Increasing production on sandy soils – narrowing down what to do and where

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Key Messages

- All sandy sites were responsive to both physical interventions and CL addition. The size of the response varied for each site ranging from up to 127% on the most productive sand (North hill top) up to 191% on the least productive sand (South mid slope).
- The grain yield response to physical incorporation method (deep ripping and spading) and CL was generally greater than 10%, but the ranking of specific treatments varied within each of the three sandy soil trial sites.
- In the absence of CL, there was no benefit from using long versus short inclusion plates in year one. However, in year two both the North sites had improved grain yield from the use of long inclusion plates suggesting greater longevity from the inclusion of more top soil.
- In the first season, spading resulted in a soft soil surface and made seed placement difficult. Consequently, the wheat crop struggled to emerge and impacted crop performance. However, in the second season the soil had consolidated and no issues with seed placement or crop establishment occurred.
- Results from the depth of ripping trials have shown responses to ripping 40-60 cm deep in all six site years. No yield responses were measured from a ripping depth of 20 cm.

Why do the trial?

It is estimated farmers manage 3 million hectares of sandy soils in the low-medium rainfall landscape of southeast Australia. These sandy soils can have a range of production constraints including; a compacted or hard-setting layer preventing root proliferation, a water repellent surface layer causing poor crop establishment, soil pH issues (both acidity and alkalinity) and/or poor nutrient supply. Sandy soils also respond differently to soil amelioration techniques, and it is not a one size fits all approach. Understanding the constraints, appropriate amelioration tools and machinery set up that will best address the constraints are critical to success.

Local research (Parker et al. 2019; Ucgul et al. 2019) has developed guides on how spading and inclusion ripping machinery are best set-up and used. The incorporation by spading of a surface-applied amendment or the mixing of a constrained sublayer achieves variable levels of mixing uniformity within the profile, which is a function of speed, depth and spader design. The mixing by the spading process is cyclical rather than continuous and controlled principally by the spading ‘bite length.’

A lower risk soil profile amelioration method consists of inclusion plates fitted behind deep ripping tines which promote the passive inclusion of the top layer into the loosened profile. Substantially enhanced inclusion capacity can be obtained when operating in loose, flowable top-soil conditions with optimised plate design and set-up, such as the plate upper-edge length and its lower-edge depth of reach. The use of inclusion plates is also about trying to extend the length of the effect from deep ripping alone.

Reasons for using one technique or another will depend on the soil constraints being addressed. This project aims to establish field sites which demonstrate amelioration techniques that growers can use to address the specific sandy soil constraints for their local landscape type and where in the landscape different tactics are best deployed.

Methods

Site Selection

Three sandy soil amelioration trial sites were identified at Bute, SA (Figure 1) in 2022. The two sites located in the North paddock (Figure 1) were a duplex sand over loamy sand (North hill top) and a loamy sand transition to a deep sand (North mid slope). Site three was in the South paddock (Figure 1) and the soil was a deep sand (Table 1). Historic crop performance indicated the South paddock was poorer performing compared to the north.

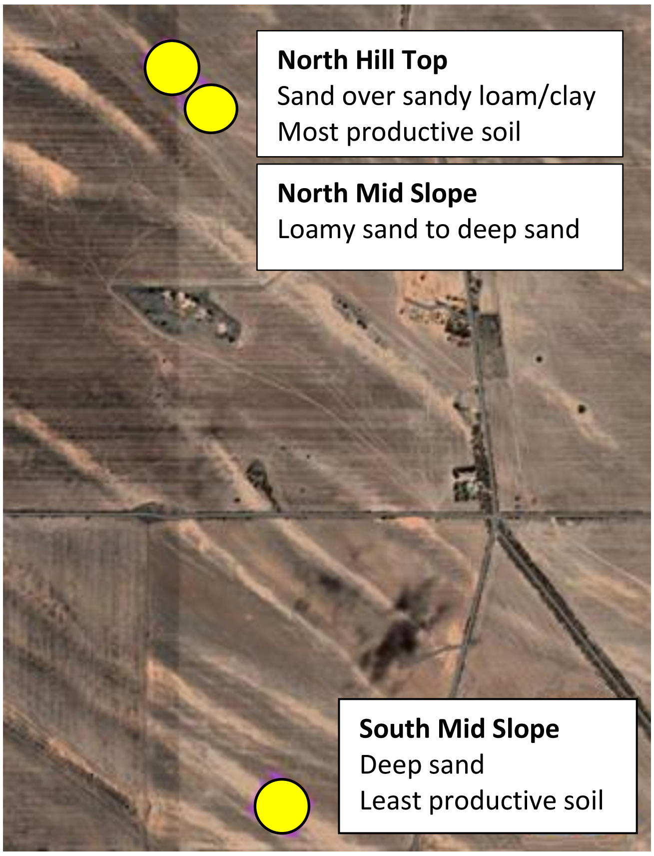


Figure 1. Image showing the three trial locations (yellow dots) for the sandy soil amelioration sites established at Bute, SA in 2022.

The two deep sands were more acidic at depth (10-20 cm and 20-30 cm) compared to the North hill top site (Table 1). The South mid-slope soil had a lower PBI and CEC compared to the north sites (Table 2). Organic carbon was generally low across all three sites. Soil phosphorus levels were in the marginal (20-30 mg/kg) to adequate (30-45 mg/kg) ranges across the three sites (Hughes 2020). Sulphur levels were low (<5 mg/kg) at the South mid slope site and become low to marginal (5-10 mg/kg) at the North sites.

Surface soil samples were also assessed for water repellence. A water repellence rating (0-5) was given based on the concentration of ethanol required to penetrate the soil surface. The higher the rating, the more water repellent the soil. The North sites were not considered water repellent with 0 and 1 ratings (data not shown). The South mid slope site was moderately repellent, scoring 2 in both the 0-5 cm and 5-10 cm layers.

Table 1. Soil pH for all three sandy soil types at Bute, SA.

Depth	North hill top	North mid slope	South mid slope
0-5 cm	5.22	5.27	5.34
5-10 cm	4.71	4.53	4.90
10-20 cm	5.61	4.82	5.03
20-30 cm	7.62	5.36	6.15

Table 2. Soil physical and chemical properties for all three sandy soil types at Bute, SA.

Depth	Soil Texture	Organic Carbon	Colwell P	PBI	Sulphur	Conductivity		Exchangeable cations		
cm		%	mg/kg		mg/kg	EC1:5 dS/m	ECe	ECEC	ESP	
North hill top (most productive sandy site)										
0-10	Sand	0.6	25	17	7.5	0.08	1.1	3.9	1.0	Non-sodic
10-30	Loamy sand	0.1	26	29	4.1	0.11	1.5	10.2	0.3	Non-sodic
30-50	Loamy sand	0.1	10	32	6.5	0.08	1.1	19.9	0.2	Non-sodic
50-100	Loamy sand	0.1	<5	41	4.6	0.08	1.1	21.7	0.2	Non-sodic
North mid slope										
0-10	Loamy sand	0.4	30	21	8.5	0.14	2.0	3.6	1.1	Non-sodic
10-30	Loamy sand	0.1	29	16	4	0.04	0.5	2.8	1.3	Non-sodic
30-50	Loamy sand	0.1	14	14	<2.5	0.04	0.6	2.8	1.2	Non-sodic
50-100	Sand	0.1	<5	16	2.5	0.06	0.8	4.5	0.8	Non-sodic
South mid slope (least productive sandy site)										
0-10	Sand	0.4	31	14	3.8	0.04	0.5	2.0	1.7	Non-sodic
10-30	Sand	0.1	26	18	3.1	0.04	0.5	2.5	1.4	Non-sodic
30-50	Sand	0.1	11	13	2.9	0.04	0.5	3.1	1.1	Non-sodic
50-100	Sand	0.1	<5	30	5.1	0.07	1.0	6.2	1.1	Non-sodic

Trial design and treatments

At each of the three locations (Figure 1) two trials were established to assess depth of deep ripping (Table 3), soil amelioration practice and chicken litter (CL) addition (Table 4). The whole trial site was spread with 5 t/ha lime (district practice) on the 9th May 2022 to address surface and subsurface acidity.

All deep ripping and amendment treatments were implemented on 10th May 2022. Deep ripping and inclusion treatments were ripped at a speed of 4.5 km/h. Subsoil placement treatments were ripped at a speed of 2.5 km/h. In the topsoil and amendment inclusion trials the South mid slope site was ripped to a depth of 60 cm compared to the North hill top and North mid slope sites at 50 cm. Tine and inclusion plate setup can be seen in Figure 2.

Table 3. Treatment list for depth of ripping sandy soil trials.

Treatment	Depth (cm)
1	Nil
2	20
3	40
4	60

Table 4. Treatment list for topsoil and amendment inclusion sandy soil trials.

Treatment	Physical	Chicken litter (t/ha)
1	Nil	nil
2	Nil	10
3	Deep rip - no inclusion plates	nil
4	Deep rip - short inclusion plates (250 mm long)	nil
5	Deep rip - long inclusion plates (600 mm long)	nil
6	Deep rip - long inclusion plates (600 mm long)	10
7	Deep rip – deep placement of CL, no inclusion plates	10
8	Deep rip – deep placement of CL, no inclusion plates attempt 2	10
9	Spade	nil
10	Spade	10

Figure 2. Deep ripper tine with short (250 mm) inclusion plates (left) and long (600 mm) inclusion plates (right).

Crop assessments

Over the past two seasons the trial has followed a wheat and barley rotation. Various in season assessments have occurred and are summarised below (Table 5) for each trial year. The long-term Bute annual rainfall is 391 mm and growing season rainfall 290 mm.

Table 5. Summary of seeding details and crop measurements in sandy soil amelioration sites at Bute, SA 2022 – 2023.

Year	Rainfall	Crop, seeding date and fertiliser	Crop assessments
2022	Annual: 451 mm GSR: 314 mm	Razor CL Plus at 110 kg/ha 31st May 2022 MAP Zn at 80 kg/ha + urea at 65 kg/ha Urea in-season 190 kg/ha at the North sites 200 kg/ha at the South site	Greenseeker NDVI Grain yield Grain quality
2023	Annual: 362 mm GSR: 225 mm	Commodus CL barley at 75 kg/ha MAP at 90 kg/ha + urea at 80 kg/ha Urea in-season 100 kg/ha at all sites	Greenseeker NDVI Grain yield Grain quality

The results were analysed using Tukey's range test which compares all possible pairs of means and identifies any difference between two means that is greater than the expected standard error.

Results and discussion

North hill top (most productive sandy site)

By late August crop biomass measured as NDVI ranged from 0.653 – 0.799 (Table 6). Treatments with higher levels of disturbance such as long inclusion, deep placement and spading resulted in higher biomass. Seed placement was an issue following spading in year one (Trengove et al. 2022). However, this was not observed in year two, with high crop emergence across all three sandy trial sites. Similar to the first season, CL applied to the surface with no incorporation was not beneficial early in the season and produced similar NDVI to the nil.

Barley grain yields ranged from 4.28 t/ha to 5.27 t/ha (Table 6). Yields were closely correlated to NDVI. The highest disturbance treatments (spading, long inclusion and deep place) producing the highest grain yields. Higher grain yields were observed from the use of long inclusion plates (5.20 t/ha) compared to short inclusion plates (4.58 t/ha). This also suggests that long inclusion plate ripping may provide a useful alternative to spading with reduced erosion risk and a more seeder-ready finish.

Grain quality results showed high retention values (81.2%- 94.0%) and low screenings (all samples <5.2%) across the trial. Commodus CL barley is currently undergoing malt accreditation. Applying the malt 1 receival standards to the current results showed test weight, screening and retention for all samples met this standard (Table 6). The only grain quality parameter to effect receival grade was protein. Generally, treatments where CL was not applied fell below or near 9% (range 8.9-9.4%). Spading was the only method to increase protein compared to the nil without CL applied. At the other end of the protein range, spading with CL was higher than 12%.

Table 6. Greenseeker NDVI, grain yield (t/ha), grain yield % of untreated control and grain quality for physical incorporation and CL trial **North hill top** sandy soil amelioration site, 2023.

Physical incorporation method	**Chicken litter (t/ha)**	**NDVI 16th Aug**	**Grain yield (t/ha)**	**Grain yield % of nil**	**Protein (%)**	**Test weight (kg/hL)**
Nil	nil	0.653 c	4.28 c	100	9.4 cd	70.5 a
Nil	10	0.713 bc	4.58 c	107	10.0 bcd	69.3 a
Deep rip - no inclusion	nil	0.707 bc	4.73 bc	111	8.9 d	70.1 a
Deep rip - short inclusion	nil	0.714 bc	4.58 c	107	9.0 cd	70.2 a
Deep rip - long inclusion	nil	0.761 ab	5.20 ab	121	9.3 cd	69.9 a
Deep rip - long inclusion	10	0.786 ab	5.19 ab	121	10.1 bcd	69.8 a
Deep rip & place	10	0.779 a	5.26 a	123	10.2 bc	70.1 a
Spade	nil	0.767 ab	5.16 ab	121	11.4 ab	68.8 a
Spade	10	0.799 a	5.27a	123	12.8 a	68.9 a
	Pr(>F)	<0.001	<0.001		<0.001	0.228

In the depth of ripping trial similar observations occurred to 2022. Ripping to a depth of 20 cm did not increase grain yields compared to the nil (Table 7). Ripping depths of 40 and 60 cm produced similar grain yields averaging 4.62 t/ha, 17% higher than the nil. Previous research (DPIRD 2020, McBeath et al. 2022) has shown grain yield response from ripping depth can be linked to a reduction in soil strength. However, the response will change depending on site and the depth at which the constraint occurs in the soil profile. The results suggest the optimal ripping depth at the North hill top site is 40 cm.

Ripping depth did not impact any of the barley grain quality parameters measured this season (data not shown). The trial average values were protein 8.9%, test weight 69.6 kg/hL, retention 90.0% and screenings 3.4%.

Table 7. Greenseeker NDVI, grain yield and grain quality for depth of ripping trial **North hill top**, 2022 and 2023.

Depth of ripping (cm)	**Grain yield (t/ha)**	**Grain yield % of nil**	**Grain yield (t/ha)**	**Grain yield % of nil**
	2022		**2023**	
0	4.95 b	100	4.22 b	100
20	4.97 b	100	4.21 b	100
40	5.36 a	108	4.56 a	112
60	5.32 a	107	4.68 a	121
Pr(>F)	<0.001		<0.001	
LSD	0.29		0.14	

North mid slope

Biomass recorded as NDVI on the 16th August 2023 ranged from 0.298 – 0.49 with the nil treatment having the lowest value (Table 8). Similar to year one, surface applied CL with no physical incorporation did not increase NDVI compared to the nil. Physical incorporation without CL increased the NDVI, averaging 0.399. This suggests physical soil disturbance without the addition of any amendment improved crop growth. Deep placement of CL was the only method to increase NDVI compared to the comparative treatment with no CL.

Grain yields at this site ranged from 1.85 t/ha in the nil to 3.28 t/ha in the long inclusion with CL treatment (Table 8). Other high yielding treatments included long inclusion without CL, and higher disturbance treatments of deep placement with CL and spading with no CL. Spading with CL was lower yielding (2.69 t/ha) compared to deep placement of CL (3.15 t/ha). This suggests the increased depth of physical disturbance from ripping compared to spading increased grain yields. Early NDVI results show the crop canopy in the spading CL treatment was not higher than other incorporation methods and it was expected water use would be similar. Crop rooting depth (likely shallower in the spading treatment compared with deep ripping) potentially lead to a reduction in grain yield. Grain quality data also indicates this treatment was water limited, with low retention (72.6%) and higher screenings (10.9%).

Similar to the North hill top site grain quality was generally high across the incorporation methods with and without CL (Table 8). Grain protein was lower (8.3% - 8.5%) in treatments with physical incorporation and no CL (except spading). As highlighted above, spading was the only incorporation method to have higher screenings compared to the remaining methods.

Table 8. Greenseeker NDVI, grain yield (t/ha), grain yield % of untreated control and grain quality for physical incorporation and CL trial **North mid slope** sandy soil amelioration site, 2023.

Physical incorporation method	**Chicken litter (t/ha)**	**NDVI 16th Aug**	**Grain yield (t/ha)**	**Grain yield % of nil**	**Protein (%)**	**Test weight (kg/hL)**	**Retention (%)**	**Screenings (%)**
Nil	nil	0.298 e	1.85 d	100	9.7 bc	65.4 a	74.4 cd	7.2 bc
Nil	10	0.365 de	1.93 d	104	10.5 ab	65.3 a	70.0 c	8.7 ab
Deep rip - no inclusion	nil	0.394 d	2.57 c	139	8.5 c	67.1 a	83.9 ab	5.6 cd
Deep rip - short inclusion	nil	0.405 cd	2.68 c	145	8.3 c	66.6 a	84.8 ab	4.4 cd
Deep rip - long inclusion	nil	0.416 bcd	3.08 ab	167	8.5 c	67.8 a	85.8 a	4.4 d
Deep rip - long inclusion	10	0.490 ab	3.28 a	177	9.0 bc	67.3 a	83.4 ab	5.3 cd
Deep rip & place	10	0.490 a	3.15 a	171	9.9 bc	67.6 a	84.0 ab	5.3 cd
Spade	nil	0.413 bcd	3.03 abc	164	9.7 bc	66.0 a	79.7 bc	7.0 bcd
Spade	10	0.468 abc	2.69 bc	146	11.6 a	66.0 a	72.6 d	10.9 a
	Pr(>F)	<0.001	<0.001		<0.001	0.053	<0.001	<0.001

In the ripping depth trial, the 20 cm depth was not sufficient to improve grain yields in year one or two of the trial (Table 9). In the first season, there was a yield benefit from ripping deeper than 40 cm. However, this season ripping depths of 40 cm and 60 cm produced similar grain yields averaging 2.9 t/ha (59% higher than the nil).

Grain quality (test weight, retention, and screenings) was improved for the 40 cm and 60 cm ripping depths compared to the nil and 20 cm (Table 9). Grain protein was the only quality parameter to be negatively impacted by ripping depth. Protein was reduced in the 40 cm and 60 cm depths (8.9%) and this result relates to yield dilution effects (higher yield = lower protein).

Table 9. Greenseeker NDVI, grain yield and grain quality for depth of ripping trial **North mid slope**, 2022 and 2023.

Depth of ripping (cm)	Grain yield (t/ha)	Grain yield % of nil	Grain yield (t/ha)	Grain yield % of nil	Protein (%)	Test weight (kg/hL)	Retention (%)	Screenings (%)
	2022		2023					
0	4.08 c	100%	1.82 b	100	10.0 a	64.8 c	70.6 c	8.1 a
20	4.08 c	100%	1.84 b	101	10.1 a	65.3 bc	70.8 c	8.9 a
40	4.55 b	112%	2.86 a	157	8.9 b	66.7 b	81.9 b	5.4 b
60	4.92 a	121%	2.93 a	161	8.9 b	68.4 a	86.4 a	4.0 b
Pr(>F)	<0.001		<0.001		<0.0001	<0.0001	<0.0001	0.003

South mid slope site (least productive sandy site)

The NDVI assessment was recorded earlier at this site (25th July) compared to the north sites. The NDVI values ranged from 0.426 in the nil to 0.600 in the long inclusion with CL treatment (Table 10). There was little variation among the physical incorporation methods with and without CL.

There were large grain yield responses, up to 265% at the South mid-slope site (Table 10). This is consistent with responses observed in 2022. Similar to NDVI there were no grain yield differences among the physical incorporation methods with or without CL. The south mid-slope site was the least productive of all three sands and it is not surprising physical disturbance and the addition of CL applied has increased grain yields. At this site the use of short or long inclusion plates has not provided any grain yield benefit to deep ripping in either season.

Grain quality results show protein levels for CL surface applied or incorporated were similar to the nil (Table 10). However, deep ripping (no inclusion, short or long) without CL reduced grain protein compared to the nil. The spading treatments with and without CL had poorer grain quality in terms of lower test weight, lower retention and high screenings. Similar to the North mid slope site, this suggests the spading depth of 30 cm has not allowed deeper root exploration to fulfill its yield potential.

Table 10. Greenseeker NDVI, grain yield (t/ha), grain yield % of untreated control and grain quality for physical incorporation and CL trial **South mid slope** sandy soil amelioration site, 2023.

Physical incorporation method	Chicken litter (t/ha)	NDVI 25th July	Grain yield (t/ha)	Grain yield % of nil	Protein (%)	Test weight (kg/hL)	Retention (%)	Screenings (%)
Nil	nil	0.426 c	1.07 c	100	13.2 ab	65.2 ab	66.7 cd	11.9 bc
Nil	10	0.434 bc	1.27 bc	119	13.9 a	66.1 ab	67.5 bcd	12.1 abcd
Deep rip - no inclusion	nil	0.454 bc	2.20 ab	206	11.1 cde	68.1 a	81.0 a	5.9 d
Deep rip - short inclusion	nil	0.511 abc	2.48 ab	232	10.8 de	67.6 a	78.7 ab	7.5 cd
Deep rip - long inclusion	nil	0.543 ab	2.67 ab	250	10.8 e	67.7 a	78.8 ab	6.9 cd
Deep rip - long inclusion	10	0.600 a	2.83 a	265	12.5 abcd	65.2 ab	75.6 abc	7.6 cd
Deep rip & place	10	0.500 abc	2.67 a	250	12.5 abc	66.1 ab	72.8 abc	7.7 cd
Spade	nil	0.549 ab	2.63 a	247	12.2 bcde	62.8 b	56.6 d	19.3 a
Spade	10	0.598 a	2.05 abc	192	13.5 ab	63.1 b	58.7 d	17.5 ab
	Pr(>F)	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001

In the deep ripping trial, the second season results are similar to 2022 (Table 11). The 20 cm ripping depth did not increase grain yields. Ripping depths of 40 cm and 60 cm produced similar yields, averaging 217% of the nil. The results suggest the optimal ripping depth at the South mid slope site is 40 cm.

Grain quality (retention, and screenings) was improved for the 40 cm and 60 cm ripping depths compared to the nil and 20 cm (Table 11). As observed at the North mid slope site, grain protein was the only quality parameter to be negatively impacted by ripping depth. Protein was reduced in the 40 cm and 60 cm depths and this result relates to yield dilution effects (higher yield = lower protein). However, the protein levels were still within the 9% - 12% range.

Table 11. Greenseeker NDVI, grain yield and grain quality for depth of ripping trial **South mid slope,** 2022 and 2023.

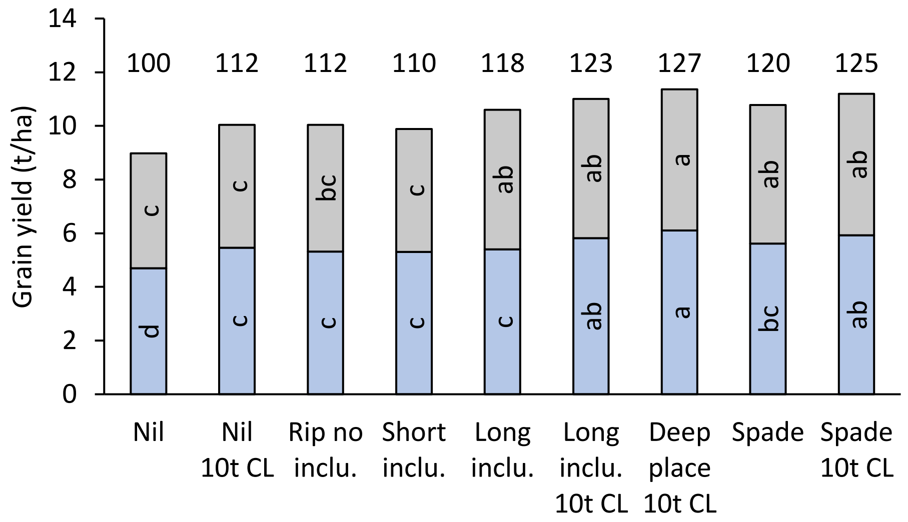
Depth of ripping (cm)	Grain yield (t/ha)	Grain yield % of nil	Grain yield (t/ha)	Grain yield % of nil	Protein (%)	Test weight (kg/hL)	Retention (%)	Screenings (%)
	2022		**2023**					
0	3.14 b	100	0.97 b	100	13.3 a	64.7 a	60.7 c	15.4 a
20	3.54 b	113	1.33 b	137	12.3 ab	64.4 a	67.7 b	11.5 b
40	4.69 a	149	2.07 a	213	10.7 b	65.8 a	73.9 a	9.3 bc
60	5.21 a	166	2.13 a	220	10.7 b	67.4 a	77.5 a	7.8 c
Pr(>F)	0.006		<0.001		<0.0001	0.219	<0.0001	0.003

Summary and conclusions

From the topsoil and amendment inclusion trials it is evident that all three sandy soil sites responded differently to the physical and CL treatments (Figure 3). As a general overview from two seasons of results:

- the North hill top site has responded to all physical interventions, with and without CL. The highest yield responses have been observed with methods that employ a high level of disturbance. The deep ripping treatments (50 cm) have not improved grain yield compared to spading (30 cm). Suggesting disturbance below 30 cm is not required to ameliorate the subsoil constraints at this site.
- at the North mid slope site, the responses were similar with the deep ripping and spading (without CL) treatments producing high grain yields. The spading with CL treatment at this site has consistently produced poor yields, compared to the other physical incorporation methods. The high yield potential in this treatment may have been limited by the spading depth of 30 cm which has not allowed deeper root exploration and therefore water use.
- at the historically least productive South mid-slope site grain yields were improved from all physical treatments (147% - 190%). Response to CL additions was generally not significant in the first or second season.

a)



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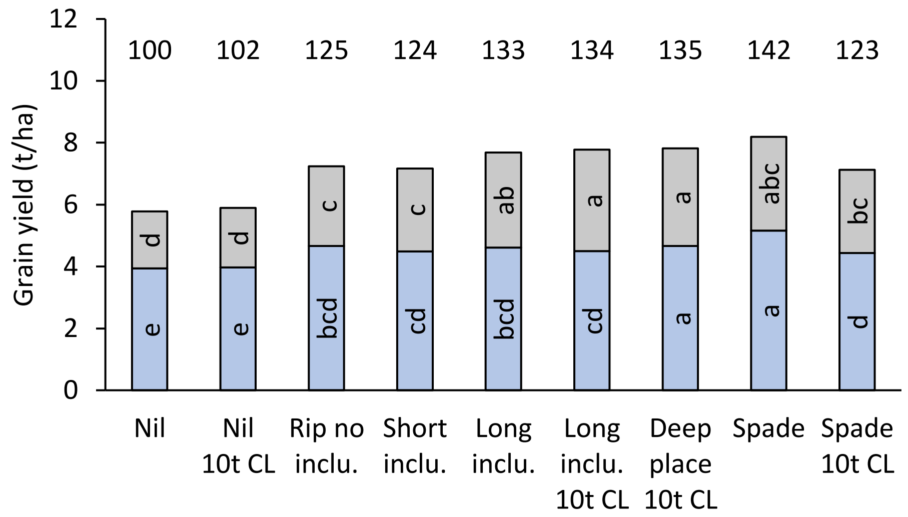

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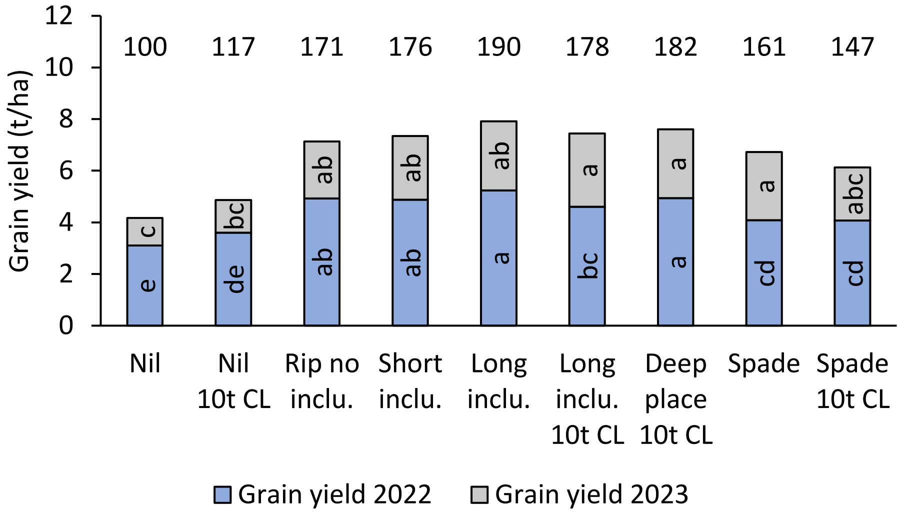

Figure 3. Grain yield (t/ha) response to amelioration technique on a) North hill top, b) North mid slope and c) South mid slope sites near Bute, SA in 2022 and 2023, letters denote significance P < 0.001 with in each season and site.

Results from the depth of ripping trials have shown in all six site years, no yield response to a ripping depth of 20 cm (Figure 4). Previous research has shown ripping depth can be linked to a reduction in soil strength. However, the response will change depending on site and the depth at which the constraint occurs in the soil profile.

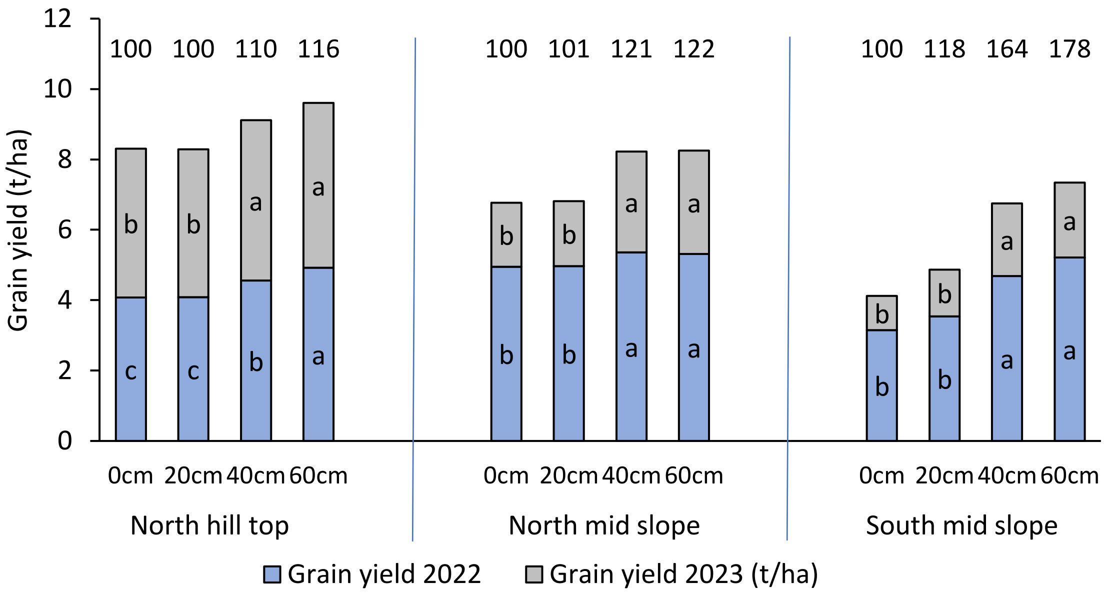

Figure 4. Grain yield (t/ha) response to ripping depth at all three sandy soil sites near Bute, SA 2022 and 2023, letters denote significance P < 0.001 with in each season and site.

Overall, the results from year one and two continue to highlight the importance of understanding your soil type and identifying the target soil constraint and depth. To date the largest yield gains have been observed at the least productive sandy site (South mid slope). When planning to ameliorate sandy areas on-farm, these results show targeting the poorest performing sands will give the greatest benefit.

The longevity of treatments in these trials will be assessed in 2024 where the sites will be sown to lentils.

Acknowledgements

This program received funding from the Australian Government's Future Drought Fund project title 'Building drought resilience by scaling out farming practices that will enhance the productive capacity of sandy soil landscapes'. Thank you to our project partners AIR EP. We also acknowledge the support of local grower James Venning for hosting the trials.

Australian Government

Future Drought Fund

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