MECHANISTIC UNDERSTANDING OF THE MODE OF ACTION OF NOVEL SOIL REENGINEERING METHODS FOR COMPLEX CHEMICAL AND PHYSICAL CONSTRAINTS.

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PROJECT PARTNERS

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KEY POINTS

Soils often exhibit multiple constraints that limit their productivity. Collaborating staff identified a local soil that had regularly underperforming crop production. Initial soil analyses identified sodicity and subsoil salinity and alkalinity to be the likely constraints to production.

Soil was taken from the field in layers 0-10, 10-50, 50-100cm to be used in glasshouse experiments to quantify the production loss due to the constraints and record the impact on soil properties following application of a range of rates of different amendments.

Based on results of experiments in the study, a final series of glasshouse experiments have been initiated which ain to understand the mechanism of amelioration of potential soil amendments.

It appears that whilst some improvements in soil properties are possible with amendments, it may be impractical to overcome the inherent constraints of deep subsoil.

Background

Australian soils often exhibit multiple constraints to plant productivity. Soil sodicity, acidity, nutrient deficiencies or toxicities and poor structure limit root growth and therefore decrease the plant's ability to efficiently exploit soil water and nutrient reserves to achieve maximum yield potentials. Historically, attempts to address these constraints have been conducted via research that addresses constraints individually. Each problem has an industry "best practice" solution but when these are then applied in combination to handle multiple constraints, the input costs and practicality of application often become barriers to adoption and the constraint remains. An opportunity exists to introduce novel amelioration methods that seek to address multiple constraints with a single application.

Six grower groups have identified priority soil constraints and soils to be included in this project. Using predominantly glasshouse studies, the effectiveness of novel amelioration methods will be evaluated in these soils, relative to the current industry best practice methods. This work will therefore set an unconstrained benchmark of soil performance and will identify successful options for future field studies.

The project will determine the mode of action of the amelioration methods enabling CRC researchers to optimise source material and/or the development of new products to improve efficiency of amelioration and will also inform effective application technologies. Many currently used surface applied ameliorants have little effect lower in the profile where subsoils constraints exist. This project will quantify the benefit of ameliorating these constraints. The data produced during these studies will input into the development of Decision Support Systems produced within the CRC. Therefore the project services researchers, grower groups and their members and possible industry stakeholders interested in development of new products.

Method

The project is conducted in collaboration with six grower groups. Each group identified underperforming soils within their region. The project team then sampled the sites for initial detailed chemical analysis. Based on expert information from growers, advisors and collaborators "best bet" treatments were designed for testing in column studies against an untreated control. The comparison in yield between these two treatments for each soil will quantify the magnitude of the constraints.

Running in parallel to the plant column studies is a series of incubation experiments. This set of experiments tests the changes to soil conditions for a range of rates and combinations of possible soil amendments. High preforming treatments have been identified and are included in a more detailed mechanistic study recently initiated.

Soil

The soil identified by Riverine Plains Inc was located near Oaklands. The grower's experience was that the soil had poor water infiltration and poor root penetration into the subsoil. This meant that crops finished early in springs that had low rainfall, however, if small but regular rain occurred crop performance was good. These observations are consistent with poor root growth due to a subsoil layer that is impenetrable by roots. Such subsoil layers can be created by compaction (stock or machinery) or by soil chemical problems such as sodicity or low (less than 2) calcium to magnesium ratio.

Examination of the soil chemistry confirmed sodicity is a problem in the soil (Table 1). The exchangeable sodium percentage (ESP) was greater than 6% in all sampled layers. In the subsoil the ESP was greater than 16% and dispersed when aggregates were placed in water. Because the ESP was so high, the soil pH was greater than pHCa 8 and pHw 9 below 50 cm profile depth. At such high pH, carbonates form and micronutrients (eg zinc, iron and copper) often become deficient and phosphate becomes less available, this increases the nutritional importance of the topsoil. Therefore, the grower's observations relating to crop performance are the product of a sodic subsoil that limits water infiltration causing waterlogging in winter and poor root exploration of the subsoil due to high

Table 1: Soil Chemical properties Oaklands

Depth (cm)	0-10	10-50	50-100
pH (1:5) (Water)	5.9	**8.2**	**9.2**
pH (1:5((CaCl2)	5.3	**6.7**	**8.1**
EC (1:5) (dS/m)	0.3	0.1	0.215
Chloride (ppm)	86	22	16.5
Nitrate Nitrogen (ppm)	81	2.9	2.45
Ammonium Nitrogen (ppm)	15	1.1	0.73
Phosphorus – Colwell (ppm)	66	5.2	<5.0
Phosphorus Buffer Index - Colwell	58	96	120
Copper (DTPA) (ppm)	2.6	2.3	1.6
Iron (DTPA) (ppm)	100	30	13.5
Manganese (DTPA) (ppm)	78	22	3.9
Zinc (DTPA) (ppm)	0.97	0.1	0.1
Boron (ppm)	1.4	2.9	5.3
Sulphur (KCl40) (ppm)	36	11.7	14
Organic Carbon (% w/w)	1.44	0.4	0.24
Calcium (cmol+/kg)	8.5	9.2	10
Potassium (cmol+/kg)	1.7	0.7	0.8
Magnesium (cmol+/kg)	6.2	11.7	13.5
Sodium (cmol+/kg)	1.4	4.3	5
CEC (cmol+/kg)	18	26	29.5
ESP %	**7.8**	**16.3**	**17**
Ca:Mg	**1.4**	**0.8**	**0.7**

Bold values identify potential limitations to plant growth
ppm = parts per million = mg/kg = ug/g

pH and poor structure associated with sodicity. These factors explain the poor root performance and water infiltration problems experienced.

It should be noted that the major soil constraints are present well below the normal depth of commercial soil testing 0-10 cm or 10-20 cm. In-field examination of deep soil cores with simple tests: colorimetric pH field kits, emersion dispersion testing for aggregate stability and EC measurement with hand-held EC meter, would be suitable to identify the main soil constraints evident in the soil. Also, because the depth of the major limitations occur below 50 cm, the effectiveness of surface application of amendments may be questionable.

Soil amendments

To quantify the magnitude of soil constraints on plant yield, soil amendments were added directly to the layer needing amelioration and repacked to form soil columns. The treatment for the Oaklands soil includes application of chicken manure pellets, gypsum, elemental sulfur and pea hay pellets (Table 2). Chicken manure was selected to provide a source of organic matter for soil biology and nutrient release for plant growth. Pea hay is also a source of organic matter but with fewer nutrients than chicken manure. Organic matter with less nutrients may provide benefits to structure and water retention without causes excessive plant growth that growing season rainfall may not be able to sustain. Gypsum is the current best practice ameliorant for sodic soils. Elemental sulfur (S) was included to decrease soil pH in the alkaline subsoil. Elemental S is converted to plant available sulfate by the action of soil microbes (Thiobacillus) in a process that also acidifies the soil and therefore it can be used to decrease soil pH to a range that is more suitable for plant growth and availability of micronutrients.

Soil columns are maintained at 70% of field capacity until anthesis after which time the plants exist on their ability to utilise subsoil moisture. Grain harvest, above ground biomass and yield components will be recorded after harvest.

This experiment sets the boundary for what is the theoretically possible yield produced from the soils if amendments are made to the soil to overcome constraints. A secondary experiment was conducted to determine rate and combination effects of treatments in incubations conducted in the absence of plants.

Results

Column Studies

The addition of amendments did not result in increased plant performance. The wheat grown on amended soil was not significantly greater than the untreated control in terms of any measured plant parameter (Table 3). Within the soil, the amendment also did not result in significantly different root biomass than the control, nor did it result in any difference in soil moisture. Root growth restricted to the 0-10 cm layer.

The addition of amendments made no statistically significant change to the salinity of the soil in any layer (Table 4). Amendment caused soil pH to increase in the 0-10 cm layer, possibly due to alkalinity of the organic matter added and subsequent microbial mineralisation. The subsoil layers receiving elemental S experienced pH decreases of 0.5 and 0.2 units in the 10-50 and 50-100 cm layers respectively, when measured in water.

Table 2: Soil treatment for column study of the Oaklands soil

Soil Layer	Treatment	Reason
Topsoil (0-10 cm)	• Chicken Manure pellet (1 t/ha)	• Nutrient release, enhance soil biology, improve structure
Subsoil 1 (10-50 cm)	• Gypsum (5 t/ha) • Elemental sulfur (1600 kg/ha) • Chicken Manure pellet (5 t/ha) • Pea Hay Pellets (10 t/ha)	• Decrease sodicity • Decrease pH (from 7 to 6) • Nutrient release, improve structure, enhance soil biology
Subsoil 2 (50-100 cm)	• Elemental sulfur (1600 kg/ha) • Chicken Manure pellet (7 t/ha) • Pea Hay Pellets (10 t/ha)	• Decrease pH (from 8.6 to 6.5) • Nutrient release, improve structure, enhance soil biology • Improve structure, enhance soil biology

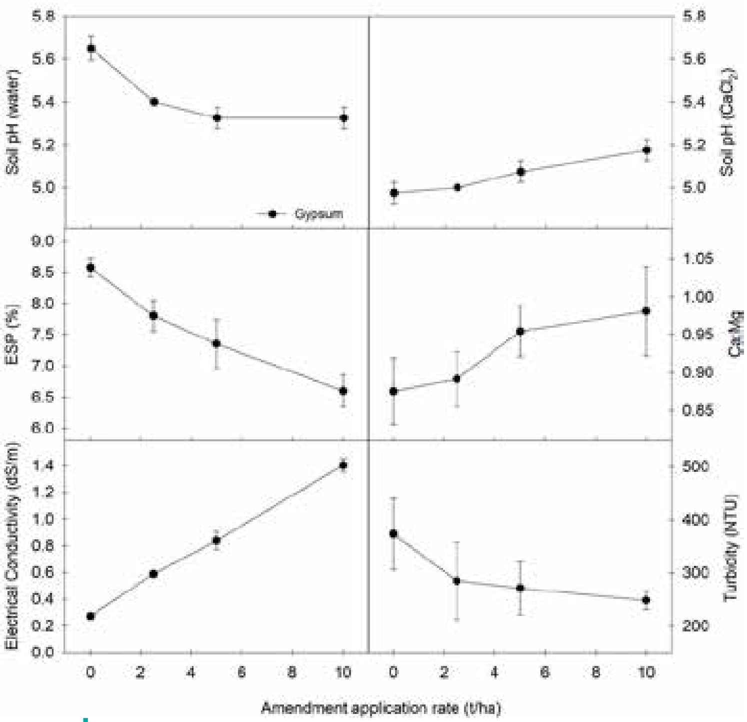
Table 3: Average shoot dry weight, grain yield, Harvest Index (HI), tiller number, number of heads and seed weight for each soil type and treatment (control and treated) (ns=not significant)

Treatment	Shoot Dry Weight (g/core)	Grain Yield (g/core)	Harvest Index	Tiller No.	Head No.	Total water use (L)
Control	9.07	4.13	0.46	5.75	5.75	1.87
Treated	11.85	4.69	0.40	7.00	7.00	1.68
l.s.d. (0.05)	ns	ns	ns	ns	ns	ns

Table 4: Soil salinity (dS/m) and soil pHCa and pHwater measured after harvest for control and amendment treated soils. Lsd was calculated at p<0.05. ns denoted no significant difference, *ns denotes significance at p<0.10.

	Soil salinity (dS/m)			Soil pHCa (1:5 CaCl2)			Soil pHw (1:5 water)		
depth (cm)	Control	Amended	*l.s.d.*	Control	Amended	*l.s.d.*	Control	Amended	*l.s.d.*
0-10	0.42	0.61	ns	5.45	5.85	0.03	6.01	6.28	ns
10-50	0.16	0.21	ns	7.02	6.79	*ns	8.37	7.87	0.16
50-100	0.25	0.34	ns	7.94	7.92	ns	9.35	9.14	0.05

Figure 1: Soil chemistry changes in the Oaklands topsoil (0-10 cm) due to amendment with Gypsum (0, 2.5, 5, 10 t/ha). Vertical bars are standard deviation of the mean (n=4).



Incubation Studies

In the laboratory incubations, which did not include growing plants, the application of gypsum to the topsoil (0-10 cm) of the Oaklands soil decreased ESP from 8.5 to 6.5% from the control to 10 t/ha gypsum, respectively (Figure 1). This change was also associated with a slight increasing trend in Ca:Mg however the maximum Ca:Mg remained less than 2 which would suggest that aggregate stability may still be compromised. However, the electrical conductivity (EC) also increased with increasing rate of gypsum application and this salt would need to be leach so as to not impair root growth when applied in the field. The combined influence of decreased ESP and increasing EC was a decreasing trend in turbidity representing improved microaggregate stability as gypsum rate increased.

Within the subsoil layers of the Oaklands soil, application of gypsum also increased EC and Ca:Mg ratio causing a decrease in ESP and turbidity.

Rate responses to the addition of S in the 10-50cm layer of the Oaklands soil was evident in the sulfate concentration, soil pH (water and CaCl2) indicating that microbial oxidation of S had occurred. The production of sulfate ions increasing electrical conductivity which may also aid flocculation, although gypsum was more effective in decreasing turbidity. The application of S to the deepest subsoil layer of the Oaklands soil did not change soil properties possibly due to a lack of the S oxidising bacteria, Thiobacillus sp., in that layer.

Conclusion

The main constraint of the Oaklands soil appears to be the sodicity and alkalinity of the subsoil (below 10 cm). Whilst gypsum was successful in decreasing the dispersion caused by sodicity, it's use did not result in greater plant performance in the column study owing to the hostile subsoil below 10 cm.

The use of elemental sulfur to lower pH was effective in the upper subsoil (10-50 cm) but largely ineffective in soil below 50 cm most probably due to a lack of the microbiology required to transform elemental S to plant available sulfate and the acidity that is required to decrease pH. Regardless, root growth and plan performance was not improved with amendments applied in this experiment. The alkalinity and structural constraints of this hostile subsoil remain challenges to overcome.

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