Deep ripping: an effective first step to lift productivity on deep sands in the Victorian Mallee?

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Abstract
Sub-optimal productivity is commonly reported for the deep sands that make up approximately 20-30% of the cropping soils in the low rainfall Victorian Mallee. Un-used water is evident despite an apparent absence of constraints commonly associated with sandy soils (e.g. non-wetting, acidification). Poor subsoil fertility and/or physical restrictions to rooting depth may be the primary constraints to production in deep Mallee sands. To explore the issues further, replicated trials were established across two sites, Ouyen (2017-18) and Carwarp (2018). These trials have investigated the interactions between physical disturbance (deep-ripping and/or rotary spading) and the incorporation of organic and inorganic inputs. Alleviating physical barriers to root growth through practices such as deep ripping and rotary spading are providing the most consistent yield increase on sandy soils in the Victorian Mallee, with yield benefits of up to 1.5 t/ha observed over two seasons. Spading of high nitrogen organic matter sources (vetch hay, chicken litter, compost) has also increased yield. Of the organic amendments, chicken litter has led to the highest cumulative grain yield response (2 t/ha across two seasons). This response from the application of chicken litter demonstrates the potential to improve crop yields by increasing the fertility of sandy soils.

Key Words
Physical disturbance, fertiliser placement, rotary spading, organic matter, chicken litter, nitrogen

Introduction
Sub-optimal productivity is commonly reported for the deep sands that make up 20 to 30% of the cropping soils in the low rainfall Victorian Mallee region (Unkovich, 2014). There is evidence of unused soil water, despite an apparent absence of constraints commonly associated with sandy soils (e.g. non-wetting, soil acidity). Diagnostic studies of local constraints have pointed to low abiotic and biological fertility in the subsoil layers and to the physical restriction of rooting depth as the most likely constraints to production on sands in the Victorian Mallee. There is considerable interest in strategic deep tillage with/without agronomic amendments (fertilisers, organic amendments) aimed at overcoming physical constraints and increasing nutrient supply within the soil profile. While ripping approaches can overcome physical constraints, more intensive soil mixing (e.g. spading, inversion ploughing) can be used to incorporate high nutrient organic amendments into the profile. Chicken litter is often a favored organic amendment (Macdonald et al. 2018), but it is largely unavailable in the Victorian Mallee. An alternative approach is to consider whether incorporation of farm-grown hay resources may have value in improving nutrient supply and biological cycling. To explore these approaches further, four replicated trials were established across two sites; Ouyen (2017-18) and Carwarp (2018). These trials are part of the GRDC project: Increasing production on sandy soils in the low-medium rainfall areas of the Southern Region. The trials are a collaboration between Frontier Farming Systems with Mallee Sustainable Farming, CSIRO and UniSA.

Methods
Sites
Two research sites were established in the Victorian Mallee at Ouyen (-35.155449° E, 142.201149° S, 2017 and 2018) and at Carwarp (-34.485648° E, 142.219663° S, 2018). The sites have similar soil properties (Table 1) but Ouyen (330 mm) receives on average 50 mm more rainfall per year than the Carwarp site (280 mm).

Trials
Nutrient placement (Ouyen 2017-18)
The first trial at Ouyen had three key factors: (1) the depth of nutrient placement (surface band at 7.5 cm deep, deep band at 20cm deep and deep ripped band at 30 cm deep), (2) the nutrient source (N only or a package of N+P+K+S+Zn+Cu+Mn) and (3) the timing of nutrient addition (all in 2017, or annually) supplying 90 kg N/ha

in total. All plots annually received a further 20 kg N/ha in basal nutrient additions as DAP applied at sowing and an early top-dress application of ammonium sulphate.

Table 1. Key soil properties at the Ouyen and Carwarp sites.

Depth (cm)	Clay (%)	Organic Carbon (%)	pH ($CaCl_2$)	Electrical Conductivity	Colwell Phosphorus ($mg.kg^{-1}$)
Ouyen					
0-10	3.8	0.3	6.3	53.7	18
10-60	4.1		6.0	25.5	
60-100	4.5		7.4	35.4	
Carwarp					
0-10	5.8	0.2	5.7	39.0	17
10-60	7.8		7.2	38.3	
60-100	7.1	0	7.8	47.3	

Organic matter quality (Ouyen 2017-18)

A second trial at Ouyen compared six types of organic matter incorporated to a depth of 30 cm depth in 2017 using a one pass spade and sow operation (Table 2). Each organic amendment was applied at a rate that supplied 2.5 t/ha of carbon (C), but the amendments varied in their C:N ratio. Spaded organic matter treatments were also compared to spading only, spaded urea (supplying equivalent quantity of N as vetch hay) and a non-spaded control.

Table 2. Treatments included in the organic matter quality trial at Ouyen. Organic matter rates were adjusted so each treatment supplied 2.5 t/ha of Carbon. Rotary spading was used to incorporate inputs to a depth of 30 cm (n.a. = not applicable).

Treatment	Application Rate (t/ha)	C:N Ratio	Total N Input (kg/ha)
Spaded Vetch Hay	6	16:1	156
Spaded Oaten Hay	5.9	72:1	35
Spaded Vetch Hay + Oaten Hay	3.3 + 2.7	25:1	102
Spaded Chicken Litter	6.8	16:1	218
Spaded Compost	15.8	10:1	252
Spaded Urea	0.34	n.a.	156
Spaded Control	0	n.a.	0
Non-spaded Control	0	n.a.	0

Organic matter placement (Carwarp 2018)

The trial at the Carwarp site compares the incorporation and placement of organic matter inputs (6 t/ha lucerne hay) by deep ripping, spading or a combination of the two operations (Table 3). Where organic matter inputs were surface applied, lucerne meal was used and where organic matter inputs were direct injected into the subsoil during the ripping process the lucerne hay was pelletised.

Trial Management

Both trials at Ouyen were sown to Spartacus barley on 29 May 2017. The site had a full profile of moisture at sowing due to 100 mm of rainfall falling in the month preceding sowing. The site received 363 mm (decile 6) for the year with 195 mm (decile 3) falling during the growing season (April – October). Low and infrequent rainfall delayed the establishment of trials at both sites in 2018. Both trials at Ouyen were sown to Kord wheat on 31 May 2018 while the Carwarp trial was sown on 7 June to Spartacus barley. Growing season rainfall at both sites was sporadic and very much below average, with only 75 mm of rainfall at Carwarp and 105 mm of rainfall at Ouyen during the 2018 growing season.

The organic matter quality and organic matter placement trials received DAP + S and Zn (16:17:0:8; 0.5% Zn) @ 62.5 kg/ha at seeding and 47 kg/ha of ammonium sulphate and a foliar application of copper, zinc and manganese was applied during tillering. Additional applications of N at seeding saw a total of 50 kg N/ha applied to the Ouyen site and 40 kg N/ha applied at Carwarp sites respectively each season.

Table 3. Treatments included in the organic matter placement trial at Carwarp.

Treatment	Physical disturbance	Depth of Disturbance (cm)	OM Addition (6 t/ha Lucerne)	Depth of OM Placement (cm)
Control	Nil	Nil	+/-	Surface
Spade	Rotary Spade	30	+/-	Surface-30
Deep rip_30	Deep rip	30	+/-	30
Deep rip_60	Deep rip	60	+/-	60
Deep rip_30/60	Deep rip	60	+/-	30+60
Spade + deep rip_60	Rotary Spade + Deep Rip	30+60	+/-	Surface-30 + 60

Results

Deep ripping provided a significant yield increase in the Ouyen nutrient placement trial (Figure 1). In 2017, the treatments that included deep ripping yielded 0.85 t/ha higher than the control (1.9 t/ha). In 2018, the annual ripping treatment (i.e. plots deep ripped in both 2017 and 2018) resulted in a yield increase of 0.6 t/ha more than the control yield of 0.97 t/ha, while treatments which were ripped in 2017 still yielded 0.3 t/ha better than the control in 2018 (Figure 1). Therefore, all ripping treatments provided a combined yield benefit of 1-1.5 t/ha over two seasons. There was no benefit from the physical disturbance of the pre-drilling operation (Figure 1). We observed that the deep ripping provided significant fracturing of the soil profile while the less aggressive pre-drilling technique provided a slotting rather than fracturing effect on the soil. There was also no benefit from the placement of N and other nutrients below the surface soil layer (Figure 1). The higher dose rate of N in the one single application in 2017 resulted in a significant increase in grain protein but not grain yield in the first year with no effect on either yield and protein in 2018 (protein data not supplied).

Incorporating a N-rich organic matter source such as vetch hay, chicken litter and compost increased grain yield by up to 1.4 t/ha in the first year of the organic matter quality trial at Ouyen (Figure 2). However, there were few significant second-year benefits in 2018 with only spaded compost and spaded chicken litter treatments having significantly higher grain yields than the non-spaded control (0.7 t/ha) (Figure 2). The spaded chicken litter treatment resulted in a cumulative yield of 4 t/ha for the two seasons, compared to only 2 t/ha of grain from the non-spaded control (Figure 2).

Both deep ripping and rotary spading significantly increased grain yields in the organic matter placement trial at Carwarp in 2018 (Figure 3). Mechanical disturbance to 30 cm by rotary spading or deep ripping resulted in additional grain yield of 0.5 t/ha compared to the unmodified control treatment yield of 0.55 t/ha. Deeper ripping to 60 cm did not provide any significant yield increase over working to a depth of 30 cm only. There was no positive impact from the addition of organic matter (lucerne hay), while there was a negative response in the spading treatment (Figure 3), possibly from more vigorous early crop growth which depleted soil water reserves in a low rainfall season.

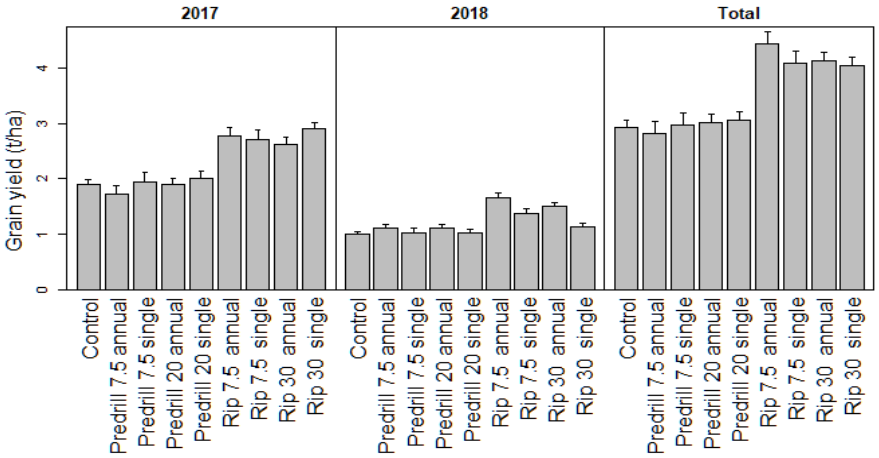

Figure 1. Annual and total cumulative grain yield for each treatment in the nutrient placement trial at Ouyen. Labels describe if pre-drilling to 20 cm or deep ripping to 30 cm was implemented prior to sowing. The number (7.5, 20 or 30 cm) indicates the depth of nutrient placement. 'Annual' means the treatment was applied each year and 'single' indicates treatment was applied in the first year (2017) of the trial only. Error bars are standard error.

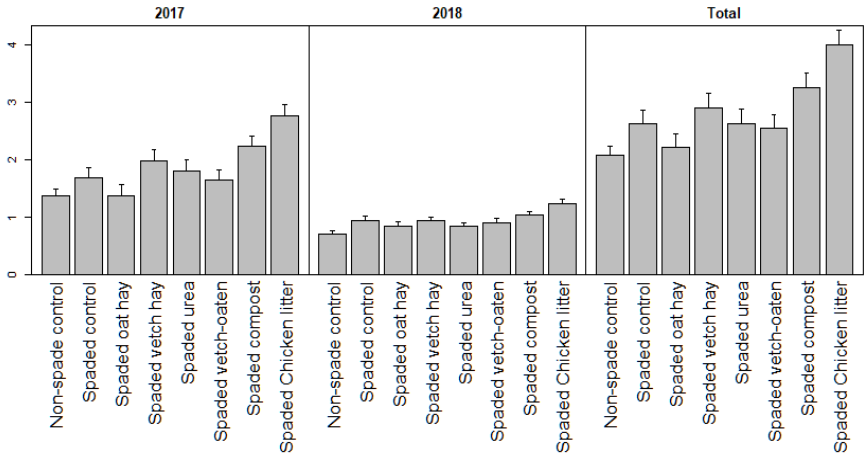

Figure 2. Annual and total cumulative grain yield for each treatment in the organic matter quality trial at Ouyen. Error bars are standard error.

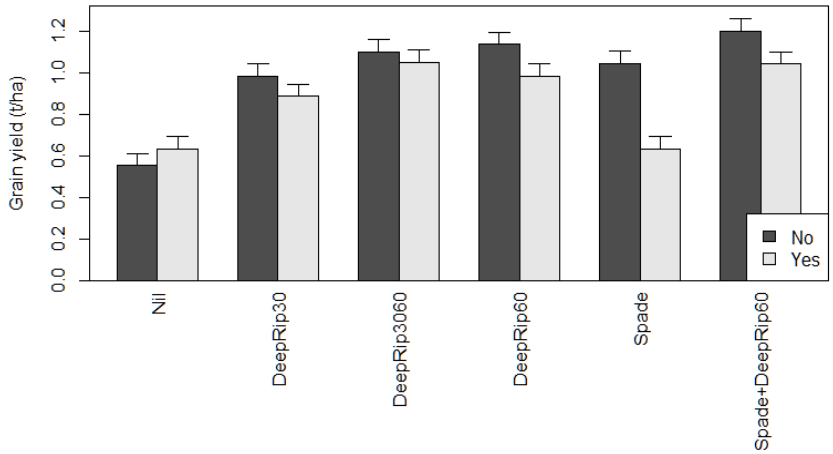

Figure 3. Grain yield for treatments each treatment in the organic matter placement trial at Carwarp. Shaded bars identify if the treatment received organic matter (yes) or if organic matter was not applied (no). Error bars are standard error.

Conclusion

Addressing soil physical constraints by deep ripping or rotary spading appears to be a good place to start for farmers looking to increase production on underperforming sands in the Victorian Mallee. Alleviating physical barriers to root growth through practices such as deep ripping and rotary spading are providing the most consistent yield increase on sandy soils in the Victorian Mallee. Thus far, yield responses from physical interventions have generally been more consistent than responses from organic inputs. The exception is the spaded chicken litter treatment at Ouyen where there has been a cumulative grain yield response of 2 t/ha across two seasons. This response from the application of chicken litter demonstrates the potential to improve crop yields by increasing the fertility of sandy soils. Further investigation is warranted to understand why chicken litter has had a greater impact on productivity relative to other organic inputs and if this benefit can be replicated by alternative input strategies in regions where chicken littler is not available to farmers.

References

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