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

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Key Messages

- The grain yield response to physical treatments (deep ripping and spading) and CL were typically greater than 10%, but the ranking of treatments varied at each of the sandy soil trial sites.
- The use of short and long inclusion plates (without CL) did not provide any yield benefit compared to deep ripping with no inclusion plates at any of the three sites in year one.
- Spading created a soft soil surface at seeding time, resulting in a deeper seeding depth at all sites. The wheat crop struggled to emerged and a lower NDVI was observed as well as reduced grain yields compared to the other physical treatments at some sites.
- At two out of the three sites, deep ripping to depth of 40 cm was sufficient to achieve maximum grain yield improvement. At the third site higher grain yields resulted from deeper ripping to 60 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 productions constraints including; 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 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 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 natural 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 plate 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). 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.

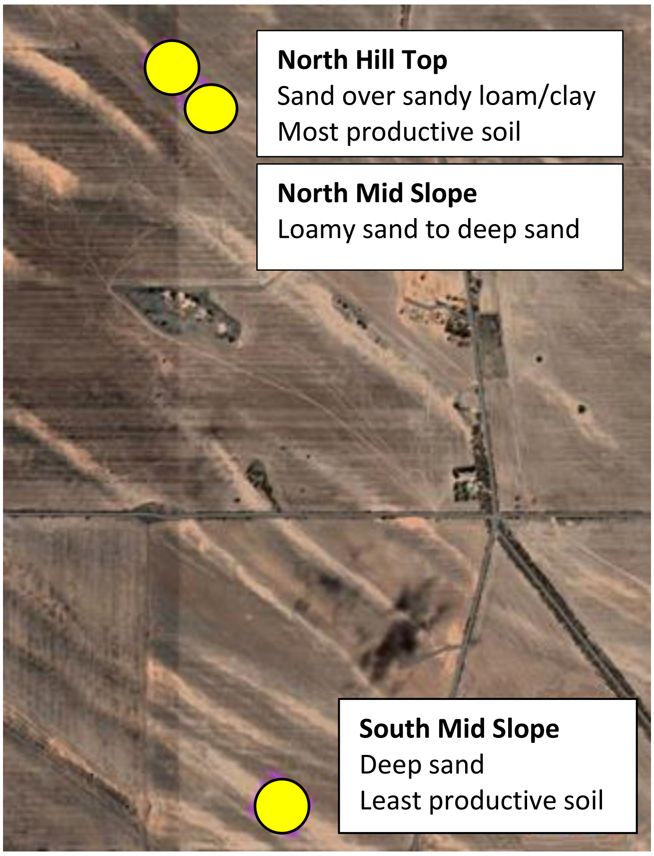

Figure 1. Image showing the three trial locations (yellow dots) for the sandy soil amelioration sites at Bute, SA 2022.

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										
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										
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 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. Soil profiles post amelioration for selected treatments can be seen in Figure 3.

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

All trials were sown to Razor CL Plus wheat at 110 kg/ha on the 31st May 2022. Fertiliser applied at seeding was MAP Zn at 80 kg/ha plus urea at 65 kg/ha. The site received 314 mm growing season rainfall (compared to long-term GSR 300 mm) in 2022. Urea was applied by the grower in-season at rates of 190 kg/ha at the North sites and 200 kg/ha at the South site.

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

Figure 3. North mid slope site treatments from left to right control, deep rip and place CL and deep ripping with long inclusion plates (no CL).

Results and discussion

North hill top (most productive sandy site)

In early August crop biomass was assessed using NDVI and ranged from 0.426 – 0.637 across all treatments (Table 5). In general, all the physical treatments apart from spading had higher crop biomass compared to the control. The spading treatments were similar or slightly lower compared to the other physical treatments, likely due to issues at seeding. After spading the soil surface in these treatments was softer resulting in deeper seeding depth and crop establishment was poorer resulting in a lower NDVI assessment of crop biomass. This was a good example of why the spade and sow technique is preferable. Chicken litter (CL) applied to the soil surface with no physical incorporation had lower biomass compared to the physical treatments alone or with the addition of CL. Without incorporation the nutrient release or other benefits to soil structure from CL are likely to take longer to have an impact on crop growth.

Grain yields were high ranging from 4.70 t/ha in the control up to 6.15 t/ha in the deep rip and CL placement (Table 5). All physical and CL amendment treatments improved grain yield compared to no amelioration in year one. All physical treatments where CL was incorporated at depth had the highest grain yields. This included deep dripping (130% of untreated control), long inclusion plates (124%) and despite lower NDVI early, spading (126%). Where plots were deep ripped (with or without inclusion plates) or spaded without CL, grain yields were lower ranging from 5.31 t/ha to 5.61 t/ha.

There were small differences measured in test weight however, all treatments were above 76 kg/hL (minimum required for maximum grade). Similarly, there were minor differences observed in grain screenings but, all treatments were below the maximum value of 5% (data not shown). Grain protein levels ranged from 9.1% to 10.8%. Higher protein was observed in treatments where CL was applied either on the surface or incorporated by spading, deep ripping with or without long inclusion plates. Higher protein levels can be attributed to the additional nitrogen supplied in the CL.

Table 5. Greenseeker NDVI, grain yield (t/ha), grain yield % of untreated control and grain quality for depth of ripping trial **North hill top** sandy soil amelioration site, 2022.

Physical	**Chicken litter (t/ha)**	**NDVI Aug 3rd**	**NDVI Aug 30th**	**Grain yield (t/ha)**	**Grain yield % of nil**	**Test weight (kg/hL)**	**Protein (%)**
Nil	nil	0.426 e	0.696 e	4.70 d	100 d	79.4 cde	9.6 cde
Nil	10	0.465 de	0.751 cd	5.46 c	116 c	80.3 a	10.8 a
Deep rip - no inclusion	nil	0.556 bc	0.774 bc	5.31 c	113 c	79.0 de	9.1 e
Deep rip - short inclusion	nil	0.570 abc	0.769 bc	5.31 c	113 c	79.1 cde	9.3 de
Deep rip - long inclusion	nil	0.541 bcd	0.780 b	5.40 c	115 c	78.7 e	9.1 e
Deep rip - long inclusion	10	0.637 a	0.809 a	5.82 ab	124 ab	79.7 abc	9.9 bc
Deep rip & place	10	0.592 ab	0.814 a	6.15 a	131 a	79.4 cde	9.8 bcd
Deep rip & place attempt 2	10	0.614 ab	0.812 a	6.07 a	129 a	79.5 bcd	10.3 ab
Spade	nil	0.501 cde	0.739 d	5.61 c	119 bc	80.2 ab	9.9 bc
Spade	10	0.617 ab	0.778 bc	5.92 ab	126 ab	79.7 abcd	10.6 a
	Pr(>F)	<0.001	<0.001	<0.001	<0.001	0.027	<0.01
	LSD (0.05)	0.080	0.027	0.345	7%	0.68	0.5

Results from the depth of ripping trial showed NDVI and grain yield for ripping depths of 40 cm or 60 cm provided greatest benefit at the North hill site (Table 6). In August the 20 cm ripping depth increased NDVI compared to the nil however at harvest grain yield was similar at 4.97 t/ha. 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 there is also little understanding on how long this impact maybe sustained.

Test weight and screenings were not affected by ripping depth averaging 79.2 kg/hL and 2.6% for all treatments (Table 6). Grain protein was the only quality parameter to be 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).

Table 6. Greenseeker NDVI, grain yield and grain quality for depth of ripping trial North hill, 2022.

Depth of ripping (cm)	NDVI Aug 3	NDVI Aug 30	Grain yield (t/ha)	Grain yield % of untreated control	Test weight (kg/hL)	Screenings (%)	Protein (%)
0	0.470 c	0.470 c	4.95 b	100 b	79.3	2.7	10.2 a
20	0.565 b	0.565 b	4.97 b	100 b	79.2	2.5	10.1 a
40	0.635 a	0.635 a	5.36 a	108 a	79.3	2.6	9.3 b
60	0.573 ab	0.573 ab	5.32 a	107 a	79.1	2.5	9.4 b
Pr(>F)	0.006	0.006	<0.001	<0.001	0.687	0.886	0.036
LSD (0.05)	0.068	0.068	0.29	6	ns	ns	0.7

North mid slope

In early August NDVI ranged from 0.330 – 0.647 compared to late August 0.578 – 0.758 across all treatments (Table 7). In general, all of the physical treatments with the exception of spading had higher crop biomass compared to the nil. The spading treatments were slightly lower in early August however, by the end of the month spading plus CL was no different to the other treatments at the North flat site. As outlined above issues within the spading treatments were related to seeding depth. Another similar result at the North hill and mid slope sites was CL applied to the soil surface without physical incorporation had lower biomass compared to the physical treatments alone or with the addition of CL.

Grain yield response was different at the mid slope versus hill top site. At the mid slope site spading with no CL was the highest yield treatment at 5.1 t/ha (131% of untreated). There were small differences among the remaining physical treatments with and without CL (Table 7). Of the physical treatments, lowest yields come from spading with CL. All physical treatments increased grain yield compared with CL surface applied and nil. The addition of CL with deep rip and place, spading and long inclusion were the highest NDVI treatments in late August, but this did not translate into yield, which was a surprise given the long cool spring and high yield potential. Powdery mildew was present at the three sites and infection may have been more severe in treatments with high NDVI (biomass) leading to a reduction in grain yield.

There were no differences in test weight for any treatment averaging 79.2 kg/hL (Table 7). There were minor differences observed in grain screenings but, all treatments were below maximum value of 5% (data not shown). Grain protein levels ranged from 10.0% to 12.0%. Higher protein was observed in treatments where CL was applied either on the surface or physically incorporated.

Table 7. Greenseeker NDVI, grain yield (t/ha), grain yield % of untreated control and grain quality for depth of ripping trial North mid slope, 2022.

Physical	Chicken litter (t/ha)	NDVI Aug 3rd	NDVI Aug 30th	Grain yield (t/ha)	Grain yield % of nil	Test weight (kg/hL)	Protein (%)
Nil	nil	0.330 f	0.578 e	3.94 f	100 e	78.8	10.5 b
Nil	10	0.382 f	0.636 d	3.97 f	101 e	78.9	11.9 a
Deep rip - no inclusion	nil	0.526 bcd	0.701 bc	4.67 bcd	119 bcd	79.0	10.3 b
Deep rip - short inclusion	nil	0.543 bcd	0.692 c	4.49 de	114 cd	78.9	10.0 b
Deep rip - long inclusion	nil	0.505 cd	0.696 bc	4.61 cde	117 bcd	79.5	10.0 b
Deep rip - long inclusion	10	0.647 a	0.747 a	4.50 de	114 cd	79.3	11.6 a
Deep rip & place	10	0.574 abc	0.745 a	4.83 b	123 b	79.6	11.7 a
Deep rip & place attempt 2	10	0.572 ab	0.758 a	4.72 bc	120 bc	79.3	12.0 a
Spade	nil	0.400 e	0.676 c	5.1a	131 a	79.6	10.1 b
Spade	10	0.493 d	0.734 ab	4.44 e	113 d	79.3	11.8 a
	Pr (>F)	<0.001	<0.001	<0.001	<0.001	0.182	<0.001
	LSD (0.05)	0.057	0.039	0.21	5%	ns	0.6

Results from the depth of ripping trial showed NDVI for depths of 40 cm or 60 cm provided the highest biomass response at the North flat site (Table 8). The difference in ripping depth had a large impact on grain yield, at 60 cm 4.92 t/ha (121% of untreated control) followed by 4.55 t/ha for the 40 cm depth. This result was different compared to North hill site (40 cm adequate to provide highest grain yield) and highlights ripping depth needs to be adjusted based on constraint depth. The shallowest ripping depth of 20 cm did not improve NDVI or grain yield compared to untreated control.

Grain quality was generally not impacted by ripping depth at the North mid slope (Table 8). Small differences were observed in test weight however, all treatments were above 76 kg/hL. Screenings and protein displayed no difference for any treatment averaging 2.7% and 10.6%.

Table 8. Greenseeker NDVI, grain yield and grain quality for depth of ripping trial North flat, 2022.

Depth of ripping (cm)	NDVI Aug 3	NDVI Aug 30	Grain yield (t/ha)	Grain yield (% of untreated control	Test weight (kg/hL)	Screenings (%)	Protein (%)
0	0.355 b	0.567 c	4.08 c	100% c	78.7 b	2.6	10.7
20	0.394 b	0.604 b	4.08 c	100% c	78.9 b	3.3	10.8
40	0.572 a	0.700 a	4.55 b	112% b	79.2 ab	2.3	10.6
60	0.551 a	0.719 a	4.92 a	121% a	79.6 a	2.4	10.2
Pr (>F)	<0.001	<0.001	<0.001	<0.001	0.024	0.248	0.376
LSD (0.05)	0.040	0.034	0.14	3%	2.7	ns	ns

South mid slope site (least productive sandy site)

In early August NDVI ranged from 0.279 – 0.501 for all treatments at the South mid-slope site (Table 9). The NDVI readings where generally higher at both the North sites. All of the physical treatments with the exception of spading had high NDVI compared to the nil at all three sites. At the south site the nil plus surface applied CL was also high. The south mid-slope site was the least productive of all three sands and it is not surprising the addition of CL applied to the surface may have increased nutrient uptake and crop growth**.** The spading treatments were low and similar to the nil due to issues at seeding.

Large grain yield responses, up to 172% of the untreated control were measured at the South mid-slope site (Table 9). The responses at the more productive North sites were not as large up to 131% at both sites. High grain yields were achieved from deep ripping treatments (no inclusion, short or long inclusion) with or without CL ranging from 4.61 t/ha - 5.33 t/ha. Similar to NDVI, issues with poor crop emergence in the spading treatments carried through to reduced grain yields of 4.08 t/ha and 4.09 t/ha. In year one the use of short or long inclusion plates did not provide any grain yield benefit to deep ripping.

There were small differences in test weight ranging from 75.4 kg/hL in the nil to 77.7 kg/hL in the short inclusion (Table 9). While range in test weights was small most treatments were only just above 76 kg/hL (minimum value for maximum grade) at this site. The nil and spade without CL were the only treatments to fall below 76 kg/hL. There were minor differences observed in grain screenings but, all treatments were below maximum value of 5% (data not shown). Grain protein levels ranged from 10.8% to 13.8%. Deep ripping without, short and long inclusion plates (no CL) resulted in grain quality for APW (10.5% to 11.5%) classification. Similar to the North mid slope site, where CL was applied at depth or on the surface grain quality met H2 (11.5% to 13%) or H1 (>13%) standard.

Table 9. Greenseeker NDVI, grain yield (t/ha), grain yield % of untreated control and grain quality for depth of ripping trial South mid-slope, 2022.

Physical	**Chicken litter (t/ha)**	**NDVI Aug 3rd**	**Grain yield (t/ha)**	**Grain yield % of nil**	**Test weight (kg/hL)**	**Protein (%)**
Nil	nil	0.316 de	3.10 e	100 e	75.4 d	13.0 ab
Nil	10	0.363 bcd	3.60 de	116 de	76.7 abc	12.8 ab
Deep rip - no inclusion	nil	0.425 abc	4.93 ab	159 ab	77.3 ab	10.8 d
Deep rip - short inclusion	nil	0.361 bcd	4.87 ab	157 ab	77.7 a	11.0 d
Deep rip - long inclusion	nil	0.370 bcd	5.24 a	169 a	77.6 a	11.2 d
Deep rip - long inclusion	10	0.501 a	4.61 bc	148 bc	76.7 abc	12.8 ab
Deep rip & place	10	0.419 abc	5.27 a	170 a	76.6 abc	12.2 bc
Deep rip & place attempt 2	10	0.434 ab	5.33 a	172 a	77.3 ab	11.8 cd
Spade	nil	0.279 e	4.09 cd	132 cd	75.7 cd	12.6 bc
Spade	10	0.347 cde	4.08 cd	131 cd	76.4 bcd	13.8 a
	Pr(>F)	<0.001	<0.001	<0.001	0.007	<0.001
	LSD (0.05)	0.082	0.55	18%	1.18	1.0

Results from the depth of ripping trial showed NDVI for ripping depths of 40 cm or 60 cm provided highest biomass response at the South mid slope site (Table 10). These treatments were also the highest yielding at 5.21 t/ha (166% of untreated control) for the 60 cm depth and 4.69 t/ha (149% of untreated control) for the 40 cm depth. This result was similar to the North hill site. All three sites showed ripping to a depth of 20 cm did not improve NDVI or grain yield compared to untreated control.

Test weight and screenings were not affected by ripping depth averaging 77.0 kg/hL and 2.8% for all treatments (Table 10). Grain protein was the only quality parameter to be impacted by ripping depth however, at this site protein was less effected. Protein was lowest at the 60 cm depth and only made APW (10.5% to 11.5%) compared to H2 for the 0, 20 cm and 40 cm treatments.

Table 10. Greenseeker NDVI, grain yield and grain quality for depth of ripping trial **South mid-slope**, 2022.

Depth of ripping (cm)	NDVI Aug 3	Grain yield (t/ha)	Grain yield (% of untreated control	Test weight (kg/hL)	Screenings (%)	Protein (%)
0	0.303 b	3.14 b	100 b	76.3	4%	12.3 a
20	0.323 b	3.54 b	113 b	76.0	4%	12.6 a
40	0.468 a	4.69 a	149 a	77.5	3%	11.7 ab
60	0.420 a	5.21 a	166 a	78.1	3%	10.6 b
Pr(>F)	0.001	0.006	0.01	0.119	0.203	0.025
LSD(0.05)	0.054	0.98	31%	Ns	ns	1.2

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 4). As a general overview:

- at the North hill top site it was responsive to both physical interventions and CL addition, and the combined physical plus CL treatments were the highest yielding. It did not matter what method of incorporation was used as long as the CL was mixed, ripped with inclusion plates or placed at depth in the soil profile.
- at the North mid slope site, the response to physical interventions ranged from 0.47 to 1.16t/ha. There was nil or negative response to CL treatments in grain yield, despite large increases in NDVI measured during the growing season.
- at the historically least productive South mid-slope site grain yields were improved from all physical treatments. Response to CL additions was not significant in the first season.

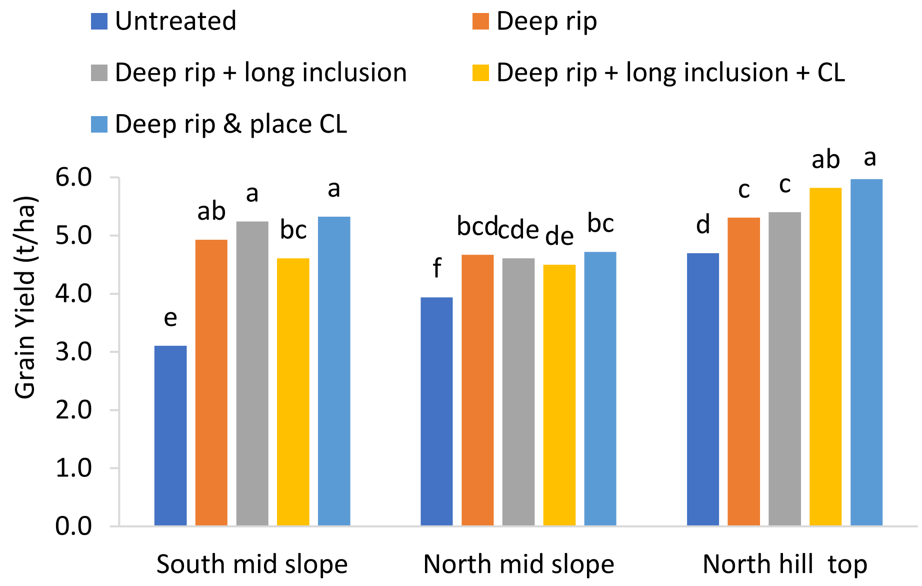

Figure 4. Grain yield (t/ha) response to amelioration technique on all three sandy soil sites near Bute, SA 2022.

Depth of ripping trials were consistent with previous research where yield responses to ripping depths of less than 40 cm have proven unreliable. At two out of three sandy sites, deep ripping to depth of 40 cm was sufficient to achieve maximum grain yield improvement (Figure 5). At the third North mid slope site, higher grain yields were achieved from deeper ripping to 60 cm.

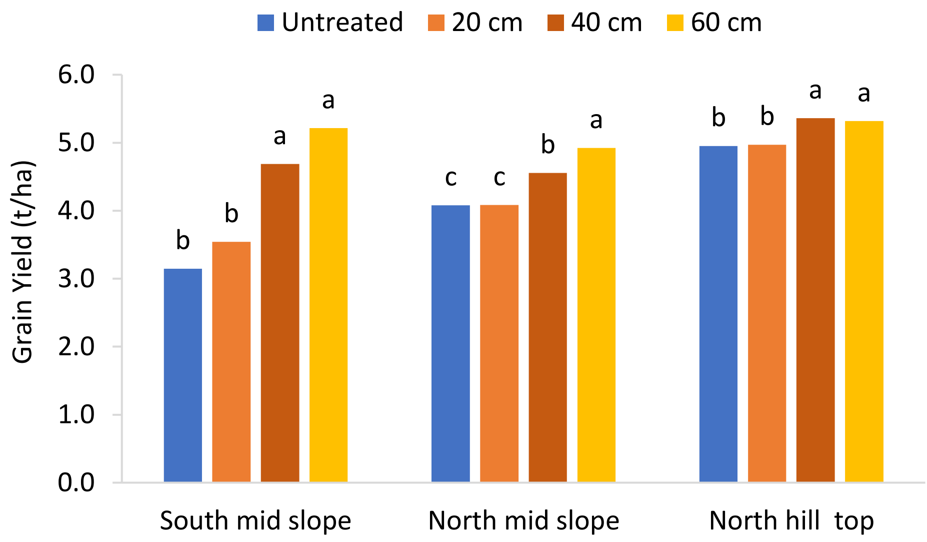

Figure 5. Grain yield (t/ha) response to ripping depth at all three sandy soil sites near Bute, SA 2022.

Overall, the initial results from year one highlights the importance of understanding your soil type and identifying the target soil constraint and depth. The longevity of treatments in these trials will be assessed in 2023 where the sites will be sown to Commodus CL barley.

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Australian Government | Future Drought Fund

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