Amending multiple soil constraints throughout the profile on a layer basis

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Abstract

The effect of amending three soil layers from three sodic soil sites in the southern region (Mallee, Wimmera, and South Australian Mid North) were assessed using reconstituted one metre soil columns. Amendments including chicken manure pellets (CMP), gypsum and elemental sulfur were applied to individual soil layers in accordance with potential constraints as indicated by soil analysis. Wheat plants were grown to grain maturity. For all soils examined, treated columns either produced no benefit or resulted in a significant reduction in wheat growth and yield. Growth responses reflected water use and negative responses corresponded to poorer root growth in the bottom subsoil layer (50-100 cm). We suspect that the placement of high rates of nutrient rich CMP in this layer increased salinity and/or induced hypoxic conditions, which inhibited growth. This research indicates there is not a linear relationship between depth of amendment placement and plant performance.

Keywords

Amendment depth, sodic soils, root growth, hypoxia

Introduction

Crop productivity throughout much of Australia is limited by soils with physicochemical constraints (Adcock et al. 2007). These can include acidity, alkalinity, nutrient deficiencies, toxicities, salinity, dispersion, high bulk density, low porosity, and waterlogging. These constraints can occur throughout the soil profile, commonly in combination with each other (Rengasamy 2002). Soil sampling and testing can reveal the severity and location of constraints in the soil profile, with this knowledge targeted amelioration strategies can be implemented. This study aimed to test the hypotheses that soils with multiple constraints can be ameliorated with the placement of amendments specific to the constraint in a particular layer.

Methods

Three sodosol soils were collected from three cropping paddocks in three layers (0-20, 20-60, 60-100 cm) from the southern region of Victoria: Wimmera (Wonwondah) 36.88 °S, 142.20 °E; Mallee (Birchip), 35.97 °S, 142.82 °E; and the South Australian mid north (Marrabel), 34.12 °S, 138.88 °E. Each soil layer was air dried, crushed and passed through a 5 mm sieve and analysed for their chemical and physical properties.

Table 1. Identified soil constraints for each site and soil layer

Depth (cm)	Birchip	Marrabel	Wonwondah
0-20		K deficiency	Acidity K deficiency Cu deficiency
20-50	Sodicity Zn deficiency Alkalinity Boron toxicity	Sodicity Zn deficiency	Sodicity K deficiency
50-100	Sodicity Alkalinity Zn deficiency Boron toxicity Salinity	Sodicity Alkalinity Zn deficiency	Sodicity Alkalinity

Soils were reconstituted in 15 cm diameter x 105 cm long PVC pipe to the following depths 0-20, 20-50 and 50-100 cm. The bottom two layers of soil were gradually moistened in a portable concrete mixer to 70 % of plant available water (PAW), amendments were added to the soil prior to mixing. This moistened soil was then gradually packed in pipe using a plunger to achieve consistent bulk densities for each soil type. The top layer of soil was reconstituted with air dry soil then gradually moistened by surface watering until 70 % PAW was achieved. A basal application of DAP fertiliser (11 kg P/ha; 10 kg N/ha) was applied to the topsoil.

Experiments were conducted in a glasshouse set to 14 hour days at 24 ºC and 10 hour nights at 12 ºC. Six pre-germinated seeds of wheat (*Triticum aestivum* cv. Schomburgk) were sown per column and thinned to three plants after emergence. Columns were kept moist while seedlings established then watered to weight twice a week (70 % PAW) from seedling to booting stages GS 14-47,after which time watering was stopped to encourage root growth in the subsoil. Ammonium nitrate (equivalent to 30 kg/ha N) was applied to all columns at 24 and 38 days.

Treatments

Treatments were customised for each soil layer at each site depending on the results of soil analysis. While deficiencies, toxicities and pH values varied between sites, all subsoils were highly sodic. Treated columns of the Birchip soil were sown with a boron tolerant near isogenic line of cv. Schomburgk. Table 1 summarises individual soil treatments for each site and depth.

Table 2. Treatments and rates, calculated on an area basis, for each site and soil layer

Depth (cm)	Birchip	(t/ha)	Marrabel	(t/ha)	Wonwondah	(t/ha)
0-20	Manure Pellets	1	Manure Pellets	1	Manure Pellets	1
			Potassium Sulphate	0.05 K	Potassium Sulphate	0.05 K
					Lime	3
					Copper Sulphate	0.005 Cu
20-50	Manure Pellets	5	Manure Pellets	5	Manure Pellets	5
	Gypsum	4	Gypsum	4	Gypsum	4
	Sulphur	0.4	Potassium Sulphate	0.05 K	Potassium Sulphate	0.05 K
	Zinc Sulphate	0.005 Zn	Zinc Sulphate	0.005 Zn		
50-100	Manure Pellets	14	Manure Pellets	14	Manure Pellets	14
	Gypsum	4	Gypsum	4	Gypsum	4
	Sulphur	1.2	Sulphur	1.2	Sulphur	1.2
	Zinc Sulphate	0.005 Zn	Zinc Sulphate	0.005 Zn		

Four replicates of control and treated columns were arranged in randomised rows, for each soil type, in the glasshouse.

Measurements and data analysis

Total evapotranspiration was recorded as the cumulative mass of water added to each column during the experiment. Plant height, tiller number and head number were measured at grain maturity. After harvest, shoots were placed in a 40 ºC oven for 48 hrs and total shoot dry weight was recorded then threshed for grain yield and 1000 seed weight. Soils were removed from the PVC pipe and soil layers separated. Maximum root depth was determined by breaking the core from the base until roots were visible. Subsamples of soil from each layer were measured for gravimetric water content, a second subsample was also taken for chemical analysis including electrical conductivity ($EC_{1:5}$), pH and exchangeable sodium percentage (ESP). Roots were then washed from the soil, oven dried at 65 ºC for 48 hrs and then weighed. Two sample t-tests were used to analyse the difference between control and treated columns with Genstat (18th version; VSNI Hertfordshire, UK) software.

Results

For all soils examined, treated columns either produced no effect or resulted in a significant ($P < 0.05$) reduction in plant growth and yield (Figure 1). Growth responses reflected water use (Figure 2) and negative responses generally corresponded to poorer root growth in the bottom subsoil layer (Figure 3). Interestingly, amendments did however produce significant increases in root growth in the middle soil layer (20-50 cm) in both the Marrabel and Wonwondah soils. Soil amendment did not produce any clear differences in the soil pH suggesting that S oxidation was not successful in reducing pH. Soil electrical conductivity was significantly increased by the application of amendments in most soil depths measured (Table 2). Interestingly soil ESP in the subsoil (50-100 cm) was not altered by amendment with gypsum, elemental S and application of the CMP, suggesting that the simultaneous application of these amendments were not effective in improving soil structure, at least in the relatively short time frame (< 6 months).

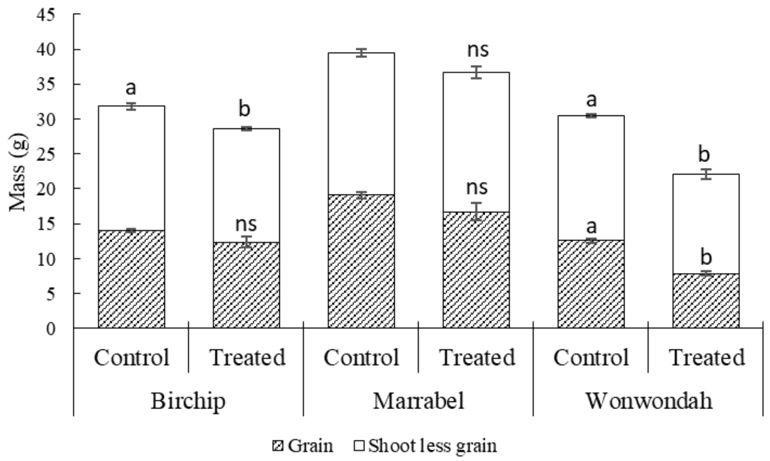

Figure 1. Shoot dry weights of three plants per column including grain yield component, error bars indicate SEM, different letters indicate a significant difference for each soil type, (2 sample t-test).

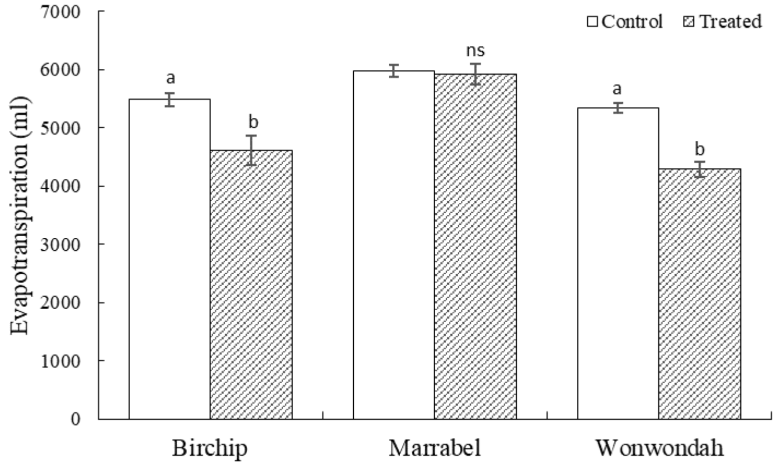

Figure 2. Total evapotranspiration per column, error bars indicate SEM, different letters indicate a significant difference for each soil type, (2 sample t-test).

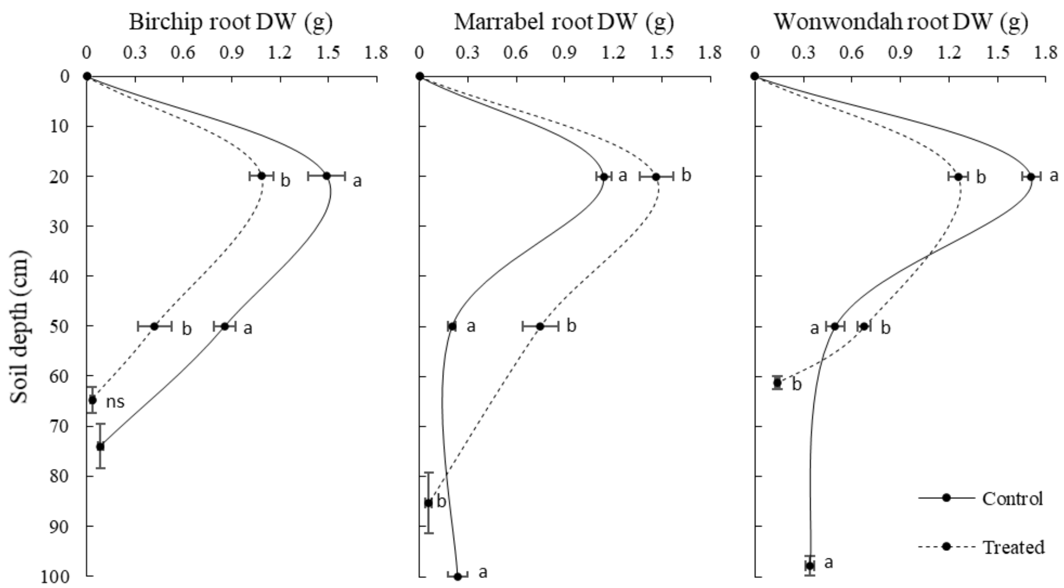

Figure 3. Root dry weights from three soil layers 0-20, 20-50, 50-100 cm and maximum root depth, horizontal error bars indicate SEM of dry weights, vertical error bars indicate SEM of maximum root depth, different letters indicate a significant difference for each soil layer, (2 sample t-test).

Table 3. Soil electrical conductivity for control and treated columns, (2 sample t-test).

Soil	Depth (cm)	$EC_{1:5}$ Control (dS/m)	$EC_{1:5}$ Treated (dS/m)	P value
Birchip	0-20	0.089	0.140	0.059
	20-50	0.393	0.628	0.052
	50-100	1.366	1.505	0.001
Marrabel	0-20	0.212	0.161	NS
	20-50	0.130	0.378	0.010
	50-100	0.360	0.444	<0.001
Wonwondah	0-20	0.086	0.103	0.042
	20-50	0.198	0.314	<0.001
	50-100	0.550	0.648	0.001

Conclusion

Results in this experiment contrast with observations seen in the field, where subsoil amelioration trials with the same amendments have produced significant positive benefits (Gill et al. 2009). A major difference of this study was the untested placement of amendments below 50 cm, although not feasible in the field this was the depth with the most severe constraints. Root growth below this depth was significantly reduced in treated columns across all soil types. With a dry finish in this experiment, access to the water stored at this depth proved key to plant performance. We suspect that the high rate of chicken manure pellets required to ameliorate this layer may have created hypoxic conditions by stimulating microbial activity, consuming the available oxygen in an environment of low porosity sodic subsoils. Interestingly root growth was improved in the middle layer (20-50 cm) for two of the treated soils, the same depth achievable for amendment placement in the field. Treated soils had higher electrical conductivity relative to untreated soils, which may have contributed to a reduction in root growth. The effect of salinity on root growth was particularly evident in the Birchip subsoil where both control and treated soils had high EC levels (>1.3 dS/m), compared to more moderate levels in the other subsoils.

It appears the short-term effectiveness of manure soil amendments on root growth is dependent on soil conditions which change down the profile, particularly porosity and oxygen concentration (Jassogne et al. 2007; Cook et al. 2013). In an environment of low porosity and available oxygen, often found in deep sodic subsoils (Rengasamy and Olsson 1991), microbial activity, stimulated by manure amendments, will compete with plant roots for available oxygen (Cook et al. 2013). Further research is required into the relationship between redox conditions in sodic subsoils and amelioration with animal manure amendments.

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