Effects of deep ripping on soil compaction and crop performance in Mallee sands

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Abstract
Soil compaction on sandy soils is one of the major problems facing modern farming systems because of frequent use of heavy machinery which comes with intensive cropping. Deep ripping on Mallee sands is becoming a common option to reduce hard pans and ameliorate compacted layers. The challenge facing growers is determining the optimal ripping depth and tine spacing for their soils. Aims of this project were to assess the impact of deep ripping on subsoil compaction and performance of several crop species and to determine the optimal ripping depth x tine spacing for Mallee sands. Our trials showed that ameliorating compacted sandy soils in low rainfall environments can lead to improved shoot DM and grain yield, and should subsequently lift farm productivity and profitability. In terms of grain yield, ripping at narrow or wide tine spacing gave similar outcomes and wider tine spacings can therefore be considered in order to use less machinery horsepower. Our trials also show that when the soil in question is compacted to depths beyond 40cm, then ripping deeper is better for grain yield, provided there are no other chemical constraints below the compaction zone.

Key words
Soil compaction, deep ripping, sands, penetration resistance, Mallee

Introduction
Sandy soils dominate the landscape across the low rainfall region of south-eastern Australia, and anecdotal evidence suggests that compaction is widespread on these soils. Soil compaction is one of the major problems facing modern farming systems on sandy soils mainly because of the use of heavy machinery and intensive cropping. Soil compaction adversely affects soil physical fertility and can affect root penetration and growth of plants. Where root growth is retarded or a greater amount of energy is required for roots to grow through compacted soil. Deep ripping or deep cultivation, is an expensive yet important option for addressing hard pans and hard setting soils. Mallee sands tend to form hard layers just below the soil surface which limit water infiltration and root penetration, hence in low rainfall South Australian (SA) Mallee farming systems deep ripping has been used to shatter these dense subsurface soil.

Deep ripping alone has been shown to increase crop production on sands, but often the effects are not sustained in the long term (Adcock et al., 2007). In a summary of deep ripping trials on Eyre Peninsula from 2006 to 2008, Paterson and Sheppard (2008) concluded that (i) sandy soils were more responsive to deep ripping than finer textured soils, and (ii) responses did not persist past two years. Thus the challenge for growers is quantifying the contribution of deep ripping to crop productivity increases, and refining how best to do it can lead to improved and prolonged benefits. If these knowledge gaps can be closed, crop productivity and farm profitability could be improved in these moisture limited environments.

Methods
Two replicated field trials were conducted in 2018 using randomised complete block designs with 4 replicates. Trial 1 (Table 1), was conducted in the southern Mallee (Peebinga) on a texture contrast grey sand over clay, to evaluate the impact of deep ripping at different tine spacing's and depth. The main objective of this trial was to identify an optimum depth of ripping where productivity gains can be maximised, and to evaluate whether narrow tine spacing improves the effectiveness and longevity of the operations. Trial 2 was conducted in the northern Mallee (Loxton) on a deep red sandy soil as a crop phase experiment with 3 different crop types. The aim was to assess the impact of deep ripping on crop performance and to determine which crop types (wheat⊕, barley⊕ and field peas⊕) respond better to deep ripping after amelioration. One tine spacing (50 cm) was used.

Table 1: Treatment details for both trials conducted in 2018

	Trial 1: Peebinga	Trial 2: Loxton
Treatments	5 Ripping depths (0, 20, 40, 60, 70 cm) 2 Tine spacings (Narrow, 30 cm and wide, 60 cm)	Ripping depth (50 cm) vs compacted (control) 1 Tine spacing (50 cm)
	Scope barley⊕ 60 kg/ha	Mace⊕ wheat (60 kg/ha), Scope⊕ barley (80 kg/ha), Gunya⊕ peas (100 kg/ha)
Total plots	40	24

Deep ripping treatments were imposed using a straight tine ripper on 11 May and 21 May 2018 at Loxton and Peebinga respectively. Penetration resistance readings were taken on 7 August at both sites using a Rimik CP40 (II) cone penetrometer to determine the depth of compaction. In season assessments of crop density, early (GS31) and flowering shoot dry matter (DM) and grain yield were carried out to quantify the impact of ameliorating compacted sands through deep ripping.

Results

With total growing season rainfall (April to October) of 116 mm (Peebinga) and 106 mm (Loxton), crop growth and productivity was heavily compromised at both sites. However, visual responses in crop establishment and shoot DM to deep ripping were evident at both sites. At the Loxton site, there was no significant response from wheat, barley and peas, to deep ripping on crop establishment. At the Peebinga site, deep ripping with narrow or wide tine spacing did not significantly affect crop establishment as the narrow (30cm) tine spacing had 46 plants/m^2 compared to wide (60cm) with 44 plants/m^2.

Penetration resistance: Crop root growth usually begins to be impeded when penetration resistance exceeds 1500 kPa, with severe restriction in sands beyond 2500 kPa. Penetrometer readings (data not shown) show that at the Loxton site, the deep ripped plots had greatly reduced soil compaction (<1500kPa) within the top 30 cm of soil. Comparatively, the unripped control had a compaction zone starting from as shallow as 20 cm going down to depth. At Peebinga, penetrometer data show that the compacted layer was shallower; starting from 18 cm to 60cm (data not shown). Ripping to 20 cm only addressed surface compaction, having no impact on sub-surface compaction below 20 cm. Deeper soil compaction was reduced (<1000kPa) when the plots were ripped to a depth greater than 60 cm.

Effect on crop performance

Loxton: Deep ripping did not affect GS31 shoot DM for wheat, however there was a significant increase in barley and peas (Table 2). There was no significant response to deep ripping on flowering shoot DM of the wheat or peas, however, barley flowering shoot DM increased by 74%. Severe frost prevented collection of grain yield in the field peas. Deep ripping did not improve grain yield for wheat, but increased barley grain yield by 100% (Table 2).

Table 2: Effect of deep ripping on GS31 and flowering shoot (DM), and grain yield at Loxton in 2018.

Crop		GS31 shoot DM (t/ha)	Flowering shoot DM (t/ha)	Grain yield (t/ha)
Barley	Ripped	1.1	2.82	1.08
	Control	0.68	1.62	0.54
	p value	*<0.01*	*<0.01*	*<0.01*
	lsd (5%)	*0.27*	*0.76*	*0.3*
Wheat	Ripped	0.86	1.94	0.69
	Control	0.86	1.7	0.58
	p value	*ns*	*ns*	*ns*
Peas	Ripped	0.66	1.24	*
	Control	0.5	0.71	*
	p value	*<0.05*	*ns*	
	lsd (5%)	*0.16*		

Peebinga: Soil water repellence in the top 10 cm of the sandy soil at this site resulted in poor crop establishment. Crop establishment at this site was very poor (average of 45 plants/m^2) and was significantly ($p<0.02$) affected by ripping depth. Apart from the control, all treatments resulted in a significant increase in plant numbers. Across all ripping depths, deep ripping with narrow tine spacing at 30 cm, resulted in an increase in GS31 and flowering shoot DM, however this did not affect barley grain yield (Table 3).

Table 3: Effect of narrow (30 cm) vs wide (60 cm) tine spacing on early and late shoot dry matter (DM) and grain yield of barley, at Peebinga 2018.

	GS31 shoot DM (t/ha)	Flowering shoot DM (t/ha)	Grain yield (t/ha)
Narrow (30cm)	0.4	0.87	0.56
Wide (60cm)	0.29	0.61	0.49
lsd (5%)	*0.08*	*0.09*	
p value	*0.01*	*<0.001*	*ns*
sed	*0.04*	*0.04*	

Increased grain yield, as well as early and late shoot DM, were achieved by increasing the depth of ripping (Table 4). These highly significant responses ($p<0.001$) were consistent across the three assessments, showing that large responses can be achieved by ripping deeper than 40 cm. Ripping to 20 cm with wide spaced tines, gave similar results to the control, indicating that the compacted layer was below 20 cm. However, narrow tine spacing (20 cm) performed better than the control at this this ripping depth, possibly indicating that greater shallow disturbance had some benefit, possibly helping reduce the impact of topsoil water repellence.

Table 4: Effect of ripping depth on early and late shoot DM, and grain yield of barley at Peebinga in 2018.

Ripping Depth	GS31 shoot DM (t/ha)	% control	Flowering shoot DM (t/ha)	% control	Grain yield (t/ha)	% control
0cm (control)	0.14	**100**	0.33	**100**	0.27	**100**
20cm	0.19	**136**	0.4	**121**	0.34	**126**
40cm	0.34	**243**	0.82	**248**	0.48	**178**
60cm	0.46	**329**	0.91	**276**	0.76	**281**
70cm	0.58	**414**	1.25	**379**	0.79	**293**
lsd (5%)	*0.13*		*0.14*		*0.13*	
p value	*<0.001*		*<0.001*		*<0.001*	

Responses from the nine individual treatments (Figure 1) exploring the best combination of ripping depth and tine spacing, show that ripping with a narrow spacing (30 cm) to a depth of 70 cm resulted in the largest flowering shoot DM response (328% more than the control). Ripping to depths greater than 60 cm gave the largest grain yield responses ranging from 155% (wide spacing, 60 cm depth) to 211% (wide spacing, 70 cm depth) more than the control.

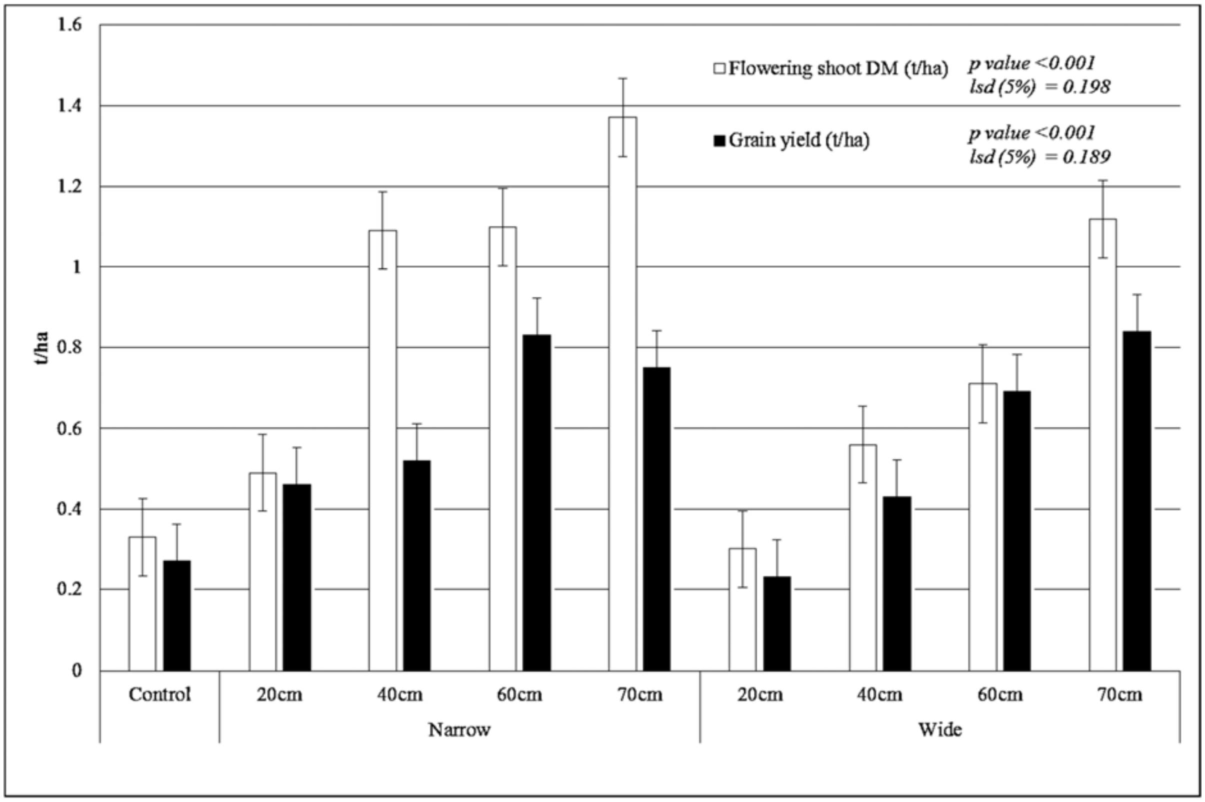

Figure 1: Grain yield and flowering shoot DM responses from individual treatments at Peebinga in 2018.

Conclusion

Slow and restricted root growth caused by subsoil compaction can often result to inefficient use of water and nutrients, and subsequent broader environmental impacts. Excess water in sandy Mallee landscapes is resulting in a phenomenon called 'dune seepage' as a consequence of water imbalances in sub-catchments dominated by sandy soils. This seepage has resulted in the loss of valuable farmland and a range of environmental, economic and social consequences – including the degradation via erosion and salinisation of bare seep areas. Thus, the challenge that growers face is refining the deep ripping methodology (e.g. ripper type, spacing, depth), to increase water and nutrient use efficiency of crops on compacted poor performing sandy soils and to determining if these benefits are profitable and sustainable. Our trials show that ameliorating compacted sandy soils in low rainfall environments can lead to improved shoot DM and grain yield, and should subsequently lift farm productivity. In terms of grain yield, ripping narrow or wide gave similar outcomes, therefore wider tine spacings with fewer tines can be considered in order to reduce machinery horsepower and wear and tear costs. Results of these trials show that when there is deep soil compaction then deeper ripping provides larger grain yield benefits, provided that no chemical constraints are present below the compaction zone.

Growers should be aware that not all soil types and crops respond positively to deep ripping every season. When considering the optimal strategy of ameliorating compacted sandy soils, tine spacing, working depth, soil moisture content, timing and soil type all need to be taken into account. A gross margin analysis will be undertaken once more long-term response data has been collected to determine the most economical ripping depth x tine spacing combination.

References

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