Office Use Only	
Project Code	
Project Type	

FINAL REPORT 2021

Applicants must read the *SAGIT Project Funding Guidelines 2020* 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	CSI219
PROJECT TITLE	(10 words maximum)
Soil water and temperature thresholds for early wheat establishment	

PROJECT DURATION *These dates **must** be the same as those stated in the Funding Agreement.*			
Project start date	**1/07/2019**		
Project end date	**30/06/2021**		
SAGIT Funding Request	**2019/20**	**2020/21**	**2022/23**

PROJECT SUPERVISOR CONTACT DETAILS *(responsible for the overall project)*		
Title:	**First Name:**	**Surname:**
Dr	Bonnie	Flohr
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Telephone:		**Email:**
Mobile:		

ADMINISTRATION CONTACT DETAILS *(responsible for all administrative matters relating to project)*		
Title:	**First Name:**	**Surname:**
Organisation:	**CSIRO**	
Mailing address:	Locked Bag 2, Glen Osmond, SA 5064	
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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.

Timely establishment of crops is increasingly challenging under autumn rainfall decline and increasing farm size. As an adaptation to these shifting climatic and farm trends, long coleoptile wheats can be sown deeper than conventional cultivars into stored sub-soil moisture, removing reliance on the autumn break for crop establishment, and ensuring timely establishment. As a case-study, we used field and growth chamber experiments in the SA Mallee to evaluate the strategy of deep sowing wheat cultivars with long-coleoptiles into stored soil moisture to allow for a wider sowing window. A concern for the strategy was that the warmer soil temperatures commonly associated with early sowing could shorten wheat coleoptiles negating the long-coleoptile benefit. We also examined whether stubble retention and deeper sowing into cooler soil could negate the high temperature risk. Our case-study suggested that soil temperatures experienced in the early sowing windows of the Southern SA Mallee were unlikely to reduce coleoptile length, but soil type and water availability will play an important role for emergence. The promise of long-coleoptile, deep sowing strategies will require further investigation under field conditions representing different field environments, soil types and farm equipment, especially sowing points.

Project objectives

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

The aim of this project was to evaluate the suitability of deep-sown wheat cultivars with long-coleoptiles to reduce the dependence on the autumn seasonal break for successful crop establishment using a case-study in the SA Mallee environment. The project had three components 1) climate modelling 2) a growth chamber experiment that simulated field conditions 3) and a soil temperature sensor experiment.

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.

A) The potential for early, deep-sown wheat cultivars with long-coleoptiles to reduce the dependence on the seasonal break for successful crop establishment was evaluated using;
- Simulation modelling (seasonal break analysis, stubble effect on soil temperature)
- A pot experiment grown in a growth chamber set at temperatures relevant to early sowing windows in the SA Mallee
- A field experiment that quantified soil temperatures under relevant moisture, stubble and depth treatments in the target environment

B) Research personnel included;
- Jackie Ouzman provided specialist skills in applying a seasonal break rules to spatial climate data
- Willie Shoobridge and Bill Davoren provided technical support to the pot and field experiments
- Therese McBeath provided guidance in experimental design and interpretation of results
- Greg Rebetzke provided seed of long and short coleoptile sister cultivars and interpretation of results
- John Kirkegaard provided expert review of interpretation of results

C) A manuscript detailing results, and interpretation has been published in the international journal Agricultural Systems;
Flohr, BM, Ouzman, J, McBeath, TM, Rebetzke, GJ, Kirkegaard, JA, Llewellyn, RS (2021) Redefining the link between rainfall and crop establishment in dryland cropping systems. Agricultural Systems 190, 103105.

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.**
Contract with SAGIT signed	Yes ☒ No ☐	
Simulation modelling to determine soil water treatments relevant to the mallee environment	Yes ☒ No ☐	
Collect intact soil cores for controlled environment experiment	Yes ☒ No ☐	
Complete controlled environment experiment	Yes ☒ No ☐	
Progress report submitted to SAGIT	Yes ☒ No ☐	
Establish field experiment under different irrigation and stubble load regimes and collect soil temperature data	Yes ☒ No ☐	
Analyse results on establishment and soil temperature and final report submitted to SAGIT	Yes ☒ No ☐	

TECHNICAL INFORMATION (Not to exceed **three** pages)
Provide sufficient data and short clear statements of outcomes.

Methodology

The case-study site located near Lameroo (-35.3139°, 140.4328°), has a mean growing season rainfall (April-October) of 253 mm (range 125-424 mm, 1970-2018, Jeffrey et al. 2001). Mean summer fallow rainfall (SRF, November-March) is 114 mm (range 50-347 mm, 1970-2018, Jeffrey et al. 2001). Given the variation in seasons experienced, this environment is one that would likely benefit from opportunistic early establishment of long-coleoptile cultivars in seasons of high summer rainfall resulting in moisture stored at depth, thus reducing reliance on the seasonal break for successful crop establishment.

Field experiment

To evaluate the potential of the deep-sown, long-coleoptile wheats in the target environment, a soil temperature sensor experiment was established near Lameroo to quantify seedbed conditions at depth during early sowing windows (1 March to 30 April) under stubble cover and moisture treatments representative of typical farming systems in the region, compared to the traditional sowing window (1 May to 1 June). Temperature sensors (Thermistor 10K3A1iA, Measurement Specialties) assembled by Campbell Scientific (model 109) were centrally installed in an interrow in each plot at 5 cm and 18 cm depths (reflecting the depth of sowing of standard and long-coleoptile cultivars respectively) on 11 February. Pre-calibrated temperature sensors (12 in total, and air temperature) were connected to a CR1000 Campbell Scientific datalogger and powered by a solar panel. Temperature (air and soil) was logged at 30-minute intervals.

At the time of sensor installation, three stubble treatments were applied: (1) bare soil, where all stubble was removed from the plot; (2) stubble load after the grower had baled straw which equated to 0.8 t/ha at 0% moisture, and remaining stubble cut and laid evenly using wire netting to prevent wind removal; and (3) original stubble load without baling straw (equivalent to 2.6 t/ha at 0% moisture), evenly distributed across the plot and wire netted to prevent wind removal. Stubble treatment was randomised within each moisture treatment. The soil was not disturbed since planting operations of the previous wheat crop from which the stubble originated. On 11 February 2020 a rainout shelter was installed over half of the stubble treatments to create two different moisture treatments and removed on 11 March. The treatments outside of the rainout shelter received a 16 mm rainfall event on 5 March, and an additional 15 mm applied using dripline irrigation on 11 March. The drier treatment was equivalent to decile 5 (96 mm) SFR, and the wetter treatment was equivalent to decile 8 (125 mm) SFR at the site. To record soil moisture, gravimetric soil water content (two cores per plot bulked for each of 0-10 cm and 10-20 cm) was measured on 11 February, 26 February, 11 March (pre-irrigation), 13 March (post-irrigation), 1 April, 5 May and 1 June 2020.

Controlled environment experiment

Using soil and air temperature information obtained from the sensor experiment to guide treatments, the effect of soil temperature, soil texture, soil water potential and seeding depth on plant establishment and coleoptile length was investigated in a growth chamber using a pair of near-isogenic-lines that differed genetically only by coleoptile length (Rebetzke et al. 2004). The two sister lines were almost identical and had been developed in the commercial genetic background cv. Mace.

Two soil types (deep sand and sandy loam) representative of soils typical of the SA the Mallee were collected to a depth of 20 cm from Lameroo, dried for 7 days at 40˚C and sieved to <2mm prior the experiment. A water retention curve was generated for each soil type and layer using the suction plate method (Klute 1986) to measure water content under -0.01, -0.06 cm, -0.1 bar, 0.5 bar and -1.5 bar MPa. The water content at different points in the curve was used to identify the water contents to use in the two water potential treatments. Day length in the growth chamber was 12 hours with temperature 1 (T1) set at a 20°C day and 15°C night cycle (average of 17°C) and temperature 2 (T2) set at a 26°C day and 20°C night cycle (average of 23°C). The water potentials evaluated in the sandy loam were -0.01 (wettest), -0.06 and -0.5 MPa (driest), while for the sand soil only -0.01 and -0.5 MPa were evaluated given the small differences in soil water content at different points on the water retention curve.

Plastic PVC cores (8.5 cm dia, 25 cm length) were packed with soil at 1.2-1.2 BD and wet to the target soil water potentials. The cores were not re-watered during the ~two-week experiment. Deep-sown seeds were placed at a depth of 16-18 cm, and shallow-sown seeds were sown at a depth of 4 cm. Seed material consisted of a pair of wheat near-isolines in the cultivar background Mace (short coleoptile, 59 mm, SC) and Mace18 (long-coleoptile, 101 mm, LC) (Rebetzke et al. 2019). Mace18 has the alternate Rht18 dwarfing gene that allows expression of increased coleoptile length while maintaining reduced plant height (Rebetzke et al. 2004). After each treatment was packed into a soil core, cores were placed into the controlled environment facility at the set temperature for ~250°Cd i.e. the T1 experiment ran for 17 days, whereas the T2 experiment ran for 13 days. Plant emergence was recorded daily at ~12 pm until ~250°Cd was reached. At that time, the coleoptile length of each plant was measured from the seed surface to the tip of the coleoptile sheath as per Rebetzke et al. (2016). Data presented is the mean of the five plants harvested from each pot.

Results

At the case-study location investigated here (Lameroo, SA Mallee), the median seasonal break ranged by up to 40 days over the study period and has been delayed by 3-9 days in recent decades. Based on this analysis, the SA Mallee is an example of an environment that may benefit from adaptive management practices to overcome reliance on the seasonal break for timely crop establishment. It is important to understand the new soil environment in which we seek to establish deep-sown crops to ensure a successful crop population and maximise productivity.

The soil temperature in the field experiment was 6-8°C warmer with earlier sowing (March-April) than with more traditional sowing windows (May). At depth (16-18 cm), soil temperature was less variable and was approximately 4°C cooler than the surface air temperatures in March. In the 1 March-30 April window, there were nine days that experienced a maximum soil temperature over 30°C but average soil temperature did not reach 31°C, the temperature reported to reduce coleoptile length (Rebetzke et al. 2016). Our sensor experiment demonstrated that such extreme soil temperature conditions are unlikely to occur under field conditions in current climates in southern cropping regions where average temperatures ranged between 17 and 23°C in 2020, which was an average temperature year (Australian Government 2017).

In our experiment, soil at both depths was 2°C cooler with retained stubble in the early sowing window, but not different in the traditional sowing window. Soil at 18cm with stubble was 3°C cooler than shallow soil without stubble. We did not measure temperature differences between 0.8 and 2.6 t/ha stubble treatments, suggesting that removing some stubble for straw or grazing livestock use may not increase seed bed soil temperatures at sowing provided at least 1 t/ha stubble cover is retained.

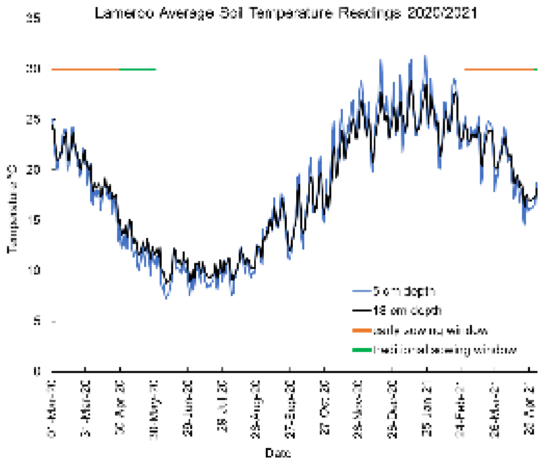


Fig. 1. Mean daily soil temperature at 5 and 18 cm depth in March 2020 -May 2021 for the control treatment in the southern Mallee field experiment. Horizontal lines mark early or traditional sowing windows.

Our study in a controlled environment facility was set at the extremes of the soil temperatures measured in the field (Lameroo, SA Mallee) during early sowing windows (17°C and 23°C) and did not affect coleoptile length. These data suggest that temperatures typical at early sowing windows in the case-study environment are unlikely to have a coleoptile shortening effect. However, long-coleoptile cultivars under low moisture were able to emerge from depth at 17°C, but not 23°C in the sand soil type. This suggests the combined stress of low water, and warmer average temperature may reduce crop establishment on some soil types.

While there were no significant effects of the temperatures tested on coleoptile length, the experiments raised some other important considerations for deep sowing. Soil type and moisture had significant effects on emergence and coleoptile length. Coleoptile lengths reported here were generally shorter than those reported by Rebetzke (2016) who used potting mix and vermiculite to reduce soil resistance in their experiments, presumably due to greater soil compaction in the re-constituted soil cores and particularly in the sandy loam soil texture. These data suggest that deep-sown, long-coleoptile cultivars will have a greater chance of successful emergence on soil less prone to post-sowing compaction. To overcome issues of soil compaction, it is likely that seeding technology will need to be adapted as has occurred in PNW in the USA (Schillinger and Young 2014) where farmers use deep-furrow drills with spacing between rows of at least 40 cm to place wheat as deep as 20 cm below the soil surface to reach adequate soil moisture (Schillinger and Young 2014). These deep-furrow drills mound soil to the sides of furrows to reduce the thickness of soil covering the seed. Although use of deep-furrow drills is extremely effective agronomically, they also cause a high degree of soil disturbance which can lead to major soil loss in ensuing dust storms. Wheat farmers in the PNW continue to evolve minimum-tillage and no-tillage fallow practices to help minimize these environmental and soil health concerns associated with deep-furrow planting.

In our controlled environment facility experiment, as moisture became more marginal, greater thermal time was required for emergence. If treatments were to successfully emerge from depth, an additional 80-100°Cd was required (or 3-6 additional days) consistent with simulation studies highlighting deeply sown cultivars required an additional six days to emerge from depth (Flohr et al. 2018). This delay in emergence should be considered in cultivar development and sowing date combinations to ensure that anthesis occurs during the optimal period in drought-prone environments where drought and heat stress commonly reduce yields (Flohr et al. 2017).

Please refer to Flohr et al. (2021) for complete results and interpretation

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

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

The seasonal break varied spatially in southern Australia, with shifts of −11 to 17 days in recent decades. A case study based in the South Australian Mallee investigating an adaptive strategy in response to declining autumn rainfall, quantified seed bed conditions at early sowing windows under moisture and stubble loads representative of a Mediterranean environment. We found that stubble and moisture lowered soil temperatures, particularly at greater depths. In this environment, soil temperatures recorded at early sowing windows are unlikely to have a coleoptile shortening effect, however soil type and low moisture may have greater influence on plant emergence from depth. Evaluation of deep sowing of long-coleoptile cultivars requires greater testing under field conditions in a range of target environments and using farm equipment to refine sowing equipment and strategies to ensure establishment success.

INTELLECTUAL PROPERTY

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

No IP generated

APPLICATION / COMMUNICATION OF RESULTS

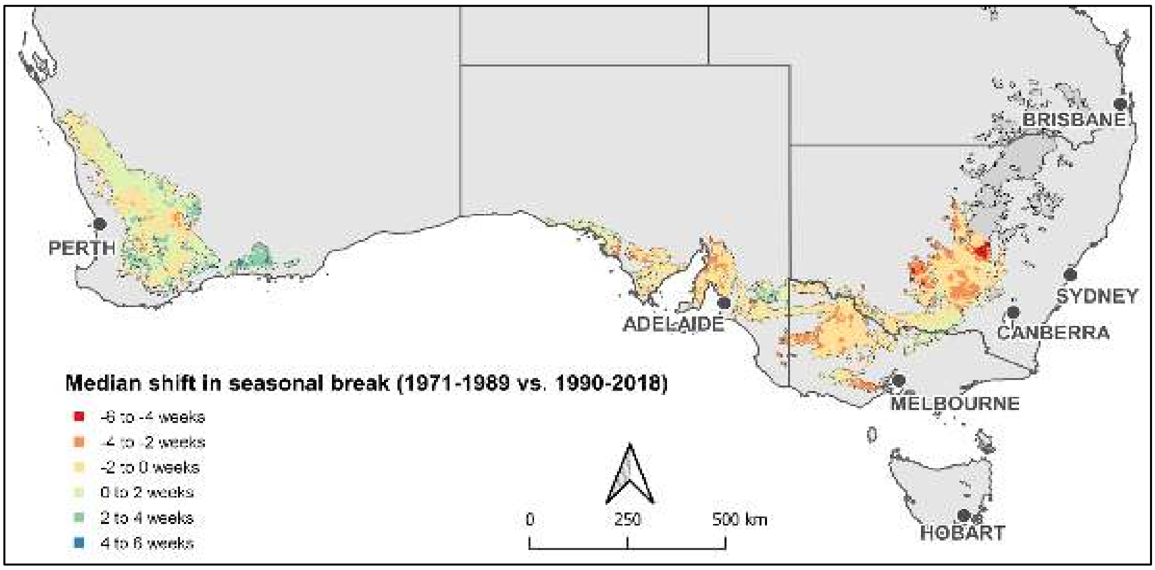
A concise statement describing activities undertaken to communicate the results of the project to the grains industry. This should include:

- *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.

Key findings and impact

- The seasonal break varied spatially in southern Australia, but it has seen shifts of −11 to 17 days in recent decades.



- Deep sowing of long coleoptile wheat cultivars is a promising option for adaptation to this shift.
- Soil temperatures during early sowing periods will not inhibit long coleoptiles at the deep sowing depths, but soil moisture and texture were critical.
- Combining knowledge of climatic shifts with successful crop emergence factors is critical to develop adaptive Genetic x Management strategies.

Publication and extension

- Flohr, BM, Ouzman, J, McBeath, TM, Rebetzke, GJ, Kirkegaard, JA, Llewellyn, RS (2021) **Redefining the link between rainfall and crop establishment in dryland cropping systems.** Agricultural Systems 190, 103105.
- MSF Podcast "Overcoming reliance on the seasonal break - Early wheat establishment findings at Lameroo, SA" https://owltail.app.link/47BQrElwzib

Suggested path to market

- Evaluation of deep sowing of long-coleoptile cultivars requires greater testing under field conditions in a range of target environments (soil types and moisture) and using farm equipment to refine sowing equipment and associated agronomy to ensure establishment success.
- To both remove reliance on the seasonal break for crop establishment and gain the production benefits of early sowing (prior to 10 May), Australian growers need access to winter wheat cultivars that can be sown at greater depth. Therefore, we need wheat breeders to breed modern wheats that combine the long coleoptile trait with winter and spring development.

POSSIBLE FUTURE WORK
Provide possible future directions for the research arising from the project including potential for further work and partnerships.
The technology reported here needs to be evaluated under field conditions (range of soil types and moisture) to further answer fundamental questions on the suitability of long coleoptile wheat cultivars to medium/ low rainfall environments in South Australia. Research questions under field conditions may include; • Is soil water accumulated during the fallow periods enough to germinate seeds sown at depth? • Is there a trade-off between emergence and deeper sowing, will a higher seeding rate be required? • Do long coleoptile wheats need to be sown earlier to flower within the optimal period and counter longer emergence time? • Is dry matter production and yield penalised with deeper sowing? The other major knowledge gap for this work is about sowing equipment and strategies that will ensure establishment success at greater depths. Farming systems scientists need to collaborate with agricultural engineers (e.g. UniSA) to refine sowing equipment for deeper sowing and explore options for deep-furrow drilling and wide row spacing which enables sowing to ~15cm below the soil surface such as practiced in the PNW of America. CSIRO will be submitting a 2022 proposal to SAGIT in pursual of the questions identified above.

References

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AUTHORISATION	
Name:	
Position:	
Signature:	
Date:	18/08/2021

Submit proposal via email to admin@sagit.com.au as a Microsoft Word document in the format shown ***within 2 months*** after the completion of the Project Term.