FINAL SUMMARY

2024

Robust Ground Cover – farming system solutions that build resilient soils

Things have come a long way since Mallee Sustainable Farming first formed in 1997. Many of us remember days when the skies turned red with dust, we may have had to pull-over to the side of the road in the car, lights-on, waiting for things to clear; waiting for safe passage. We might have watched our topsoil become airborne and envelop our homes, leaving a mess to clean-up.

It seems trivial to think of life's interruptions when the issue at hand is so significant, but it offers a reminder about how mobile our topsoil can become in the right (or wrong) circumstances. Much of the Mallee Sustainable Farming movement has been born out of a desire to keep our topsoil in our paddocks—respecting it as the medium so important to the productivity of our farms.

The move to conservative farming practices has been a tremendous success. We know that exposed soils—those with no or minimum cover—are vulnerable soils. And we know that vulnerable soils can quickly become degraded soils. It's clear that low rainfall farmers in Australia are some of the most advanced farmers in the world; supported by well organised industry structures, with an interest in the practical application of research and development.

All that said, maintaining ground cover isn't easy. Dry years limit biomass production. Then there's crop rotations to consider. Pulse crops for example, diversify our systems, bring nitrogen fixing capability and disease management benefits but they often leave less standing residue in the paddock after harvest.

There are plenty of risks in our cereal crops too, like managing dry starts to the season. We know that some ground cover is better than no ground cover, but we still want to maximise productivity. Can long coleoptile wheat varieties open the sowing window in lighter textured soils, with dry topsoils but available subsoil moisture?

Then there's grazing, and the challenge of strategically cultivating hardsetting or non-wetting sands. There's plenty to manage, and success takes more than just good luck. Droughts, an inevitable part of the landscape, can upend even the best-laid plans. In the face of such challenges, let's focus on coming together, sharing experiences, and embracing continuous learning as a united effort.

The Australian Government Future Drought Fund supported project, led by MSF and titled "*Developing robust ground cover to enable resilience in low rainfall mixed farms"* has explored and advanced in-field proof-of-concept work by considering systems-based approaches to building soil resilience. Fancy words, yes, but what it means is that different treatments were investigated based on their ability to contribute to the following cycle:

Prepare and Promote—crop establishment uniformity:

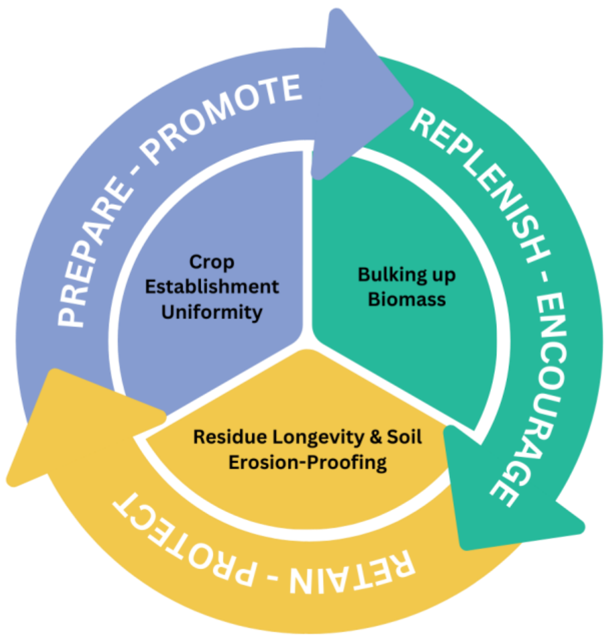
1. Long coleoptile wheat
2. Seed priming
3. Disc seeding

Replenish and Encourage—bulk up plant biomass:

4. Low risk residue friendly strip amelioration practices

Retain and Protect—residue longevity & soil erosion proofing

5. Stripper front harvesting



This was a project with many moving parts.

Perhaps the busiest area of investigation was under the Prepare and Promote segment of the cycle. Sowing strategies that targeted stored soil moisture, or sought to advance the germination process prior to seeding, or exploit pathways developed by the previous seasons crop, were all explored in an effort to advance crop establishment uniformity.

In addition, understanding that farming relies on how the system as whole performs, the project also looked at opportunities to Replenish, Encourage, Retain and Protect stubble (and topsoil) with a view to building soil resilience. Strip and disc harvesting and sowing strategies for example, seek to limit erosion and conserve soil moisture by retaining taller stubble through the summer fallow. To overcome the taller stubble left by the stripper front header, disc seeders are used to retain as much of the standing stubble as possible.

A further complexity was considering the benefits and challenges of growing pulse crops in low rainfall farming systems. The benefits of pulse crops are many (diversification, nitrogen fixing, disease management and advantages to future cereal crops) but there are challenges too. Low stubble retention from pulse crops can compromise soils and leave them vulnerable to erosion. The rationale of a strip and disc system is to increase the stubble load before sowing the pulse crop, with a view to carrying some of the benefits of the larger stubble load into the following fallow.

Investment in strip and disc to provide the right stubble architecture for pulse crops is hard to justify, so does it improve outcomes for cereals? Trials in the Victorian and New South Wales Mallee also looked at barley and wheat. With shallow planting depth and high stubble loads, weed and disease management were also subject to investigation.

In line with the theme of increasing stubble load to extract benefits over multiple seasons, strip row amelioration was included among the strategies to build robust ground cover. This technique reduces the erosion risks of soil disturbance by leaving standing stubble in alternating rows, providing wind protection. An additional advantage is improved trafficability, though the goal of reducing traffic is also supported by single-pass strip amelioration and sowing. However, this approach requires a philosophical shift, as its benefits are spread over two seasons. This can limit crop yield initially and, when blanket sowing is applied to both treated and untreated areas, introduce challenges in managing variability in crop maturity.

So, what did we learn?

Table of Contents

Prepare and Promote - crop establishment uniformity

1. Long coleoptile wheat field trials

Wheat varieties with long coleoptiles can germinate from deeper in the soil than their conventional counterparts. By sowing deeper into residual summer moisture, crops can access water immediately. Other benefits include sowing beneath a non-wetting soil layer, better crop emergence when seeding depth is harder to control, such as after mechanical soil amelioration, seeding deeper to avoid pre-emergent herbicides.

These trials aimed to evaluate how long coleoptile wheat varieties perform when sown at various depths, particularly under challenging soil and climatic conditions.

Key messages:

- Deep sowing (around 10 cm) consistently provided better crop establishment and early ground cover compared to shallow sowing (around 4 cm) across four years of trials on sandy soils in the SA Mallee.
- Although deep sowing provided early establishment benefits, these did not always translate to significant yield increases.
- Differences between varieties at different planting depths were minor. The exception was Scepter, which produced 53% more biomass than Mace18 at Lowaldie in 2022. Conventional varieties generally performed similarly to specifically bred long coleoptile varieties (Rht18 or Rht13 genetics).
- Long coleoptile genetics can be used to aid crop emergence if sowing very deep to chase moisture. Results from Wharinda concur with those from Cootra, which demonstrated that in years where surface soils are dry, but there is moisture at depth, LC cultivars established better from deeper sowing.
- Successful sowing strategies depend on knowing where the moisture is (or is likely to be) in the soil, particularly if sowing before the season break. Sandy soils in low rainfall areas are more likely to have deeper soil moisture that favours deeper sowing before the season break. Heavier soils tend to retain shallower soil moisture and can support shallower sowing more often.

1.1 Waikerie, South Australia

CSIRO

- Varieties: Yipti, Yipt18*, Scepter, Mace, Mace18*, Vetch. (Rht18 long coleoptile genetics)
- Planting depths: 4 cm and 10 cm
- Soil: Alkaline sand

In 2022, trials were sown on 5 May following a season break (>10 mm on 26 April). Summer fallow rainfall was 103 mm. Growing season rainfall (320 mm) was above average (164 mm). Deep sown (10 cm) treatments had greater plant establishment at four weeks, supported by greater soil moisture at 10-20 cm versus 0-5 cm. Early crop establishment benefits, however, did not translate into yield or crop biomass benefits (Table 1).

Table 1: Wheat yield and Harvest Index for wheat varieties and treatments at Waikerie, 2022.

	Wheat grain yield t/ha		Wheat harvest index	
Treatment	Deep sown	Shallow sown	Deep sown	Shallow sown
Mace	1.4	1.4	0.44	0.44
Mace18	1.3	1.2	0.39	0.35
Scepter delved	*	1.5	*	0.41
Scepter high SR	1.4	1.7	0.39	0.42
Scepter std SR	1.5	1.8	0.41	0.45
Yitpi	1.7	1.5	0.41	0.39
Yitpi18	1.3	1.2	0.38	0.34
P (Treatment)	0.002		0.057	
l.s.d.	0.32		0.07	

* No treatment.

There was no significant difference in vetch yield when sown deep or shallow, but vetch conserved more soil moisture than wheat.

Sowing depth did not have an impact on residue load and groundcover after harvest.

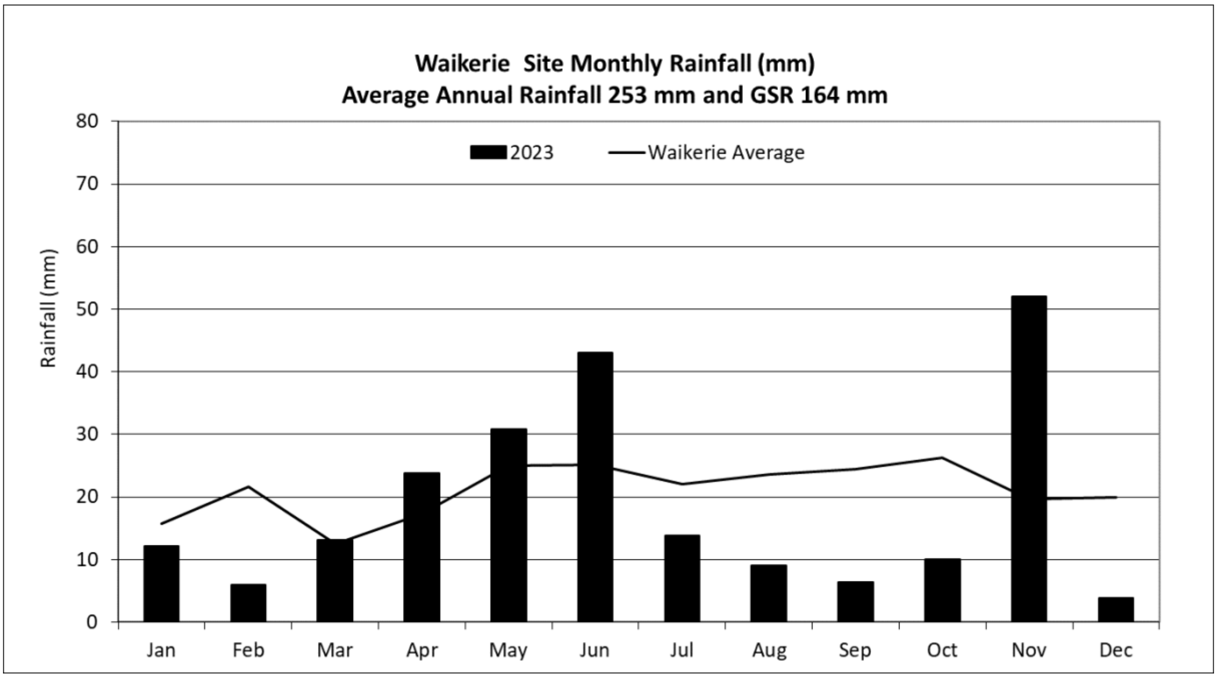


Figure 1. Waikerie site monthly rainfall vs average rainfall in 2022 (top) and 2023 (bottom)

In 2023, trials were sown on 9 May following a season break on 15 April and summer fallow rainfall of 88 mm. Growing season rainfall (137 mm) was below average (164 mm; Figure 1). Again, crop establishment benefited from deep sowing for up to four weeks but there were ongoing biomass or yield benefits. The average grain yield in 2023 (both shallow and deep sown) of 0.4 t/ha was very low, attributed to below average rainfall and high disease pressure. Grain yield from the vetch rotation plot was significantly higher than from cereal rotation (0.6 vs 0.4 t/ha).

1.2 Lowaldie, South Australia

CSIRO

- Varieties: Yipti, Yipt18*, Scepter, Mace, Mace18*, Vetch
- Planting depths: 4 cm and 10 cm
- Soil: Non-wetting sandy soil

In 2022, trials were sown on 10 May followed by a season break on 31 May and into soil that had received summer fallow of 77 mm. Growing season rainfall (325 mm) was above average (237 mm). Deeper sown crops established better than shallow sown crops (Figure 2), which translated into yield benefits. Deep sown crops averaged 3.1t/ha versus 2.6t/ha for shallow sown crops. Higher sowing rates (110 kg/ha for 220plant/m^2 versus 75 kg/ha for 120 plants/m^2) had a positive influence on shallow-sown Scepter.

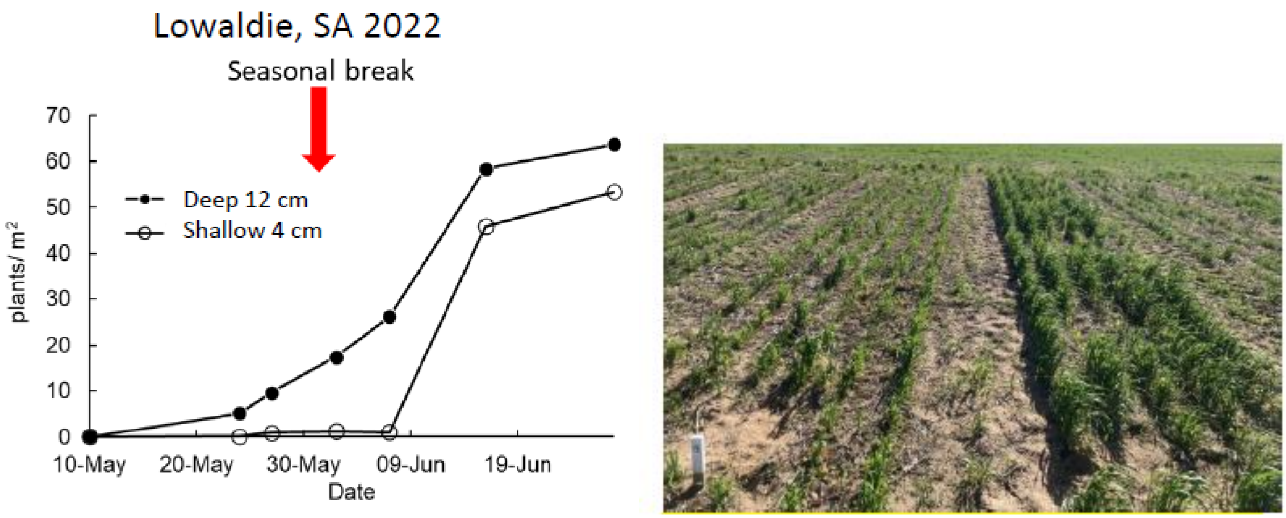


Figure 2. left) Crop establishment numbers; **right**) Earlier shoot and root growth on deep sown (12 cm, right) compared to shallow sown (4 cm left).

Although there was no difference between stubble biomass at either planting depth between the cultivars, Scepter produced 53% more overall stubble biomass (mean of both sowing depths) than Mace 18 at harvest (Figure 3).

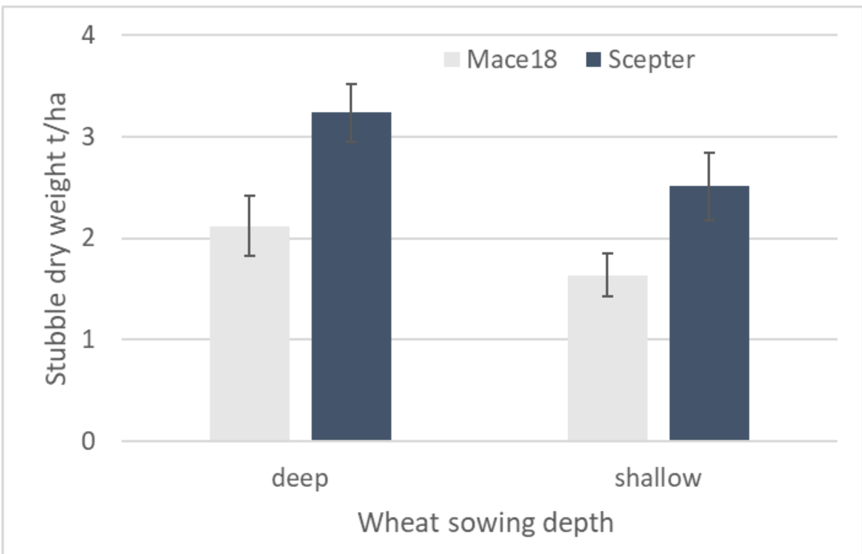


Figure 3. 2022 stubble residue post-harvest at Lowaldie for deep and shallow shown Mace 18 and Scepter.

Deeper sowing provided a four-week head start in crop establishment, which led to a higher yield (Figure 4). However, this yield benefit was only observed at Lowaldie in 2022, and not in 2023 or at Waikerie.

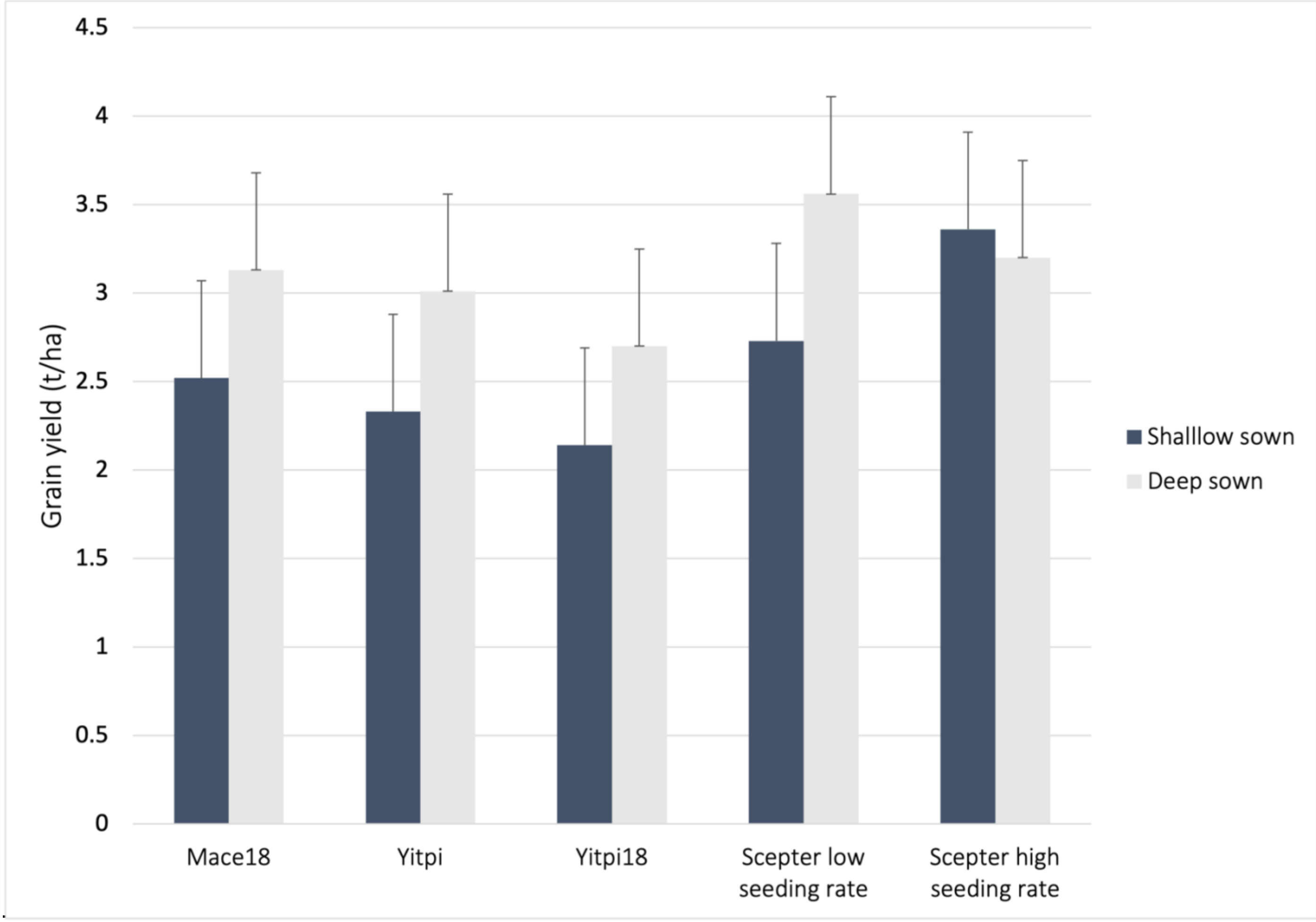


Figure 4. Harvest data for wheat varieties and treatments at Lowaldie, 2022.

There was no significant difference in vetch numbers at deep or shallow planting depths and there was no difference in remaining soil moisture between wheat and vetch treatments.

In 2023, spading was introduced as treatment in addition to deep and shallow sowing depths. Spading (one week before sowing) increased moisture levels in the top 20 cm of the soil at the time of sowing (Table 2). The season break occurred on 25 May.

Deep sowing improved crop establishment. Without spading, deep sowing had a 22% higher establishment rate than deep sowing with spading in the first four weeks. Spading, however, enhanced establishment by 12% in shallow-sown treatments. Unlike 2022, the establishment benefits from deep sowing did not lead to increased yields. Nevertheless, spading boosted yield by 26% (2.8 t/ha compared to 2.2 t/ha) across both shallow and deep sowing depths, even though crop establishment took longer.

Table 2. Seedbed soil water (mm/0.2mm)

Soil depth (cm)	Control	Spaded
0–5	2.5	5.8
5–10	4.5	8.4
10–20	6.0	7.0
Mean	4.4	7.0
P	0.003	
L.S.D	1.6	

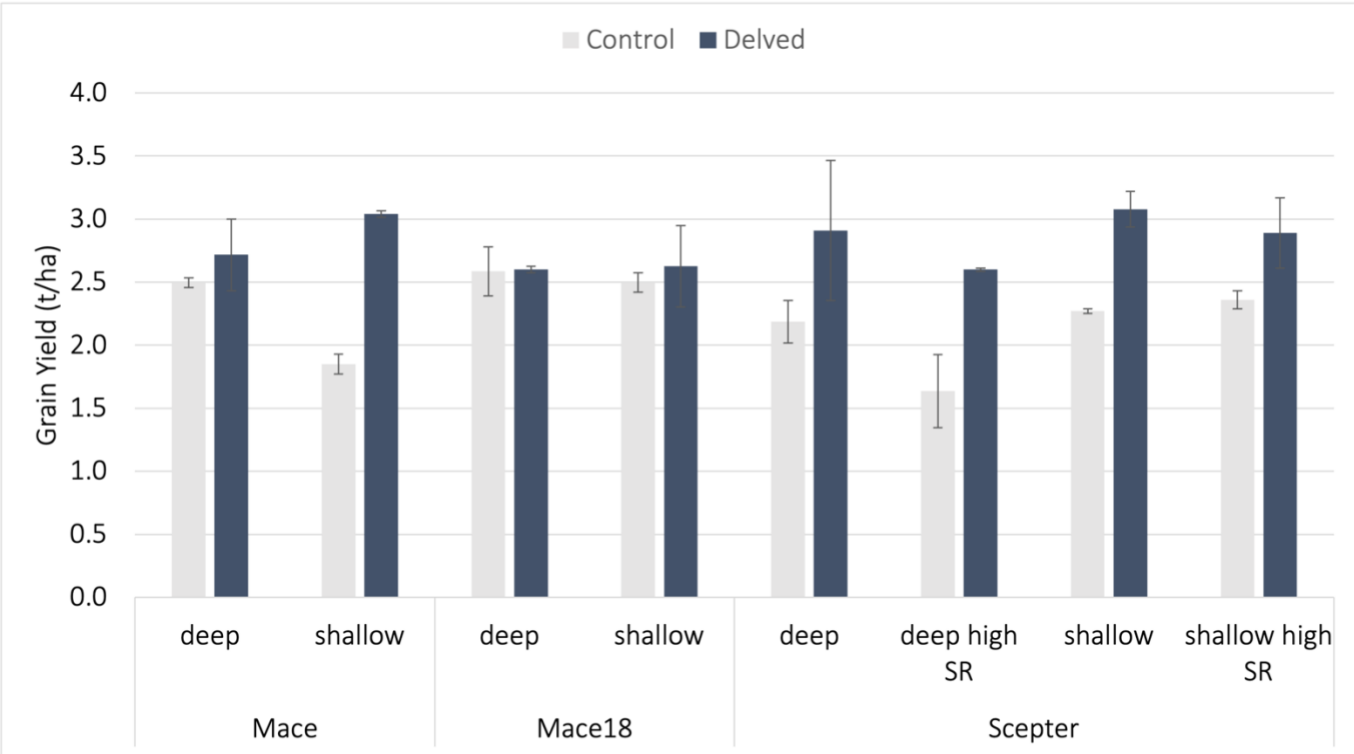


Figure 5: Improved yield in response to spading at Lowaldie in 2023. SR = seeding rate.

1.3 Cootra, South Australia

EPAG Research

- Varieties: LC Rht13, LC Rht18, Normal and Normal Long wheat varieties
- Planting depths: 3.5 cm, 8.5 cm and 11 cm
- Soil: sand over sandy loam

In 2022, trials were sown on 29 April into a favourable soil moisture profile and received growing season rainfall of 304 mm (average GSR 245 mm). The trial was harvested on 15 December. Deep sown treatments had fewer plants establish and lower yield (Figure 6). Reduced plant establishment was also thought to have reduced competition for weeds, which in turn impacted yield.

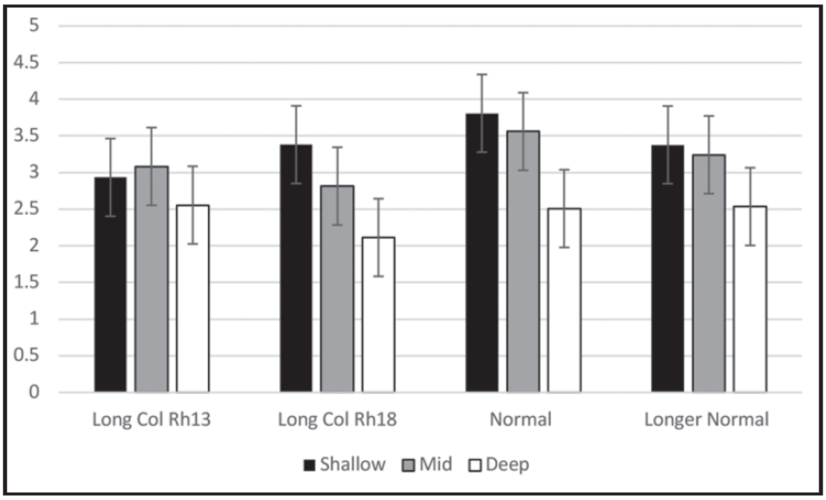


Figure 6: Yield from various sown depth treatments at Cootra in 2022.

1.4 Cockaleechie, South Australia

EPAG Research

- Varieties: LC Rht13, LC Rht18, Normal and Normal Long varieties
- Planting depths: 6 cm, 9.5 cm and 10.5 cm
- Soil: clay loam

In 2022, trials were sown on 12 May into favourable soil conditions. Growing season rainfall (387 mm) was above average GSR (336 mm). Results were similar to Cootra, with the deepest planting depth negatively impacting plant establishment (Figure 7) in all varieties. Yield assessments were compromised by high levels of disease.

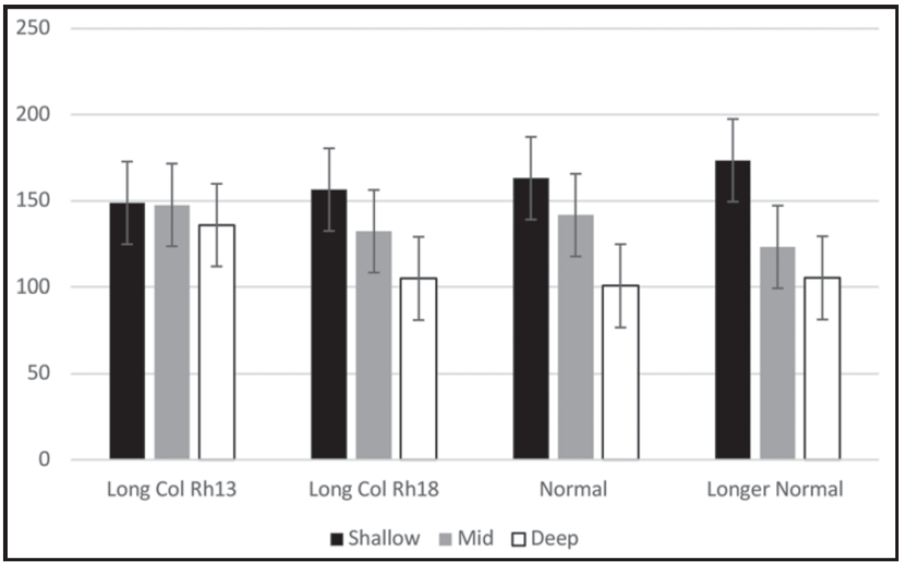


Figure 7: Plant establishment 41 days after seeding at Cockaleechie in 2022

1.5 Wharminda Trial 1, South Australia

EPAG Research

- Varieties: Sceptre, Calibre and Mace18
- Planting depths: 4-5.5 cm and 14-15 cm
- Soil: non-wetting sand

In 2023, trials were sown on 5 May into good subsoil moisture and received a further 12.6 mm of rain in the five days after sowing. Growing season rainfall (191 mm) was below average growing season rainfall (252 mm). The trials were harvested on 7 November. Crop emergence was delayed in the deeper sown treatments and this carried through to lower plant numbers at establishment and yield (Table 3).

Table 3: Plant emergence and yield data from varieties sown at shallow and deep sowing depths at Wharminda 2023. EPAG. DAS = days after sowing.

	Plants/m²			% of final plant numbers at establishment			Crop establishment when variety sown deep compared to shallow.	Yield Metrics	
Treatment	**15 May (10 DAS)**	**23 May (18DAS)**	**5 June (30 DAS)**	**15 May (10DAS)**	**23 May (18DAS)**	**5 June (30DAS)**	**(% of shallow sown treatment)**	**t/ha**	**Screenings (%)**
Shallow Scepter	58	92	96	61%	98%	100%	*	2.24	0.6
Shallow Calibre	66	84	84	76%	97%	97%	*	2.56	0.9
Shallow Mace18	45	75	85	52%	87%	98%	*	2.30	0.5
Deep Scepter	0	36	49	0%	72%	97%	53%	1.84	1.7
Deep Calibre	0	46	57	0%	80%	99%	66%	1.8	2.8
Deep Mace 18	0	69	71	0%	96%	99%	83%	1.68	1.4

Figure 8: Crop establishment at Wharminda trial site 23 June 2023. Calibre wheat shallow sown (foreground left); deep-sown Calibre (right).

1.6 Wharminda Trial 2, South Australia

EPAG Research

- Varieties: Sceptre, Calibre, Magenta, Magenta13, Scout, Scout18, Mace and Mace 18
- Planting depths: 4 cm, 8 cm and 12 cm
- Soil: non-wetting sand

A second GRDC-funded trial at Wharminda tested more varieties and included an intermediate sowing depth of 8 cm. For most varieties, plant numbers when sown at 8 cm were similar to shallow sowing. Scepter and Scout had a 13-20% reduction in plant numbers.

When sown at 12 cm, most conventional varieties had a 45-65 % reduction in plant numbers. Dedicated long coleoptile varieties were less impacted, with 25-35% reductions in plant numbers (Figure 9).

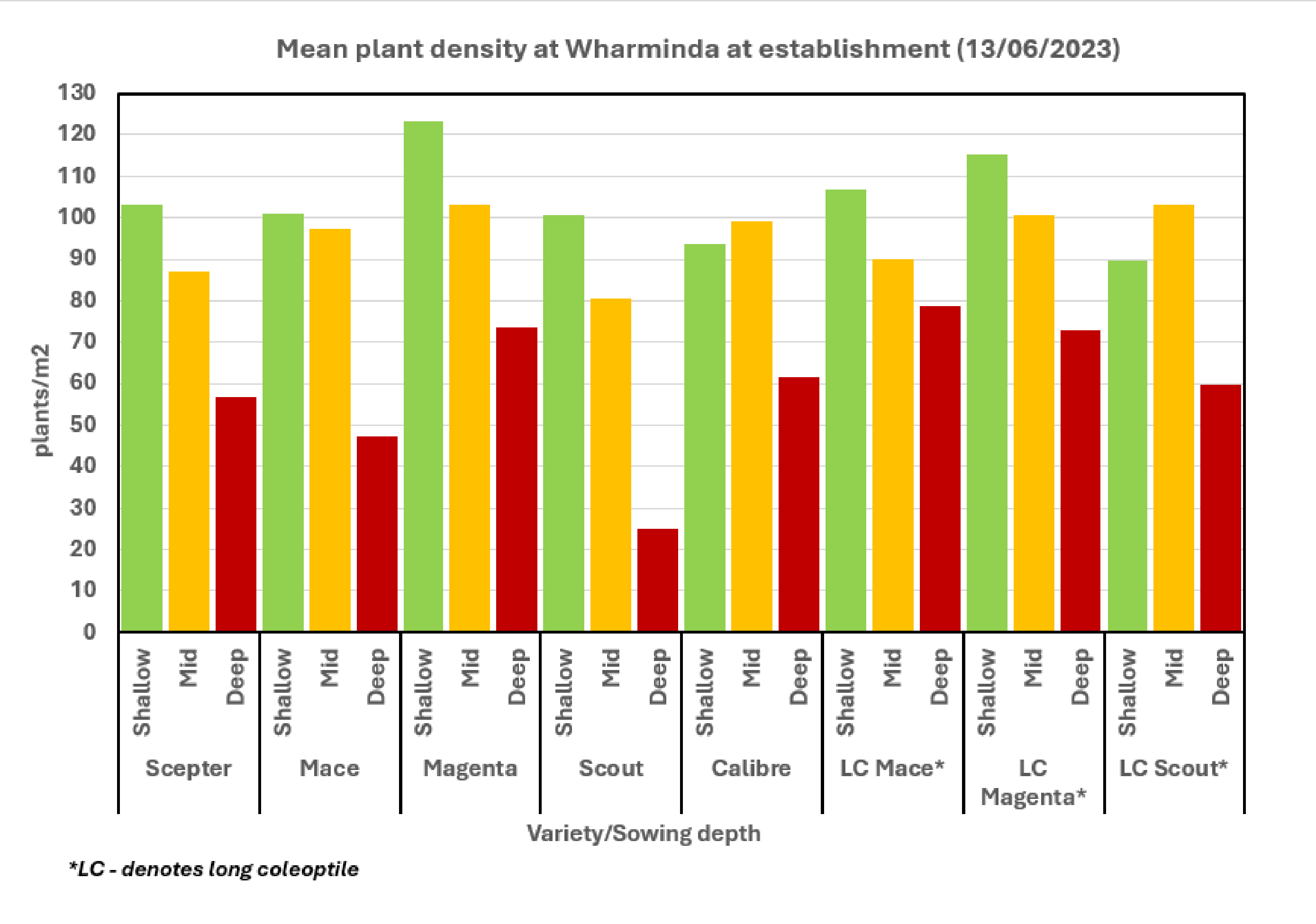


Figure 9: Plant establishment number by variety and planting depth at Wharminda in 2023.

1.7 Modelling seasonal impacts that influence soil moisture conditions which favour deeper sowing

CSIRO used APSIM (Agricultural Production Systems Simulator) to assess how seasonal impacts influence soil moisture conditions that may favour deeper sowing. This simulation analysed soil moisture for shallow (0-10 cm) and deep (10-20 cm) sowing across 267 locations in South Australia, Victoria, and southern New South Wales, using climate data from 1993 to 2023.

The general findings of the simulation highlighted that:

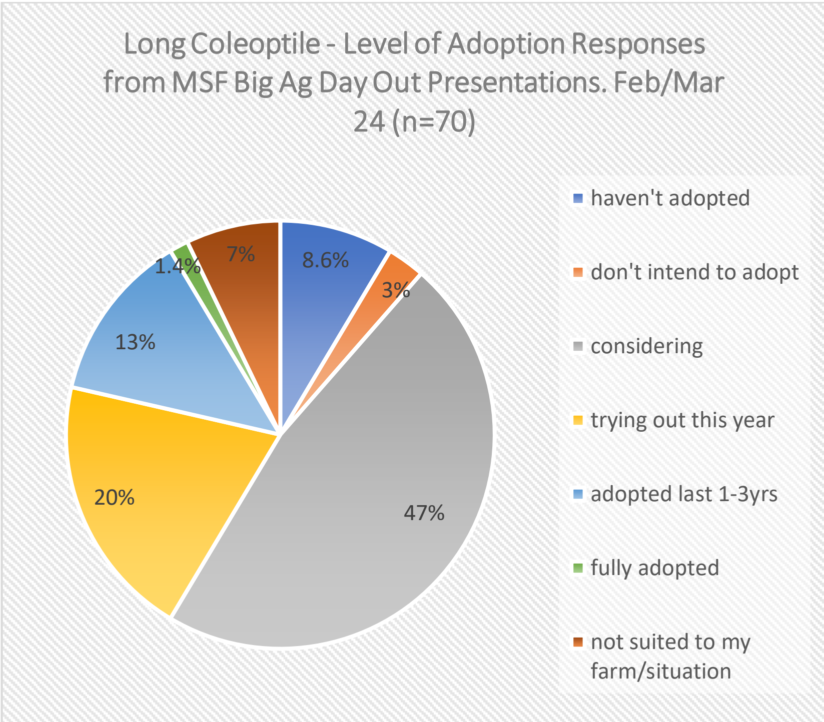
- In higher rainfall regions, deeper sowing offers fewer benefits because rainfall is more reliable in late April and early May, allowing shallow soil moisture to support crop establishment.
- Heavier textured soils in low rainfall regions tend to retain moisture near the surface and have limited deeper infiltration, making shallow sowing more favourable.
- Sandier soils are more suited to deeper sowing since moisture can infiltrate further and is less likely to remain near the surface (especially in seasons with dry fallows).

What's required to improve confidence in adoption?

- Access to higher vigour Long Coleoptile varieties with longer duration to flowering for early sowing and establishment
- Increased knowledge on seasonal conditions and soil types that favour deep sowing.
- Greater understanding of disease vulnerabilities for deep sown crops.
- More information on the impacts of fertiliser placement.
- Further investigation on system improvements such weed management (post-sowing pre-emergent)

Survey feedback—interest in and level of adoption?

We asked our members if they would adopt long coleoptile varieties. There is interest; 13% of interviewed grower are already using them, 20% of are going to give them a go in the near future, and nearly half are considering using long coleoptile varieties.



2. Seed priming to advance germination

Seed priming—soaking the seed before sowing—aims to initiate the early stages of germination. The process reduces the amount of moisture needed to complete germination, meaning that seeds can germinate faster and more uniformly once sown and can germinate in lower soil moisture than normal. On sandy, non-wetting soils, seed priming could help establish more vigorous groundcover in drier seasons and provide an increased yield potential. Two trials investigated if seed priming could improve crop establishment in low rainfall conditions.

Key messages:

- In wheat, seed priming improved early germination and initial crop establishment but did not translate into better crop numbers or yields by season's end.
- Soil moisture may amplify the benefits of seed priming. In field trials, seeding into the soil moisture zone maximised plant establishment and stubble groundcover in non-wetting sandy soil conditions.
- At Lowaldie, lupins had a small but significant benefit from priming. There was no benefit from soaking lentils. Overall emergence numbers were low, and this trial was only run for one season.
- The concept of imbibing seeds with water to initiate germination without full germination has proven challenging in low-rainfall systems. Once sown, primed seeds may lose absorbed water to dry or rapidly drying soil, negating the benefits of priming or even causing issues if seeds are prematurely committed to germination.
- Optimal results may require primed seeds to be sown deep within a well-insulated seed zone that maintains high relative humidity to minimise moisture loss. This approach could be more compatible with long coleoptile wheat varieties designed for deep sowing.

2.1 Minnipa, South Australia

South Australian Research and Development Institute, University of South Australia, South Australian No-Till Farmers Association, Agricultural Innovation & Research Eyre Peninsula

Figure 10: Laboratory seed soaking and pot trials at Minnipa.

<u>Seed weight</u>

Wheat seeds were soaked for various durations (3, 6, 12, 21 hours) and tested in both laboratory and field conditions. In the laboratory, seed weight increased by nearly 50% in the first 10 hours (Figure 11). After 25 hours, the seeds had not started softening. Soft seed is vulnerable to damage by mechanical handling (e.g., grain augers).

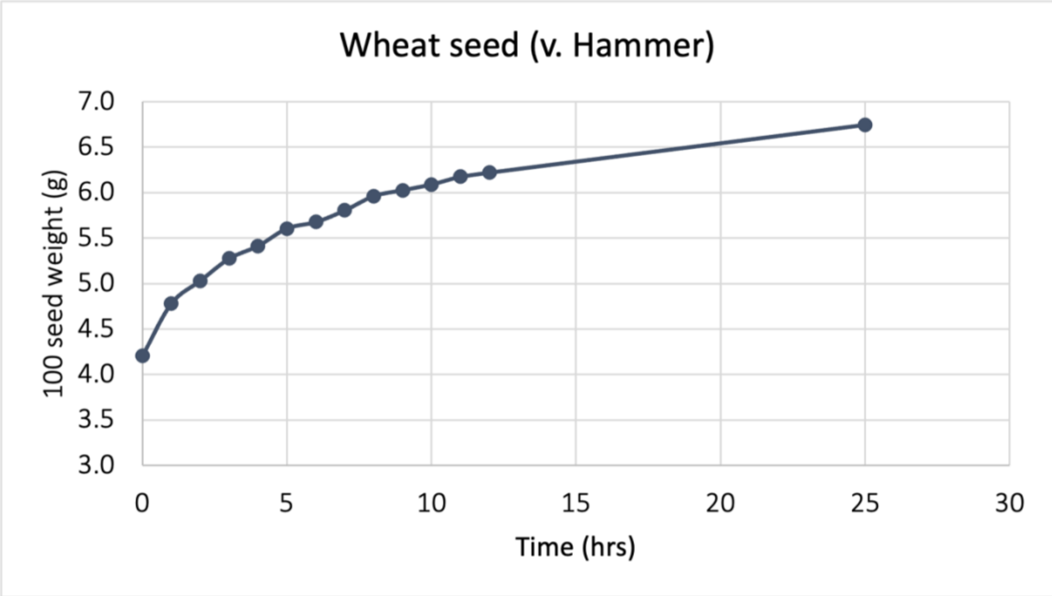


Figure 11: Hammer wheat seed weight increases in relation to time in soakage 2022.

<u>Emergence</u>

Seeds soaked for 3 hours had a slight (7%) emergence benefit within 72 hours, but no long-term advantage over un-primed seeds.

<u>Plant establishment</u>

A replicated small plot field trial was established in a non-wetting sand to evaluate the impact of soaking seeds for 6 vs 12 hours, and seeding shallow, medium, or deep.

There was no significant benefit in crop establishment or yield from seed priming at any sowing depth. Although seed 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.

Figure 12. Photo of Minnipa Seed Priming trial site showing the effect of seeding position at plant establishment counts on 17 June 2022. Foreground Plot 1: seeding above moisture, wetter, primed 6 hr; Plot 2 (middle) seeding into moisture, primed 6 hr, Plot 3 seeding above moisture, wetter, primed 12 hr. Photo from SARDI.

In-field priming

In May 2023, seeds were soaked in the field for 12 and 21 hours in 200 L plastic drums (Figure 13) then sown in the paddock. While the longer seed priming (21 hours) showed early plant establishment benefits at 10 days over seed primed for 12 hours, this did not follow through to any improvement in NDVI, grain yield or quality.

After 21 hours of soaking, some leftover seeds began germinating in the soaking barrel. This suggests that, unlike controlled laboratory conditions, the seeds may soften under different water pressure levels, which could negatively affect sowing.

Figure 13: Photos of the seed soaking techniques adapted for farm-scale paddock trial. Photos from UniSA.

Seed priming did not improve crop establishment at any sowing depth; placing seed into soil moisture had more of an impact. In 2022, planting into moisture-rich soil at depth resulted in a 4.7-fold increase in early dry matter. In 2023, uniform soil moisture distribution favoured shallow-sown treatments, suggesting that under certain conditions, shallow sowing may outperform deep sowing, potentially diminishing the benefits of seed priming if deep sowing is not required.

2.2 Lowaldie, South Australia

University of South Australia's Agriculture Machinery and Design Centre, CSIRO

Lupins are notoriously difficult to uniformly establish in the Mallee environment, especially in non-wetting sand conditions, while lentils represent a new and high value pulse opportunity for the region. Seeds were soaked for 12 hours, then used in a low footprint disc seeding into tall stubble either edge-row or on-row.

In lupins, seed weight increased by 105% after soaking (Figure 14), and there was a small (+17%) emergence benefit when sown edge-row into non-wetting soils. However, overall emergence was low, and this was a single-year trial.

Figure 14: The size of hydrated lupin seeds (top) versus non-primed seed bottom.

In lentils, seed weight increased 33% after 12 hours of soaking, but emergence numbers were lower than dry seed. Soaking lentils did not improve emergence or yield (Figure 15 left).

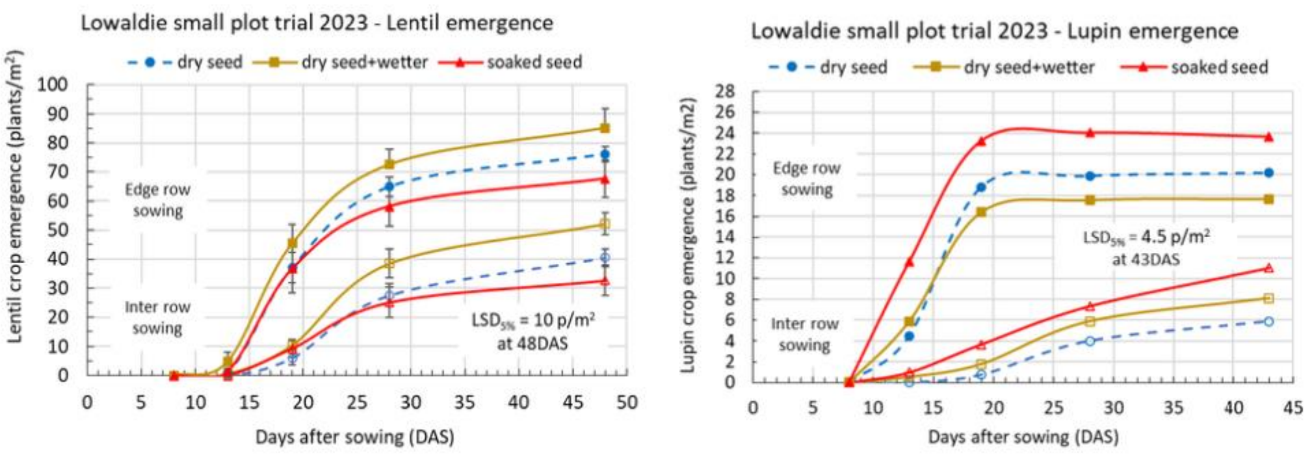


Figure 15. Crop emergence curves for lentils (left) and lupins (right)

What's required to improve confidence in adoption?

- Demonstrate in-field proof of concept.
- Improve understanding of soakage times across varieties, the value of different priming solutions and moisture dynamics in the seed through the sowing process.
- Further develop bulk priming and sowing techniques and equipment.
- Address issues of how to handle bulk quantities of primed seed.

3. Disc seeding

Disc seeders are designed to retain more groundcover, minimise soil disturbance, and conserve soil moisture. However, they can pose challenges, including difficulties with weed control (such as herbicide damage to crops), disease management—especially after a dry summer fallow when residue decomposition is slow and inoculum from the previous season persists—and issues with crop establishment.

Multiple trials were conducted at Manangatang, Wentworth, and Lowaldie to evaluate the effectiveness of disc seeding in low rainfall regions. These trials compared disc seeding with traditional tyned systems, examining crop establishment, stubble retention, and herbicide management for pulse crops and cereals.

3.1 Impacts of pre-emergent herbicide on crops using disc seeding, Manangatang, Victoria

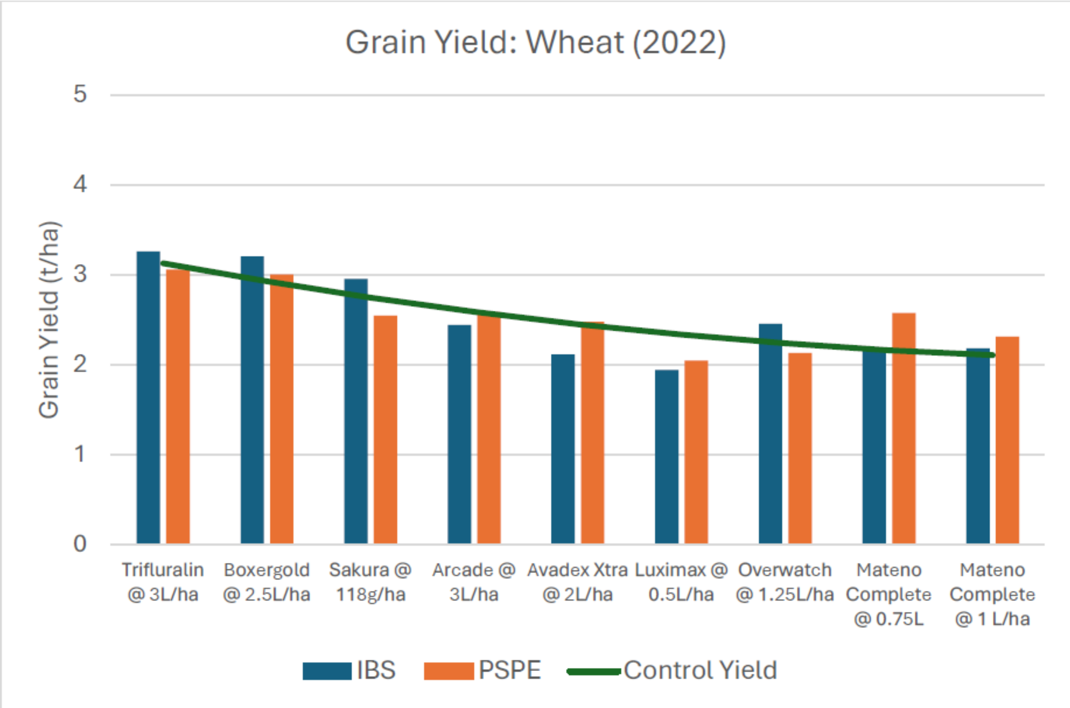
Frontier Farming Systems

Key messages:

- Sandy soils are susceptible to herbicide damage in disc sown systems.
- Crop damage from herbicide treatments was observed at early growth stages in all trials. Care is needed when selecting and applying herbicides to crops sown with disc seeding systems.
- Early post emergence (EPE) applications, where permitted, reduce the risk to crops but require rainfall to wash the chemical into the soil for plant uptake.
- The throw of treated soil from the disc seeder needs to create enough separation between the seed and herbicide. Disc seeders with greater disturbance (throw between rows) reduce the risk of damage from IBS applications.

These trials compared the crop safety of pre-emergent herbicides when applied to wheat and barley (2022) and wheat and lentils (2023) established with a disc seeder. Herbicides were incorporated by sowing (IBS) or applied post-sowing, pre-emergence (PSPE).

In 2022, early season crop damage from herbicide treatments was common but, in favourable growing conditions, the damage was overcome by the end of the season. The exception in 2022 was the negative impact of Overwatch® (@1.25L/ha) in both application methods in barley (Figure 16 bottom).



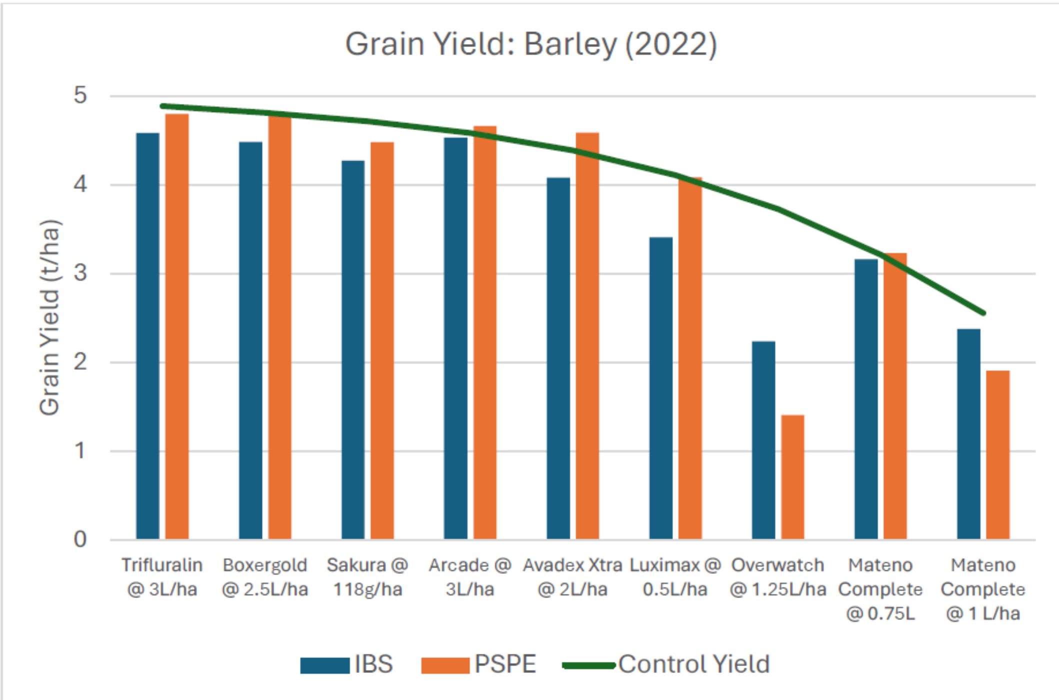


Figure 16: Yield impacts on wheat (top) and barley (bottom) from herbicides applied via IBS or PPSE in 2022 (crops sown perpendicular to treatments @7.5inch row spacing).

In 2023 in wheat, visual observations and NDVI measurements showed that IBS applications were more damaging than early post emergence (EPE) applications (Figure 17). Grain yield, however, was not significantly affected.

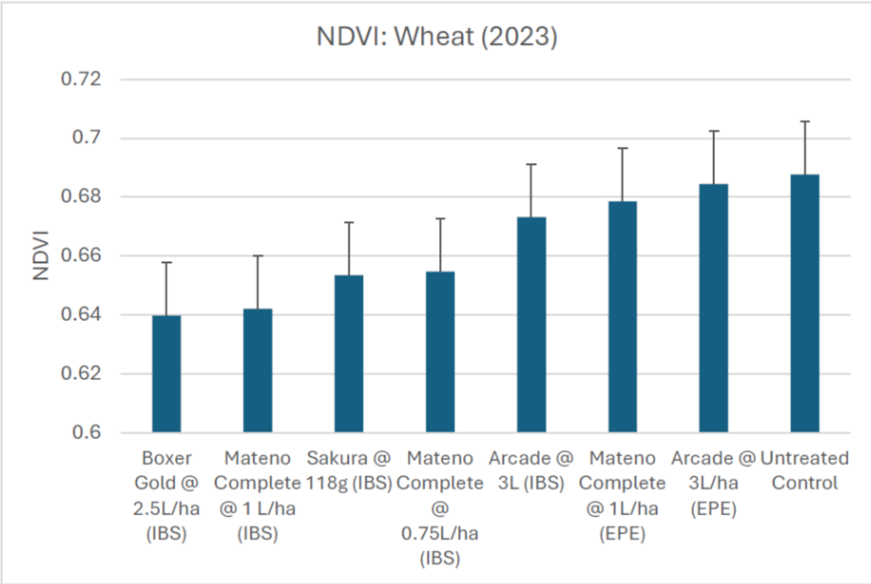


Figure 17: NDVI measurements of growth in wheat against herbicide treatments.

In lentils, all herbicides were incorporated by sowing. There was a significant level of mouse damage in the crop which meant the trial was not harvested. However, NDVI data showed that Metribuzin® and the higher rate of Simazine® impacted plant growth (Figure 18). Visual inspection indicated these treatments had 5-15% less biomass than the adjacent control treatments.

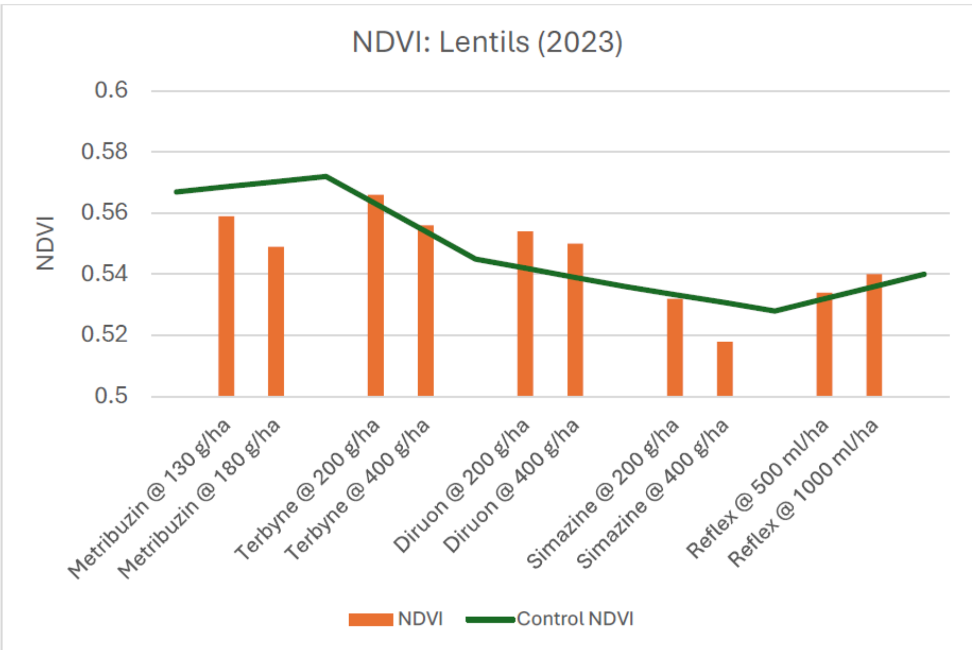


Figure 18: NDVI measurements of growth in lentils against herbicide treatments.

3.2 Impact of Rhizoctonia on cereal crops sown with a disc seeding system, Manangatang, Victoria

Frontier Farming Systems

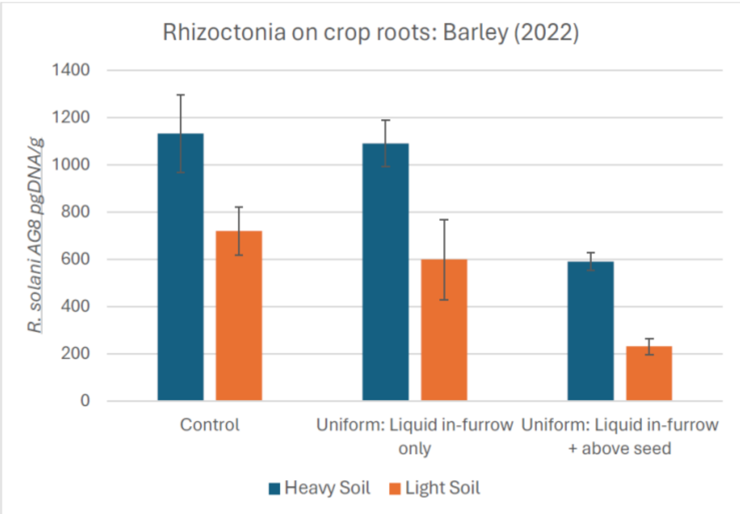
Key messages:

- Liquid injection of Uniform→ fungicide reduced the level and symptoms of Rhizoctonia in barely in 2022 and 2023. Despite beneficial impacts of the fungicide treatments on barley root systems in both seasons, yield benefits were only observed in the wet 2022 season.
- Fungicide treatments were most effective in sandy soils when applied as split applied (placed in the furrow and on-top of the seed bed).

Rhizoctonia poses a higher risk in disc seeding systems as there are larger stubble loads which can harbour the disease.

This trial assessed the impact of in-furrow Uniform® fungicide on root heath and crop yield in sandy Mallee soil. Fungicide was applied either in the seed furrow (400 mL/ha) or as a split treatment in the seed furrow (200 mL/ha) and on the soil surface on-top of the seed row (200 mL/ha).

Split applications (in furrow and on top of the row) were the most effective treatment and improved barley yield (up to 1t/ha above the control) in 2022 (Figure 19 bottom). Favourable growing conditions in 2022 are thought to have allowed healthy roots systems, with reduced disease, to explore more soil and take advantage of the high soil moisture content, filling the grain head and increasing yield.



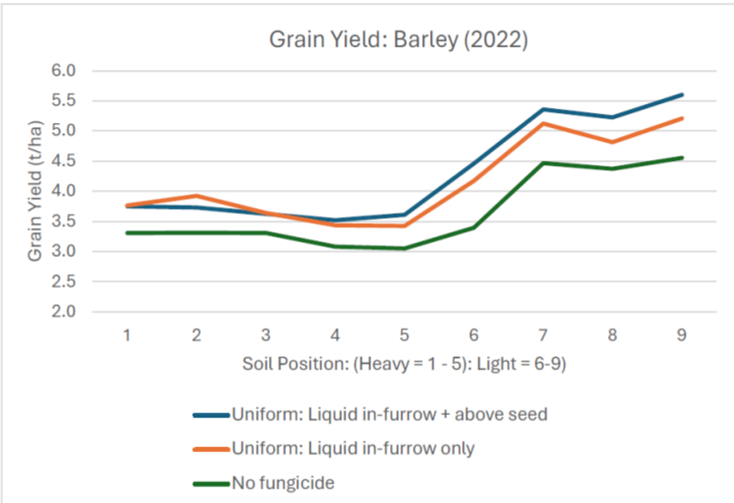


Figure 19: Rhizoctonia on barley roots (top): barley grain yield (bottom).

The split application treatment was repeated in 2023, on paddocks previously sown to wheat and chickpeas. There were lower levels of Rhizoctonia under plots that had chickpeas in 2022 compared to wheat in 2022, and overall lower levels of Rhizoctonia, attributed to nearly 300 mm of rain falling between Spring 2022 and autumn 2023.

The split application of fungicide in and above the seed furrow reduced the level of damage (spear tipping) to both crown and seminal roots (crown roots shown in Figure 20). The fungicide application was most effective at reducing crown root damage in the light sandy soil types. Existing research has shown that when Uniform® fungicide is placed on top of the seed row, it is washed down into to the zone where crown roots are growing, and this provides protection for this shallow root system. However, when the fungicide is only placed in the seed furrow, it is leached downwards away from where the crown roots are growing.

Despite the reduced the level of Rhizoctonia damage, there were no significant differences in grain yield between the treated and untreated crop (Figure 21).

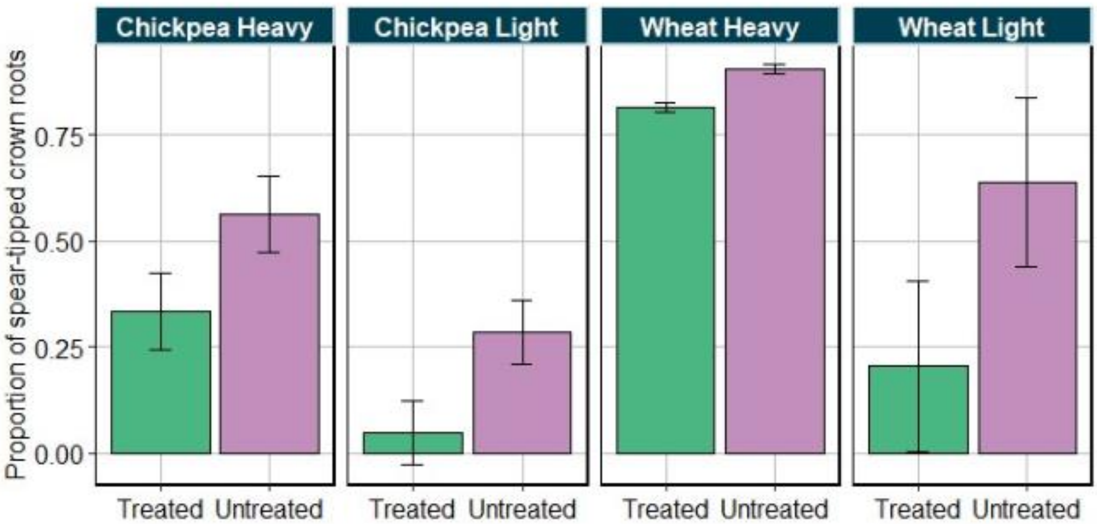


Figure 20: The proportion of spear tipped crown roots in barley treated with and with Uniform fungicide injected into and above the seed furrow during seeding. Assessments were made for heavy and light soil types where either chickpea or wheat was grown in the previous season.

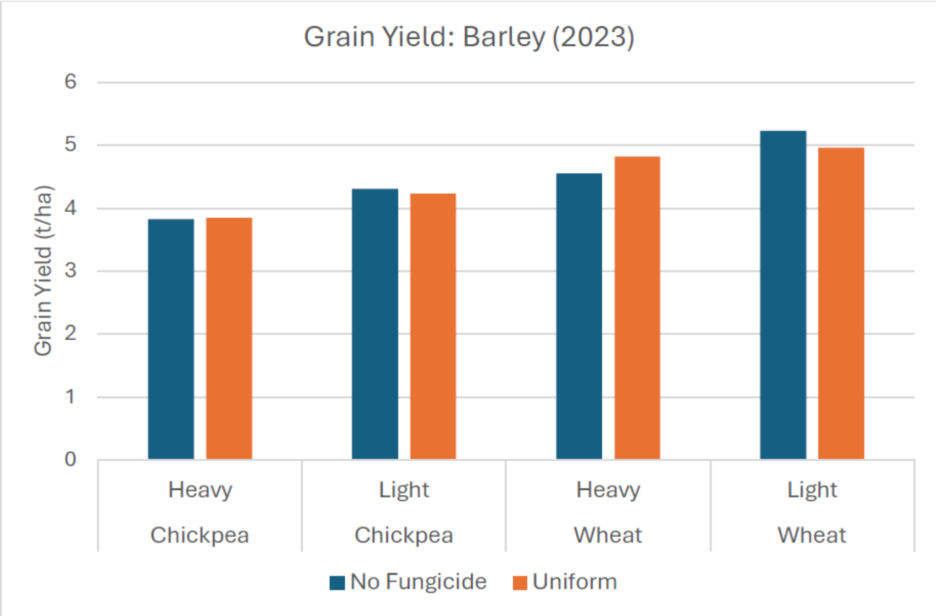


Figure 21: 2023 barley grain yield.

Fungicide treatments were most effective on the light sandy soil types where it was placed both in and above the seed furrow with a liquid injection system.

3.3 Comparing disc and tyne seeding systems for pulse crop establishment, Wentworth, New South Wales

Frontier Farming Systems

<u>Key messages:</u>

- When compared with a tyne seeder, disc sown crops of field pea, chickpea and lentils had lower crop establishment rates. Favourable conditions at Wentworth in 2022 limited yield impacts and helped overcome lower establishment rates in disc sown systems.
- Disc seeders preserve more standing stubble residue but also increase the risk of pre-emergent herbicide damage, particularly on sandy soils and in lentils.
- Despite residue benefits, reduced growth and production resulted in less new groundcover being recruited during the legume phase. This was evident at both Wentworth and Meringur in 2023 where lentils and field peas sown with disc systems produced significantly less green vegetative groundcover than the crops sown with the tyne systems.
- Taller standing stubble from a 'Strip and Disc' system can harbour mice and pest monitoring and control needs to be managed to avoid crop losses.

This trial compared three disc seeding machines (Figure 22) with tyned seeding systems for pulse crops (field pea and chickpea 2022; lentils and field pea 2023) on soil ranging from light sandy soil to heavier clay loam.

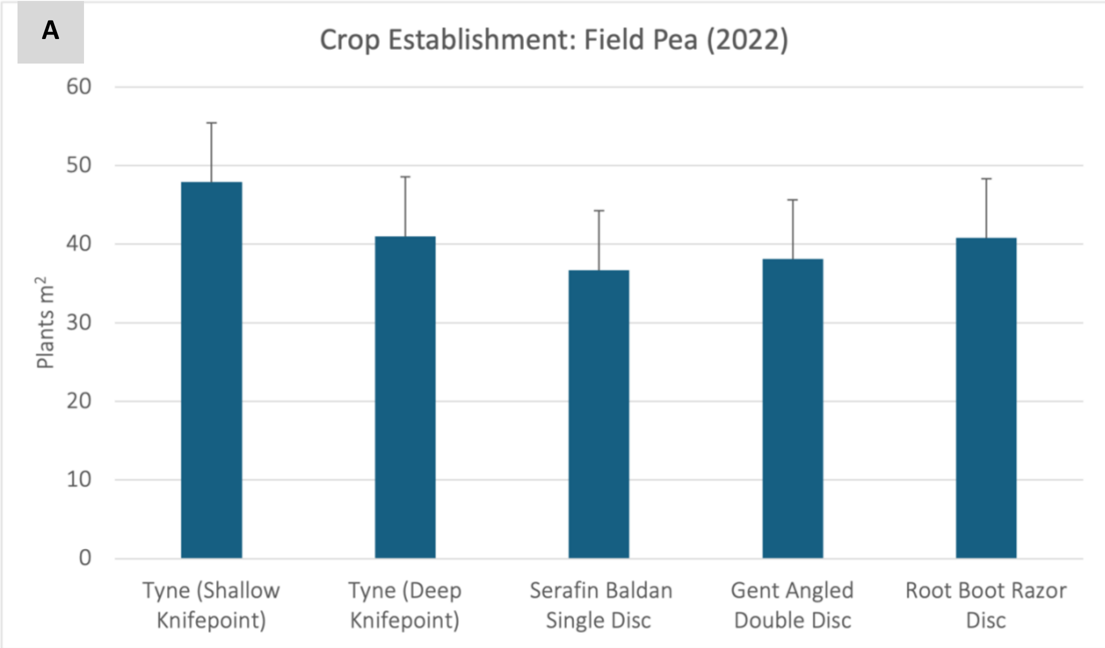
Figure 22: Disc seeder types. Photos from Frontier Farming Systems.

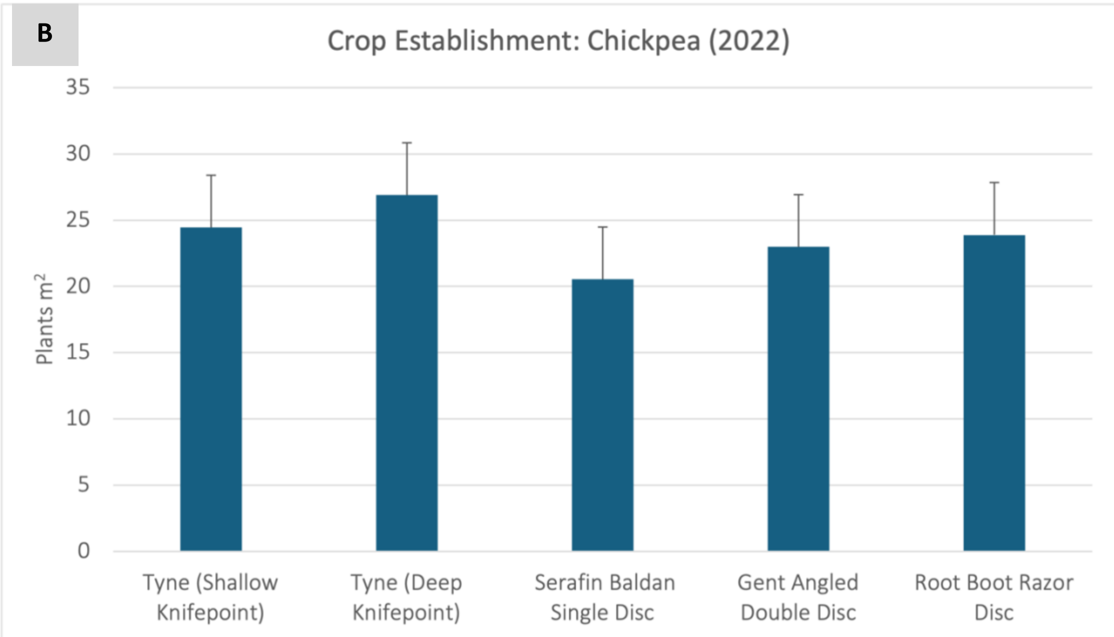
In 2022, the low disturbance Gent Angled Double Disc and Serafin Baldan Single Disc preserved approximately 60% of the existing ground cover (Figure 23). The Root Boot Razor Disc, with greater disturbance, retained approximately 40% of existing ground cover and the conventional tyned seeders had the lowest retention at 30%.

Figure 23: The groundcover that remains under various disc seeding systems/

Crop establishment, however, was lowest for the low disturbance seeders (Gent, Serafin; Figure 24 top). The Root Boot Razor Disc had plant establishment rates comparable to both low disturbance and conventional seeding systems.

Dry matter results were not significant between the treatments. With yield, chickpeas favoured conventional tyned seeding over low disturbance methods (Figure 24 bottom).


A
Crop Establishment: Field Pea (2022)
Plants m2
60
50
40
30
20
10
0
Tyne (Shallow Knifepoint)
Tyne (Deep Knifepoint)
Serafin Baldan Single Disc
Gent Angled Double Disc
Root Boot Razor Disc


B
Crop Establishment: Chickpea (2022)
Plants m2
35
30
25
20
15
10
5
0
Tyne (Shallow Knifepoint)
Tyne (Deep Knifepoint)
Serafin Baldan Single Disc
Gent Angled Double Disc
Root Boot Razor Disc

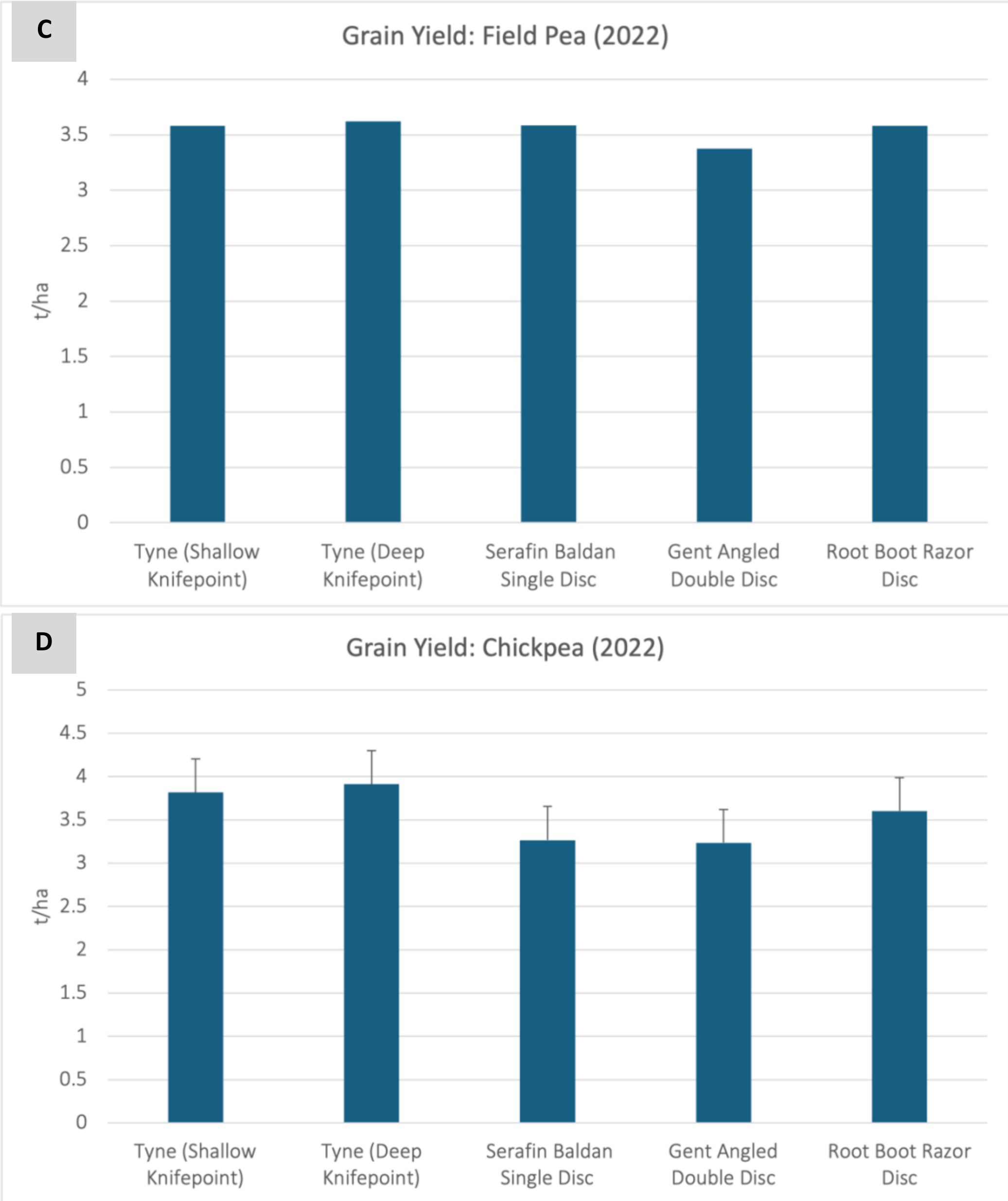


Figure 24: Crop establishment for A) field peas, B) chickpeas and yield for C) field peas and D) chickpeas in 2022.

<u>Lentils 2023</u>

In 2023, lentils were sown using Root Boot Razor discs and Serafin Baldan Single discs and compared to a tyne seeder fitted with a paired row Root Boot opener.

Lentil yields were low across all treatments but overall, the tyned systems performed better, with much of the gain attributed to improved performance and less herbicide damage on sandy soils. Lentils sown using the disc seeders had at least a 15% reduction in plant establishment due to herbicide damage (Figure 25). Soil texture played a role. Crop establishment improved with both disc seeders as the soil became heavier (Figure 26). Disc seeding resulted in lower yields on the sandy soils, as the conditions during grain fill were not adequate to offset the early establishment challenges.

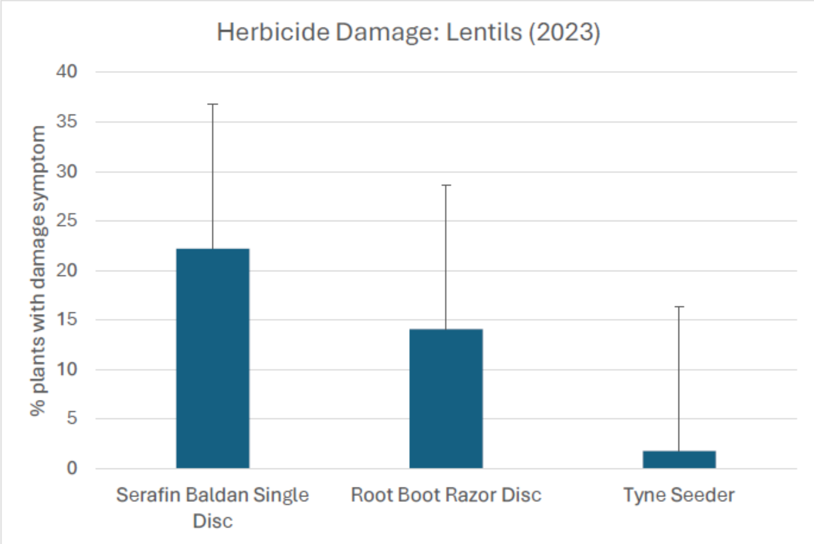


Figure 25: Herbicide damage in lentils in 2023.

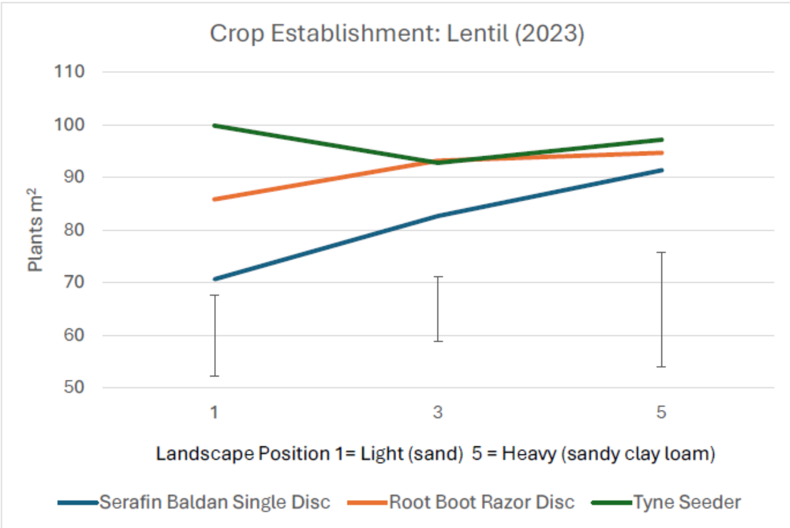


Figure 26: Lentil crop establishment in 2023.

Field peas 2023 (Meringur, Victoria)

A commercial scale trial in the Victorian Mallee was also established in 2023. The trial demonstrated the 'Strip and Disc' system. Field peas were sown, using the Serafin Baldwin Single Disc and Root Boot Razor Disc seeders, into barley and wheat stubbles harvested in 2022 with a Shelbourne stripper front. These strip and disc strips were compared to the farmers' current practice of planting field peas with a tyne seeder into stubbles harvested with a draper front.

Normalized Difference Vegetation Index (NDVI) mapping, supported by visual observation highlighted early growth penalties from disc seeding. Mice in the previous season's barley stubble (harvested with a stripper front) had substantial impacts early that carried through to harvest. Field pea crops in the strip and disc system yielded 15% lower than the farmer's conventional practice.

3.4 Low footprint disc seeding into standing stubble, Lowaldie, South Australia

CSIRO, UniSA

Key messages:

- The low footprint disc seeder demonstrates promise but needs more work at bigger scale and under different conditions.
- Under the experimental conditions, low disturbance edge-row sowing by disc seeder demonstrated the potential for sizeable benefits when establishing crops under marginal moisture conditions.
- While edge-row sowing into standing stubble after rain may be difficult to replicate reliably at a farm seeder scale, the potential benefits on crop productivity where this is achieved would be very significant and reliable.
- On-farm benefits will depend on achieving good target plant densities. This experiment suffered from late sowing (moisture constraints), some residue hairpinning (deeper sowing likely required) and a tight finish to the season.

This trial was an in-field proof of concept using disc seeding to establish pulse crops into standing stubble.

The trial used a double disc system with depth gauging press wheel trailing (in-line) behind the disc opener to sow lentils and lupins. The disc system was designed to flatten the standing stubble and allow for edge-row and inter-row sowing.

Figure 27: Edge-row sown standing barley stubble plot showing undisturbed standing stubble following seeding with a low-footprint, double disc system (depicted in centre and right images). Photos from Uni SA.

Unfortunately, due unfavourable soil moisture conditions, the trial was sown late (16-17 June 2023). The average soil moisture at sowing was 4.3% under the stubble row and 1.7% in the inter-row.

Overall grain yields were low due to the season; however, edge-row sowing gave better yield results than inter-row sowing (Figure 28).

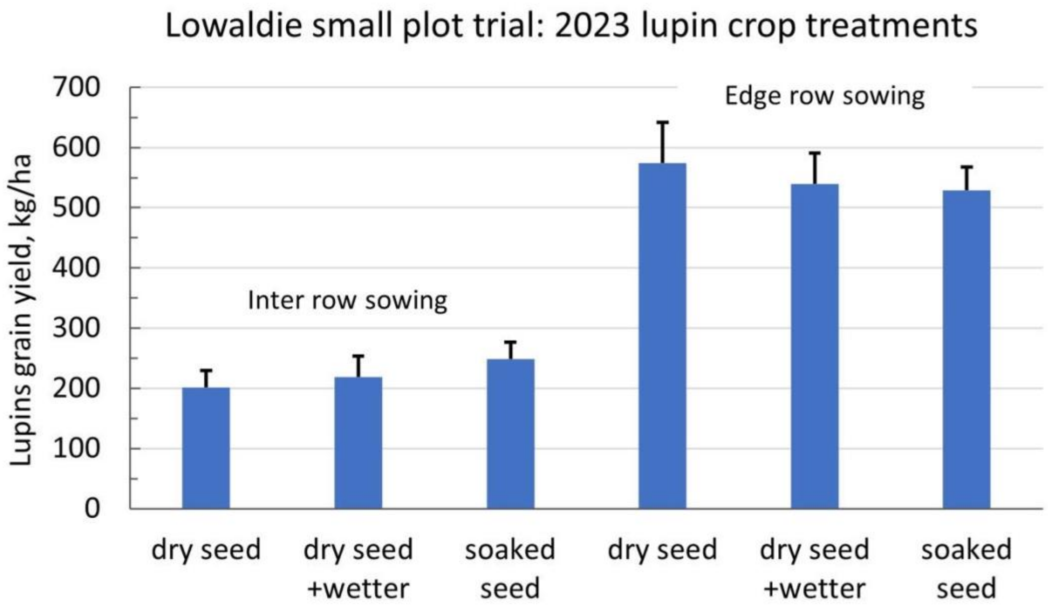


Figure 28: Yield data from edge row and inter row sowing of lupins at Lowaldie in 2023. More detail on the soaked (primed) seed results are on page 16.

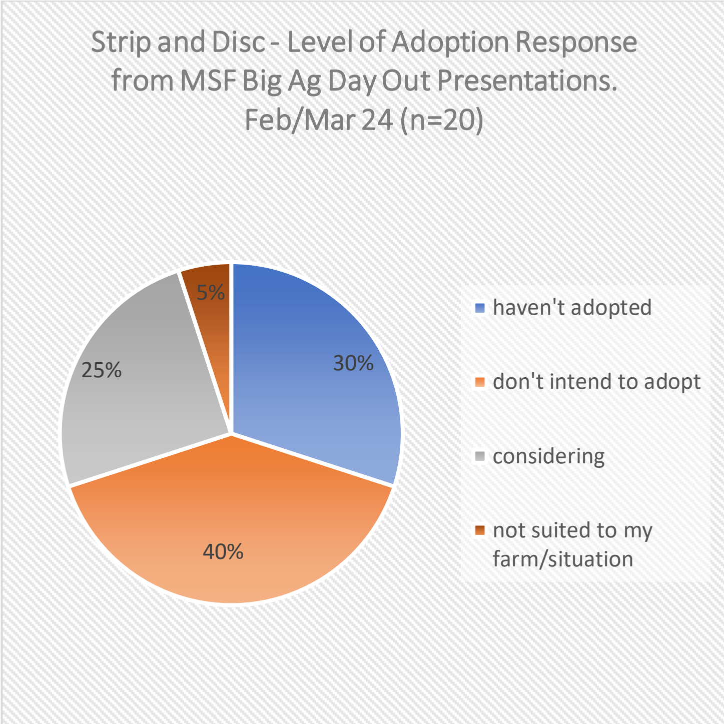
From an infield proof of concept perspective, the low footprint disc seeder demonstrated its merit but it's clear that more work needs to be done, over multiple seasons and increasing scale, in order to reliably replicate the benefits.

What's required to improve confidence in adoption?

- Cost benefit analysis—cost of equipment and harvest losses versus increased speed of operation and benefits of improved stubble retention.
- More information on herbicide impacts and how to adapt seeder to throw herbicide laden soil from the furrow, close the furrow and ensure good seed contact.
- Further farming system adaptation investigation for pulse crops and soil types that require strategic amelioration (when to use and where?)
- Edge row sowing at scale–improvements required to achieve the necessary row guidance precision across paddock conditions with full size (disc) seeder.
- Split fungicide applications—considerable set up costs, requiring two liquid lines per disc seeding unit, increasing set-up costs and water usage, which slows down seeding due to more frequent refills. Before farmers invest in this technology, further work is required to determine the reliability of yield benefits.

Survey feedback—interest in and level of adoption?

We asked our members if they would adopt a strip and disc system. One-quarter of responders are considering doing so, but the technology is largely considered unsuitable.


Strip and Disc - Level of Adoption Response from MSF Big Ag Day Out Presentations. Feb/Mar 24 (n=20)
5%
30%
25%
40%
haven't adopted
don't intend to adopt
considering
not suited to my farm/situation

Replenish & Encourage – Bulk up plant biomass

4. Low risk residue friendly strip amelioration

University of South Australia's Agriculture Machinery and Design Centre

Key messages:

- All ameliorated treatments significantly increased relative crop growth during a tight season, achieving harvestable grain.
- Strip amelioration reduces erosion risk compared to whole-paddock amelioration, by retaining standing stubble strips.
- Strip amelioration with blanket sowing requires a willingness to manage non-uniform crop maturation.
- Strip spading and sowing in a single pass provides the basis for a safe strip cropping option in the first year and addresses issues with trafficability.

Ameliorating soil constraints such as compaction and non-wetting can improve crop establishment and boost yield but comes at the expense of groundcover, especially in pulses in low rainfall environments. Deep ripping can spare some stubble but spading and inversion ploughing leave the soil bare. Strip amelioration allows growers to ameliorate paddocks in stages while maintaining functional groundcover. Strip amelioration works a portion of the paddock by leaving alternating strips of ameliorated soil and undisturbed standing stubble.

These trials in Lowaldie, South Australia, compared active inclusion ripping (ripping with inclusion plates) and single pass delving and disc seeding on a non-wetting sandy rise. The strip spader was modified to spade 0.4m wide strips at a 0.8m spacing, and sow 2-3 rows over the spaded strips (Figure 29). More information on the active inclusion ripping equipment used in the project can be found at: https://www.youtube.com/watch?v=d74GaJQExSg

Figure 29: Single pass strip spading and sowing. Supplied Uni SA

In 2022, the site was blanket sown with barley and 40% of one plot was strip-ripped (Table 4). These ripped strips yielded 0.64 t/ha (28%) more than the unripped areas. The control plot yielded 2.3 t/ha. The barley stubble from 2022 was retained and fenced off for use in the 2023 trials.

Table 4. Strip amelioration treatment sequence.

Year	Crop	T0: Control	T1b: Strip rip 1	T1a: Strip rip 2 (out of phase)	T2: One pass inclusion rip	T3: Strip spading
2022 Set up phase	Barley	--	1st pass strip area = 40%	--	--	--
		Blanket sowing Year 1				
2023 Main trial year	Pulse	--	2nd pass strip area = 60%	1st pass strip area = 40%	Single pass strip area =100%	1st pass strip area = 50%
		Blanket sowing Year 2				Strip sowing

In 2023, the rest of the treatments were implemented, including:

- T2: 100% ripped area
- T1a: 40% ripped area
- T1b: Ripping the remaining 60% of the plot from 2022
- T3: Strip spade and sow

All active inclusion treatments were blanket sown with lentils (12 May, with triple disc seeder) and had to be rolled due to an uneven surface finish (28 June post-emergence). The single pass strip (50%) spade and sow treatment was sown on 15 May 2023 with a floating seeding system.

Crops established best in the spade and sow plot (Figure 30), with 60% emergence and 90 plants/m^2. Blanket sowing over the strip inclusion ripping treatments produced a staggered crop maturity.

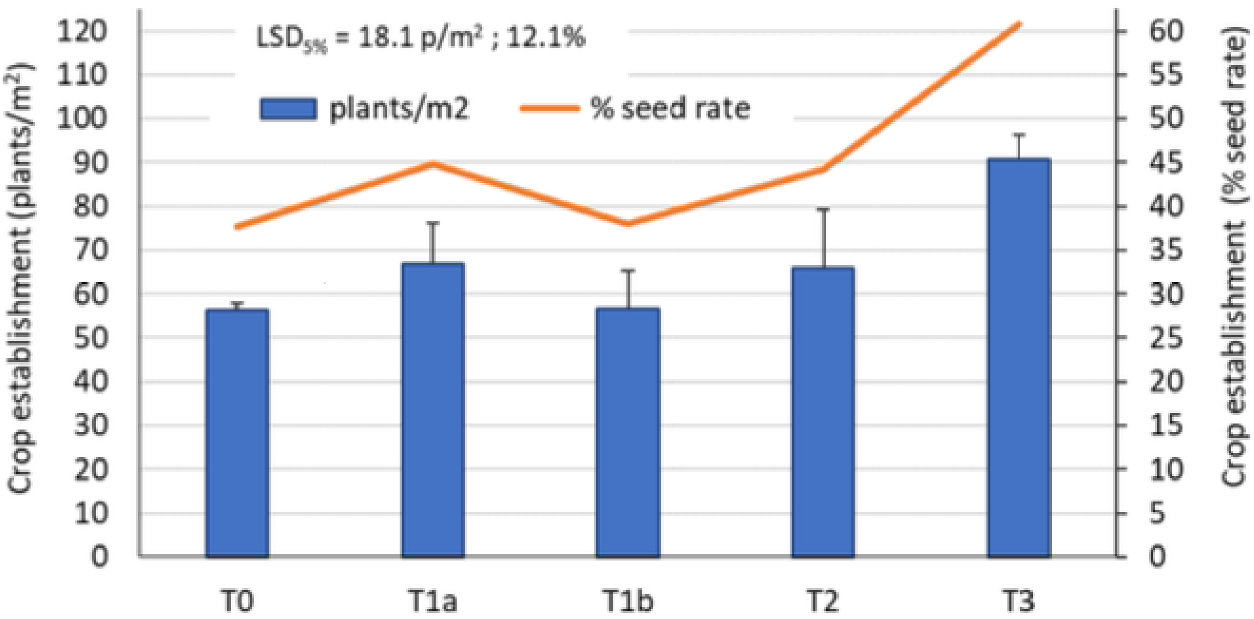


Figure 30. Lentil crop establishment at Lowaldie in 2023. T0 = control, T1a = 40% ripped, T1b = 60% rip (+40% 2022 rip), T2 = 100% ripped, T3 = spade and sow.

The control and 40% phase 1 treatment (T1a) suffered most from water repellence, while the 100% inclusion ripping treatment (T2) suffered from wind damage. Rolling the ripping treatments is thought to have impacted emergence results, while herbicide damage was also observed. Un-ameliorated plot zones (control plus the 60% not treated in T1a) experienced moisture stress first and subsequently matured earlier. Growing season rainfall (187.4 mm) as lower than the average GSR (233.5 mm). These zones were harvested by hand on 31 October while the rest of the treatments were harvested on 6 November.

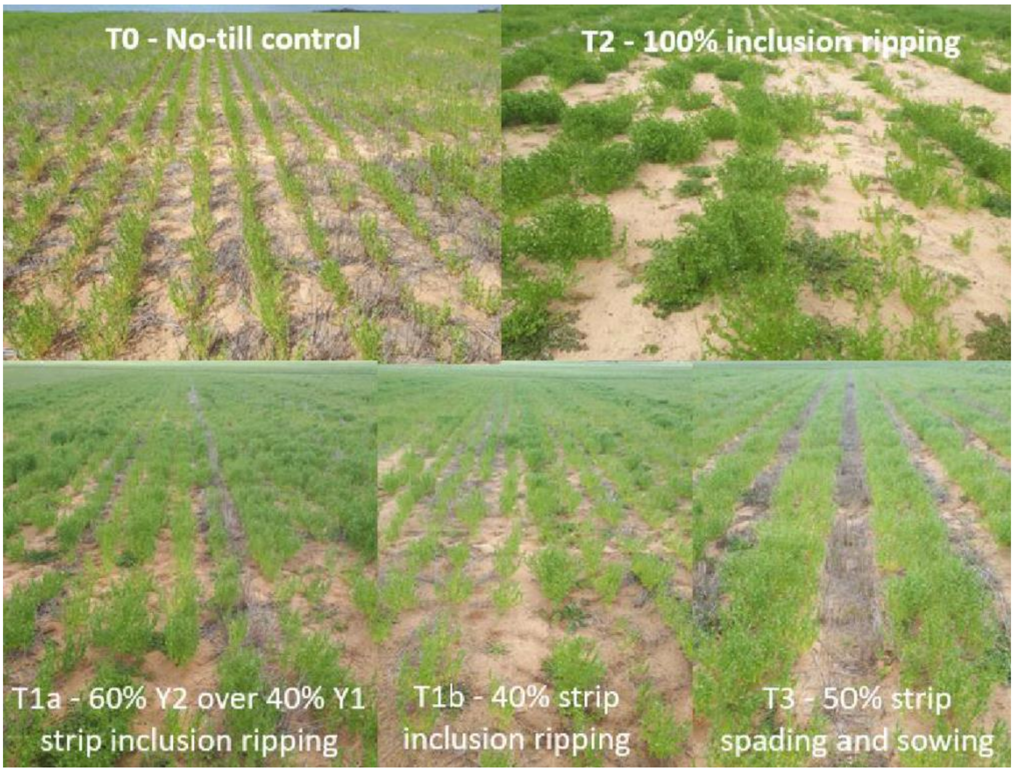


Figure 31: Depicts the different treatments on 15 September 23. Uni SA

All treatments outperformed the control by at least 50% (Table 5). The 100% inclusion ripping, single season treatment yielded highest at 0.88t/ha followed by the 50% strip spade and sow at 0.73t/ha and 60% year 2 plus 40% year 1 at 0.72t/ha. The 40% treatment yielded 0.47t/ha.

Table 5. Harvest data at Lowaldie in 2023 on strip amelioration.

Treatments (2023)		Harvest biomass (t/ha)	Grain yield (t/ha)	Harvest Index
T0	Control	0.64	0.20	0.31
T1a	40% strip rip	1.11	0.47	0.43
T1b	60% strip rip (+40% rip in 2022)	1.61	0.72	0.45
T2	100% rip	1.82	0.88	0.48
T3	Strip spade and sow	1.86	0.73	0.39

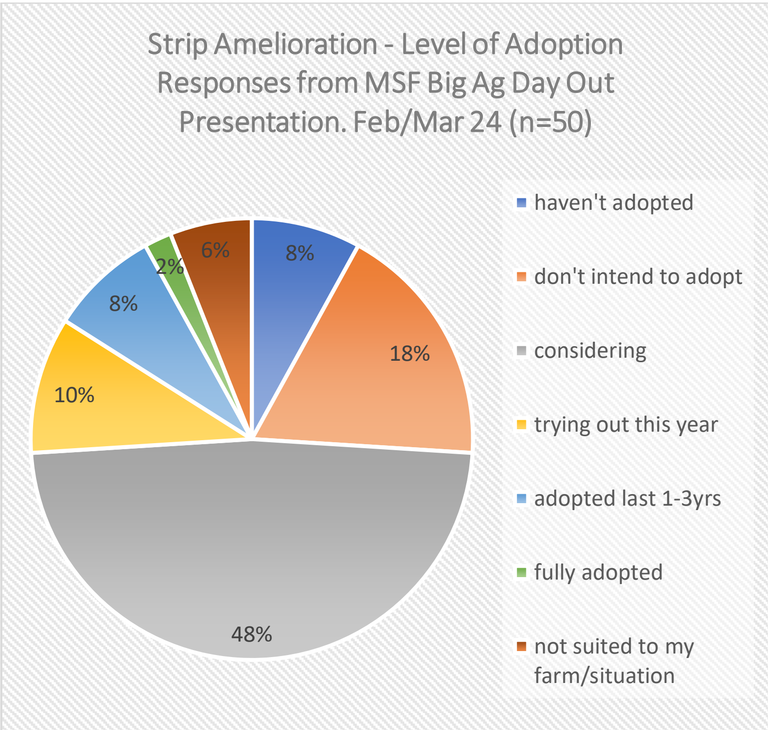
Overall, strip inclusion ripping and strip spading techniques provide a safer approach to soil amelioration by keeping effective stubble protection during the early crop establishment phase. In 2023, strip amelioration improved crop growth (the control did not have harvestable grain), while managing erosion risk.

What's required to improve confidence in adoption?

- Improved understanding on the range of benefits across multiple demonstration contexts relative to full amelioration alternatives and no amelioration controls.
- Increased knowledge on optimum time in crop rotations and when to respond to other environmental cues.
- Analysis of the cost effectiveness of staged amelioration practices (when to use and where? Can it offset risks in highly vulnerable – at risk of erosion – settings) and comparisons to potential build long term system resilience needs to be captured.
- Options for blanket sowing strip ameliorated (inclusion ripped) paddocks are required to manage variation in crop maturity.
- Farming system scenarios for including organic material into inclusion rips and the potential to remediate degraded land (saline, overgrazed, compacted etc.) requires ongoing investigation.

Survey feedback—interest in and level of adoption?

We asked our members if they would adopt strip amelioration. A few members are already using strip amelioration or are trying it out, while nearly half of respondents are considering strip amelioration.



5. Stripper front harvesting

UniSA, Frontier Farming Systems.

Key messages:

- Stripper fronts retained stubble effectively but required careful speed and settings management to minimise crop loss.
- The stripper fronts almost always led to more grain losses than a conventional open front. However, losses should be weighed against the benefits of increased standing residue, moisture conservation and harvest efficiency (potential higher speeds).
- Higher speeds of stripper front harvesters (above 11 km/hr) generally do not increase losses compared to lower speeds. Higher speeds are recommended to make the most of harvester capacity and maximise work rate.
- Low hood settings are detrimental in high density crops.
- Harvesting across the crops was not beneficial and was, in some cases, detrimental compared to harvesting along the row.
- Stripper fronts should be avoided in shedding prone crops and varieties.
- Taller standing stubble can harbour mice.

A stripper front is an alternative header front attachment which minimises the disturbance of crop stubbles. Compared to a conventional draper front which removed most of the standing stubble, the stripper front 'picks' the heads off the wheat, leaving tall standing stubble (Figure 32). This method aims to minimise soil disturbance and maintain ground cover.

These trials compared various stripper front setups and operating speeds on combine throughput and harvester losses.

Figure 32. Tall wheat stubble after harvesting with the Shelbourne Reynolds stripper front (Left) compared to stubble after harvesting with a conventional draper front (right) near Manangatang in the Victorian Mallee.

Figure 33: Grower's Shelbourne XCV 42 Stripper Front at Manangatang (left) and Frontier Farming Systems' older Shelbourne CVS 20 Stripper Front at Werrimull (right).

5.1 Manangatang, Victoria

At the 21ha Manangatang site, wheat (Razor CL) and barley (Maximus CL) were sown at either narrow (7.5 inch) or wide (15 inch) row spacings. Catching trays were placed across the treatments (Figures 34 and 35) and investigated the losses from those treatments at harvest speeds of 8km/hr (normal/high/low hood position settings), 11km/hr (normal hood position) and 14Km/hr (normal hood position). The treatments were compared to a conventional draper front at 8km/hr. Crops were harvested either along or across the sowing direction.

Figure 34. Tray positions for harvesting across the row in 15-inch (left) and 7-inch (right) row spacings. Photos from UniSA.

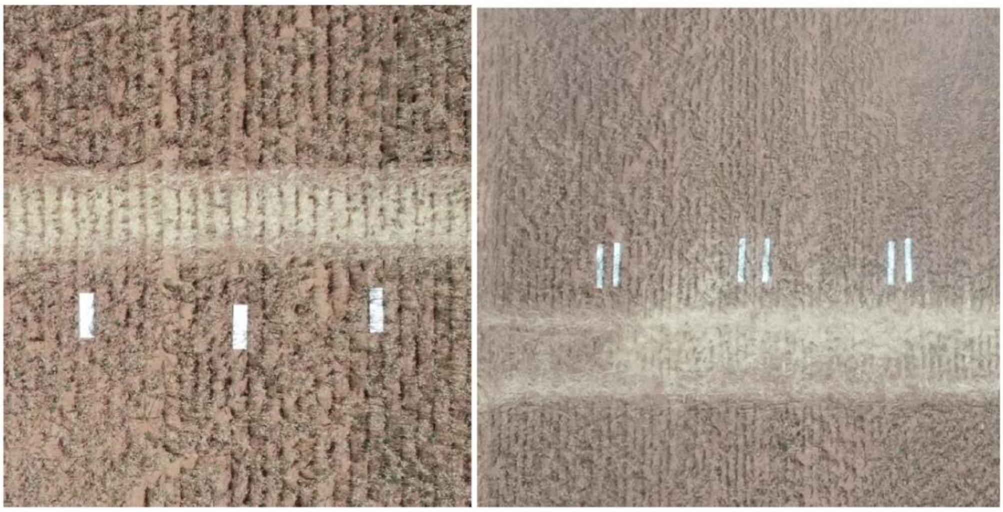


Figure 35: Tray positions for harvesting along the row in 15-inch (left) and 7-inch (right) row spacings. Photos from Uni SA.

A wet 2022 harvest season meant the crop was harvested in January 2023, increasing shedding potential.

Stripper front losses were higher at all settings compared to a conventional draper front (Figure 36). Setting the hood low increased the losses, especially when harvesting across the row.

When compared to the draper front at 8km/hr, the stripper front at 14 km/hr had losses of 4% to 18% when harvesting across the row at 15 inch spacing, and along rows with 15- and 7-inch spacings. Losses increased to 15%–24% when harvesting across rows at 7.5-inch spacing.

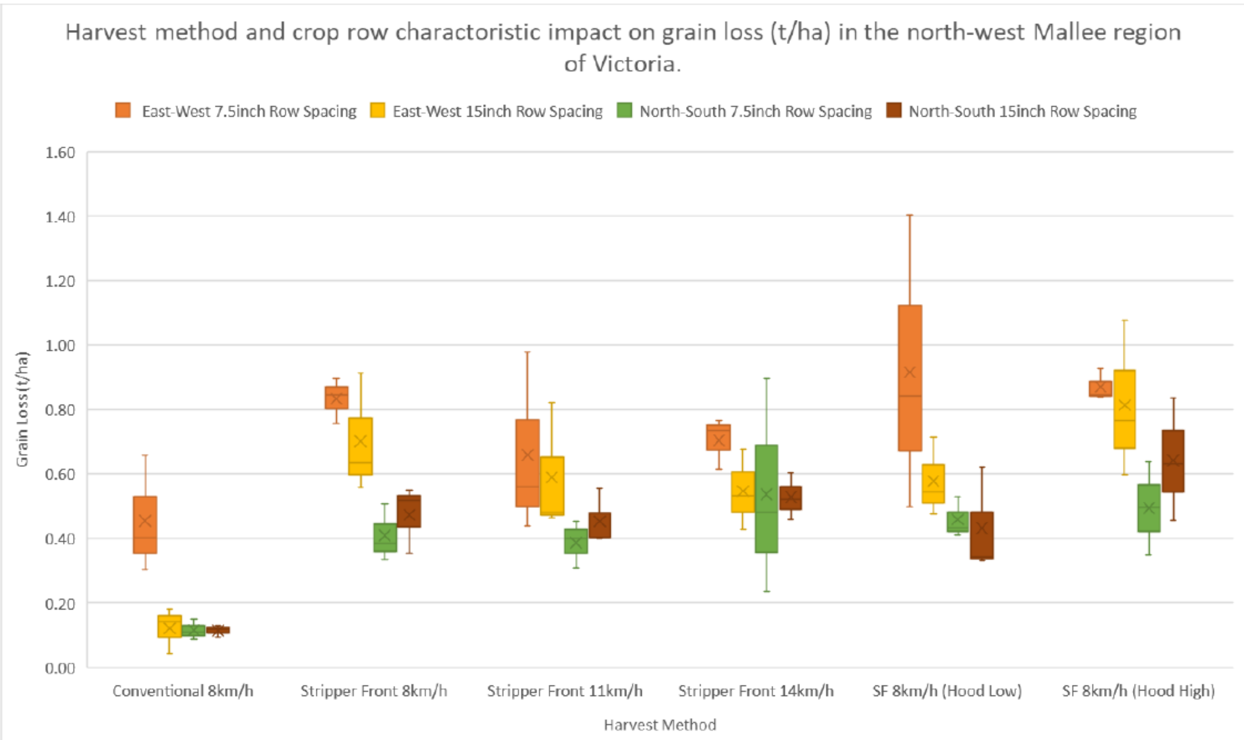


Figure 36. Grain loss (t/ha) from various stripper front settings, row spacings, and harvest directions.

5.2 Werrimull, Victoria

At the 32ha Werrimull demonstration site, wheat (Kord cv.) and barley (Commodus and Spartcus cv.) crops were harvested to evaluate the impact of high versus low biomass (seeding rate 30 vs 60 kg/ha) at speeds of 4km/hr and 8km/hr along the row (same direction as the seeder).

Seasonal difficulties meant harvest was delayed until very late in December and there was a lot of natural shedding in barley. Additionally, short crop heights across the site meant the fronts had to be very low to the ground with the risk of picking up stones or causing damage.

Crop type and variety had a greater influence on harvest losses than header type or speed (Figure 37). Wheat fared better than barely, with 4-5% losses in wheat compared to 15% losses with Commodus barely.

Given the very wet year the crop had ample opportunity to compensate with additional tillers and there was no difference in biomass at the end of the year between seeding rates.

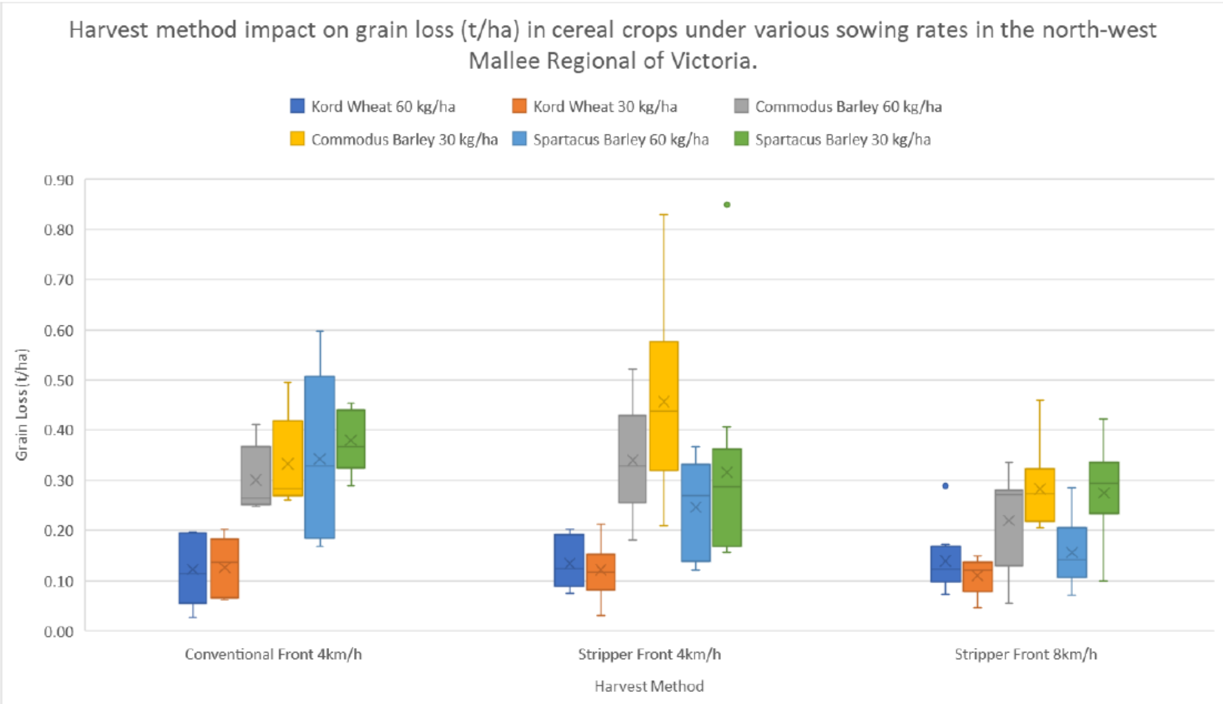


Figure 37. Harvest method impact on grain loss (t/ha) in cereal crops under various sowing rates at Werrimull.

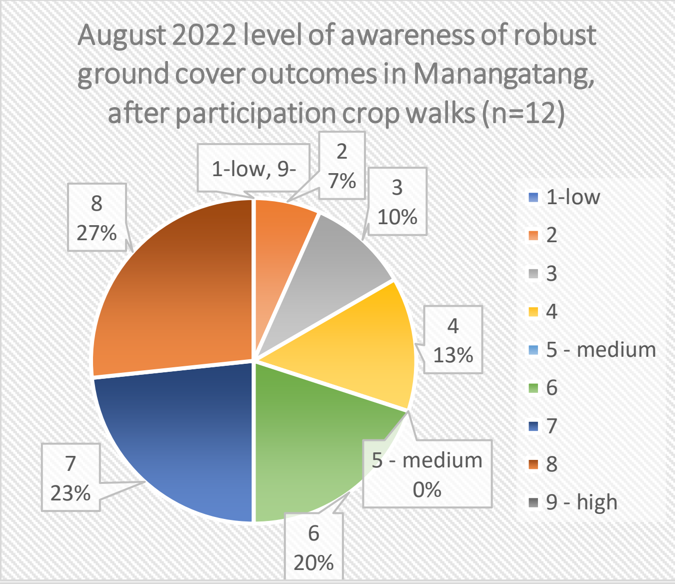
Overall, given the seasonal challenges of the single year harvest trials carried out as part of this project, there has not been chance to determine if stripper fronts are more suitable in low yielding Mallee crops.

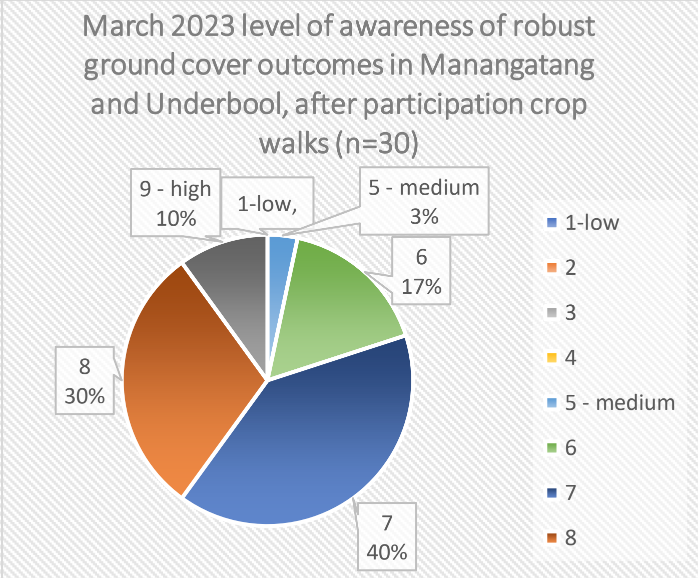
What's required to improve confidence in adoption?

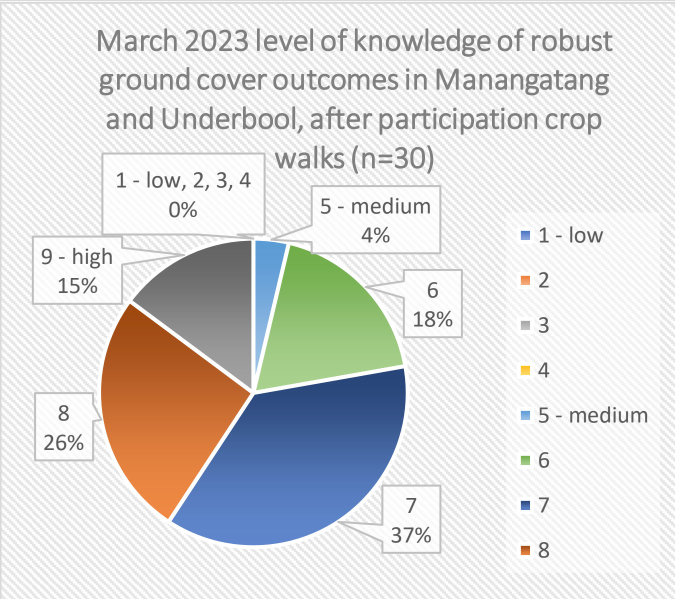
- Specific low rainfall farming system conditions warrant further investigation to determine when and where strip and disc systems can help overcome or manage key vulnerabilities (e.g., soil stabilisation requires increased stubble load or crop rotations require accumulative increases in stubble load to build system resilience).
- Further demonstration is required to consider farming system responses to increase pest load (mice).
- Machinery set-up and design improvements for low rainfall environment. Consider header drivers preparedness, concentration, and lots of adjustments with the stripper front, plus the need to be swapping fronts during the season to suit crops in rotation.

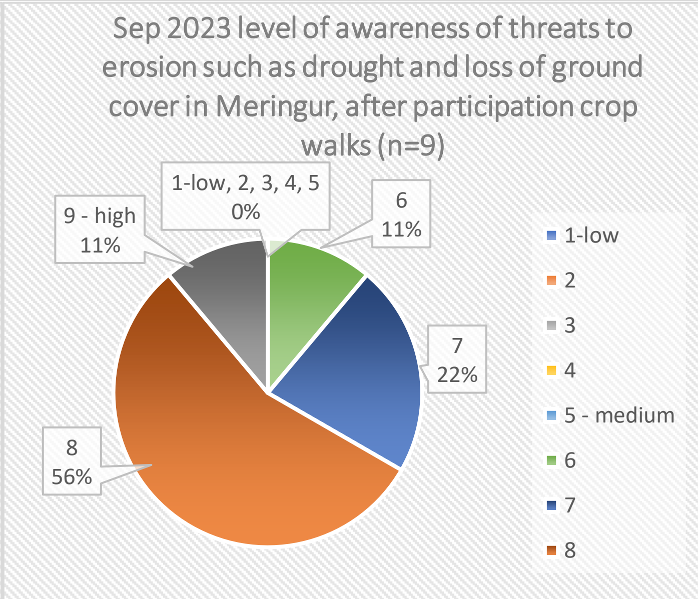
- The use of a stripper front need to be part of a systems approach because other factors are affected. Things such as grain carting transport from the paddock, if capacity is doubled by using a stripper front this grain must be carted away to not limit potential capacity. Additionally, logistic of managing two fronts for the whole season, transport and maintenance.

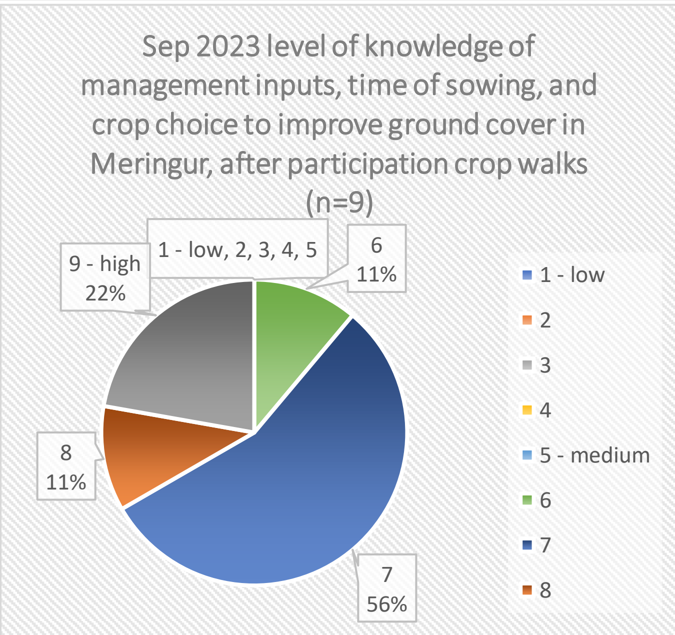
Evaluation

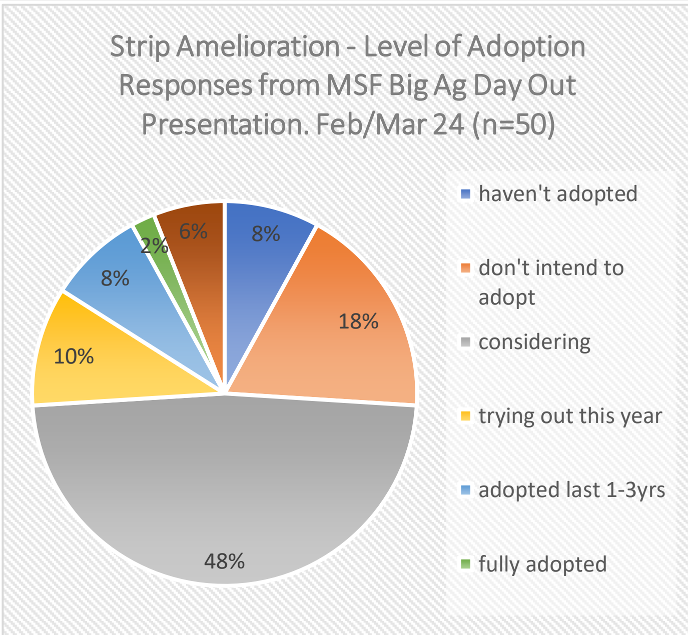

August 2022 level of awareness of robust ground cover outcomes in Manangatang, after participation crop walks (n=12)
1-low, 9-
2
7%
3
10%
4
13%
5 - medium
0%
6
20%
7
23%
8
27%
1-low
2
3
4
5 - medium
6
7
8
9 - high

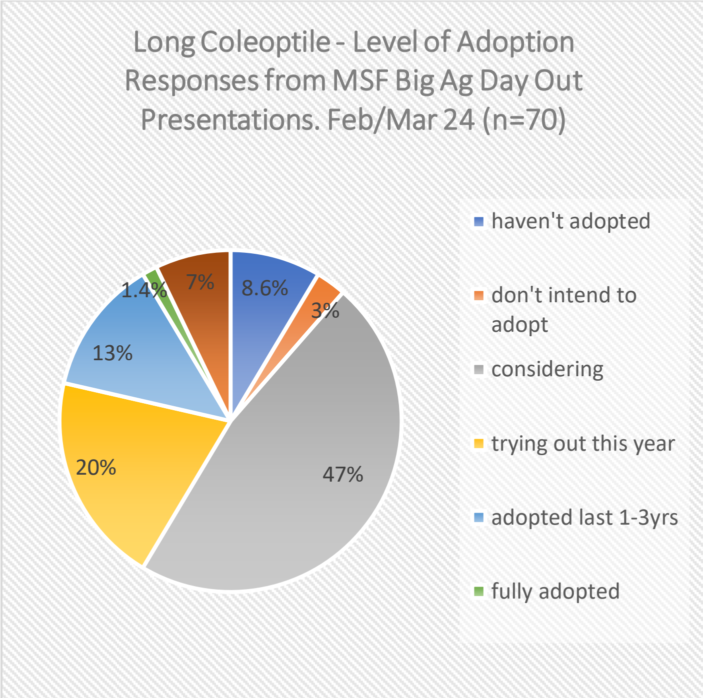

March 2023 level of awareness of robust ground cover outcomes in Manangatang and Underbool, after participation crop walks (n=30)
9 - high
10%
1-low,
5 - medium
3%
6
17%
7
40%
8
30%
1-low
2
3
4
5 - medium
6
7
8

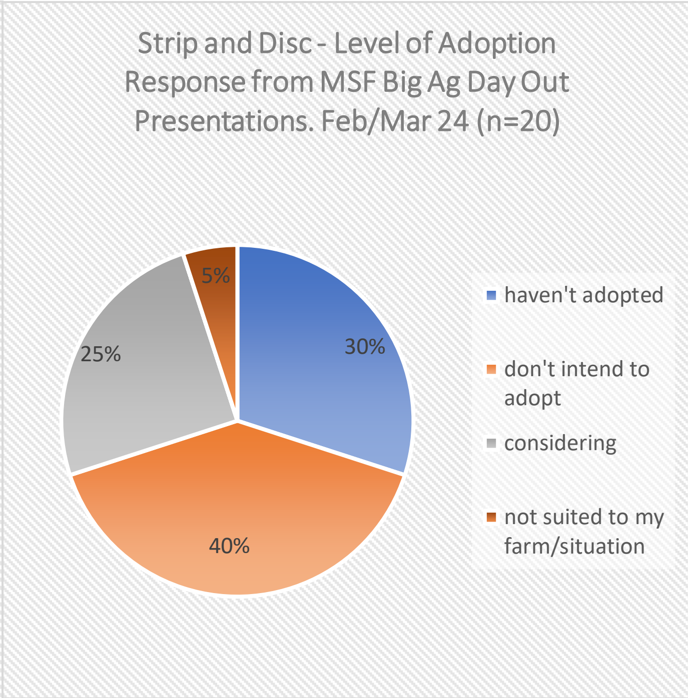

March 2023 level of knowledge of robust ground cover outcomes in Manangatang and Underbool, after participation crop walks (n=30)
1 - low, 2, 3, 4
0%
5 - medium
4%
9 - high
15%
6
18%
8
26%
7
37%
1 - low
2
3
4
5 - medium
6
7
8

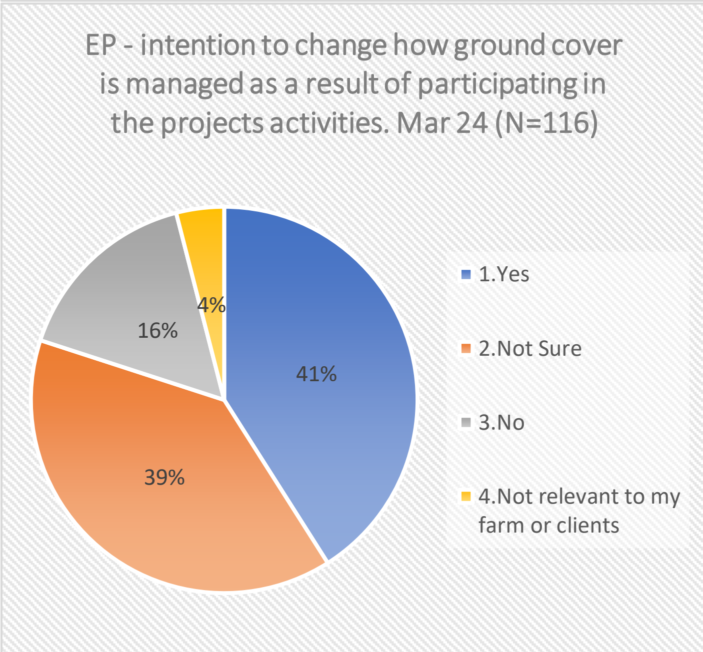

Sep 2023 level of awareness of threats to erosion such as drought and loss of ground cover in Meringur, after participation crop walks (n=9)
1-low, 2, 3, 4, 5
0%
9 - high
11%
6
11%
7
22%
8
56%
1-low
2
3
4
5 - medium
6
7
8


Sep 2023 level of knowledge of management inputs, time of sowing, and crop choice to improve ground cover in Meringur, after participation crop walks (n=9)
9 - high
22%
1 - low, 2, 3, 4, 5
6
11%
8
11%
7
56%
1 - low
2
3
4
5 - medium
6
7
8


Strip Amelioration - Level of Adoption Responses from MSF Big Ag Day Out Presentation. Feb/Mar 24 (n=50)
6%
2%
8%
8%
18%
10%
48%
haven't adopted
don't intend to adopt
considering
trying out this year
adopted last 1-3yrs
fully adopted


Long Coleoptile - Level of Adoption Responses from MSF Big Ag Day Out Presentations. Feb/Mar 24 (n=70)
8.6%
3%
47%
20%
13%
1.4%
7%
haven't adopted
don't intend to adopt
considering
trying out this year
adopted last 1-3yrs
fully adopted


Strip and Disc - Level of Adoption Response from MSF Big Ag Day Out Presentations. Feb/Mar 24 (n=20)
30%
40%
25%
5%
haven't adopted
don't intend to adopt
considering
not suited to my farm/situation


EP - intention to change how ground cover is managed as a result of participating in the projects activities. Mar 24 (N=116)
41%
39%
16%
4%
1.Yes
2.Not Sure
3.No
4.Not relevant to my farm or clients

This project received funding from the Australian Government's Future Drought Fund.