Developing robust groundcover to promote resilience in low rainfall mixed farms using seed priming

Jack Desbiolles[1], Amanda Cook[2,3], Farzad Aslani[2], Gareth Scholz[4], Ian Richter[2] and Craig Standley[2]
[1]University of South Australia; [2]SARDI; [3]University of Adelaide; [4]SANTFA

Location
Minnipa
G & R Scholz

Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2022 Total: 485 mm
2022 GSR: 235 mm

Paddock history
2022: CL Hammer wheat
2021: Self-regenerating medic pasture
2020: Longsword wheat

Soil type
Sand (non-wetting)

Plot size
10 m x 1.7 m x 3 replicates

Key messages

- **Deeper seeding was the most effective factor improving wheat crop establishment and early/late development. While no grain yield benefits were detected in 2022, deeper sowing increased both protein content and grain size.**
- **Seed priming showed some potential to improve wheat seed germination rate under laboratory conditions but did not express any clear benefits under field conditions.**
- **Soil wetter resulted in a small improvement in wheat crop establishment and early vigour.**
- **The year 1 results suggest seeding into deeper moisture with a long coleoptile variety can best maximise stubble groundcover in non-wetting sandy soil conditions. This work is continuing in 2023.**

Background

The project 'Developing robust groundcover to enable resilience in low rainfall mixed farms' led by Mallee Sustainable Farming aims to demonstrate, evaluate, and communicate innovative farming practices to low rainfall farmers in the tri-state Mallee and Eyre Peninsula regions to enable them to implement farming systems that increase and maintain groundcover resilient to the pressures imposed by climate variability and management practices.

The focus of this project is to demonstrate new and innovative technologies and practices that support the maintenance of functional groundcover across the spectrum of seasons and sequences of enterprises. The outputs will be a synthesis of research - proven innovative practices, that are validated locally at paddock-scale and that can assist with maximising surface residue retention and longevity. Example strategies include reducing the disturbance and degradation of stubbles during seeding, harvest, and grazing; optimising stubble-friendly soil amelioration practices; and drought proofing crop establishment via seed priming or seeding into stubble-row moisture.

Seed priming refers to the process of pre-soaking seeds in a solution to kickstart the process of germination and advance it sufficiently such that 'primed' seeds placed in soil will require less soil moisture to finish germination and more successfully establish as seedlings. This concept is well proven internationally with increasing adoption by smallholder farms and is most beneficial under marginal soil moisture conditions, which are becoming increasingly prevalent in rainfed farming systems. Primed seeds can be re-dried for storage or used straight away 'wet' in the crop sowing operation.

Why do the trials?

A collaboration activity between SARDI, UniSA, SANTFA and AIR EP is focussing on validating and demonstrating a strategy under the drought-proofed crop establishment component of the project, which is seed-priming. A feature of the demonstration activity will be the development of a scalable, proof-of-concept mechanised solution for implementing on-farm hydro-priming and tailoring of air-seeder technology to deliver 'wet' seeds.

Seed germination is a 3-phase process, which includes I: 'imbibition' (or rapid hydration), II: 'activation' where water uptake slows down and major metabolic changes take place in preparation for embryo development, and III: 'physical germination' following a renewed rate of water uptake to sustain the emergence of the first root (radicle) followed by the first shoot. Only phases I and II are reversible with no impact on seed viability. Seed priming thus initiates the early stage of seed germination (up to phase II above) and ultimately reduces the amount of soil moisture and time required to complete the germination, hastening seedling emergence.

'Hydro-priming' was used in this trial and refers to the soaking of seeds in water. Various solutions may be used instead of water to seek additional agronomic benefits in specific soil and crop contexts with techniques such as nutri-priming (to fortify seeds with trace elements such as zinc or molybdenum), 'osmo-priming' (to improve germination ability in saline-environment) and bio-priming (with beneficial micro-organisms).

How was it done?

In 2022 three experiments were implemented:

- To assess changes in wheat seed weight during 25 hours of soaking (imbibition).
- To investigate the impact of a short seed imbibition period on emergence in pots.
- To assess value of hydro-priming on a non-wetting sand in the field.

Experiment 1

A first pot experiment was undertaken in mid March, whereby eight replicates of 100 wheat seeds (variety Hammer CL) were each placed in 50 ml of distilled water in a sealed container and weighed hourly (after air drying on paper towel) over a 12 hour period, with a final seed weight taken at 25 hours. Soaking periods of 6-24 hours are often cited in seed priming literature.

Experiment 2

A second pot experiment was undertaken pre-sowing whereby four replicates of 100 wheat seeds (variety Hammer CL) were each placed in 50 ml of water in a sealed container for 3 hours, before planting in pots. The soil type was a non-wetting sand taken from the 2022 trial site. The seeds were planted at 3 cm deep in two rows 175 mm apart (7 inch row spacing) in containers 250 mm (wide) by 350 mm (length) by 200 mm (deep). Pots were placed in a glasshouse on 12 March and first emergence was recorded 48 hrs later on 14 March. Emergence was monitored daily over 6 days.

Experiment 3

A replicated small plot field trial was established in a non-wetting sand near Minnipa to evaluate the impact of two seed priming levels (6 vs 12 hours soaking), seeding depth (shallow, medium, deep) and a soil wetter. Using a knife point press-wheel plot seeder, twelve treatments (shown in Table 1) were applied to 6 rows (0.255 m) x 10 m long field plots which were arranged in a randomised complete block design with three replicates.

The trial was sown on 29 April with AGT Calibre (110-115 mm long coleoptile) at 70 kg/ha with 55 kg/ha MAP banded above the seeds. A soil wetter (SE14 at 3 L/ha) was delivered in furrow in 80 L/ha volume for appropriate treatments. The trial area was sprayed pre-sowing and in-crop by the grower. Extra urea (25 kg/ha) was broadcast after sowing and another 50 kg/ha was broadcast in-crop on 13 July.

Initial soil moisture samples were taken at 3 cm intervals directly before seeding (Table 2). Seeds were weighed into bags to the calibrated rate of 70 kg/ha and 12 samples were separately soaked for either 6 or 12 hours. The imbibed seeds were air dried on paper towel then placed into seeding envelopes for immediate sowing with a cone seeder. Crop establishment was assessed twelve times in the five weeks after sowing. Early dry matter cuts and NDVI were taken on 6 July (10 weeks after sowing), and late dry matter cuts on 13 October (late flowering for the deep sown treatment). The trial was harvested on 12 December for grain yield and quality assessment.

The 2022 season was an ideal growing season with stored soil moisture due to good February rains and an early seeding opportunity following a 14 mm break of the season on 26 April. Post seeding rainfall is shown for the 6 week period in Table 3a, highlighting only little rainfall post seeding until week 4 and 5 when 18 mm and 58 mm fell, respectively. Minnipa monthly rainfall for 2022 is listed in Table 3b. Minnipa recorded a decile 9 rainfall in 2022 complemented by stored subsoil moisture from summer rains in late 2021.

What happened?

Experiment 1

Soaking wheat seeds in water increased seed weight rapidly at first, and then more gradually, up to a maximum of 57% over the 25 hour period (Figure 1). It would appear that longer soaking would have increased seed weight further by imbibition, albeit at a decreasing rate which suggest the process had reached activation phase II of germination. Wheat germination starts once the weight gain during imbibition reaches around 35-45%. The significant weight change in primed seeds also implies that seeder calibration must be adjusted pro-rata to maintain the targeted plant population.

Table 1. Experimental treatments and targeted settings.

Treatments	Seeding depth (NB: seeds placed at the bottom of the furrow)	Soil wetter	Hydro-priming (hours)	Furrow tilling depth from surface (mm)
1			No	
2	Baseline: at the moisture front ("INTO")	No	6	up to 75
3			12	
4			No	
5	30mm deeper than baseline ("BELOW")	No	6	up to 105
6			12	
7		No	No	
8		Yes	No	
9	30mm shallower than baseline ("ABOVE")	No	6	up to 45
10		Yes	6	
11		No	12	
12		Yes	12	

Table 2. Soil moisture profile data with depth.

Depth (cm)	0-3	3- 6	6- 9	9-12	12-15	15-30	30-60	60-90	90-120
Average Gravimetric water content (% w/w)	1.3 c	1.3 bc	3.3 b	3.6 b	3.6 b	5.5 a	6.3 a	6.3 a	6.3 a

Note: Means with the same letter are not significantly different (P<0.05).

Table 3. 2022 post-seeding weekly rainfall and monthly growing season rainfall for Minnipa (mm).

a) weekly rainfall post seeding	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Total
	4.7	2.3	1.0	18.0	57.6	10.6	

b)	Jan-March	April	May	June	July	Aug	Sept	Oct	Nov-Dec	GS (mm)
2022 Season rainfall	100.6	36.2	75.5	27.8	28.4	50.8	54.0	59.6	96.4	332
Long Term Average	46.3	18.0	34.3	42.5	44.8	43.1	32.6	26.1	39.3	241

At 25 hour soaking time, it was observed that seeds had yet to start softening, which would make them vulnerable to damage by mechanical handling (e.g. grain augers). Seed priming thus needs to be carefully calibrated to remain within the 2nd phase of germination where the process may safely be reversed by slow drying (in case soil moisture conditions become too marginal) without loss in seed viability. Re-drying of primed seeds in the furrow implies a delayed opportunity to benefit early crop establishment, but such risks can be mitigated by sowing to greater depth where more soil moisture is typically available to finish the germination process and be better insulated against early evaporation.

Experiment 2

A three hour soaking in water caused a significant emergence improvement on the third day, whereby un-primed seeds had no emergence at all, while nearly 7% of primed seeds emerged in the first 72 hours. However, in both treatments, emergence became similar from day 3 onward (Figure 2). It is unclear why a relative slow-down was measured on day two with primed seeds. The initial burst is likely to be linked to a subset of seeds having more effectively imbibed initially and reached early phase 3 stage. A bigger benefit of seed priming may be expected following longer soaking duration which might result in a greater difference between the two curves of Figure 2. A more detailed pot trial will be conducted in 2023.

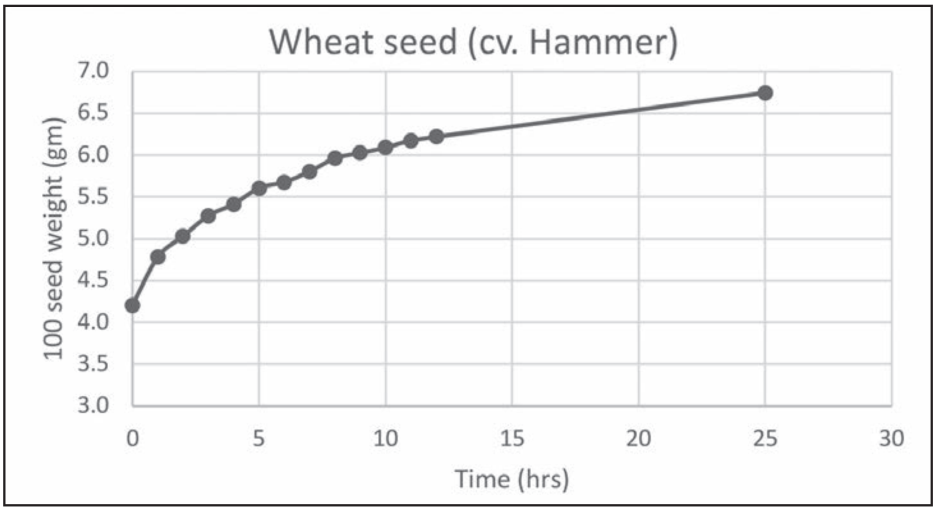

Figure 1. Change in wheat seed weight during soaking in water over a 25 hour period.

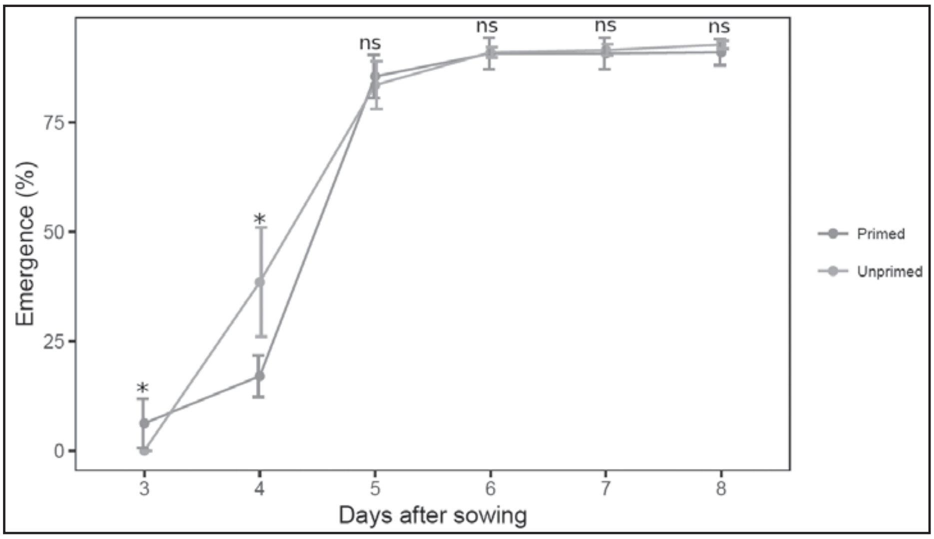

Figure 2. 3hr primed wheat seed (cv Hammer) emergence in pots.

Field Trial

Plant Establishment - Figure 3

Deep seeding resulted in remarkably higher early plant density, a difference which remained consistent over the sampling period until both shallow and baseline sowing finally reached similar plant density levels 46 days after sowing, following significant rain at 4 - 5 weeks.

Seed priming showed no benefit at any of the depths. Conversely, the addition of a soil wetter at the shallow depth provided a significant benefit (21-38 plants/ m^2) over the period specifically with unprimed seeds. Under the experimental conditions, deeper sowing into higher soil moisture was therefore the most reliable technique to enhance establishment with visual benefits also observed on initial growth of wheat.

Early NDVI and Dry Matter (t/ha) - Figure 4

Similar pattern to crop establishment data was observed for Early Dry Matter (EDM), measuring a 4.7-fold increase over the seeding depth range, whereby the highest EDM was obtained under the deep seeding treatments, followed by the baseline seeding depth and least under the shallow seeding depth (NB: similar trends were exhibited for NDVI, data not shown). In line with its effect on plant establishment, soil wetter significantly improved EDM, measuring a 1.8-fold increase. No consistent benefit of seed priming on EDM (data not shown) could be detected at any of the depths, while NDVI data suggested a slight negative impact (-12%) of seed priming.

Late Dry Matter (t/ha) – Figure 5

Treatment differences measured later in the season (late flowering to late booting) became less obvious, with a trend of slightly higher (+27%, borderline significance) crop dry matter under deeper seeding. No benefits of soil wetter or seed priming were detected.

Grain yield and quality (t/ha) – Figure 6

No differences in wheat grain yield were measured, with the trial averaging 3.6 t/ha. In contrast, grain quality was affected by seeding position (Figure 6), whereby deep seeding slightly increased protein content and more particularly grain size (1000-grain weight).

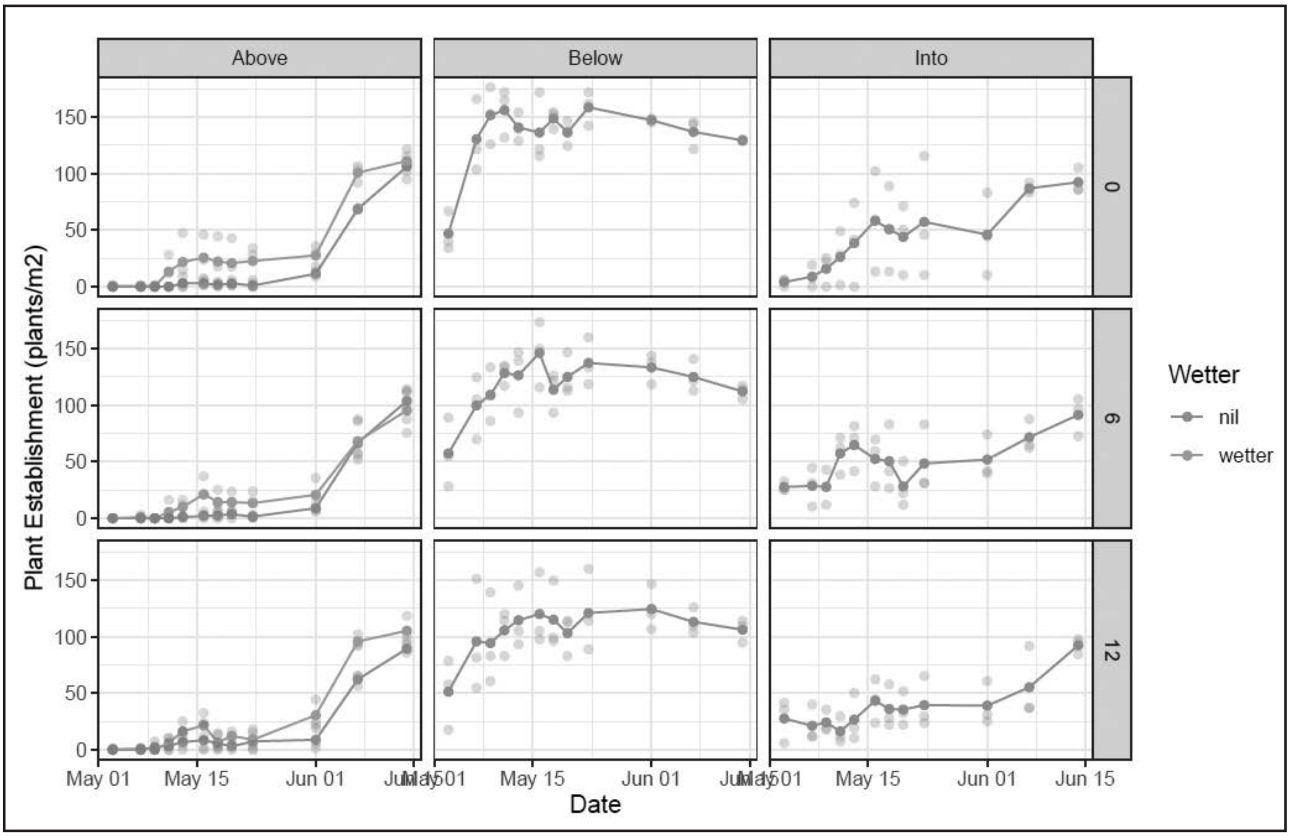

Figure 3. Crop establishment for the 12 treatments over a 6 week period post-sowing (Coloured lines represent the mean values of 3 replicates) - see Table 1 for details on treatment labels.

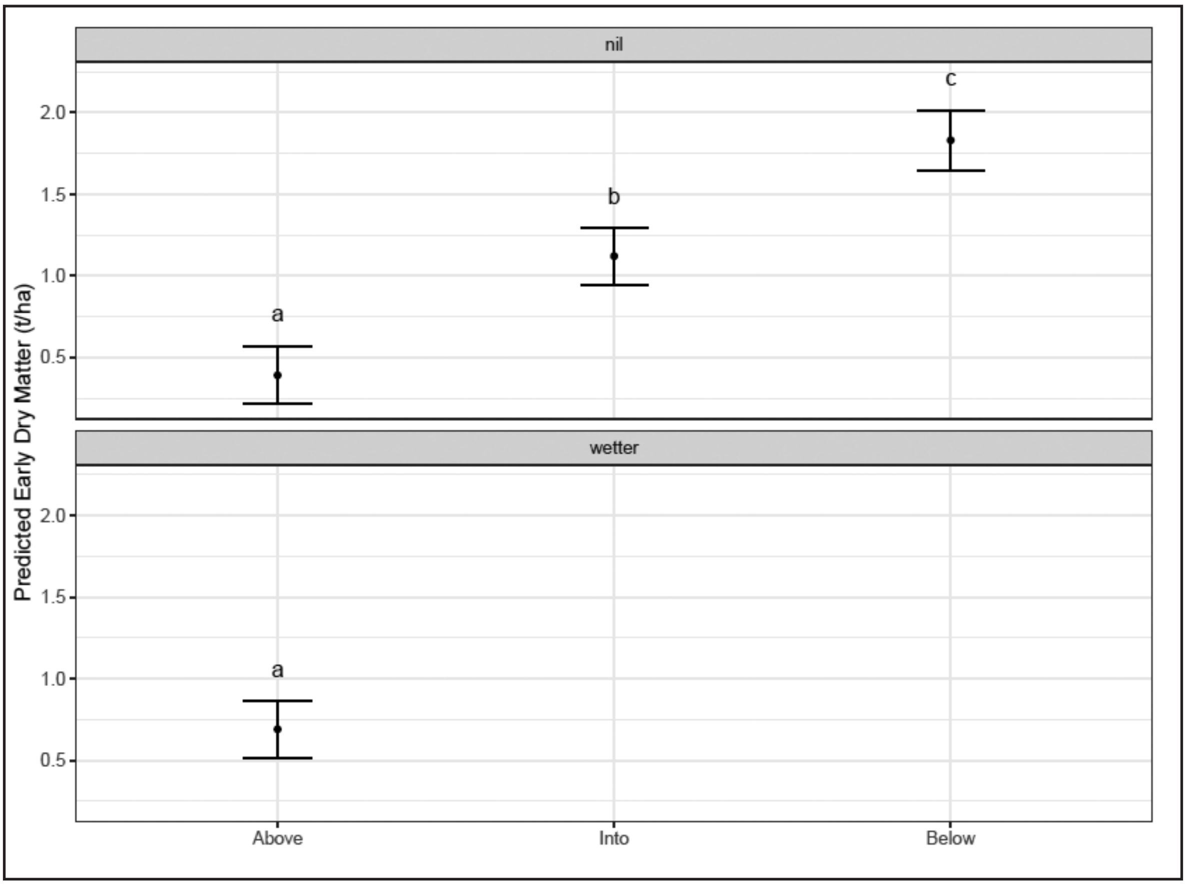

Figure 4. Main effects of soil wetter and seeding position on early dry matter. Different letters indicate significantly different means.

Farming Systems

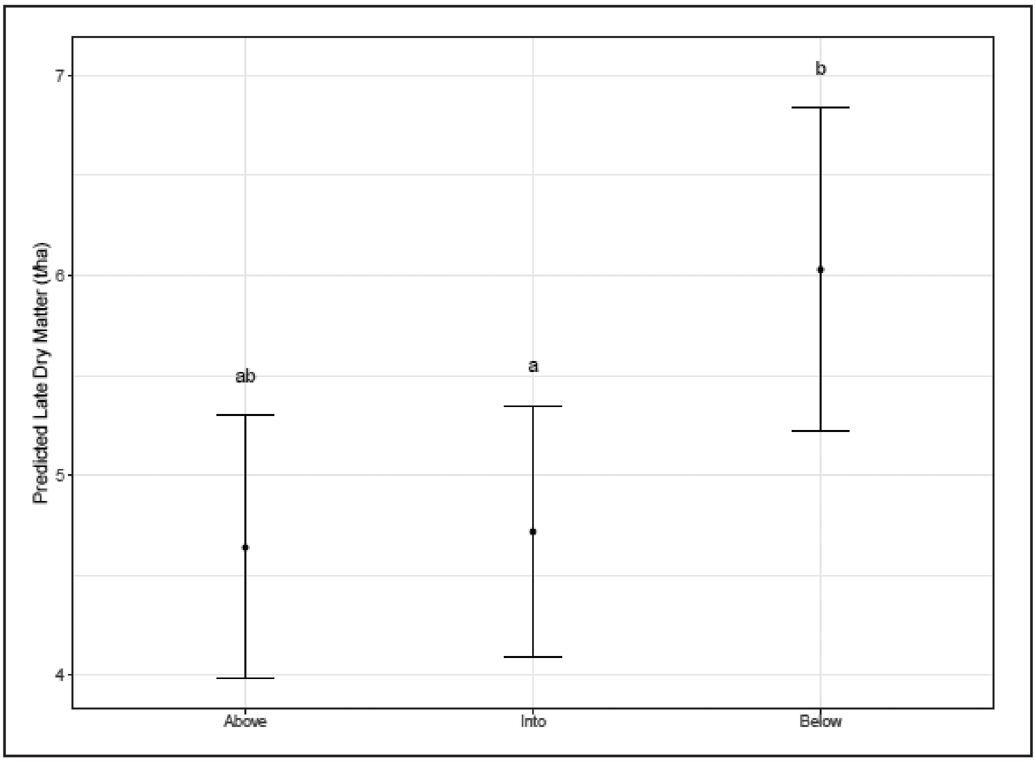

Figure 5. Main effect of seeding position on late dry matter. Error bars represent the 95% confidence intervals and different letters indicate significantly different means.

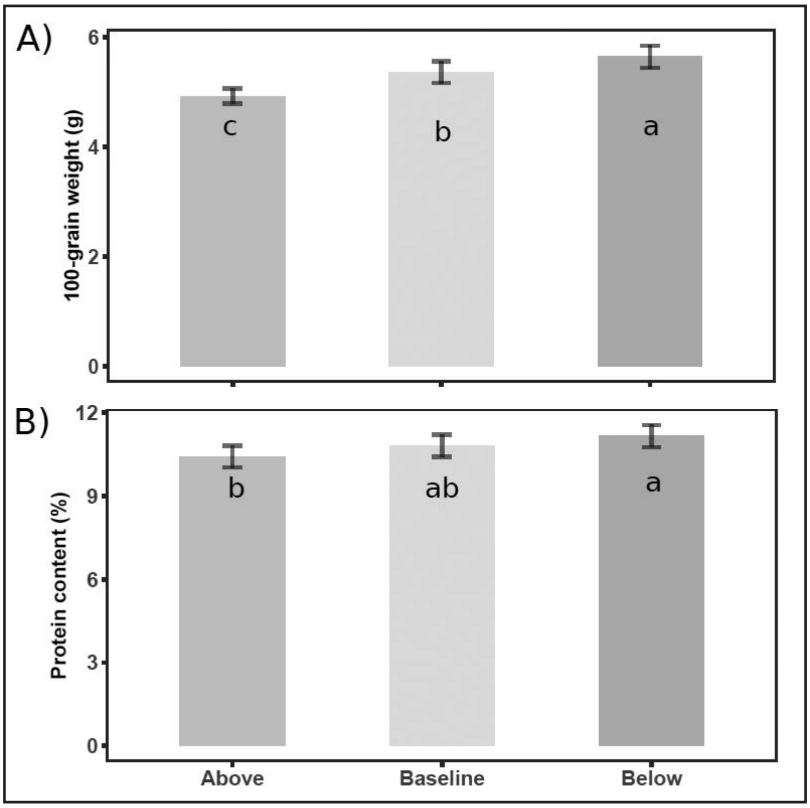

Figure 6. Main effect of seeding position on wheat seed 100-grain weight (left) and protein content (right).

What does this mean?

This research provided evidence for the potential role of novel sowing strategies for improving crop performance biomass of wheat on a non-wetting sand.

Overall, the results confirmed the importance of deeper seeding into greater soil moisture to potentially benefit both quality and productivity of wheat production in sandy soil conditions. The deeper seeding treatment (30 mm below the moisture front) using a long coleoptile wheat variety (AGT Calibre, 105-110 mm coleoptile) showed clear benefits at the crucial stages of emergence and initial crop growth, carrying through to late crop development. Under a decile 9 season with significant subsoil moisture storage pre-season, these deeper seeding benefits did not eventuate in grain yield benefits. A deeper sowing strategy however should provide extra benefits over summer with improved residue groundcover. The trial showed the potential complementary benefit - albeit limited - of applying a soil wetter in the seed zone, to facilitate seed germination and improve early crop growth, but with no persisting impact on late biomass production under the experimental conditions.

Although seed hydro-priming enhanced seed weight and triggered faster initial germination under laboratory conditions, it did not improve crop establishment in the field. In practice, primed seeds might readily lose absorbed water to surrounding soil when placed in sub-optimal conditions such as shallow seeding, thus cancelling any positive effect of priming. In contrast, deeper sowing into greater soil moisture (Table 2) would also provide more protected moisture levels, expected to allow seed priming benefits to be more reliably expressed. The significant but late post-seeding rainfall (Table 3a) also resulted in more favourable soil moisture levels, reducing the potential benefits of seed priming due to overly dry soil in the first 3 weeks. While any positive impact of seed priming was not detected in this first year of field trials, a longer seed priming duration may have been necessary.

Further assessment will be performed in 2023 to assess some of these hypotheses in both a small plot replicated trial and a paddock-scale demonstration.

Acknowledgements

This research was funded by the Australian Government's Future Drought Fund Drought Resilience Innovation Grants (Project led by Mallee Sustainable Farming) and is supported by the SA Drought Resilience and Adoption Hub. Thank you to Katrina Brands, Marina Mudge and Rebbecca Tomney for their help with scoring and sampling and Greg Butler (SANTFA) for initial project input.