The how's and why's for deep ripping sandy soils

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Location
Lameroo
Pocock Family
Rainfall
Av. GSR: 205 mm
2019 GSR: 270 mm
Paddock history
2018: Scope CL barley
2017: Scepter wheat
2016: Medic based pasture
Soil type
Non-wetting slightly acidic deep sand
Plot size
20 m x 2 m 4 reps
Trial design
Experimental: randomised complete block
Yield limiting factors
Non-wetting, nitrogen, moderate soil strength

Location
Waikerie
Schmidt family
Rainfall
Av. GSR: 164 mm
2019 GSR: 119 mm
Paddock history
2018: Scepter wheat
2017: Scepter wheat
2016: Stingray canola
Soil type
Deep neutral pH sand
Plot size
20 m x 2 m 4 reps
Trial design
Experimental: randomised complete block
Yield limiting factors
Non-wetting, nitrogen, high soil strength, root disease

Key messages

- **Deep ripping is most effective in deep sandy-textured soils, and when the ripper tines go beyond the compacted layer. Large grain yield increases over at least several years are common on deep sands.**
- **Deep ripping with ripper tines spaced less than 60 cm did not increase final grain yield therefore wider (up to 60 cm) tine spacing can be considered in order to use less machinery horsepower.**
- **The risk of wind erosion is very high when deep ripping is done in legume stubble and in cereal paddocks with very low stubble cover.**
- **The largest potential downside associated with deep ripping in low rainfall areas is that it increases the risk of haying off when soil water reserves are low and the finish to the season is harsh and dry.**
- **Controlled traffic should increase the longevity of the deep ripping benefit and reduce the need to repeat the deep ripping with its associated cost.**
- **Overcoming multiple soil constraints (compaction, sodicity, acidity, etc.) can improve the longevity of benefits and overall return on investment in the long-term.**

Why do the trials?

Sandy soils dominate the landscape across the low rainfall region of south-eastern Australia, and there is increasing evidence that compaction is widespread on these soils. Soil compaction is one of many problems facing modern farming systems on coarse textured soils mainly because of the widespread use of heavy machinery and intensive cropping. Subsoil compaction is a subsoil constraint that can adversely affect soil biological activity and soil physical condition, particularly storage and supply of water and nutrients. Compaction increases soil bulk density and soil strength, while decreasing porosity, soil water infiltration and water holding capacity. Sandy soils have a natural tendency to form hard layers just below the soil surface, hence deep ripping is becoming a common strategy for addressing soil compaction, hard pans and ameliorating hard setting soils.

Deep ripping is most effective in deep sandy-textured soils (Paterson and Sheppard, 2008) where roots need to grow deep to access subsoil moisture and nutrients. However, not all soil and crop types respond positively to deep ripping every season. Isbister *et al*. (2018) have reported that responses to deep ripping in WA were greater in sandy soils (20-37% yield increase) than loamy duplex >30 cm deep (22%) or shallow duplex soils (4%).

Location
Lowaldie
Loller Family

Rainfall
Av. GSR: 237 mm
2019 GSR: 184 mm

Paddock history
2018: Stingray canola
2017: Scepter wheat
2016: Stingray canola

Soil type
Deep neutral pH sand

Plot size
20 m x 2 m 4 reps

Trial design
Experimental: randomised complete block

Yield limiting factors
Non-wetting, nitrogen, moderate soil strength

Tine spacing, working depth, shallow leading tines or discs, soil moisture content, timing and soil type all need to be taken into account in order to maximise productivity gains and also to make this strategy cost effective. Research by the Department of Agriculture and Food Western Australia (DAFWA), funded by GRDC, estimates that the costs associated with deep ripping can range from $50-60 per hectare for standard ripping (to a depth of 30-40 cm) and up to $70-90/ha for ripping to a depth of 50-70 cm (depending on machinery and soil conditions). Therefore, the challenge that growers face is refining how best to ameliorate compacted soils while keeping costs down but at the same time, maximising and prolonging the benefits. It is important to note that if the soil in, or below, the ripping depth contains other constraints such as acidity, poor structure from sodicity or subsoil salinity, the benefits of deep ripping may not be fully realised.

To gain insight into how deep ripping is impacting crop performance and how best to conduct it on different soil types, this paper summarises the results from replicated trials conducted in different low–medium rainfall cropping regions of Australia. The expectation is that collation of data from these trials will assist in making sound guidelines for growers which address key questions around if and why they should be considering deep ripping as a soil amelioration strategy, and how best to undertake it to achieve sustainable and improved crop yields and good returns for every dollar invested.

Justification for deep ripping

Research conducted in the 1970s and 80s demonstrated that on deep sands and sandy earths in WA, wheat roots can extract water from depths ranging from 1.4 to 2.5 metres (Hamblin *et al*. 1982, Hamblin *et a*l. 1988). The capacity of roots to extract water and nitrogen from such depths is critical on these soil types, in moisture limited environments. These soils tend to have relatively low water holding capacity, and the use of deeper subsoil moisture is critical for grain filling. In compacted sandy soils where penetration resistance exceeds 2500 kPa, crop root growth is severely restricted and these crop potentials cannot be realised. In these situations, deep ripping can be a strategy to break up that compaction, improve root penetration and ultimately crop performance.

Historically peak soil strength in deep sands and sandy earths typically occurred at depths of 30-35 cm and reached strengths of 2000–2500 kPa as shown in Figure 1b. However, as machinery sizes and axle loads have increased, the severity of the compaction problem has continued to worsen. Recent soil strength measurements indicate that peak soil strength now occurs at depths as shallow as 20 cm, with strengths ranging from 3000-3500 kPa (Figure 1 a and b). Therefore, when considering shattering compaction, deeper ripping past the compacted layer is recommended in order to maximise the benefits.

Crop responses to deep ripping

Reviews of historic deep ripping trials have shown substantial benefits with cereal yield increases of 22-37% in the first year (Crabtree 1989, Davies *et a*l. 2006, Jarvis 2000). In recent experiments conducted in WA (Davies *et al*. 2017) during 2014-16, ripping increased average wheat yields by 8% for shallow 30-40 cm ripping, 35% for deeper ripping to depths of 50 cm or more, and 53% for deeper ripping with topsoil slotting (Table 1).

Similar results of significantly improved grain yields when ripping was deeper (+60 cm) were reported at Waikerie recently (McBeath *et al*. 2018). However, deeper intervention to 60 cm did not provide any significant yield benefits over a depth of 30 cm at several other SA and Vic sites (Moodie *et al*. 2018, McBeath *et al*. 2019).

What happened?

SA Mallee trials

Five replicated field trials (Table 2) were conducted during the 2018 and 2019 cropping seasons on sandy soils across the northern and southern Australian Mallee, and the upper Eyre Peninsula (UEP). Trial 1 (depth x spacing) was set up at Peebinga (2018 and 2019) and at Buckleboo (2019) to investigate the impact of depth of ripping on crop productivity, to evaluate whether narrow or wide tine spacing changed crop responses and to estimate the longevity of the amelioration benefits.

Trial 2 was set up at Loxton as a crop rotation experiment with three different crop types (wheat, barley and field peas each year), with the aim of assessing which crop types respond better to deep ripping in the first, second and third year after amelioration.

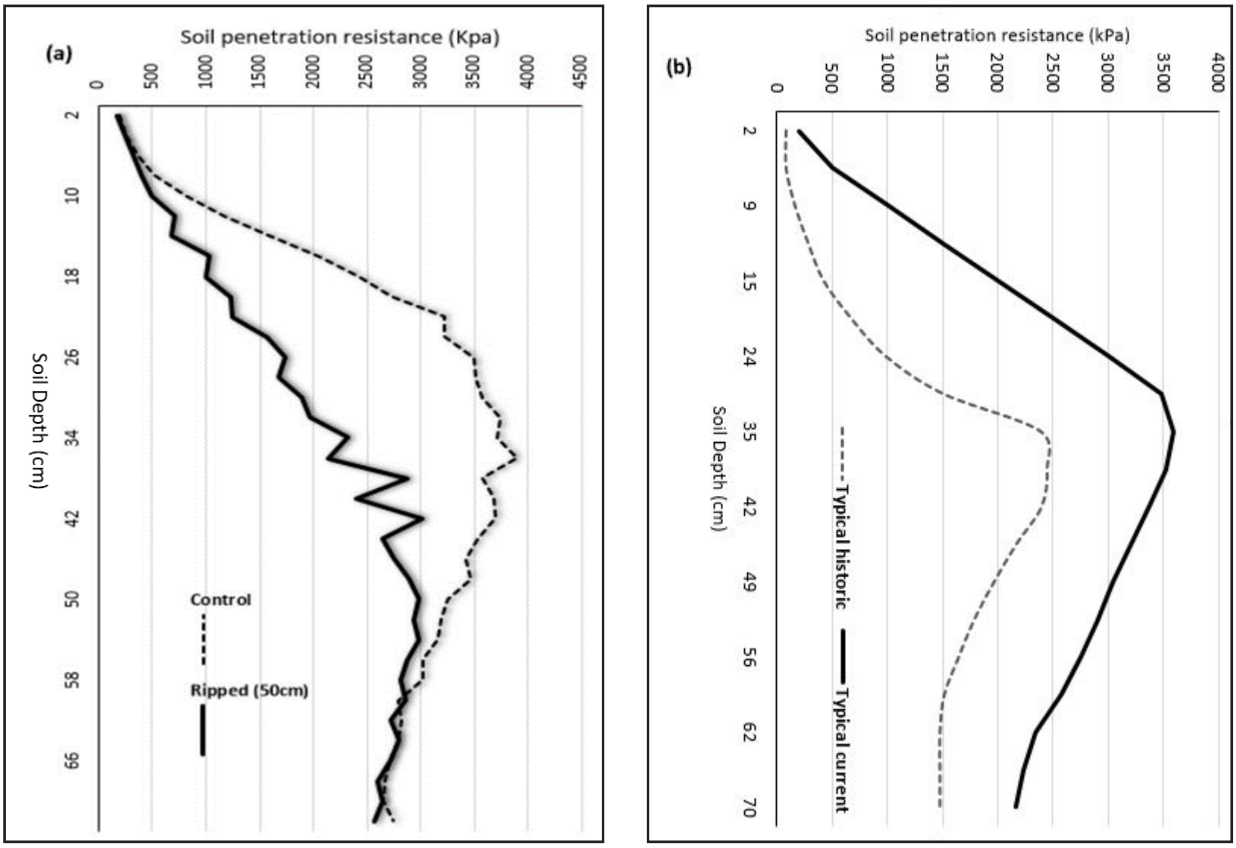

Figure 1. Plots showing penetration resistance for a SA sandy soil at Loxton (a), and typical historical and current soil penetration resistance measures for deep WA sandy soils (b). Values of 1500-2500 kPa are considered moderate compaction, 2500-3500 kPa severe compaction and >3500 kPa extreme compaction.

Table 1. Crop responses to deep ripping at different depths and the impact of topsoil slotting (with inclusion plates). Trials conducted in WA during 2014-2016 (Davies** et al. **2017).

Location, crop	Soil type	GSR (mm)	Control yield (t/ha)	Ripped 30-40 cm		Ripped 50-70 cm		Ripped 50-70 cm + topsoil slotting	
				Yield	%	Yield	%	Yield	%
Moora, canola	Loamy sand	177	1.9	2.2	**16**	2.8	**47**	2.9	**53**
Wubin, wheat	Deep sand	228	2.1	2.7	**29**	3.0	**43**	-	**-**
Binnu, wheat	Deep sand	219	0.8	0.8	**0**	1.4	**75**	1.8	**123**
Binnu, wheat	Loamy sand	219	2.1	2.1	**0**	2.8	**33**	3.6	**71**
Beacon, wheat	Sandy duplex	240	3.8	3.9	**3**	3.5	**-11**	4.5	**15**
Broomehill, wheat	Sandy duplex	227	1.8	2	**11**	3	**67**	-	**-**
Munglinup, wheat	Sandy duplex	280	3.6	3.6	**0**	3.6	**0**	4.2	**17**
Meckering, wheat	Sand over gravel	323	2.7	-	**-**	3.4	**26**	-	**-**
Meckering, wheat	Deep sand	323	2.4	-	**-**	3.4	**46**	-	**-**
Meckering, wheat	Sand over gravel	323	2.2	2.5	**15**	3	**38**	3	**38**
Walkaway, lupin	Deep sand	219	1.2	-	**-**	2.3	**92**	-	**-**

Table 2. Deep ripping locations and treatment details for 2018 and 2019 cropping seasons.

Year	Trial	Location (crop)	Region	Treatments
2018	Trial 1	**Peebinga** (barley)	southern Mallee	Depths (0, 20, 40, 60, 70 cm) Tine spacings (Narrow=30 cm and wide=60 cm)
	Trial 2	**Loxton** (wheat, barley, peas)	northern Mallee	Ripped (50 cm) vs compacted (control) Tine spacing 50 cm
2019	Trial 1	**Peebinga** (wheat)	southern Mallee	Depths (0, 20, 40, 60, 70 cm) Tine spacings (Narrow=30 cm and wide=60 cm)
		Buckleboo (barley)	upper EP	
	Trial 2	**Loxton** (wheat, barley, peas)	northern Mallee	Ripped (50 cm) vs compacted (control) Tine spacing 50 cm

GSR: 2018 Loxton (105 mm), Peebinga (116 mm); 2019 Loxton (93 mm), Peebinga (152 mm), Buckleboo (143 mm).

Deep ripping treatments were imposed using a straight tine ripper on 11 May and 21 May 2018 at Loxton and Peebinga respectively, and at Buckleboo on 10 April 2019. Penetration resistance readings were taken on 7 August 2018 at both Mallee sites using a Rimik CP40 (II) cone penetrometer to estimate the magnitude and depth of compaction. In season assessments of crop density, dry matter (DM) production, grain yield and quality were undertaken to help understand the effect of ameliorating compaction in typical deep sands of the SA mallee.

With total growing season rainfall (GSR) ranging from only 93–152 mm crop growth and productivity were severely limited at all sites. However, visual and positive responses in crop establishment and biomass to ripping were evident throughout the growing season in all trials. No grain yield was achieved in field peas at the Loxton site for 2018 and 2019 because of severe frost which resulted in pod damage. Overall, our trials have demonstrated that ameliorating compacted sandy soils in low rainfall environments can lead to substantially improved crop biomass (data not shown) and grain yield over at least 2 seasons. Deep ripping increased wheat yields by up to 135% for shallow 20-40 cm ripping and up to 235% for deeper ripping to depths of 50 cm or more. Barley grain yield was increased by up to 93% for shallow 20-40 cm ripping and up to 193% for deeper ripping to depths of 50 cm or more (Table 3). Only shallow ripping did not cause large grain yield gains.

Averaged over all ripping depths, deep ripping with tines spaced narrowly at 30 cm resulted in an increase in early and late shoot DM (data not shown). However, this benefit did not carry through to grain yield (Figure 2). Deep ripping has the potential to promote early biomass growth but in moisture limited environments, one of the largest potential downsides associated with deep ripping is that it increases the risk of haying off when soil water reserves are low and the finish to the season is dry (Davies *et al*. 2017). In some situations, faster water use and increased vegetative biomass caused by deep ripping can leave inadequate stored soil water for grain filling resulting in haying off and reduced yields.

Our trials also show that when the compacted soil in question is compacted to depth, then ripping deeper is better for grain yield, provided there are no other chemical constraints below the compaction zone. There was a consistent general trend of increasing grain yield with increasing ripping depth across all sites in 2 years of conducting these trials (Figure 3). Cumulative grain yields over the 2 seasons have shown that the deepest ripping treatment (70 cm) is achieving the highest yield. This could be attributed to increased plant root growth, access to nutrients and water down the soil profile, and similar results of better grain yields with deeper ripping have been reported by several authors (Davies *et al*. 2017, Isbister *et al*. 2018, McBeath *et al*. 2018, McBeath *et al*. 2019, Moodie *et al*. 2018). However, it is important to note that the highest yielding ripping treatment does not necessarily translate to the most profitable and most sustainable tillage strategy. Apart from these productivity gains from deeper tillage, there are also natural resource benefits such as nitrate leaching can be reduced through deeper rooting and greater water and nitrogen uptake by the higher-yielding cereal crops and in the long-term should reduce saline seeps developing in lower parts of the landscapes.

Table 3. Summary of deep ripping trials conducted during 2018 and 2019, showing crop responses to deep ripping at different depths and tine spacing on grain yields.

Year	Location	Crop	Tine spacing (cm)	Control	Ripped 20 cm		Ripped 40 cm		Ripped 50 cm		Ripped 60-70 cm	
				Yield (t/ha)	Yield (t/ha)	% change	Yield (t/ha)	% change	Yield (t/ha)	% change	Yield (t/ha)	% change
2018	Loxton	Wheat	50	0.58	-	**-**	-	**-**	0.69	**19**	-	**-**
	Loxton	Barley	50	0.54	-	**-**	-	**-**	1.08	**100**	-	**-**
	Peebinga	Barley	30	0.27	0.46	**70**	0.52	**93**	-	**-**	0.79	**193**
	Peebinga		60		0.23	**-15**	0.43	**59**	-	**-**	0.77	**185**
2019	Loxton	Barley	50	0.13	-	**-**	-	**-**	0.18	**38**	-	**-**
	Loxton	Wheat	50	0.22	-	**-**	-	**-**	0.56	**155**	-	**-**
	Peebinga	Wheat	30	0.20	0.20	**0**	0.47	**135**	-	**-**	0.67	**235**
	Peebinga		60		0.28	**40**	0.29	**45**	-	**-**	0.62	**210**
	Buckleboo	Barley	30	2.13	2.79	**31**	2.88	**35**	-	**-**	3.35	**57**
	Buckleboo		60		2.38	**12**	3.46	**62**	-	**-**	3.33	**56**

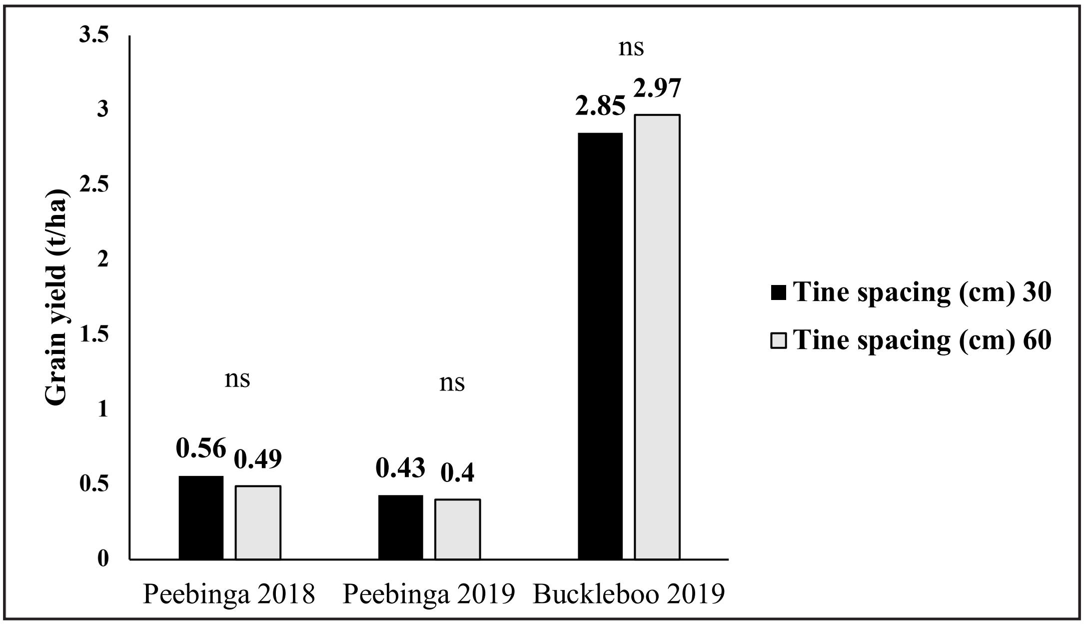

Figure 2. Cereal grain yield (t/ha) on 30 cm and 60 cm tine spacing at Peebinga and Buckleboo.

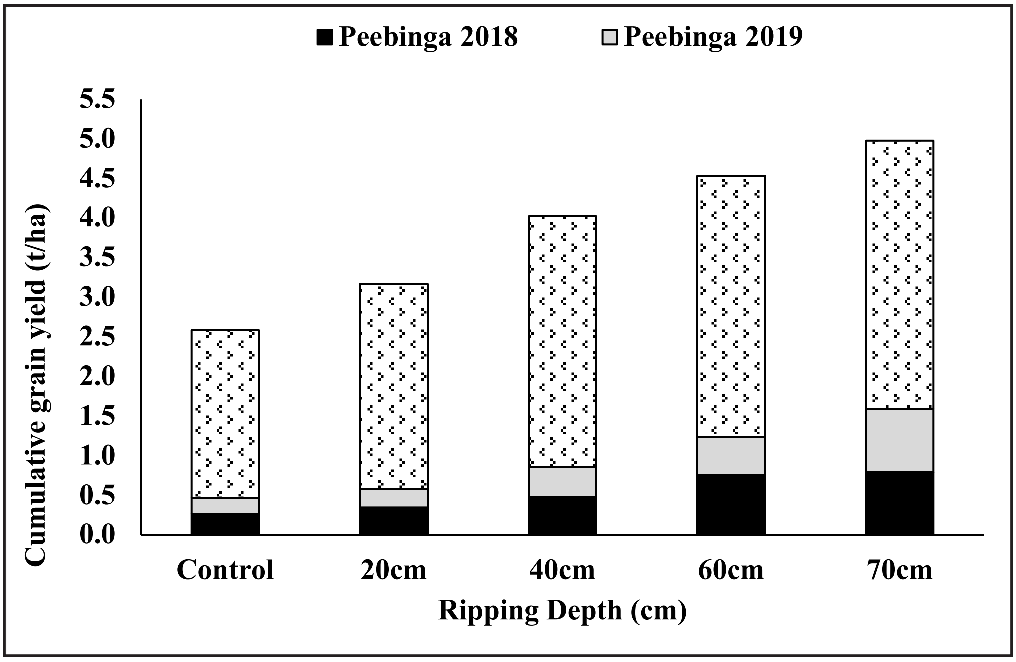

Figure 3. Cumulative cereal grain yield (t/ha) at Peebinga (2018, 2019) and Buckleboo (2019).

Soils

Economics of deep ripping

Economics are an important factor when evaluating whether an amelioration strategy should be implemented or not. Soil amelioration is slow and costly, so it is necessary to have long-term benefits to achieve a good return on investment. Large physical interventions like deep ripping have the potential to improve crop productivity in compacted sandy soils, but there is a risk of low returns in low rainfall seasons. Our results from 2 years (Table 4) of conducting the "ripping depth x tine spacing" trials, are showing that better returns are achieved when deep ripping below 60 cm. When narrower tine spacing is considered, going deeper than 60 cm will not give the best economical return in the first year because the yield gain does not economically justify the extra cost of ripping further down the soil profile. However, the data for Peebinga is showing that the marginal benefits in year 2 significantly improve by more than 100% by ripping down to 70 cm. There is no evidence from our data of a drop off in yield in the second year after ripping, which implies that the benefits of deep ripping could extend into year 3, improving the economic returns even more.

Tackling more than just one constraint

Our experiments have focused only on the physical intervention of ripping to ameliorate subsoil compaction, however, other research has acknowledged that tackling more than one constraint is better in the long run to improve and sustain crop yields, particularly on sands in medium to low rainfall environments. Trials in the Western Australian wheat belt have found deep ripping combined with topsoil slotting with inclusion plates can increase yields from sandy soils by more than deep ripping alone. At Meckering, WA in 2016 shallow ripping of pale sand over gravel increased wheat grain yield by 11% (320 kg/ha) over the control with the addition of topsoil slotting increasing the yield by 26% (560 kg/ha) (Davies *et al*. 2017). Research is continuing to investigate if topsoil slotting will improve the longevity of the benefits of deep ripping.

Ripped soil can be very soft and more susceptible to re-compaction which can cause trafficking issues for field operations. To maximise the benefits of deep ripping and minimise risks of re-compaction, adopting a controlled traffic farming (CTF) system should be considered. CTF is a farming system built on permanent wheel tracks where the crop zone and traffic lanes are permanently separated. For many deep sandplain soils, deep ripped areas can remain soft for at least 4 to 5 years in controlled traffic situations (Davies et al. 2017), and the benefits can be maximised by adopting CTF (Wilhelm *et al*. 2018). CTF should ultimately result in a much improved return on investment through increased longevity of the deep ripping benefit and a reduced need to repeat the deep ripping with its associated cost.

Other research activities are also investigating how best to overcome subsoil constraints to further improve and sustain grain yield with cost effective soil modification and ameliorants (Masters and Davenport 2015, McBeath *et al*. 2018). However, it is important to take into consideration the risk of wind erosion when soil renovation is done in legume stubble and in cereal paddocks with very low stubble cover. Common modifications and ameliorants being investigated include delving and spading, and incorporating gypsum, lime, clay, fertilisers or organic matter.

Table 4. Summary of marginal benefits from deep ripping at Peebinga (2018, 2019) and Buckleboo (2019).

		Tine spacing (30 cm)				**Tine spacing (60 cm)**			
	Depth (cm)	**20**	**40**	**60**	**70**	**20**	**40**	**60**	**70**
	Estimated cost ($/ha)*	**40**	**60**	**90**	**100**	**30**	**50**	**70**	**80**
Peebinga 2018	Yield change from control (t/ha)	0.19	0.25	0.56	0.48	-0.04	0.16	0.42	0.57
	Value of extra yield ($/ha)	42	55	123	106	-9	35	92	125
	Marginal benefit ($/ha)	**2**	**-5**	**33**	**6**	**-39**	**-15**	**22**	**45**
Peebinga 2019	Yield change from control (t/ha)	0	0.27	0.3	0.62	0.08	0.09	0.26	0.57
	Value of extra yield ($/ha)	0	78	87	180	23	26	75	165
	Marginal benefit ($/ha)	**0**	**78**	**87**	**180**	**23**	**26**	**75**	**165**
Buckleboo 2019	Yield change from control (t/ha)	0.58	0.67	1.34	0.94	0.17	1.25	0.82	1.42
	Value of extra yield ($/ha)	145	168	335	235	43	313	205	355
	Marginal benefit ($/ha)	**105**	**108**	**245**	**135**	**13**	**263**	**135**	**275**

**Estimated cost of deep ripping extrapolated from Davies et al. 2017*
Assumptions. Prices of wheat @ $250/t (2018), $290/t (2019), and barley @ $220/t (2018), $250/t (2019)
http://image.info.cargill.com/lib/fe911574736c0c7e75/m/1/Wheat_SA_Mallee_UpperSE.pdf
http://image.info.cargill.com/lib/fe911574736c0c7e75/m/1/Barley_Feed_SA.pdf

What does this mean?

Slow and restricted root growth caused by subsoil compaction can often lead to reduced crop productivity and profitability and also lead to other on- and off-farm effects such as increased wind and water erosion, dryland salinity and waterway degradation. Soil amelioration using strategic deep ripping is costly and usually slow to implement which means it can only be implemented on a small scale in a given year. Our trials have shown that ameliorating compacted sandy soils in low rainfall environments can lead to improved crop biomass and grain yield. Ripping narrow (30 cm) or wide (60 cm) gave similar outcomes in terms of grain yield, therefore wider tine spacing should be considered to use less machinery horsepower. These ongoing research activities are showing that deep ripping is not the ultimate strategy to improving crop performance but that a more holistic approach of tackling more than just one subsoil constraint can improve the longevity of benefits and overall returns on investment.

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Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers (Gum-Peebinga, Schaefer-Loxton, Baldock-Buckleboo) through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support. SAGI for statistical analysis and support.

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