First Name:**	**Surname:**
Dr	Courtney	Peirce

Organisation:
South Australian Research and Development Institute (a Division of Primary Industries and Regions SA)
Mailing address:

Telephone:	**Facsimile:**	**Mobile:**	**Email:**

ADMINISTRATION CONTACT DETAILS

Title:	First Name:	Surname:
Ms	Adrienne	Twisk

Organisation:
South Australian Research and Development Institute (a Division of Primary Industries and Regions SA)
Mailing address:

Telephone:	Facsimile:	Mobile:	Email:

PROJECT REPORT

Executive Summary

The main drivers of flowering in durum are photoperiod and temperature, with varieties and breeding lines having limited variation in controls and time to flower. As such, there is currently no durum variety suited to early sowing (pre-ANZAC day in SA) as they will all flower too early, with the optimum sowing window in early-mid May. Our results demonstrate the optimum flowering period for commercial durum varieties will be similar to either Scepter or Trojan for a given environment, however the relative yield of durum is likely to be lower than bread wheat for a given flowering date. Durum varieties are more sensitive to environmental (frost and heat) and biotic factors (crown rot) than bread wheat with yield and sterility negatively correlated in all environments in our study. Since these factors will cause greater yield penalties in durum than bread wheat, it is of greater importance that durum growers sow on time and thus flower at an optimum time, particularly in frosty or heat prone environments.

Project Objectives

This project aims to provide information on the phenology drivers of durum wheat. This will allow us to:

- Enable SA growers to better match durum varieties to environment to achieve maximum yield stability;
- Correct and update flowering models to accurately describe optimum sowing and flowering dates for durum in SA;
- Validate the suitability of durum for early sowing (pre-ANZAC day) in SA;

The project also aims to build capacity in SA for agronomic research

Overall Performance

<u>Personnel</u>

The researchers on the project were Courtney Peirce, Melissa McCallum and Kenton Porker from the SARDI Waite Agronomy group. Technical staff Wayne Reid, Paul Swain and other casual staff from the Agronomy group also helped with field trials and processing samples. Jason Able from the University of Adelaide supplied durum lines and varieties.

Thank you to Bulla Burra and the Mid North High Rainfall Zone group for hosting our field trials at Loxton and Tarlee.

Experiment 1 was conducted in controlled environment cabinets in The Plant Accelerator, Australian Plant Phenomics Facility, a research facility funded by the National Collaborative Research Infrastructure Strategy (NCRIS).

<u>Difficulties</u>

Due to availability of growth cabinets, we only used two photoperiod lengths instead of three as initially proposed to quantify vernalisation, photoperiod, and earliness *per se* responses. The lengths chosen were 8 and 18 hours as used for previous studies of different crop types utilizing controlled environment cabinets and also because these lengths are the parameters used in APSIM to characterise varieties. A few durum varieties and breeding lines grew poorly under the 8-hour days and did not flower. It is likely that these varieties were photoperiod responsive, requiring more than 8 hours of daylight to induce flowering. In Adelaide, the shortest day of the year is 9 hours and 48 minutes. Therefore, it may have been more appropriate to have a day length of 10 hours as this is more consistent with environmental conditions of South Australia where the majority of the lines are bred and grown. At the time this was the method proposed by APSIM researchers, however there is now evidence to suggest this day length should be increased.

Difficult growing conditions were experienced in 2018 at the Loxton field site. The site experienced one of the driest autumns on record, and resulted in sand blasting and drought, which affected yield results primarily for the first time of sowing. Due to the well below average rainfall, the second time of sowing resulted in varieties experiencing moisture stress during critical growth periods with poor yields exacerbated by crown rot, which produced a large number of sterile white heads.

Key Performance Indicators (KPI)

KPI	***Achieved (Y/N)***	***If not achieved, please state reason.***
Experiment 1: controlled growth room study data collection complete Experiment 1 was completed in December 2018. We compared two photoperiod lengths (8 and 18 hours) for vernalised and non-vernalised seeds of 26 diverse durums (9 commercial varieties, 11 University of Adelaide breeding lines, and 6 landraces) and 2 bread wheats as	Yes with some modifications	Experiment 1 was changed from three to two photoperiod lengths of 8 h and 18 h as these are the photoperiod lengths required for characterisation of varieties in APSIM.

benchmarks with known flowering controls. We assessed each variety for the rate of leaf initiation and the timing of phenology stages including stem elongation, heading and flowering.		
Flowering time data collected from field experiments (NVT or UA breeding site, Marg Evans trial, single row trial at Waite) Flowering data was collected from two field trials (Giles Corner and Loxton) with two times of sowing at each site. Nine commercial durum varieties, one University of Adelaide breeding line and two bread wheat varieties (to provide a benchmark) were sown at both sites and times of sowing. We also collected flowering data from the same varieties at six times of sowing ranging from the 10th of April to the 19th of June in a double row trial in the Waite bird-proof enclosure. Marg Evans' trial at Palmer which was planned to be utilised experienced severe drought stress, so was not included in the data collection.	Yes	
Scientific report completed for Experiment 1 Submitted with progress report	Yes	
Final Report submitted to SAGIT including summary on output 1 (experiment 1) and output 2 (determination of OFP for Hart, Roseworthy, and previous Durum agronomy trials)	Yes but with modifications	We have derived OFPs for Loxton and Tarlee (Giles Corner) where we had field trials in 2018. We also did an OFP for Hart but skipped Roseworthy since we did not have trials there and replaced our monitoring of breeding trials at Roseworthy with the two field trials at Loxton and Tarlee.

Technical Information

Quantification of vernalisation, photoperiod and earliness per se response

The drivers of flowering in durum wheat in South Australia are predominantly temperature accumulation and response to photoperiod (day length). Figure 1 (see appendix) shows the accumulated thermal time required to reach Zadoks growth stage 55 (head 50% emerged) for plants grown under 18 hour day lengths with 5 weeks of vernalisation time at 2°C prior to sowing. This shows the earliness per se (Eps) or response to temperature of the varieties, as all other flowering controls (photoperiod and vernalisation) are saturated under these conditions. There was limited variation between durum varieties with a range of 920°Cd for 4WA 737 a durum landrace of unknown origins to 1180°Cd for Goal a French durum. Of the commercial varieties available to growers, Eps ranged from 939°Cd for DBA Vittaroi to 1122°Cd for Tjilkuri, which required significantly more thermal time than DBA Vittaroi, DBA Aurora, and Tamaroi and bread wheats Scepter and Trojan.

Photoperiod played a role in driving flowering time. Thermal time to z55 decreased significantly for all varieties when grown under long days, with some varieties not achieving heading under the short photoperiod length (Figure 2 in appendix). Under short days, Scepter, DBA Spes and Saintly had the shortest time to z55 indicating that they are less responsive to photoperiod than other durum and bread wheat varieties in this experiment, particularly those that did not flower at all under short days.

Vernalisation influenced the thermal time to flowering of six of the tested varieties (Figure 3 in appendix). Tjilkuri had the greatest response to vernalisation with the time to z55 decreasing by more than 350°Cd when seeds were vernalised for 5 weeks. Although these 6 varieties responded to vernalisation, it was determined to be a facultative (i.e. a cold period accelerates the time to flower but is not essential) rather than an obligate response because all varieties under the long days progressed to reproductive growth stages in the absence of a vernalisation period.

Phenology under field conditions

Field data showed that the difference in phenology between the fastest and slowest durum variety was small, particularly when compared to bread wheats (Figure 4 in appendix). From an April 24th sowing in the bird-proof enclosure at Waite there was just over 2 weeks difference between the first flowering durum and the last, whereas for the bread wheat there was more than 4 weeks. Even from the later times of sowing there was around 3 weeks variation in the bread wheats but only 1-2 weeks for the durum. The bread wheats chosen included a true winter wheat (Longsword) which requires vernalisation, a photoperiod responsive wheat (Cutlass) and some mid/fast developing wheats (Trojan and Scepter).

Data from the bird-proof enclosure supported findings from output 1 in the controlled environment room. In the bird-proof enclosure, Saintly and Scepter flowered either on the same day or within a few days of each other from all times of sowing. Results from output 1 showed they had very similar flowering controls and reached 50% heading at similar times except in response to vernalisation.

Field trials at Loxton and Giles Corner also showed that Scepter and Saintly had very similar flowering dates but overall there was limited variation between flowering dates of durum within each environment (TOS) (Table 1 in appendix). These trials also showed that across all 4 environments, the best performing durum could not yield more than Scepter or Trojan. There was a significant yield gap between Scepter and Saintly despite their similar flowering controls. We believe that this yield difference between varieties is primarily due to their response to heat and cold stress. At both Loxton and Giles Corner there were numerous cold events and a few heat events which are likely to have impacted yield (Table 2 in appendix). Under all environments Saintly had at least double the sterility of Scepter. Compared to bread wheats, most durum varieties had high levels of sterility although there were some exceptions such as Yawa (Table 1 in appendix).

Updating APSIM and validation of phenology responses in the field

The current APSIM model has most of the current durum varieties from our field trials characterized (Caparoi, DBA-Aurora, Saintly, Tamaroi, Yallaroi, Yawa) however simulations using these APSIM varieties did not match flowering dates to those observed at any of our field sites or in the bird-proof enclosure at Waite (Figure 5 of the appendix). We believe this may be due to the lack of phenology information for durum varieties in South Australia and incorrectly assuming that stress responses for durum will be that same as for bread wheat. It is also possible that the cultivars have been parameterised in different environments to SA and the differences between patch-point meteorological data used by APSIM and the local weather conditions experienced by the crop do not match closely enough. Therefore, growth stages did not correspond from either earlier or later times of sowing. For DBA-Aurora at Waite, flowering occurred on average more than a week before it occurred in the simulations, while for Saintly observed flowering dates were a week after the simulation dates (Figure 5 of the appendix).

From our field results, we thought the optimum flowering period (OFP) for durum would be narrower than that of bread wheats due to the increased sensitivity to environmental stresses. Using APSIM, we modelled the OFP for a mid to fast developing bread wheat variety (like Mace or Scepter) for Loxton, Giles Corner (Tarlee) (see example of OFP in Figure 6 of the appendix), and Hart based on the methods outlined by Flohr et al. 2017 and Hochman and Horan 2018. To match our experiences in the field with the bread wheat OFP we adjusted the yield reduction and/or temperature thresholds for the frost and heat rules in APSIM. We found that this adjusted the OFP only slightly by a few days but accounted for a reduction in yield. The biggest shift in the OFP was between the water limited yield and the yield when frost and heat rules were applied. Due to the low correlation between modelled and observed flowering dates for our field locations, we are skeptical about the data APSIM currently generates for an optimum sowing window (Table 3 in appendix).

Instead we would suggest based on our observations from the field that if growers target sowing at a similar time to Scepter for fast durum varieties (DBA Vittaroi, Saintly) or Trojan for mid developing durum varieties (DBA Aurora, DBA Spes, Tjulkuri, Yawa), then they would achieve flowering during the OFP for their region. Based on the OFP for each of these regions and the fast development speed of durum varieties, there are currently no commercial durum varieties suitable for a pre-Anzac day sowing.

Conclusions Reached &/or Discoveries Made

From the controlled environment study investigating the controls of flowering time in durums, we found:

- There is very limited diversity in flowering controls within current commercial germplasm.
- The main control of most durum varieties is accumulated temperature and photoperiod (day length) with a very small amount of vernalisation contributing to some varieties.
- The vernalisation response in durum is facultative, meaning it is not required but a period of cold will accelerate crop development. This is a new finding for SA durum cultivars most noticeable in Tjilkuri.
- Saintly has very similar flowering controls to Scepter.

Field trial phenology results:

- Our field trials suggest there is a lack of suitable durum cultivars for pre Anzac day sowing (25 April), as they flower too early, exposing them to cold stress and poor biomass accumulation
- Bread wheat is more diverse in flowering time than durum – from sowing on the 24th of April at Urrbrae, flowering dates in durum ranged over a two week period starting from early to mid-August whereas bread wheat ranged over a four week period from the same sowing date. This means growers have a narrow window in which to sow durum at optimum time.

Yield results:

- The best performing durum at each time of sowing and location was never higher than Scepter despite similar flowering dates.
- Durum varieties have a higher susceptibility to frost and crown rot than bread wheats. Sterility of heads at both field sites was negatively correlated with yield; however, there is significant genotypic variation for sterility in durum among cultivars flowering at a similar time.

APSIM results:

- APSIM incorrectly estimates yield and flowering time for Saintly and DBA-Aurora (two of the durum varieties already available in APSIM) most likely due to poor parameterisation of phenology and inability to incorporate biotic stresses such as Crown rot.
- Optimum flowering period (OFP) for a given environment is driven more by water availability than heat and frost stress although environments with strong frost or heat stressors will narrow the OFP.
- For improved optimum flowering period for durum a greater understanding of the yield loss functions due to heat and frost events is needed.
- The interaction between flowering time, grain fill stress and crown rot expression needs to be resolved and incorporated into models before more accurate OFPs and yield can be developed.

Intellectual Property

N/A

Application / Communication of Results

Main findings

- Durum flowering is driven by temperature and photoperiod, with limited diversity in varieties and breeding lines
- Currently no durum variety is suited to pre-ANZAC day sowing
- Durum varieties have a greater sensitivity to cold stress than bread wheat and are likely to have a greater yield penalty under frost prone environments
- Targeting sowing of durum varieties at a similar time as fast – mid developing spring wheats (i.e. Scepter) will allow them to flower within the optimum flowering period for durum production environments of SA
- There is significant variation in grain number, sterility and thus yield loss from abiotic stresses among durum cultivars that requires further investigation.

Potential Industry Impact

These findings provide the most up to date information on crop development for SA durum growers. This will ensure growers have a greater ability to flower on time and avoid significant yield losses from cold and heat stress in SA. The findings presented here pave the way for crop modellers to consider biotic stresses when determining flowering windows and to test the suitability of durum for new production zones. The data has highlighted the need for breeders to consider alternate development patterns in durum for a wider range of planting dates to enable greater flexibility for growers. Optimal sowing times for new durum cultivars will be presented at the 2020 durum forums and will be made available in the 2019 Crop Variety Sowing Guide.

Melissa McCallum has taken every opportunity to promote this project and any preliminary results relating to flowering and differences between varieties at numerous grower events throughout 2018.

- 8th August 2018 Mid North High Rainfall Zone winter walk at Giles Corner
- 29th August 2018 National Frost Initiative group at Loxton
- 14th September 2018 Mallee Sustainable Farming field day at Loxton
- 19th September 2018 Hart Field day (three times)
- 26th September 2018 Mid North High Rainfall Zone field day at Giles Corner
- 10th October 2018 Durum growers association spring walk at Kaniva and Bordertown
- 6th March 2019 Presentation at the SA Durum Growers Association Forum in Tarlee (+ sat on question panel)
- 20th March 2019 Presentation at the SA Durum Growers Association Forum in Horsham

Courtney Peirce presented results at the 2019 SAGIT updates 11th July 2019.

Future presentations

Melissa will present findings from this project at the 19th Australian Agronomy Conference in Wagga Wagga on the 27th August 2019. She will also present findings at the Hart field day on the 17th September 2019.

Research Articles

McCallum M, Peirce C, and Porker K (2019) 'Drivers of flowering time in durum' *Hart 2018 Trial Results* pg. 30-34. http://www.hartfieldsite.org.au/pages/resources/trials-results/2018-trial-results.php

McCallum, Peirce C, and Porker K (2019) 'Drivers of flowering time in durum' *Mallee Sustainable Farming* https://www.msfp.org.au/wp-content/uploads/Drivers-of-flowering-time-in-durum_McCallum_2018_Summary.pdf

McCallum M, Peirce C, and Porker K (2019) 'What drives the yield gap between durum and bread wheat?' 2019 Agronomy Conference Wagga Wagga

Peirce C, McCallum M, Porker K and Flohr B (TBC) 'Evaluation of opportunities to close the yield gap in durum wheat production in South Australia' Frontiers in Plant Science (under draft submission)

POSSIBLE FUTURE WORK

The next step for this research is to work on further validation of APSIM for durum. This will primarily involve looking at the impact of heat and cold stress on yield. We have obtained funding through the GRDC-SARDI bilateral to investigate how heat and frost impacts yield. We will grow Scepter and Saintly in a controlled environment room and impose heat and cold events of varying durations and severity on the plants at targeted growth stages. This will allow us to investigate whether the difference in response to stresses between bread wheats and durum is driven by a change in temperature thresholds (durum is more sensitive at a lower or higher temperature) or due to an increased impact (durum has a higher yield loss than bread wheat at the same temperature). Currently APSIM adjusts the OFP for water, heat, and cold stress however the interaction between flowering time, grain fill stress and biotic stresses such as crown rot needs to be resolved and incorporated into models before more accurate OFPs and yield predictions across environments can be developed. There is also scope to have durum incorporated into the GRDC national phenology initiative for 2020, which currently only looks at bread wheat and barley.

AUTHORISATION	
Name:	Dr Tim Sutton
Position:	Acting Research Director, Crop Sciences
Signature:	
Date:	3 September 2019

Appendix SAGIT Final Report – S518 Drivers of Flowering Time in Durum

Experiment 1: Controlled growth room study to characterise drivers of flowering time

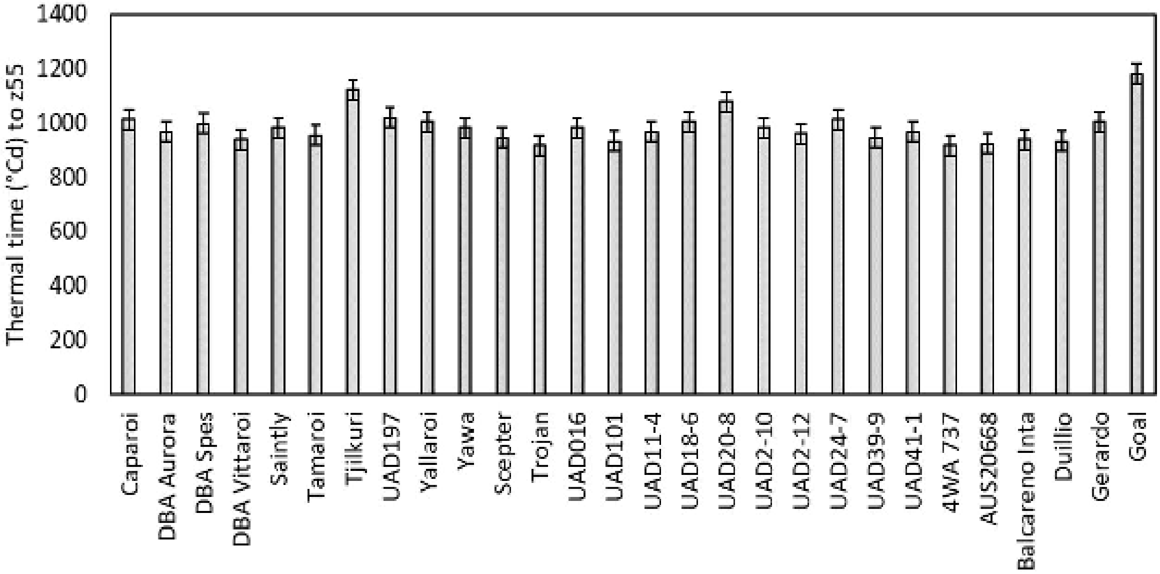

Figure 1: *Thermal time to 50% head emergence for durum varieties, breeding lines and landraces as well as two bread wheat varieties (Scepter and Trojan) under saturated conditions (photoperiod and vernalized). (Lsd 74 °Cd p≤0.001, shown as error bars).*

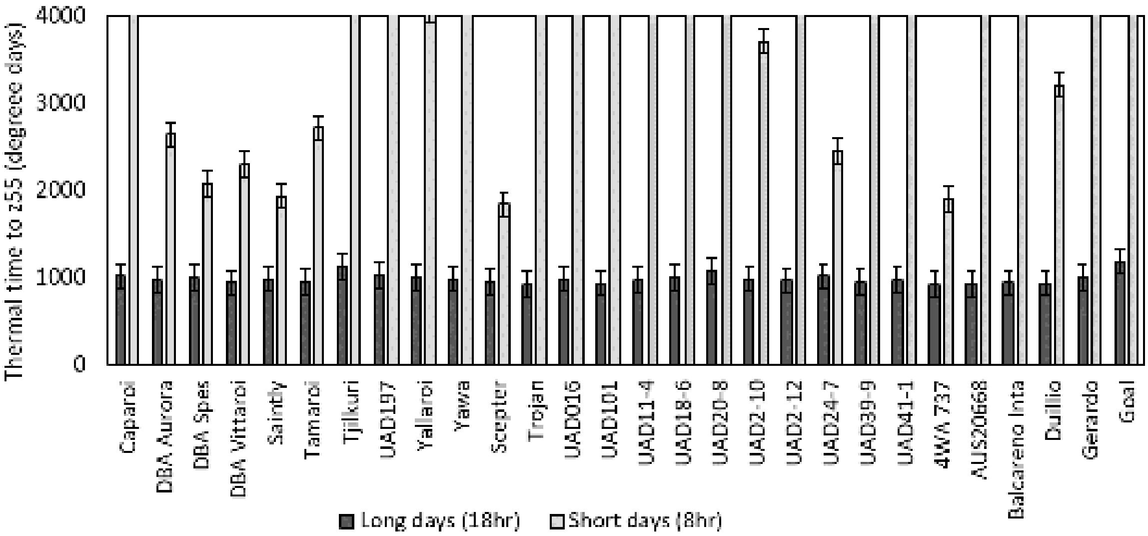

Figure 2: *Comparison of thermal time to 50% head emergence under long (18hr, dark) and short (8hr, light) day lengths for the commercial varieties that were also grown under field conditions. (Lsd variety x photoperiod 290°Cd p≤0.001, shown as error bars).*

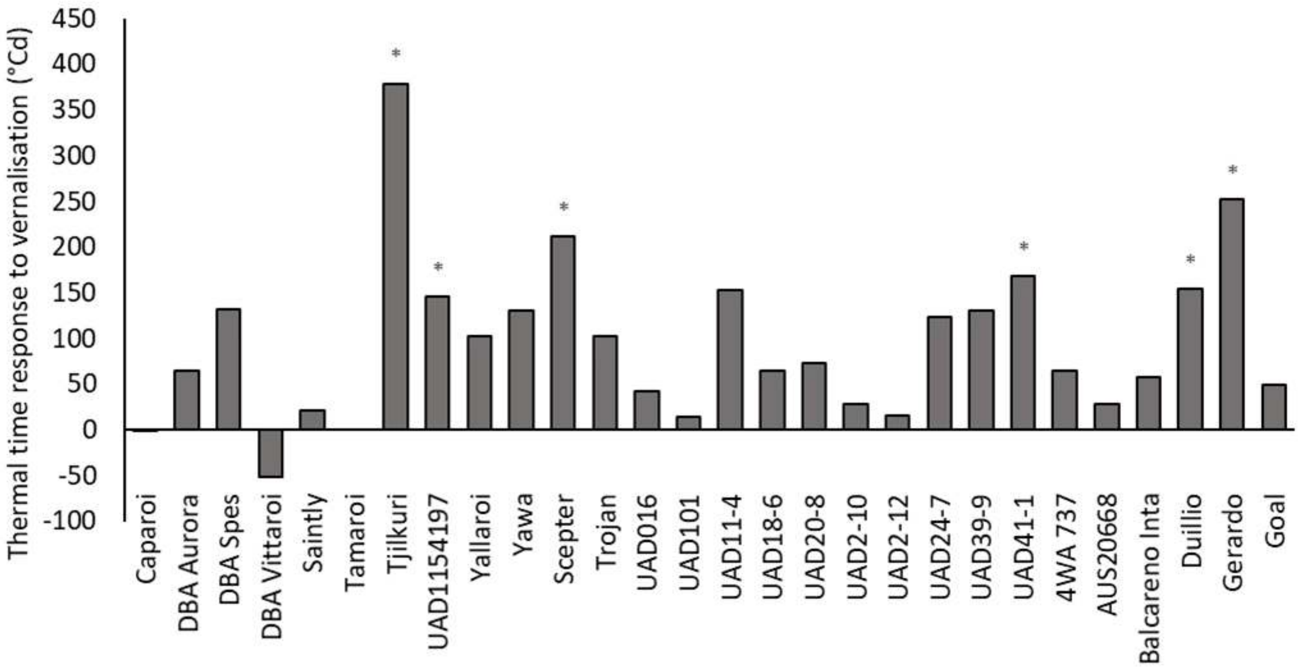

Figure 3: *Influence of seed vernalisation (difference between vernalised and unvernalised seeds) on thermal time to 50% heading (z55) under 18 hr day lengths for a range of durum and bread wheats. (Lsd 133°Cd p≤0.05) *indicates varieties where vernalisation decreased thermal time to z55.*

<u>Phenology and yield under field conditions from sowing dates ranging from the 10th of April through to the 19th of June</u>

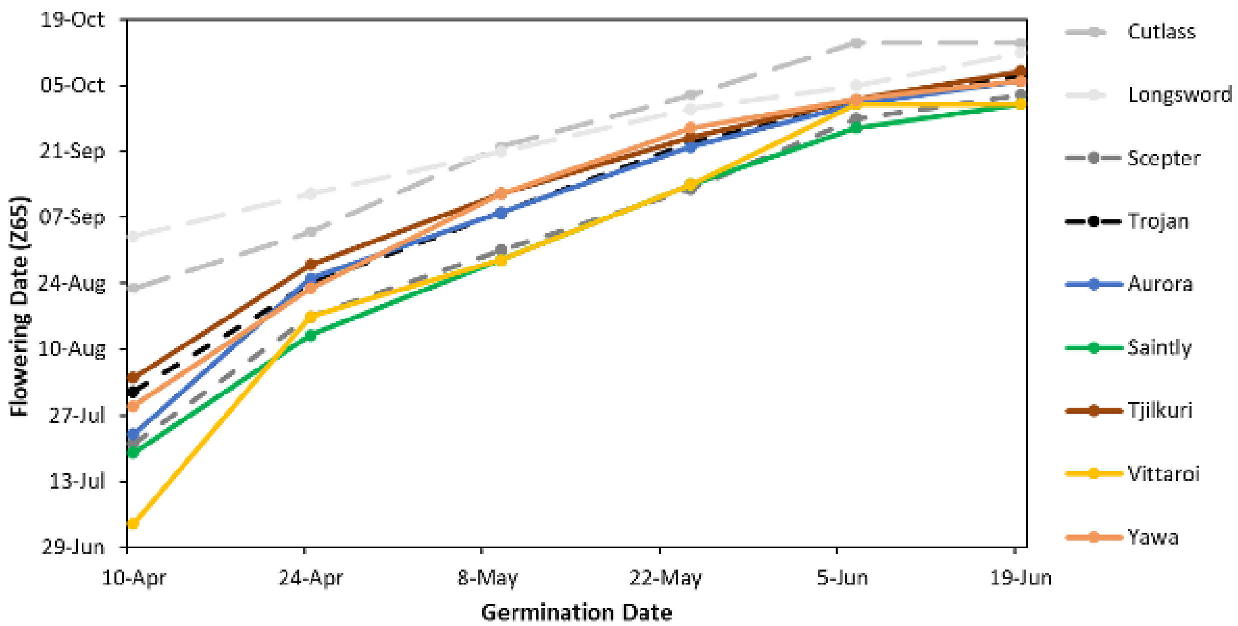

Figure 4: *Comparison of flowering date of bread wheat (dotted line) and durum (solid line) across a diverse number of germination dates in the Waite bird-proof enclosure.*

Table 1: *Average sterility, flowering date (Z65) and machine harvest yield (t/ha) within each environment for selected varieties and correlation between yield and sterility for each site.*

	Giles Corner			**Loxton**		
	Sterility (%)	Z65	Yield (t/ha)	Sterility (%)	Z65	Yield (t/ha)
TOS 1	Yield:Sterility -0.53***			Plot Yield:Sterility -0.45**		
Scepter	13	23 Aug	4.2 a	5	31 Aug	1.6
Saintly	26	23 Aug	3.3 b	33	31 Aug	0.8
Trojan	12	28 Aug	4.5 a	11	4 Sep	1.2
Tjilkuri	50	10 Sep	3.3 b	19	4 Sep	1.2
Yawa	32	11 Sep	3.4 b	8	8 Sep	1.3
TOS 2	Yield:Sterility -0.66***			Yield:Sterility -0.30*		
Scepter	12	25 Sep	4.8 a	12	22 Sep	1.9 a
Saintly	24	27 Sep	3.3 c	27	22 Sep	0.4 c
Trojan	12	1 Oct	4.4 ab	18	30 Sep	1.7 ab
Tjilkuri	43	1 Oct	2.6 d	24	2 Oct	0.7 c
Yawa	16	1 Oct	4.0 b	5	3 Oct	0.8 bc

*indicates correlations that were significant at *(p≤0.10), **(p≤0.01), and ***(p≤0.001)
Letters indicate significant differences between varieties within each sowing date (Giles Corner lsd 0.38 TOS1, 0.65 TOS2, Loxton n.s TOS1, 0.51 TOS 2)

Table 2: *Location of field experiments in 2018, including growing season rainfall (GSR) and the number of heat and frost events recorded at each site between 5th September and the 10th of October.*

Site	**Location**	**Sowing Date**	**Average GSR (mm)**	**2018 GSR (mm)**	**Frost events (<2°C)**	**Heat events (>30°C)**
Giles Corner	34° 13' 05.3" S 138° 44' 12.4" E	17 April (TOS1) 22 May (TOS2)	284	166	20	2
Loxton	34° 30' 23.0" S 140° 34' 12.3" E	3 May (TOS1) 4 June (TOS2)	171	92	18	6

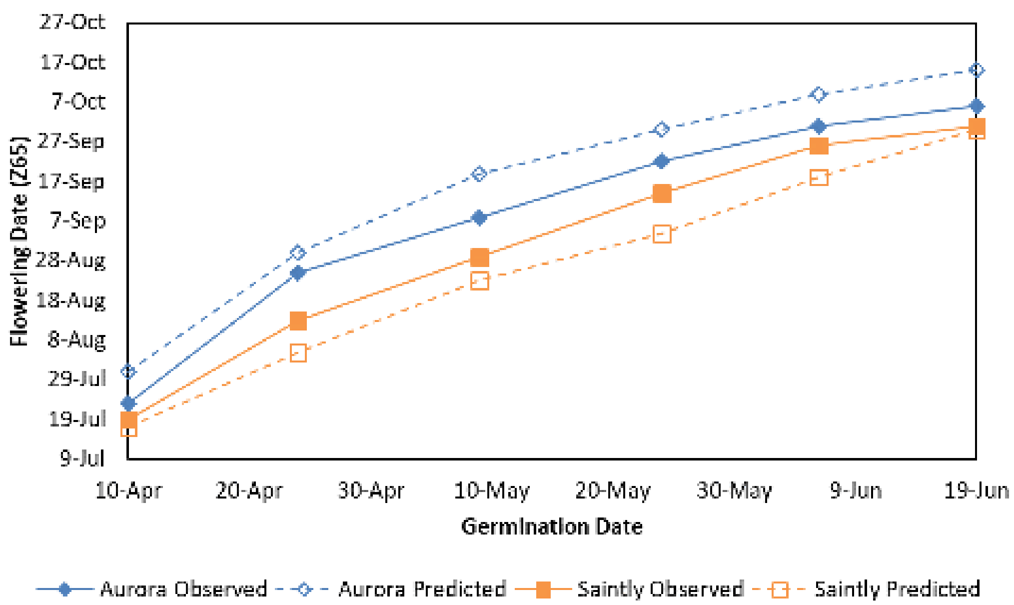

Figure 5: *Observed and APSIM predicted flowering dates for Aurora and Saintly sown at 6 different dates in the bird-proof enclosure at Waite campus.*

Modelling Optimum flowering period (OFP) of durum varieties for selected environments using APSIM

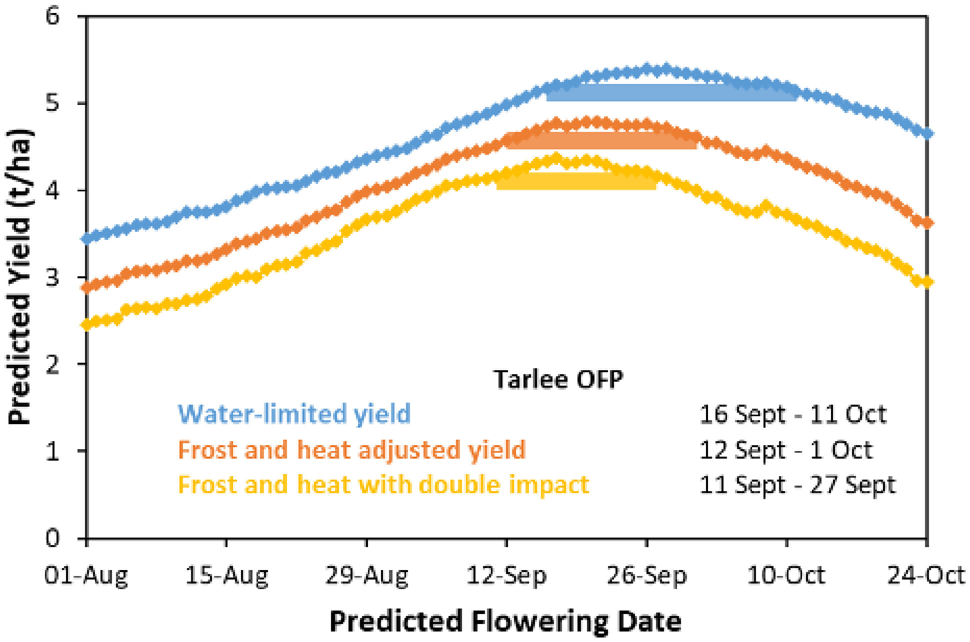

Figure 6: *Example for Tarlee field site of the OFP (95% maximum yield) for a water limited, frost and heat adjusted (bread wheat) and frost and heat adjusted with double impact (durum) based on the last 30 years of weather data.*

Table 3: *Calculated optimum flowering period (OFP) and sowing date (SD) from APSIM based on the methods of Hochman and Horan 2018 (Bread Wheat) and Flohr et. al 2017 (Durum) using Hartog (fast – mid spring cultivar) as the cultivar.*

	Water limited Yield		**Bread Wheat**		**Durum**	
	OFP	**SD**	**OFP**	**SD**	**OFP**	**SD**
Tarlee	16/10 to 11/10	9/5 to 12/6	12/9 to 1/10	5/5 to 27/5	11/9 to 27/9	5/5 to 22/5
Loxton	5/8 to 25/8	12/4 to 23/4	24/8 to 8/9	22/4 to 4/5	30/8 to 8/9	26/4 to 4/5
Hart	10/9 to 30/9	30/4 to 22/5	11/9 to 29/9	1/5 to 21/5	12/9 to 29/9	2/5 to 21/5