Crop production responses to soil amelioration treatments on an infertile sand over clay in South Australia

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Abstract

An important proportion of crop production in South Australia is carried out on neutral-alkaline soils comprising infertile siliceous sands overlaying sodic subsoils. Crop growth is limited by the infertile nature of the non-wetting, rapidly draining upper soil horizons and also by the lower soil horizons which are generally dense sandy clays, often sodic and with poor physical structure. A replicated experiment was established at Stansbury, SA in 2004 to compare production under best district practice management with that from several 'once off' soil amelioration treatments; surface applied organic matter (composted pig bedding litter), three subsoil treatments involving deep ripping to 0.4 m and addition of an ameliorant (either liquid nutrients, gypsum or organic matter as lupin grain), and a treatment that combined the surface and all the subsoil treatments together. Treatments were designed to improve soil chemical and physical properties and enhance root and crop growth. Of the treatments tested, deep ripping (0.4 m) and associated placement of nutrients in fluid form provided the most consistent crop responses, with the response being greater where the clay was closer to the surface. Some crop responses to the once off subsoil amelioration were still evident after 4 crops. Differences in crop water use (evapotranspiration) were not apparent from gravimetric measurements at sowing and harvest suggesting that other soil chemical and physical properties may be responsible for the yield responses, or there may have been undetected differences in the partitioning of water use between evaporation and transpiration within seasons. Among the crops studied, wheat was the most responsive to amelioration treatments and canola slightly less so, whereas lupin was generally unresponsive to soil amelioration strategies at this site.

Key Words

Subsoil amelioration, deep ripping, nutrient placement, gypsum, organic matter, residual value

Introduction

Alkaline soils comprising siliceous sands over sodic subsoils occur across a considerable proportion of South Australia's cropping land, largely in the Southeast, Murray Mallee, Eyre Peninsula and Yorke Peninsula. Crop production on these soils is often reduced as the upper soil horizons are non-wetting which affects emergence, and also have a low water holding capacity and poor nutrient availability that together restrict root growth and nutrient uptake. Crop growth is further limited by an abrupt textural change to the lower soil horizons which are generally dense sandy clays, often sodic and with poor physical structure, which leads to increased resistance to root penetration, soil dispersion, instability and seasonally perched water tables. There is evidence of the effect of subsoil chemical and physical constraints on crop performance (e.g. Chartres *et al.* 1992; Dracup *et al.* 1992). Yield benefits from amelioration, especially ripping with addition of deep nutrients or gypsum (Ellington 1986; Graham *et al.* 1992; Hamza and Anderson 2002), have been reported but results can vary with soil type (Hamza and Anderson 2003; Holloway *et al.* 2001), and there needs to be confidence that the results will last for several seasons in order to justify the relatively high costs involved. In this study the effects of several subsoil amelioration treatments were examined to determine if the productivity of different crops could be improved and sustained over a number of growing seasons when compared to the district 'best' practice where subsoil amelioration is not usually conducted.

Materials and Methods

The site for the study was 13 km NW of Stansbury (33?54?S, 137?47?E) on the Yorke Peninsula in SA on a calcic mottled-hypernatric yellow sodosol (Isbell 1996). Selected soil properties are given in Table 1 and illustrate the strong texture contrast between A and B horizons. The B horizon can be considered rather hostile to plant growth due to sodicity and high soil strength. The A2 horizon has a higher bulk density than the A1 and a very low cation exchange capacity.

Table 1 Soil properties for the site at Stansbury in South Australia

Site	Horizon	Soil depth (cm)	pH ($CaCl_2$)	$EC_{1:5}$ (dS/m)	CEC (meq/100g)	ESP (%)	Bulk density (g/cm^3)	Clay (%)	Sand (%)
Stansbury	A1	0-14	7.0	0.09	5.4	1.8	1.48	9	88
	A2	14-42	6.4	0.03	1.0	4.4	1.60	1	98
	B1	42-57	7.6	0.19	18.8	24.4	1.95	27	70
	B2	57-100	8.1	0.23	21.9	22.3	1.83	53	32

A three phase rotation trial comprising canola, wheat and lupins, with every phase present in each year, was established with a series of subsoil amelioration treatments (2, 3, 4 and 6 in Table 2) applied in 2004 only. The trial also included a surface amelioration treatment of organic matter (treatment 5, Table 2) and a ‘district practice’ treatment of no surface or subsoil amelioration (treatment 1, Table 2). Four replicates of each treatment were randomly arranged in a split-split-plot design with crop type as the main plots, reps as the subplots and soil amelioration treatment as the subsubplots. Plot size was 4 runs of 15 m x 1.8 m, each with 8 rows spaced at 22.5 cm. In May 2004 plots for treatments 2 to 4 and 6 were deep ripped at 47.5 cm spacings between tynes (deep working knife points) to a depth of 0.4 m and amelioration treatments applied in the same operation. The site was sown on 12th June 2004.

Table 2. Description of subsoil or topsoil amelioration treatment applied in 2004.

Treatment	Description
1	District practice (no surface or subsoil amelioration)
2*	Deep ripping and injection of liquid nutrients at 0.4 m
3	Deep ripping and organic matter (1,800 kg/ha lupin grain) at 0.4 m
4	Deep ripping and Calcium (790 L/ha of liquid gypsum) at 0.4 m
5	Surface application of approx. 30 t/ha of composted piggery bedding straw

6	A combination of treatments 2 to 5.

*Liquid nutrients contained 60 kg N/ha, 20 kg P/ha, 2 kg Zn/ha, 4 kg Mn/ha and 2 kg Cu/ha.

All plots in 2004 received 10 N, 5 P, 6 S and 1.7 Zn kg/ha with the seed and plots in treatments 1, 3 and 5 received an additional 20 N, 15 P, 8 S and 3.5 Zn kg/ha banded under the seed row by 3 cm. Wheat and canola plots received an additional 110 kg/ha of ammonium sulphate mid season. Widely grown commercial varieties of wheat, canola and lupins were seeded each year at typical seeding rates for the district. The site was kept weed and pest free with recommended herbicides and pesticides.

No soil amelioration treatments were applied for the remaining three years of the study in order to assess the residual value of the amelioration treatments. In these following years all crops were direct drilled with 100 kg/ha DAP + Zn (5%) (75 kg/ha banded below the seed and 25 kg/ha with the seed). All plots received an additional 100 kg/ha of sulphate of potash (broadcast) post-sowing in 2005. All wheat, barley and canola plots were top-dressed mid-season with urea if necessary.

Results

Rainfall for the 2004 and 2005 seasons was above average but the two subsequent years of the study were both severe droughts (Table 3).

Table 3 Annual and growing season (sowing to harvest, GSR) rainfall for Stansbury during the four year study period. GSR rainfall deciles are also indicated, along with the ratio of growing season pan evaporation to GSR. Long term (1889-2007) averages are also given.

Year	Annual	GSR	Decile	Evapn/GSR
2004	352	287	7	2.5
2005	393	351	9	2.1
2006	275	105	1	8.6
2007	393	188	2	4.7
Long term Ave	*399*	*262*		*3.1*

There were no differences in wheat anthesis dry matter production or grain yield between the non-ameliorated treatment and the treatment with surface organic matter applied, in any year (Table 4), which was also the same for the other crops in the rotation phases (data not shown). The dry matter production of wheat at anthesis in 2004 in all ‘deep rip (DR) plus’ amelioration treatments was significantly greater than non-ripped treatments (Table 4a). In subsequent years dry matter responses to amelioration were less than in 2004. For example in 2005 there were generally no differences compared to the district practice control, although the ‘DR plus all’ treatment was greater than the district practice and the surface organic matter treatments in 2006 (Table 4a). There were also varying effects of treatments in the different crops in the one season, for example in the 2005 lupin crop the ‘DR plus gypsum’ treatment produced more DM at anthesis than the surface organic matter treatment whilst in canola in 2005 the ‘DR plus all’ treatment was greater than ‘DR plus liquid nutrients’ (data not shown). Further, in 2006 there were no observed differences in anthesis dry matter for lupin across all treatments whereas in canola the

‘DR plus gypsum’ treatment produced more than the district practice or ‘DR plus organic matter’ treatment (data not shown).

Table 4 (a) Dry matter (DM) at anthesis (t/ha) and (b) grain yield (t/ha) at Stansbury for wheat in the rotation sequences from 2004-2007 after application of treatments in 2004 only. Values within a year followed by the same letter are not significantly different by analysis of variance (P<0.05)

(**a) Anthesis DM**	2004	2005	2006	2007
	Treatment			
District practice	2.59 a	4.32	0.75 a	na
DR + liquid nutrients	6.41 c	4.18	1.22 bc	na
DR + organic matter	5.55 bc	4.72	1.06 abc	na
DR + liquid gypsum	5.01 b	4.84	0.98 abc	na
Surface organic matter	3.58 a	5.36	0.87 ab	na
DR +All	5.35 bc	4.29	1.32 c	na
l.s.d (*P* < 0.05)	*1.31*	*1.08*	*0.43*	
(b) Grain yield				
	Treatment			
District practice	1.42 a	2.76	0.88 a	0.82 a
DR + liquid nutrient	3.56 d	3.67	1.51 bc	1.74 b
DR + organic matter	2.63	3.19	1.41 bc	1.11 ab
DR +liquid gypsum	2.77 cd	3.23	1.21 ab	1.19 ab
Surface organic matter	1.67 ab	2.99	1.13 ab	0.89 a
DR +All	2.41 abc	3.34	1.73 c	1.29 ab

l.s.d (P < 0.05)	*1.08*	*0.69*	*0.39*

na – not available

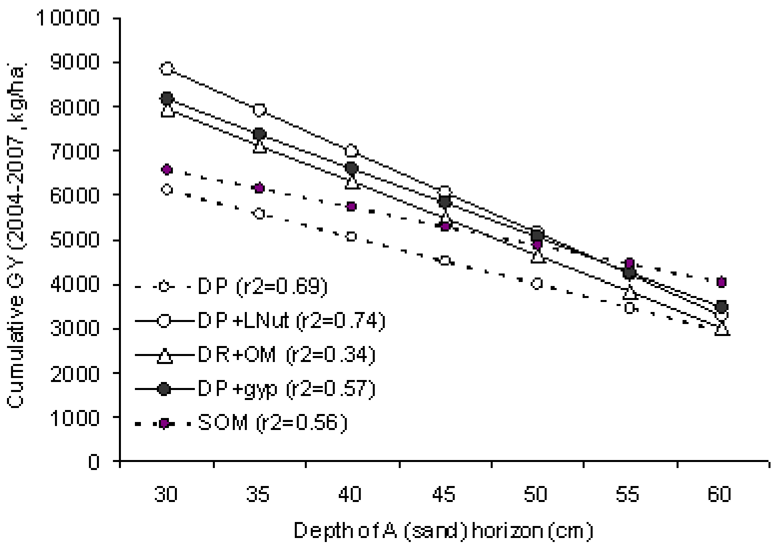

Figure 1 Regression line of cumulative grain yield and depth of A horizon (sand) across all the years of the study (2004-7) for each amelioration treatment (except DR plus all)

Largely, the treatment differences present at anthesis were reflected in final grain yields. In 2004 the lowest wheat yields occurred in the surface ameliorated and non-ameliorated treatments which were lower than the 'DR plus liquid nutrients or gypsum' treatments (Table 4b). Across the other crops in 2004 the non-ameliorated had lower yield than every 'DR plus' treatment in canola and the 'DR plus liquid nutrients' and 'DR plus all' treatments in lupin (data not shown). There were no treatment effects on wheat grain yield in 2005 (Table 4b), or for the other crops (data not shown). In 2006 wheat grain yield for the 'DR plus all' treatment was greater than for the non-ameliorated, surface ameliorated and the 'DR plus gypsum' treatments (Table 4b) whereas in canola the 'DR plus all' treatment was different from the non-ameliorated and surface ameliorated treatments only, and lupin yield was greatest for the surface amelioration treatment (data not shown). In 2007 grain yield of wheat in the 'DR plus liquid nutrients' treatment was greater than the surface ameliorated and non-ameliorated, but all other DR treatments were not significantly different (Table 4b). Lupin yields in 2007 were not different across all treatments and in canola the 'DR plus all' treatment yielded more than the non-ameliorated (data not shown).

Observations made during soil sampling for gravimetric moisture content determinations indicated that the depth to clay (ie the depth of the sandy A horizon) varied considerably across the site, ranging from 0.2 to 0.76 m. Regression analysis showed that yields were higher where the depth to clay was shallower in all treatments (Figure 1), except for the 'DR plus all' (data not shown). Separate slope analysis of data indicated that DR plus liquid nutrients gave greater responses on the shallower soils than all the other treatments, except DR plus all which did not show a relationship with depth to clay (data not shown).

Discussion and Conclusions

Grain yield responses of crops to a range of amelioration strategies interacted strongly with the depth to the clay horizon. Nevertheless some effects have persisted through to the fourth crop after subsoil amelioration. With the range of treatments applied, deep ripping (0.4 m) and associated placement of nutrients in fluid form appears to provide the more consistent crop responses, and the response is greater where the clay is closer to the surface. Differences in crop water use are not readily apparent from gravimetric measurements done at sowing and harvest, suggesting that either other soil chemical and physical properties may be responsible for the yield responses, or there may have been undetected differences in the pattern of water use within seasons. Among the crops studied, wheat was the most responsive to amelioration treatments, canola slightly less so, but lupin was generally found to be unresponsive to soil amelioration strategies at this site.

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