17

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# Mechanistic understanding of the mode of action of novel soil reengineering methods for complex chemical and physical constraints.


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**Trial Site Location** 'Gladstone', Trungley Hall

## Introduction

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, 10-40, 40-100 cm to be used in glasshouse experiments to i) quantify the production loss due to the constraints and ii) understand the mechanism of amelioration of potential soil amendments.


**Project Partners**

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**Funding Partner**

Soil CRC — Performance through collaboration

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## 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.

## Strategy

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 will be investigated in more detailed mechanistic studies during 2020.

# Soil

The soil identified by FarmLink is located near Trungley Hall. The grower's experience was that the soil became easily waterlogged in winter, 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 to water and 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. The exchangeable sodium percentage (ESP) was greater than 6% in all sampled layers. In the soil deeper than 40 cm the ESP was almost 30% and dispersed when aggregates were placed in water. Because the ESP was so high, the soil pH was increased to greater than pH 8.5 below 40 cm profile depth. At such high pH, micronutrients (eg zinc and copper) often become deficient and phosphate becomes less available. The soil also exhibited high electrical conductivity (EC) of 0.4 dS/m in a 1:5 soil :water extract and very high chloride concentrations (240 ppm) (Table 1). These data are indicative of saline conditions which would both inhibit root growth and water held in the soil would be less available for plant uptake. 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 salinity, high pH and poor structure associated with sodicity. Even if roots could get to depth, the salinity would make any soil water harder for plants to use. These factors explain the crops drying off in dry springs. In seasons where regular small rainfall events occur, the plant roots in the surface 40 cm are able to use that water which is replenished by the next rainfall event. That is, the plants do not need to access water from deeper in the profile.

**Table 1. Soil Chemical properties Trungley Hall soil**

| Depth (cm) | 0-10 | 10-40 | 40-100 |
|---|---|---|---|
| pH (1:5) (Water) | 6.5 | 8.6 | 9.55 |
| pH (1:5( ($CaCl_2$) | 5.6 | 7.2 | 8.6 |
| EC (1:5) (dS/m) | 0.14 | 0.12 | 0.43 |
| Chloride (ppm) | 27 | 30 | 205 |
| Nitrate Nitrogen (ppm) | 20 | 8.25 | 2.1 |
| Ammonium Nitrogen (ppm) | 5 | 1.55 | 0.92 |
| Phosphorus – Colwell (ppm) | 50 | 9.25 | 7.3 |
| Phosphorus Buffer Index - Colwell | 47 | 65.5 | 60 |
| Copper (DTPA) (ppm) | 0.48 | 0.63 | 0.84 |
| Iron (DTPA) (ppm) | 77 | 25.5 | 10.7 |
| Manganese (DTPA) (ppm) | 15 | 4.55 | 2.15 |
| Zinc (DTPA) (ppm) | 1 | 0.625 | 0.13 |
| Boron (ppm) | 0.53 | 1.215 | 1.85 |
| Sulphur ($KCl_{40}$) (ppm) | 34 | 9.7 | 51 |
| Organic Carbon (% w/w) | 0.76 | 0.275 | <0.15 |
| Calcium (cmol+/kg) | 6 | 6 | 5.75 |
| Potassium (cmol+/kg) | 0.74 | 0.46 | 0.70 |
| Magnesium (cmol+/kg) | 2.2 | 7.1 | 10.0 |
| Sodium (cmol+/kg) | 1 | 3.15 | 7 |
| CEC (cmol+/kg) | 10.0 | 16.7 | 23.5 |
| ESP % | 10 | 19 | 29.5 |
| Ca:Mg | 2.7 | 0.8 | 0.6 |

ppm = parts per million = mg/kg = ug/g

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 40 cm, the effectiveness of surface application of amendments may be questionable.

## Soil amendments

In the soil column experiments, which aim to quantify the magnitude of soil constraints on plant yield, the soil amendments have been added directly to the layer needing amelioration. The treatment for the Trungley Hall soil includes application of chicken manure pellets, gypsum, elemental sulfur and pea hay pellets (Table 2). Chicken manure will provide a source of organic matter for soil biology and will release nutrients for plant growth. Pea hay is also a source of organic matter but with fewer nutrients than chicken manure. Gypsum is the current best practice ameliorant for sodic soils however as it is a salt (calcium sulfate) its use in saline soils should be limited. Elemental sulfur is converted to plant available sulfate by the action of soil microbes 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 90% 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. Questions of the optimal rate and combination of treatments are being addressed in a parallel experiment being conducted in 2020.

**Table 2. Soil treatment for column study of the Trungley Hall soil.**

| Soil layer | Treatment | Reason |
|---|---|---|
| Topsoil (0-10 cm) | • Chicken Manure pellet (1 t/ha) | • Nutrient release, enhance soil biology, improve structure |
| Subsoil 1 (10-40 cm) | • Gypsum (3 t/ha) | • decrease sodicity |
| | • Elemental sulfur (300 kg/ha) | • Decrease pH (from 7 to 6) |
| | • Chicken Manure pellet (5 t/ha) | • Nutrient release, improve structure, enhance soil biology |
| Subsoil 2 (40-100 cm) | • Elemental sulfur (1200 kg/ha) | • Decrease pH (from 8.6 to 6.5) |
| | • Chicken Manure pellet (7 t/ha) | • Nutrient release, improve structure, enhance soil biology |
| | • Pea Hay Pellets (7 t/ha) | • Improve structure, enhance soil biology |
| | (no gypsum used due to salinity) | |


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