Effects of deep placed soil amendments at Esperance, Ongerup and Nangeenan.

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Key messages

- In higher rainfall regions (Esperance - sandplain, Ongerup- clay moort soils) the surface application and deep incorporation of composted chicken manure has resulted in significant yield increases. However seasonal frost and waterlogging have minimised yield differences in some years.
- Preserving moisture through straw mulch and improving soil structure through acidic amendments and organic matter has improved yields in Morrel soils but not in all years.
- The aim of these experiments has been to develop a better understanding of how we might re –engineer problems soils which in the longer term could lead to practical and economic solutions.

Aims

This paper outlines three experiments conducted at Nangeenan (alkaline, saline, boron toxic subsoils: Morrel soils), Ongerup (hard sodic subsoils: Moort soils) and Esperance (compact and mildly acidic subsoils: Sandplain). The treatments included deep placement of soil specific amendments (lime, gypsum, elemental sulphur, acid sand or composted chicken manure) as a means to "re-engineer" and improve subsoil physical and chemical fertility. The aim is to refine our scientific understanding of how modifying subsoils can impact on crop production, with a longer term view of distilling the information to find practical and economically viable solutions.

Method

Three trials were established at Nangeenan (S31.511, E118.145), Ongerup (S33.971, E118.663) and Esperance Downs Research Station (S33.610, E121.781) in early autumn 2015. Gypsum (80 – 90 % purity) and lime with neutralizing values (NV) of 70 to 90% were sourced from local suppliers. Two acidifying amendments (Yellow sandy earth (pH 4.1), elemental sulphur) were applied to alkaline subsoils to reduce the pH and potentially improve water infiltration. A composted chicken manure, 'Organic2000®', (4.9%N, 0.9%P, 1.7%K, 0.5%S) was applied as the organic matter treatment. Amendments were either surface spread or were "trenched". Where trenched, the amendments were laid out on the surface along the length of the plots at 900 mm intervals resulting in four trenches per plot. A PTO driven auger (TrenchMaster 150®) was used to incorporate the amendments into trenches 600mm deep by 100mm wide at the Esperance and Nangeenan sites. A similar process was used at Ongerup using a 'Ditch Witch®' trencher. A surface mulch (5 t/ha) of cereal straw was applied over half the plots at Nangeenan. Details of the experiments and treatments are provided in Table 1.

Soil strength was measured with a digital recording cone penetrometer to a depth of 600mm in approximately nine locations within each plot. Crop yields were measured using plot headers at Esperance and Ongerup and from biomass cuts at Nangeenan.

Table 1. Crop type and rainfall (April – October), soil types and treatments for the subsoil amendment trials at Nangeenan, Ongerup and Esperance

	Nangeenan	Ongerup	Esperance
Crop 2015	Barley (cv Scope) 220 mm	Wheat (cv Mace) 215 mm	Barley (cv Bass) 359 mm
Crop 2016	Barley (cv Scope) 191 mm	Barley (cv La Trobe) 281mm	Canola (cv Wahoo) 398 mm
Crop 2017	Barley (cv Spartacus) 175 mm	Canola (cv Bonito) 275 mm	Wheat (cv Mace) 308 mm
Soil types	Alkaline red shallow loamy duplex (Transitional and Salmon Gum) Calcareous loamy earth (Morrel)	Grey non cracking clay (Moort soil)	Pale deep sandy duplex.

Trial design	Strip trial with replicated controls for each soil type	Complete factorial, randomised block with 4 replicates	Randomised block with 4 replicates
Treatments	Control ± Straw mulch (10 t/ha)	Control	Control
	Trench to 60 cm (T) ± Mulch	Trench to 40 cm (T)	Manure 10 t/ha
	T + Gypsum (5 t/ha) ± Mulch	Gypsum 3 t/ha (G)	Trench to 60 cm
	T + acid sand (75% of total weight in trench) ± Mulch	Manure 10 t/ha	Trench + Lime 2 t/ha
	T + elemental sulphur (5% of total weight in trench) ± Mulch	Manure 20 t/ha	Trench + Manure 10 t/ha
	T + Manure 10 t/ha ± Mulch	Manure 10 t/ha + G	Trench + Manure 20 t/ha
	T + Manure + Sulphur ± Mulch	Manure 20 t/ha + G	Trench + Lime + Manure 10 t/ha
		T + G	Trench + Lime + Manure 20 t/ha
		T + Manure 10 t/ha	
		T + Manure 20t/ha	
		T + Manure 10 t/ha + G	
		T + Manure 20 t/ha + G	

Results 2015 - 2017

1) Pale deep sandy duplex, Esperance

Grain yields were significantly increased as a result of the soil amendment treatments in 2016 and 2017 when compared to the Control (Table 2). Much of the yield increase was due to the manure treatments alone. Increased tillering and grains per head were found in the manure treatments when compared to the control (data not shown). Trenching and lime did not significantly ($P<0.05$) affect yields at this site. There were no significant interactions between manure, trenching and lime main treatments. No differences in grain yield were found between treatments in 2015 as a result of waterlogging, lodging and head loss within the barley crop which compromised yields in treatments with the highest yield potential.

Improved crop yields in all years are mainly attributed to improved nutrient levels associated with the composted manure treatments. P, K and S concentrations were significantly increased in plant tissue as a result of the composted chicken manure applications (data not shown). Yield responses to the 10 and 20 t/ha of manure were statistically equivalent.

Table 2 Grain yields (t/ha) for Barley (2015), Canola (2016), Wheat (2017) and combined (Total) total grain yield harvested. Treatments that differ significantly (P<0.05) to the Control treatment are highlighted in bold.

Treatment	Barley 2015 t/ha	Canola 2016 t/ha	Wheat 2017 t/ha	Total All years t/ha
Control	4.64	1.08	6.77	12.49
Manure 10 t/ha	4.38	***1.87***	***7.46***	13.71
Trench	4.20	0.88	7.26	12.34
Trench+Lime	4.71	1.32	6.93	12.96
Trench+Manure 10	4.95	1.49	***7.84***	***14.28***
Trench+Manure 20	4.78	1.57	***7.59***	***13.94***
Trench+Manure 10 +Lime	4.79	***1.98***	***7.53***	***14.30***
Trench+Manure 20 + Lime	4.88	***2.28***	***7.83***	***14.99***
Lsd5%	0.61	0.52	0.69	1.33

Soil strength was found to exceed 4000kPa below 30 cm depth in the Control, indicating severe compaction, compared to 2500kPa within the trenched treatments to a depth of 50cm. Improved root growth was noted along the trench lines, however, overall yields were not increased as a result of the trenching treatment. The surface application of manure (Manure 10 t/ha) resulted in similar yields to those where it had been incorporated to depth (Trench+Manure10 or 20 t/ha) (Table 1). Crops in 2015 and 2016 were subjected to water logging which would have restricted root growth and negated the potential benefits of lower soil strength within the trenched treatments. Inclusion of lime within the trenches had little impact on grain yields due to low acidity within the modified root zone.

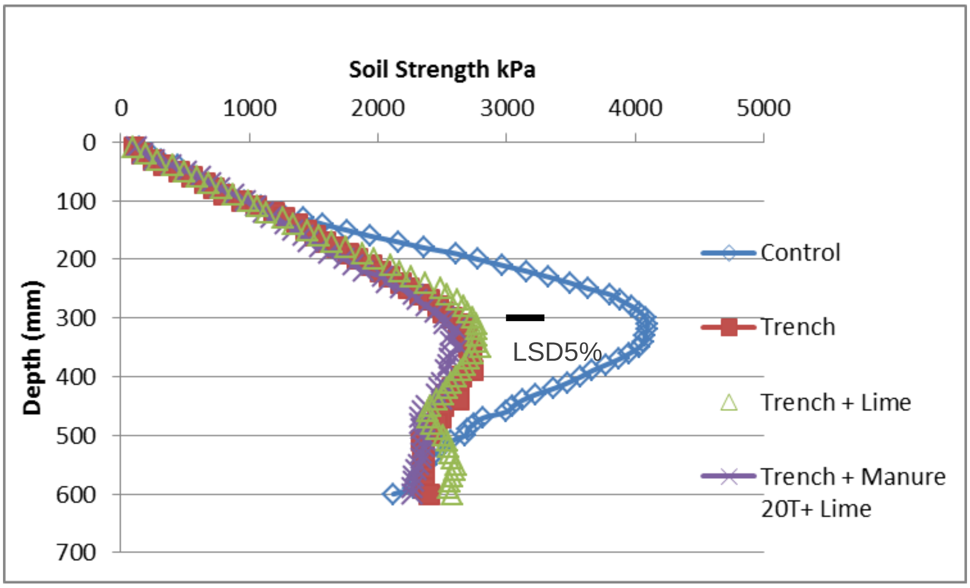

Figure 1. **Soil strength to a depth of 600mm as affected by the trenched, lime and manure treatments. Data recorded 8/8/17.**

2) *Grey non-cracking clay,* Ongerup

Grain yields in 2016 and 2017 were highest when combinations of amelioration options were applied compared to the control (Table 3). This was not observed in 2015 due to clay smearing following trenching and uneven soil surface which reduced crop establishment (data not shown). As a result of this no positive treatment responses were observed in this first year over the control.

For 2016 most of the yield improvement came from the higher manure application (20 t/ha) and trenching. When these factors were combined the yield increases were additive (Table 3). Gypsum applications had no significant effect on the barley yields. Transient waterlogging occurred during crop establishment but vegetative crop performance was not affected. A severe frost was observed in 2016 which reduced main stem grain production by 50-70%. The trenching and manure plots provided a more favourable environment for crop development which promoted more tillering in these treatments. These extra tillers and the more favourable conditions from amelioration, allowed the crop to reallocate resources from the frosted stems to the later tillers, thereby compensating for lost grain yield due to frost.

The 2017 canola crop was challenged by marginal moisture during germination and establishment, and then by a severe frost near the end of flowering. The lack of moisture during establishment resulted in sulphur deficiency being observed which was less severe where gypsum had been applied. The manure treatments, in the absence of trenching did not record higher yields, despite higher biomass observed for these treatments compared to the Control (Table 3). Shallower roots without trenching and the severe frost are likely to have contributed to this. Trenching with manure produced bigger individual plants which flowered over a longer period of time. We believe that this allowed the plants to reset pods and recover some yield after the frost event. Overall, the highest yields in all years have occurred where manure has been deep incorporated through trenching (Table 3).

Table 3 **Grain yields (t/ha) for Wheat (2015), Barley (2016), Canola (2017) and combined (Total) at Ongerup. Treatments that are significantly higher than the Control treatment are highlighted in bold (LSD 5%) or underlined (LSD 10%). Bracketed values are significantly lower**.

	Wheat 2015 t/ha	Barley 2016 t/ha	Canola 2017 t/ha	Total all years t/ha
Control	3.13	2.44	0.66	6.24
Gypsum (G)	3.15	2.59	0.73	6.47
Manure10 (M10)	3.13	<u>2.90</u>	0.54	6.57
Manure20 (M20)	2.96	**3.62**	0.63	**7.21**
Trench (T)	3.03	**3.34**	0.70	**7.07**
G+ M10	3.04	**3.06**	0.56	6.65
G+M20	3.02	**3.83**	0.61	**7.46**
G + T	2.98	**3.21**	0.71	**6.90**
M10 + T	3.03	**4.16**	**0.98**	**8.17**
M20 +T	**(2.64)**	**4.60**	<u>0.86</u>	**8.09**
G + M10 + T	2.92	**3.93**	0.74	**7.59**
G + M20 + T	<u>2.82</u>	**4.70**	**0.94**	**8.46**
LSD5%	0.33	0.46	0.23	0.60
LSD10%	0.27	0.38	0.19	0.50

3) Alkaline red shallow loamy duplex and Calcareous loamy earth, Nangeenan

The Nangeenan trial was replicated across a change in soil types (Morrel, Salmon Gum and Transitional). The soil types increased in pH, subsoil salinity and boron across the trial site with the transitional soil having the lowest values and the Morrel having the highest values within the soil profile. Only data for 2016 and 2017 are presented in this paper. The addition of straw mulch significantly increased barley grain yields in the Morrel soils both in 2016 and 2017. The mechanisms for the straw effect are not clear but appear to be related to reduced water evaporating from the soil surface and concentration of salts. The mulch had no effect on grain yields on the Salmon Gums and Transitional soils in either year.

There were no significant differences between the amendment treatments across all soil types in 2016 (Table 4). Grain yields in the Morrel soil were however increased by the Acid sand, Sulphur and Organic matter treatments when compared to the Control in 2017. No treatment differed to the Control in the Salmon Gums soil in either 2016 or 2017. The application of Sulphur did however reduce yields in the Transitional soil in 2017. Soil sampling in 2017 indicated that in some instances the elemental sulphur had reduced subsoil pH to below pH 4. This indicates that *Thiobacillis* bacteria that convert elemental sulphur to sulphate are present in these highly alkaline soils and can result in marked changes in soil pH within two years of application. Determining rates of elemental sulphur addition to achieve a desired pH is currently being undertaken (D. Mulvany pers. com). The addition of organic matter did result in increased yields the Morrel soil only. Increased biomass production has been observed across all three soil types, however the additional biomass has not always led to increased grain yields.

Table 4 **Barley grain yields as affected by the soil amendment treatments on the three soil types in 2016 and 2017. For each soil type and year, yields followed by different letters are significantly (P<0.05) different.**

Soil type	Treatment	Barley 2016 t/ha		Barley 2017 t/ha	
Morrel	Control	1.129	a	0.2172	a
	Trench (T)	1.018	a	0.1578	a
	T+Gypsum	1.199	a	0.2614	ab
	T+Acidic sand	1.259	a	0.3264	bc
	T+Sulphur (S)	1.139	a	0.3425	bc
	T+Org matter (OM)	1.13	a	0.4034	c
	T+S+OM	1.076	a	0.4079	c

Salmon Gum	Control	0.832	a	0.3589	a
	Trench (T)	1.503	a	0.203	a
	T+Gypsum	1.403	a	0.2656	a
	T+Acidic sand	0.995	a	0.2741	a
	T+Sulphur (S)	0.819	a	0.2609	a
	T+Org matter (OM)	1.254	a	0.2992	a
	T+S+OM	1.043	a	0.4395	a
Transitional	Control	1.19	a	0.5877	b
	Trench (T)	1.603	a	0.5754	b
	T+Gypsum	1.702	a	0.6531	b
	T+Acidic sand	1.698	a	0.8425	b
	T+Sulphur (S)	0.925	a	0.1408	a
	T+Org matter (OM)	1.298	a	0.764	b
	T+S+OM	1.064	a	0.5804	b

Conclusion

A range of experimental soil amelioration treatments were used to improve crop yields on contrasting soil types and seasons. On the Esperance sandplain the composted manure treatments resulted in significant yield increases in most years due in part to their high nutrient levels. Deep placement of the composted manure aided crop yields particularly in seasons where plant roots were not restricted by waterlogging (i.e. 2017). The high yields achieved in 2017 are a testament to seasonal conditions combined with the high yield potential of these soils where nutrient and soil strength limitations can be ameliorated.

The alkaline clay soils at Nangeenan are the most challenging soils to ameliorate. The addition of straw mulch to the Morrel soil has resulted in yield increases. Acidifying the Morrel subsoil using sulphur and acid sand led to yield increases in 2017 in the Morrel soils. Generally yield responses to the soil treatments have not been consistent and the sulphur treatment was associated with poorer growth particularly in the Transitional soils in 2017. The addition of composted manure (organic matter) has not led to any consistent increase in crop yields despite higher biomass being observed in these treatments in most years. Excess early crop growth can cause reductions in yield through haying off when the stored soil water is depleted prior to grain fill.

Significant yield increases have been found at Ongerup on the Moort soils as a result of the trenching and manure treatments only. Part of the yield response to trenched and manure treatments is attributed to the observed increase in crop growth over the trench lines in what are regarded as very hostile subsoils. The site at Ongerup is subject to transient waterlogging and frost, both of which have limited crop yields. Improvements in crop yields associated with the trenching and manure treatments reflect the plants ability to recover from these climatic events either through improved drainage (waterlogging 2016) or through extended flowering (frost 2017).

Key words

Soil amendments, organic matter, compost, mulch, lime, gypsum, sulphur, acid sand, Moort soils, Morrel soils.

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