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

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

Location
Minnipa - G & R Scholz
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2023 Total: 280 mm
2023 GSR: 169 mm
Paddock history
2023: Wheat
2022: Self-regenerating medic pasture
2021: Wheat
Soil type
Sand (non-wetting)
Plot size
12 m x 1.7 m x 3 reps

Key messages

- **Seeding into the soil moisture zone either shallow (2023) or deeper with a long coleoptile variety (2022 and 2023) can best maximise plant establishment and stubble groundcover in non-wetting sandy soil conditions.**
- **In 2022, deeper seeding improved 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 under laboratory conditions, but it did not improve plant establishment under field conditions in 2022 and 2023.**
- **Soil wetter on a non-wetting sandy soil resulted in a small improvement in wheat crop establishment and early vigour in 2022.**

Background

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

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 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 2023 a trial was implemented to assess value of hydro-priming on a non-wetting sand in the field. The replicated small plot field trial was established in a non-wetting sand near Minnipa to evaluate the impact of two seed priming levels (12 vs 21 h soaking in water), seeding depth (shallow, medium, deep) and a soil wetter. Using a knife point press-wheel plot seeder, twelve treatments (Table 1) were applied to 6 rows wide x 12 m long field plots which were arranged in a randomised complete block design with three replicates.

The trial was sown on 31 May with AGT Calibre (110-115 mm long coleoptile) at 70 kg/ha with 55 kg/ha MAP banded above the seed. A soil wetter (SE14 at 3 L/ha) was delivered in furrow at 80 L/ha volume for appropriate treatments. The trial area was sprayed pre-sowing and in-crop by the grower.

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 12 or 21 h. The imbibed seeds were air dried on paper towel then placed into seeding envelopes for immediate sowing with a cone seeder. In 2022 seed priming was undertaken at 6 and 12 h.

Crop establishment was assessed twice after sowing (9 and 27 June). Early dry matter cuts and NDVI were taken on 25 August. The trial was harvested on 15 November for grain yield and quality assessment.

Table 1. Experimental treatments and targeted settings.

Treatments	Seeding depth (NB: seeds placed at the bottom of the furrow)	Soil wetter	Hydro-priming (hours)
1	Baseline: at the moisture front ("INTO")	No	0
2			12
3			21
4	30 mm deeper than baseline ("BELOW")	No	0
5			12
6			21
7	30 mm shallower than baseline ("ABOVE")	No	0
8		Yes	0
9		No	12
10		Yes	12
11		No	21
12		Yes	21

Table 2. Soil moisture profile data with depth.

Depth (mm)	0-30	30-60	60-90
Average Gravimetric water content (% w/w)	8.1	7.8	7.2

Table 3. 2023 monthly growing season rainfall for Minnipa (mm).

	Jan-March	April	May	June	July	Aug	Sept	Oct	Nov-Dec	GS (mm)
2023 Season rainfall	38	33	19	48	21	25	15	7	75	169
Long Term Average	46	18	34	43	45	43	32	26	40	241

The 2023 growing season rainfall was below average, with stored soil moisture from the previous summer (November 2022). There was opportunity for very early seeding following a 13 mm break of the season on 15 April, but with an increased risk of frost. Most seeding programs started in mid-late April and were completed in drier conditions with only smaller rainfall events in May. Late May saw two 4.5 mm rainfall events which wet up the soil profile before seeding the trial and broad acre demonstration in late May/early June. The Minnipa monthly rainfall for 2023 is listed in Table 3. In the 2023 season Minnipa recorded a decile 2 growing season rainfall (April-October) and a decile 4 total rainfall, which was complemented by stored subsoil moisture from summer 2022.

What happened?

Plant Establishment

Seeding conditions in 2023 were into moist conditions with 9 mm of rainfall occurring the week before. The first crop establishment count was taken 10 days after sowing on 9 June. Shallower sowing had higher initial plant numbers (extra 24 plants/m^2) compared to sowing deeper (Table 4).

The second plant counts were taken 28 days after seeding and seeding depth still impacted on plant germination with the shallower sowing and the deeper sowing having better establishment of 123 plant/m^2 (an extra 15 plants/m^2) than the intermediate sowing depth 'into' moisture (Table 4).

Table 4. Crop establishment on 9 and 27 June 2023 for the 3 seeding depth treatments. The letters within the table represent the LSD of treatments which are significantly different at LSD (P=0.05).

Seeding depth	Plant establishment (plants/m^2) 9 June	Plant establishment (plants/m^2) 27 June
30 mm shallower than baseline ("ABOVE")	70 b	123 b
Baseline: at the moisture front ("INTO")	60 ab	110 a
30 mm deeper than baseline ("BELOW")	46 a	123 b

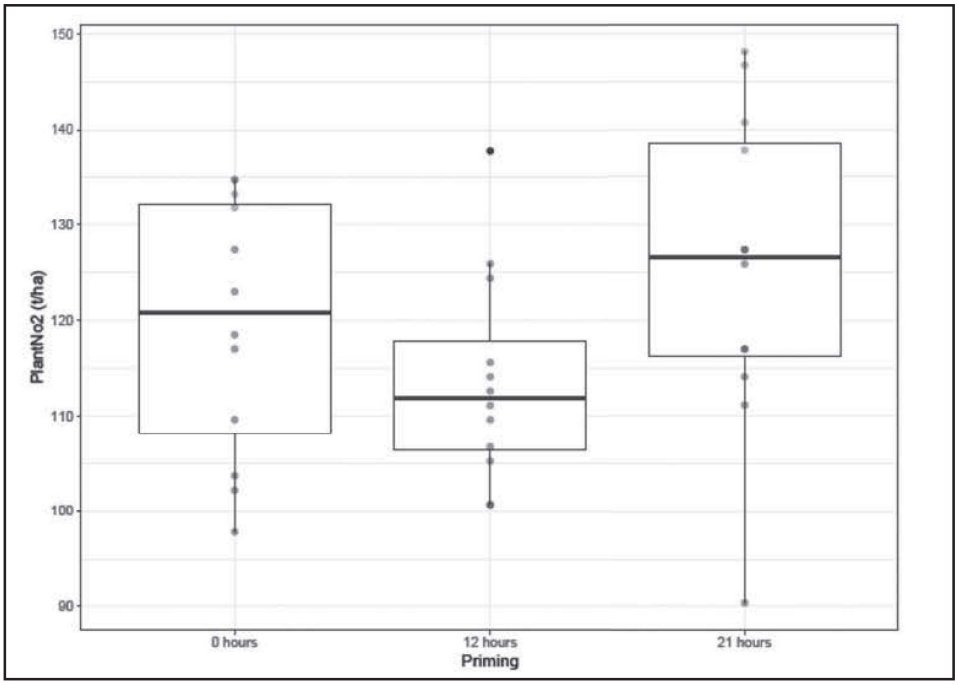

Figure 1. Crop establishment on 27 June 2023 for the 3 seed priming treatments. The letters within the graph represent the LSD of treatments which are significantly different at LSD (P=0.05).

Seed priming for 21 hrs showed a significant benefit over priming for 12 hours (Figure 1) with an extra 13 plants/m^2 on average. The addition of a soil wetter in furrow provided no significant benefit in plant establishment at seeding in 2023.

Early dry matter (t/ha) and NDVI

In 2023 there were no treatment differences in early dry matter (t/ha) and NDVI readings in season. In 2022 the treatment impact on early dry matter were similar to that on crop establishment with the highest values in the deep seeding treatments.

Grain yield (t/ha) and quality

In 2023 there were no differences in wheat grain yield with seeding position, seed priming or soil wetter, with the trial averaging 0.86 t/ha. 2023 was a decile 2 growing season with a dry winter and spring which limited grain fill.

Grain protein, screenings, test weight or 1000-grain weight were not affected by seeding position, seed priming or soil wetter in 2023. In 2022 deep seeding slightly increased protein content and grain size (1000-grain weight).

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 and the importance of sowing into soil moisture to improve crop establishment.

Overall, the results from the 2022 and 2023 trials confirmed the importance of seeding wheat into soil moisture, most commonly found deeper, to potentially capture benefits in crop establishment, with the potential for both quality and productivity gains in sandy soil conditions.

In an above average season in 2022, 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 in a decile 7 season with significant subsoil moisture storage pre-season.

In 2023, a contrasting decile 2 growing season showed sowing shallow after a 9 mm rainfall event provided better early plant establishment, which was equivalent to deeper sowing by 28 days after sowing. Seed priming for 21 hours showed a benefit over priming for 12 hours for improving crop establishment 28 days after sowing but this was not different to Nil priming. There were no differences in either plant growth or grain yield in this dry season.

Overall, the results provide further evidence that using longer coleoptile varieties to position seed within the soil moisture zone (deeper if needed) will provide better plant establishment, with potential impact on reducing the risk of early erosion. The 2022 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 little effect on late biomass production.

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 both 2022 and 2023. In practice, primed seeds might readily lose absorbed water to surrounding soil when placed in sub-optimal conditions in the soil depending on where the moisture is in the seed furrow, thus potentially cancelling any positive effect of priming. In contrast, sowing into greater soil moisture would also provide more protected moisture levels, expected to allow seed priming benefits to be more reliably expressed. In 2022 the significant but late post-seeding rainfall had resulted in more favourable soil moisture levels, reducing the potential benefits of seed priming due to overly dry soil in the first 3 weeks.

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