Crop responses to deep incorporation of soil amendments in contrasting soils and climates

David Hall, Glenn McDonald, Grant Stainer, Caroline Peek and Ed Barrett-Lennard

Department of Agriculture and Food WA.

Key messages

- High rates of composted chicken manure led to increased grain yields only in high rainfall environments. In low rainfall environments, early to mid season biomass was increased but there was no yield benefit.
- Deep incorporation of amendments resulted in inconsistent results. Deep placement of sulphur, acid sand and gypsum increased yields at the Nangeenan site in 2015 but not in 2016. Deep incorporation of gypsum and manures resulted in yield increases at Ongerup in 2016 but not in 2015. No benefit from deep incorporation of manure or lime was found at Esperance.
- Surface straw mulching at Nangeenan resulted in higher biomass but did not affect grain yield.

Aims

Subsoil constraints to crop production cost farmers more than $1 billion in lost production annually (Petersen 2016). The causes of these losses are varied, but in all cases they can be attributed to restricted root growth that impairs water and nutrient uptake. The aim of this paper is to outline 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 the deep placement of soil specific amendments (lime, gypsum, elemental sulphur, acid sand and a composted chicken manure as a means to "re-engineer" and improve subsoil physical and chemical fertility. The treatments implemented are intended 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 economic 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 were sourced from local suppliers. The lime ranged in neutralising value from 70 – 90 %. Two acidifying amendments (Wodjil acid sand, 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 in strips along the length of the plots. This was repeated four times within each plot at 900 mm intervals. A PTO driven auger (Trench Master 150) was used to incorporate the amendments into trenches 600 mm deep by 100 mm wide at the Esperance and Nangeenan sites. A similar process was used at Ongerup using a "Ditch Witch". A surface mulch (5 t/ha) of cereal straw was applied over half the plots at Nangeenan. Details of the experiments and treatments are given in Table 1.

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

	Nangeenan	Ongerup	Esperance
Crop 2015	Barley (cv Scope) 230 mm	Wheat (cv Mace) 215 mm	Barley (cv Bass) 359 mm
Crop 2016	Barley (cv Scope) 253 mm	Barley (cv Latrobe) 281mm	Canola (cv Wahoo) 398 mm
Soil types	Alkaline red shallow loamy duplex (Salmon gum)) Alkaline red shallow loamy duplex (Transitional) 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	Control	Control
	Trench to 60 cm ± Mulch	Trench to 40 cm	Trench to 60 cm
	Trench + Gypsum (5 t/ha) ± Mulch	Gypsum 3 t/ha	Manure 10t /ha
	Trench + acid sand (75% of total weight in trench) ± Mulch	Manure 10 t/ha	Trench + Manure 10 t/ha
	Trench + sulphur (5% of total weight in trench) ± Mulch	Manure 20 t/ha	Trench + Manure 20 t/ha
	Trench + Manure 10 t/ha ± Mulch	Manure 10 t/ha + Gypsum	Trench+ Lime 2 t/ha
	Trench + Manure + Sulphur ± Mulch	Manure 20 t/ha + Gypsum	Trench + Lime + Manure 10 t/ha
		Trench to 40 cm + Gypsum	Trench + Lime + Manure 20 t/ha
		Trench + Manure 10 t/ha	
		Trench + Manure 20t/ha	
		Trench + Manure 10 t/ha + Gypsum	
		Trench + Manure 20 t/ha + Gypsum	

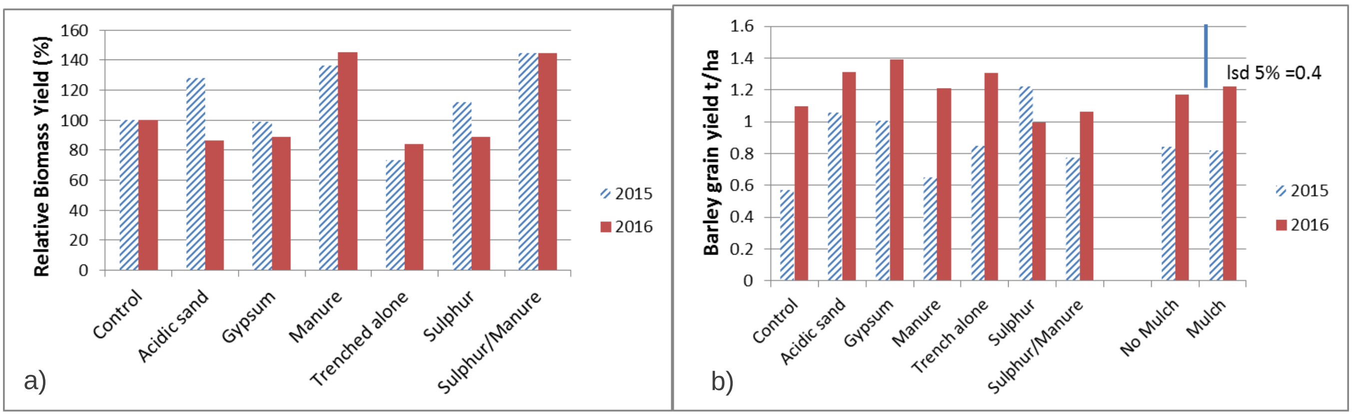
Results

Nangeenan

Soil type had a marked effect on crop production more so than any treatment implemented at the Nangeenan site. Crop production decreased in the order Transitional>Salmon Gums>Morrel. The underlying salinity within the subsoils, as measured by EM38 readings, was inversely correlated with crop yields. EM38 values exceeding 150 mS/m halved crop yields with the greatest percentage of these values associated with the Morrel soil type.

Biomass prior to anthesis in each year was significantly ($P<0.003$) increased as a result of the manure treatment (Figure 1a). However, the increased biomass produced by the inclusion of the manure did not increase crop yields (Figure 1b). Whereas the acid sand, sulphur and gypsum treatments increased yields in 2015, there was no significant amendment effect on barley yields in 2016. The reasons for the yield improvements in 2015 are likely to be related to improved water infiltration from above average rainfall in July and August resulting in increased water availability later in the season. There was no soil type by treatment interactions in either year. This indicates that the treatment effects were consistent across the three soil types.

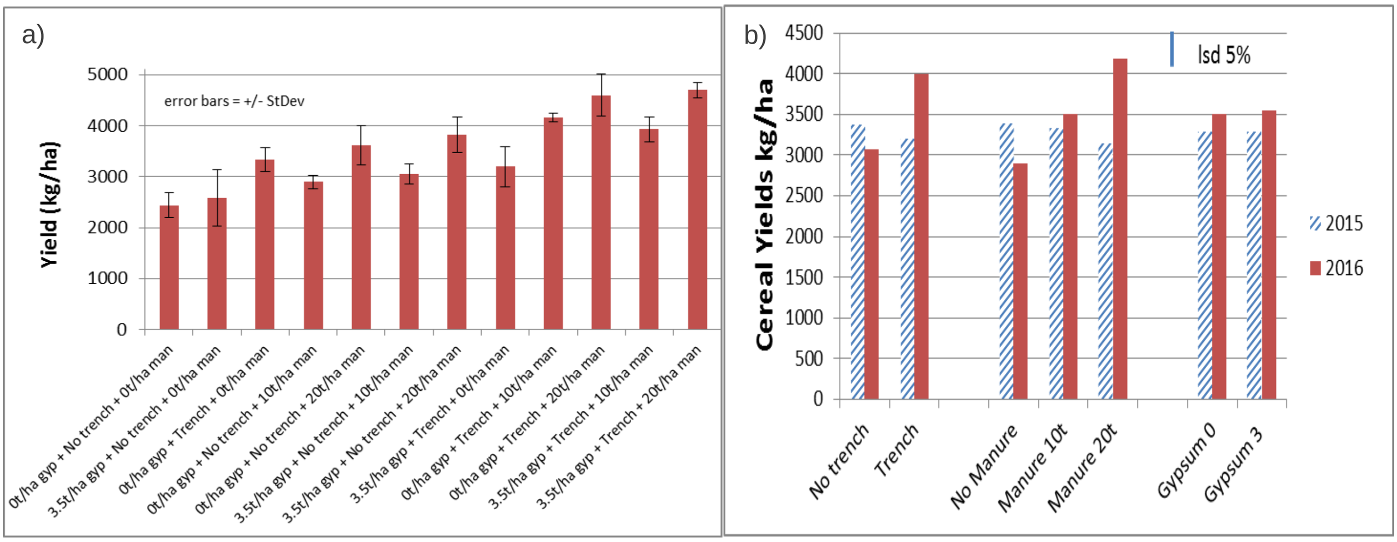
Figure 1. a) Barley biomass at late tillering as a % of the Control and b) barley grain yields (t/ha) for 2015 and 2016 averaged over the three soil types. Note that apart from the Control all amendments were incorporated to 60 cm using a trencher.



Ongerup

In 2015 there were no significant effects of the treatments on wheat yield when compared to the control. Overall, the trenching treatments resulted in a minor yield decline. While the causes of this are not fully known, incomplete backfill within the trenches resulting in air voids, uneven seeding depths, and smearing of the soil surface with sodic sub-soil during the trenching process may have contributed to this result. Where manure had been added, the crop remained greener for longer. However, with the dry finish to the season, the additional growth was not converted into grain. Barley yields in 2016 increased with trenching and addition of manure. Gypsum had no apparent effect on crop yields in either year (Figures 2a&b). There were no significant interactions between the trenching, manure and gypsum main treatments. This suggests that the effects of the main treatments are additive.

Figure 2. a) 2016 barley yields for the individual treatments. (b) Crop yields as affected by the trenching, composted manure and gypsum main treatments in 2015 (Wheat) and 2016 (Barley)



Esperance

The manure treatments increased (P<0.001) barley biomass production by 2 – 3 t/ha just prior to anthesis in 2015. The greater biomass of the manure treatments was associated with increased tiller numbers and height. The increased early biomass production associated with the manure treatment did not lead to increased yield. This is mainly due to lodging prior to grain fill associated with increased plant height in the organic amended treatments (Table 2).

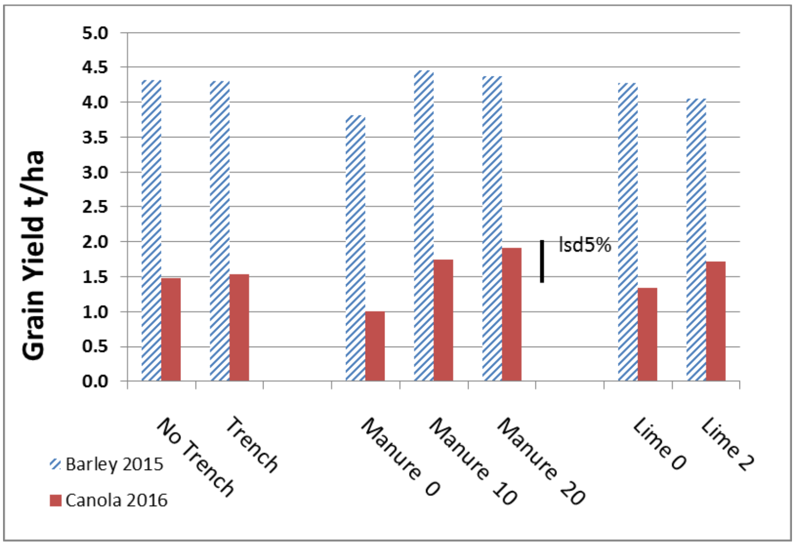
The trenching and lime treatments had minimal impact on biomass and grain production. This is despite the trenching treatments reducing soil strength to less than 2000 kPa, and also the degree of non wetting as indicated by the molarity of ethanol droplet (MED) test values (Table 2).

Table 2 Effect of treatments on non wetting (MED), barley biomass, height, lodging and barley and canola grain yields measured in 2015 and 2016 . The lodging score ranges from 9 (vertical) to 0 (horizontal).

	2015					2016
Treatment	MED	Biomass	Height	Lodging	Barley	Canola
		t/ha	cm	Score	t/ha	t/ha
Control	2.2	8.8	56	7.3	4.64	1.08
Manure 10 t/ha	2.3	11.7	80	3.0	4.38	1.87
Trench	1.0	8.3	54	7.5	4.20	0.88
Trench+Lime	0.9	8.8	56	8.0	4.71	1.32
Trench+Manure 10	1.5	10.1	70	5.5	4.95	1.49
Trench+Manure 20	0.8	10.3	67	5.5	4.78	1.57
Trench+Manure 10 +Lime	1.6	10.2	67	6.3	4.79	1.98
Trench+Manure 20 + Lime	1.4	10.5	73	3.8	4.88	2.28
Prob	P<0.005	P<0.002	P<0.001	P<0.001		P<0.001
Lsd5%	0.79	1.5	7.33	0.94	ns	0.51

Canola yields in 2016 were significantly increased where composed manure had been applied. This is despite the soils being waterlogged for much of September (Table 2). At this site the effects of trenching and lime had no effect on grain production. The relative effects of the composted manure, trenching and lime main treatments are shown in Figure 3.

Figure 3 Grain yields for barley (2015) and canola (2016) as affected by the trenching, manure and lime main treatments



Conclusion

Composted chicken manure has been shown to increase yields in highly sodic subsoil clays in high rainfall zones of Victoria (Gill et al. 2008). The results presented here are mixed. At Nangeenan, the manure treatment increased early season growth but did not result in higher grain yields. This lack of conversion from dry matter to yield is most likely water related. Although the trenching and manure had improved the physical and nutritional properties of the soil, subsoil salinity remains the key limitation to crop production. The manure treatments at the higher rainfall (lower evaporation) sites at Ongerup and Esperance proved to be beneficial to yields in the wetter 2016 season but not the drier finishing 2015 season. Adequate moisture is therefore required for the manure treatments to result in consistent yield increases. It is likely to take several years after ameliorants are added to the soil for changes to stabilise. During which time, the effect of seasonal variability can be better accessed, especially at higher rainfall sites such as Ongerup.

The trenching treatments resulted in reduced soil strength which should enhance root growth and aeration. However, only the Ongerup site showed a clear improvement in crop yields due to trenching in 2016. This is most likely a result of improved drainage in the trenching treatments which assisted water infiltration through to the subsoil early in the season and then reduced the effect of surface waterlogging mid-season. At Esperance, waterlogging in both years reduced the benefits of trenches on root growth, while at Nangeenan the mixing of topsoil and sodic/saline subsoils may have reduced improvements in root zone chemistry, particularly in dry seasons.

Gypsum, sulphur and acid sand only increased crop yields at Nangeenan in 2015. Further work is required to define the mechanisms for this result. In theory, all three treatments can improve water infiltration in highly sodic/alkaline subsoils.

Key words

Deep incorporation, soil amelioration, gypsum, lime, composted manure, acid sand, sulphur.

Acknowledgments/Reference

We thank the Sutherland and Harding families for allowing this research to be conducted on their properties. We are indebted to David Dodge, Chris Matthews, Grey Poulish, Jolie Delroy and the Merredin RSU for their expert technical support.

Gill JS, Sale PWG, Tang C (2008). *Field Crops Research* 107, 265-275.

GRDC Project Number: DAW00242

Paper reviewed by: Kerry Regan