SA Drought Hub Technical Report

PROJECT NAME: Demonstrating new bread wheat germplasm with potential for improved osmotic adjustment and thus yield under water limited environments

PROJECT LEAD: ***South Australian Research and Development Institute***

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PROJECT SUMMARY

The objective of this project was to assess the yield potential of novel bread wheat germplasms developed by SARDI (Mace/MW#293 genetic population) and University of Adelaide (Mocho de Espiga Branca genetic population) for improved yield potential in a water limited environment. For comparison, twenty bread wheat cultivars released between 1958 and 2022 were also included in the trial. Parental lines of these two genetic populations, MW#293 and Mocho de Espiga Branca, accumulate unusually high levels of sodium in their leaves. This high sodium accumulation presumably provides a better osmotic adjustment which in turn enables the plant to draw more water which is otherwise unavailable due to high salt in soil solution. The hypothesis here is that higher water uptake would lead to higher yields. This may also be true for drought as drought and salinity have similar effects on plant water uptake. A trial was established at Roseworthy Campus to test this hypothesis and determine yield potential of novel germplasms. Unfortunately, there was less than ideal crop establishment with 50% of the plots having less than 80% establishment. This was further complicated by the unexpected late heavy rains which caused by up to 90% pre-harvest sprouting. This resulted in reduced grain weight and quality. For these reasons, grain yield analysis could not be performed, and yield potential of novel wheat germplasms could not be determined. However, we observed germplasm lines with longer and wider spikes than commercial wheats, which is exciting as this indicates higher grain numbers. This higher grain number per spike trait was expressed despite a very dry year indicating this trait's yield potential across different environments. The spike samples are currently being scanned by X-ray CT (The plant Accelerator, University of Adelaide) to validate visual observations and identify germplasm lines with increased grain number for breeding and further evaluation in multiple environments. However, how the increased grain number relates to yield could not be assessed. For this, this work needs to be repeated if/when further funding is secured.

EXECUTIVE SUMMARY

The proposed project addresses the SA Drought Hub objective of 'enhancing drought resilience and recovery across all farming sectors' and National Agricultural Innovation Priority 2. 'Australia will champion climate resilience to increase the productivity, profitability and sustainability of the agricultural sector by 2030'. It fits within Activity 2 'deliver demonstration sties to increase adoption of existing research'.

SA Drought Hub funding was obtained to field assess yield potential of two novel bread wheat genetic populations with varying levels of sodium (Na^+) uptake (Mace/MW#293 and Mocho de Espiga Branco /Gladius), and bench mark them against a historical set of 24 wheat varieties (released between 1958 and 2022). The expectation was to **identify lines with superior performance to currently available germplasm under water limited or soil constrained environments** due to a capacity to utilise accumulated Na+ as an osmotic adjustment mechanism leading to improved water use efficiency.

The trial was conducted at Roseworthy campus of University of Adelaide. A number of grower groups, breeders and researchers visited the field site and expressed that they felt the work conducted was important. Unfortunately, we encountered crop establishment issues and unseasonal late rains causing significant damage to grains, hence, we could not perform yield analysis to determine yield potential of novel wheat germplasm against historical wheats. However, we observed germplasm lines with longer and wider spikes than commercial wheats, which is exciting as this indicates higher grain

numbers. This higher grain number per spike trait was expressed despite a very dry year indicating this trait's yield potential across different environments. The spike samples are currently being scanned by X-ray CT (The plant Accelerator, University of Adelaide) to validate visual observations and identify germplasm lines with increased grain number for breeding and further evaluation in multiple environments. However, how the increased grain number relates to yield could not be assessed. For this, this work needs to be repeated if/when further funding is secured.

PROJECT BACKGROUND AND OBJECTIVES

This project was considered unique within the current suite of SA Drought Hub efforts in targeting germplasm selection for better drought resilience.

Background

The proposed project addresses the SA Drought Hub objective of 'enhancing drought resilience and recovery across all farming sectors' and National Agricultural Innovation Priority 2. 'Australia will champion climate resilience to increase the productivity, profitability and sustainability of the agricultural sector by 2030'. It fits within Activity 2 'deliver demonstration sties to increase adoption of existing research'.

Drought is the most prevalent abiotic stress affecting production of wheat in Australia. Over the last three decades, there has been a significant GRDC and state investment into understanding drought tolerance (ability to maintain biomass and yield under drought conditions) and its mechanisms. As a result, researchers have identified mechanisms related to the capacity of plants to tolerate drought, the genetic variation available within breeding germplasm and diagnostic markers for genes of interest. Despite these advances, there remains strong grower interest in the development of varieties that incorporate further drought tolerance.

Concurrently, GRDC, grower organisations and SA government have invested >$9.2 M* in local cereal crop salinity tolerance research. SARDI and UoA researchers Dr Yusuf Genc and A/Prof Stuart Roy and their colleagues have identified a novel Na+ tolerance mechanism that enables wheat lines to accumulate sodium within their leaves, rather than exclude Na+ from roots. A key output of this investment has been two bread wheat germplasm sets totaling 460 recombinant inbred lines (RILs), designed to capture salinity tolerance into a better adapted background.

Objectives

To demonstrate, and field-assess wheat lines designed to accumulate salt (at 100x wheat cultivar Mace) in their leaves rather than exclude salt at root level. This accumulation mechanism opens the possibility of improved water use efficiency through osmotic adjustment. This novel germplasm is the result of ten years of sustained effort by The University of Adelaide (UoA) and SARDI researchers and represents an exciting opportunity to stabilise yield under rainfed conditions.

The project lead, Dr Yusuf Genc, worked with colleagues at UoA, SARDI and CSSSA to develop a field demonstration site to assess the germplasm for traits that contribute to stable yield, and to extend these findings to growers, consultants and breeders. We expect germplasm with advantageous traits will be taken up by plant breeding companies for further development, providing growers with

expanded variety options for dry years and assisting them to reduce risk and improve mixed farming resilience.

Aims:

i) To assess the potential of 460 novel fixed bread wheat lines for improved water use efficiency on constrained soil types and compare growth and yield against 24 historical and current bread wheat varieties.

ii) Coordinated by The Crop Science Society of South Australia (CSSSA), a society of c. 450 members, showcase the germplasm in the field to growers, consultants, and breeding companies.

Methodology

A bread wheat field trial was established by at Roseworthy farm of University of Adelaide. The trial included two novel genetic populations (Mace/MW#293 RIL , n=396; Mocho de Espiga Branco/Gladius, n=64), and a historical set of 24 wheat cultivars released between 1958 and 2022. There were 636 plots in total). The experimental design was a check plot design where replicates of the parents and commercial wheats were used as checks and allocated to plots with unreplicated RILs. Allocation of lines to plots were achieved using a spatially optimal model-based design approach. Trial was sown on 25 May 2023 by SARDI Agronomy Group. In early July, crop emergence was assessed , and more than 50% of the plots had suboptimal (<80%) emergence (**Figure 1).** Suboptimal emergence was attributed to interaction between chemical used to spray out the existing crop prior to plot sowing interacting with unseasonably high rainfall directly post-sowing. The plots with low and no emergence (109 plots <20%) were hand sown on 14 July 2023. All wheat lines were scored for maturity when most of the were at or near heading.

Due to heavy rain, harvest was delayed until 17 December 2023. Unfortunately, these rains caused significant sprouting (up to 95%; **Figu**res **2** and **3**). Sprouted seed had weight loss, hence grain yield analysis was not possible, and yield potential of novel wheat germplasm could not be determined. Sprouted seeds had very low germination (<10%; **Figure 4**). Therefore, seed multiplication of this novel germplasm is necessary for any yield assessment in the future.

In allied work, (SAGIT Funded), 15 randomly selected spikes from each plot were sampled for X-ray Computed Tomography to determine spike and spikelet architecture. Mace and MW#293 and the population vary significantly in spike and spikelet architecture (**Figure 5**; MW#293 has longer spikes and more seeds per spikelet than Mace), hence the field trial presents the opportunity to determine the impact of these traits on yield and to identify genetic markers for breeding programs.

Aligned work form the ARC ITTC Future Crops, Adelaide University Ph.D. student Alex Seward studied Mocho de Espiga Branca/Gladius RILs in the greenhouse to verify phenotypes seen in the field (ability to accumulate high Na+ and not suffer biomass reduction) as well as investigate the amount of Na+ accumulating in floral and seed tissue to see if that is linked to salinity tolerance and/or issues with grain quality.



Figure 1. Examples of suboptimal (right, <80%) and optimal (right, >80%) establishment. Photos were taken on 23 November 2023 by Yusuf Genc.



Figure 2. Pre-harvest sprouting in the field. Photos were taken on 17 December 2023 by Yusuf Genc.

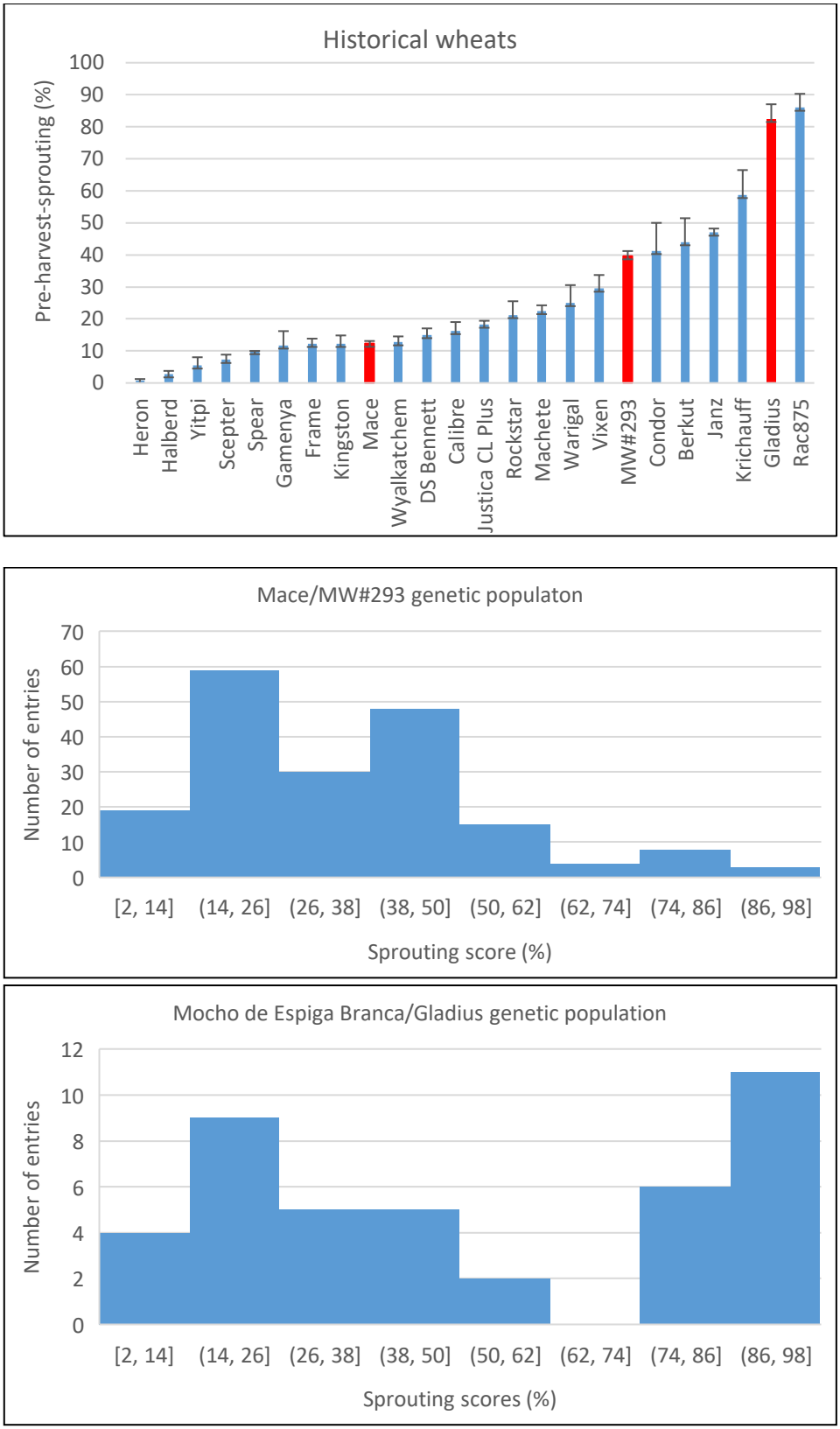


Figure 3. Pre-harvest sprouting (%) in historical wheat varieties and parental lines Mace, MW#293 and Gladius (top), Mace/MW#293 (186 lines with optimal crop establishment (bottom right) and Mocho de Espiga Branca (42 lines with optimal crop establishment (bottom right).

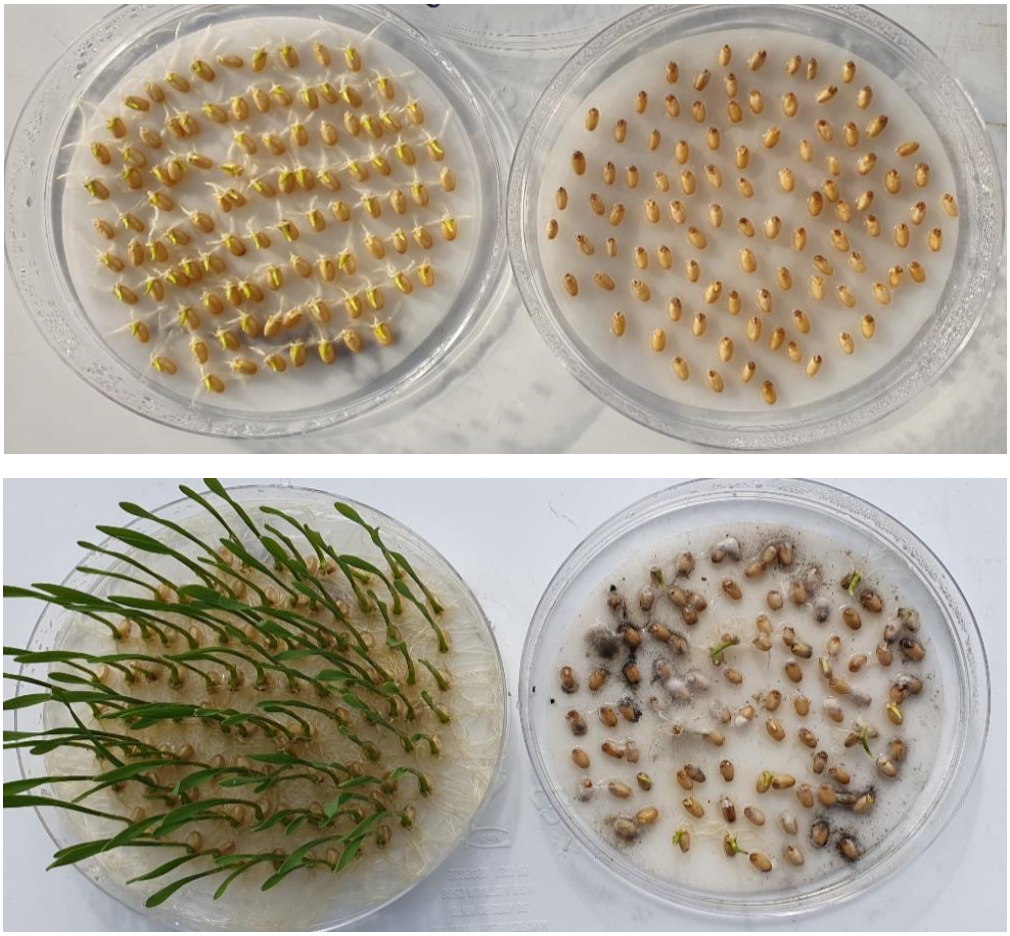


Figure 4. Germination in sprouted and normal seeds; three days after imbibition (top figure), and seven days safter imbibition (bottom figure). Photos were taken by Yusuf Genc



Figure 5. A selection of spikes from the field trial; from left to right, germplasm line with Mace type maturity with shorter spike, germplasm line with Mace type maturity and longer spike, Mace and MW#293 with later maturity than Mace. Photo was taken on 28 May 2024 by Yusuf Genc.

LOCATION

Where demonstration sites, field trials, events or other activities have been conducted, provide the following location details in the table below: latitude and longitude for field trials, or LGA for events and other activities. (Add additional rows as required.)

Site # and name	Latitude (decimal degrees)	Longitude (decimal degrees)	LGA
Roseworthy# Demonstrating new bread wheat germplasm with potential for improved osmotic adjustment and thus yield under water limited environments	-34.532122,	138.692204	

RESULTS

Sowing of the field trial took place on 25th May 2023. When performing establishment counts, plots on the Eastern and Northern areas of the trial had suboptimal establishment (i.e., emergence <80%) affecting 52% of the Mace/MW#293 RIL population and 36% the Mocho/Gladius RIL population. The site received high rainfall soon after sowing, likely leading to leaching of herbicide from the spray-out of the crop to facilitate site establishment compounded by waterlogging in lower lying areas of the site. To address this issue, a number of plots were re-sown by hand (14th July 2023), however, some of these plots still performed poorly due to severe drought stress in early-mid spring. Despite the establishment issue, the project progressed well until crop maturity. The various lines were scored for their developmental stages. Plots looked like they would yield well. Between Nov 20 and Nov 24, 15 mature spikes per plot were sampled for X-ray CT analysis of spike traits. This activity is funded through SAGIT (UAD 03123 Manipulating spike architecture to improve wheat yield_2023/2024). Differences in number of spikelets per spike and grains per spikelet were also observed in the field, validating our previous observations in the glasshouse. These observations in the field are currently being quantified through X-ray CT analysis which will enable us to gain an understanding of any genotype x environment influences that could be the basis of further research. Unfortunately, late heavy rains delayed harvest, with equipment unable to access the plots until dried. The rain resulted in up to 95 % pre-harvest sprouting across plots. It is well-known that pre-harvest sprouting leads to losses in grain yield and quality (Dallinger et al., 2022). In the present trial, we also observed substantial grain weight losses (data reported in accompanying Progress Report June 2024). This pre-harvesting sprouting phenomenon hampered our ability to perform yield analysis based on weight and to obtain good quality grain for further multi-environment field trials. Therefore, we could not determine yield potential of novel wheat germplasm against commercial wheat. Further seed multiplication will be necessary of the Mace/MW#293 and Mocho de Espiga Branca populations for future projects, and subsequent yield potential and spike trait analysis. It is also important to note that while studying Mocho de Espiga Branca/Gladius RILs, University of Adelaide Ph.D. student Alex Stewart verified the tolerance and Na+ accumulation of lines that were in the field in the greenhouse. He also observed that there was still a bit of variation for height and flowering time in the Mocho de Espiga Branca RILs in field conditions, which requires more backcrossing to remove those effects.

CONCLUSION

As we encountered crop establishment and pre-harvest sprouting issues in the field trial, we were unable to conduct yield analysis, hence, could not determine yield potential of novel bread wheat germplasms against historical wheats. On a positive note, we observed significant variation in spike traits (funded by SAGIT) and are currently analysing spike samples by X-Ray CT at the Plant Accelerator (University of Adelaide). We identified novel bread wheat lines with significantly higher grains per spike than commercial wheats, indicating their potential to improve wheat yields. However, it remains to be seen in future field trials how these spike traits relate to grain yield.

REFERENCES

Dallinger HG, Franziska Löschenberger F, Azrak N, Ametz C, Michel S, Bürstmayr H (2022). Genome-wide association mapping for pre-harvest sprouting in European winter wheat detects novel resistance QTL, pleiotropic effects, and structural variation in multiple genomes.The Plant Genome, DOI: 10.1002/tpg2.20301

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