Improving crop performance on Mallee sands through subsoil injection of organic matter

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Location
Loxton
Paul Rudiger

Rainfall
Av. Annual: 282 mm
Av. GSR: 190 mm
2018 Total: 136 mm
2018 GSR: 103 mm

Paddock history
2019: Barley
2018: Wheat

Soil type
Sand

Soil test
pH(water) 7.3

Plot size
15 m x 2 m x 3 rep

Trial design
RCBD with 3 replicates

Yield limiting factors
Moisture, nitrogen

Key messages

- **Deep ripping increased grain yield of wheat in 2019 on the midslope of a sand hill but not on the crest.**
- **Manures have the potential to increase crop yields, especially when applied deep into the soil profile, however there is a risk of the cereal crop haying off particularly on the crests of sandhills in very dry seasons.**

Why do the trial?

Soil amelioration is slow and costly, so it is necessary to have long-term benefits to achieve a good return on investment. Recent 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. The main aim of this trial is to evaluate the impact of a range of organic materials on crop performance when applied into the subsoil of a poorly performing Mallee sand. These types of sands are common across the low rainfall region of south-eastern Australia. The approach was to inject different organic materials (locally available to the Loxton district) in the form of a liquid slurry into the subsoil behind ripper tines. The hypothesis was that deep placed organic materials would promote root growth, improve subsoil fertility and result in better crop yields. A considerable amount of research over the last decade has shown the benefits of deep ripping and subsurface addition of organic material to crop production (Masters and Davenport 2015; Davies *et al*. 2017; McBeath *et al*. 2018; Moodie *et al*. 2018; McBeath *et al*. 2019) but making these approaches profitable has been difficult. In this trial, only locally available and low cost manures were tested.

How was it done?

Organic materials used were composted chicken manure, pig manure, sheep or cattle manure (from feedlots). Two identical and replicated field trials were implemented on a deep sandy soil in the northern Mallee (Loxton) in 2019. One trial was established on the crest of a sandhill and the other on the midslope of the same sandhill to investigate whether crop responses would differ depending on their position in the landscape.

The manures were injected into the subsoil (40 cm deep) on 5 April with the "Philips New Horizon" subsoil machine (Figure 1) fitted with a hopper and two ripper tines spaced 50 cm apart. To make the slurry, water was added to the manure in the hopper with a rotating mixer until it could be pumped down the ripper tines.

The manures had different nutrient compositions (Table 1) so they were applied at different rates to ensure 150 kg N/ha was added in each treatment.

Chicken and pig manure had the highest N content, and were therefore applied at half the rate of sheep and cattle manure (Table 2).

The trials were established with two controls to evaluate the manure responses against common district practice (control 2) and best management practice (control 1 but with deep ripping).

The manures were also spread on the surface for comparison at the same rates as injected into the subsoil. Surface treatments were broadcast evenly over the entire plot areas by hand on 16 April. This was after they had been deep ripped so that a direct comparison of manure placement on crop production could be assessed.

Table 1. Composition of the manures for four major nutrients per tonne of dry matter.

Manure	kg nutrient per tonne			
	N	P	K	S
Chicken	30	17	27	6
Pig	30	9	27	6
Sheep	16	6	14	3
Cattle	15	4	23	3

Table 2. Manure type, placement and application rate (t/ha).

Treatment	Manure placement	Deep rip	Application rate (t/ha)
Control 1	none	+	0
Control 2	none	-	0
Cattle manure	surface	+	10
Chicken manure	surface	+	5
Pig manure	surface	+	5
Sheep manure	subsoil	+	10
Cattle manure	subsoil	+	10
Chicken manure	subsoil	+	5
Pig manure	subsoil	+	5

+ Deep ripping to 40 cm; - no deep ripping

The trial was sown on 20 May with Spartacus CL barley at 55 kg/ha and 100 kg DAP/ha. Crop establishment was assessed on 13 June and urea was applied only to the controls at 50 kg/ha on 26 June. MCPA 750 was applied on 12 August to control broadleaf weeds, and flowering dry matter (DM) cuts were taken on 17 September. Due to the nature of the season with inconsistent and low rainfall, penetration resistance of the soil was not assessed as had been planned. Penetration resistance of all plots will be measured in 2020 when the soil is wet to depth.

What happened?

Crop responses were evident during vegetative growth with the most vigorous barley in the subsoil manure treatments. However, with only 93 mm of growing season rainfall, the crop on the crest of the sandhill did not finish as well as the midslope. Crop establishment was a little better on the sandhill (113 plants/m^2) compared to the midslope (103 plants/m^2). However, late tillering shoot DM, flowering shoot DM and grain yield were all higher on the midslope.

Crest

There were large decreases in plant density due to ripping (Table 3). Deep ripping alone caused a 37% reduction in crop establishment, compared to the district practice of ‘no rip, no manure’. However, the presence of manures, regardless of where they had been placed reduced the impact of ripping on crop establishment. Rolling after deep ripping would have been a good strategy to improve trafficability and crop establishment. Placing manures on the surface or into the subsoil did not change either early vegetative or flowering biomass. Ripping alone (control 1) resulted in similar flowering DM to the unripped control (control 2) despite having nearly 40% fewer plants.

Midslope

Plant establishment was not affected by deep ripping or addition of manures.

Late tillering and flowering DM increased with injected manures, although cattle manure was the least effective. Deep ripping alone had little impact on crop growth during the season. Sheep manure placed into the subsoil resulted in a 60% increase in late tillering DM, while pig manure resulted in the highest flowering shoot DM (72% higher than district practice - control 2).

Crest

There was no yield response to deep ripping or addition of manure on the crest with all treatments averaging about 1 t/ha (Table 4). Grain yield on the crest was heavily compromised by lack of good soil moisture during the critical part of the growing season.

Figure 1. Philips New Horizon machine used to mix slurry and inject manures into the subsoil.

Table 3. Barley responses to manure and deep ripping on the crest or midslope of a sandhill at Loxton in 2019.

Site	Treatment	Manure placement	Deep rip	Plants/ m^2		Late tillering DM (t/ha)		Flowering DM (t/ha)	
Crest	Control 1	none	+	86	*a*	0.57		2.08	
	Control 2	none	-	136	*d*	0.67		1.83	
	Cattle manure	surface	+	127	*cd*	0.76		2.07	
	Chicken manure	surface	+	123	*cd*	0.94		1.95	
	Pig manure	surface	+	116	*bcd*	0.58		1.95	
	Chicken manure	subsoil	+	107	*abc*	0.68		2.21	
	Cattle manure	subsoil	+	87	*ab*	0.87		2.26	
	Sheep manure	subsoil	+	115	*bcd*	0.67		2.16	
	Pig manure	subsoil	+	120	*cd*	0.76		2.36	
	F pr			*0.03*		*ns*		*ns*	
	LSD			*29*					
Midslope	Control 1	none	+	80		1.14	*abc*	4.56	*abcd*
	Control 2	none	-	113		0.83	*a*	3.53	*a*
	Cattle manure	surface	+	111		0.84	*a*	3.67	*ab*
	Chicken manure	surface	+	112		1.23	*bc*	5.44	*de*
	Pig manure	surface	+	127		0.97	*ab*	4.04	*abc*
	Chicken manure	subsoil	+	94		1.22	*bc*	4.98	*bcde*
	Cattle manure	subsoil	+	79		1.02	*abc*	5.18	*cde*
	Sheep manure	subsoil	+	116		1.33	*c*	4.88	*bcde*
	Pig manure	subsoil	+	96		1.26	*bc*	6.08	*e*
	F pr			*ns*		*0.05*		*0.01*	
	LSD					*0.35*		*1.32*	

Table 4. Grain yield of barley (t/ha) on the crest and midslope of a sandhill at Loxton in 2019 after ripping and manuring.

Site	Manure treatment	Actual grain yield (t/ha)	Ripping + manure effect (t/ha)
Crest	Pig manure – SR	0.79	-0.17
	Control 2 – not ripped	0.96	0.00
	Sheep manure - SS	0.99	0.03
	Cattle manure – SR	1.01	0.05
	Control 1 - ripped	1.02	0.06
	Chicken manure - SS	1.03	0.07
	Cattle manure - SS	1.05	0.09
	Pig manure - SS	1.10	0.14
	Chicken manure – SR	1.20	0.24
	F pr	*ns*	
Midslope	Control 2 – not ripped	1.44	0.00
	Cattle manure – SR	1.79	0.35
	Pig manure – SR	2.25	0.81
	Cattle manure - SS	2.38	0.94
	Chicken manure - SS	2.64	1.20
	Chicken manure – SR	2.68	1.24
	Sheep manure - SS	2.69	1.25
	Control 1 - ripped	2.74	1.30
	Pig manure - SS	3.32	1.88
	F pr	*0.05*	
	LSD	*1.08*	

SS = Subsoil; SR = Surface application and ripping

Midslope

The ripping benefit (calculated as the difference between control 1 (ripped) and control 2 (not ripped)) was 0.06 t/ha on the crest and 1.3t/ha on the midslope. The benefit of applying manure and deep ripping was very marginal on the crest as compared to the midslope. Barley on pig manure (subsoil) treatment had the biggest response to deep ripping and manure (1.88 t/ha) (Table 4).

There was a 90% gain in yield from deep ripping, with control 1 (ripped) achieving 2.74 t/ha and control 2 (not ripped), 1.44 t/ha. On the midslope, the physical intervention of deep ripping contributed more to final grain yield than organic manures placed either on the surface or subsoil (0.58 t/ha). Overall, ripping with the application of manure contributed a maximum response of 0.24 t/ha on the crest and 1.88 t/ha on the midslope.

Soil moisture cores were sampled post-harvest on 22 November by taking 2 soil cores (0–50 cm) per plot. These soil cores were subsampled into 0-10 cm, 10-30 cm and 30-50 cm layers, however the data presented in this paper is the total volumetric soil moisture and total shoot N (%) (Figure 2). Our data highlights that post-harvest volumetric soil moisture in the 0-10 cm, 10-30 cm and 30-50 cm zone was not affected by the physical disturbance of the soil or the addition of organic manure. The total volumetric soil moisture ranged from 22 mm (sheep manure subsoil) to 31 mm (pig manure – surface).

Plant samples collected on 17 September to determine early flowering shoot DM were also used to determine shoot nitrogen (%) as an indicator of N uptake by the plant. Past trial results from Bill Bowden from the Department Primary Industry and Regional Development (DPIRD, WA), have shown deep ripping can improve N uptake. As highlighted by our data in Figure 2, there were no significant differences in shoot N on the crest and midslope after deep ripping and addition of organic manure.

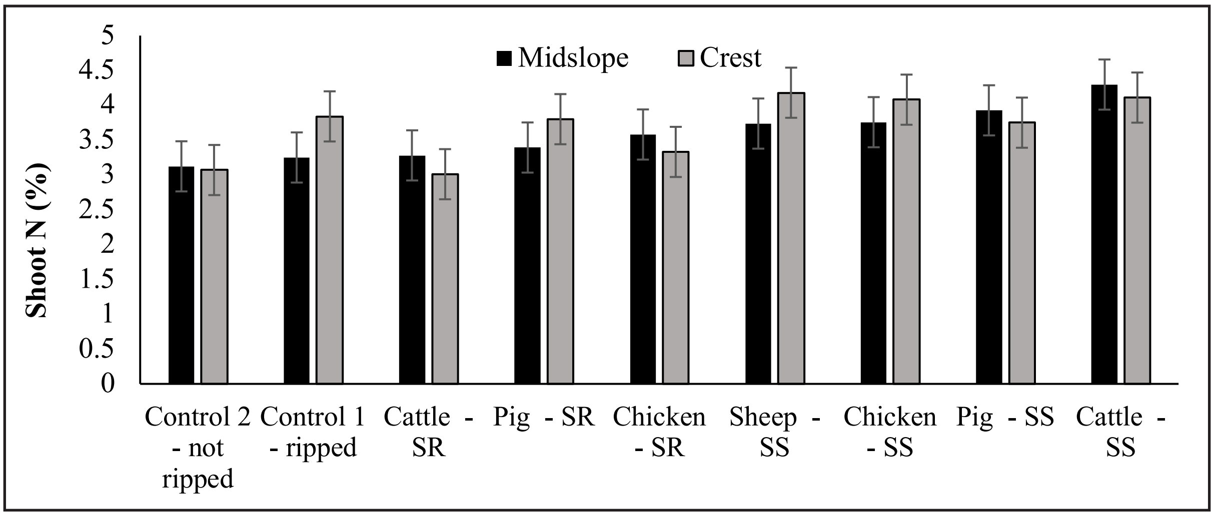

Figure 2. Shoot nitrogen (%) across manure treatments on the crest and midslope.

What does this mean?

Moisture and nitrogen use and productivity on sandy soils are commonly limited by a range of co-occurring soil constraints that limit root growth. Physical soil disturbance and use of organic ameliorants are effective interventions that can improve plant root growth, access to nutrients and water down the soil profile, however, this has to be achieved at low cost to attain the best possible profit-risk outcomes. This trial was conducted to evaluate if locally available manures can be used as a cost effective soil ameliorants by the method of injecting slurry into the subsoils of performing sandy soils. Our results have shown that on the crest there is very little gain from using the manures on the surface or subsoil in seasons where moisture is severely limiting. On the midslope the benefit of physical soil disturbance and manure addition into the subsoil is greater, however these productivity gains have to be assessed in terms of longevity, cost and returns, as all of these factors have an influence on profit and risk. The trial will continue in 2020/2021 season, monitoring responses and collecting more data that will assist in making meaningful recommendations to growers.

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