THE EFFECTS OF GREEN MANURE ON SOIL STRUCTURE IN CALCAREOUS SODIC AND NON-SODIC SOILS

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SUMMARY

Inappropriate soil management has resulted in structural degradation of red-brown earths in southern Australia. Decades of continuous cropping have caused some red brown earths of South Australia to have a weakly structured surface horizon that is prone to further deterioration under further cultivation and exposure. Further, accumulation of sodium in some sub-soil layers has exacerbated the structural problems due to damaging effects of sodicity. Dense subsoils have few macropores, restricting profile drainage and depth of wetting. A proper management system to improve and maintain soil structure while concurrently allowing opportunities for cropping is necessary to sustain the productivity in these soils.

It is well known that organic matter is essential for the improvement of soil structure. Addition of organic residues has been shown to improve the structure of non-sodic red brown earths. Clay swelling and dispersion are the major factors affecting structural degradation in sodic soils. Most of the sodic red brown earths in Australia are highly alkaline and also contain lime ($CaCO_3$) in an insoluble form. Dissolution of this lime will help in generating Ca ions in solution to provide electrolyte effect in flocculating the soil clays and exchanging Na from the clay surfaces. Decomposition of organic matter can produce CO_2 and organic acids which may help in dissolving the native lime. Therefore, the aim of the present study was to investigate the efficiency of green manuring to ameliorate the degraded soil structure both in non-sodic and calcareous sodic soils.

A non-sodic red-brown earth from Urrbrae (0 - 15 cm) and two calcareous sodic soils of the B-horizons (15 - 30 cm) from Strathalbyn and Two Wells were used in this study. All experiments were carried out in glasshouse conditions in pots containing 1 kg soil. The non-sodic soils from Urrbrae rotation plots (maintained over > 50 years duration) were taken from the treatments wheat/fallow, continuous wheat, and permanent pasture. In the sodic soils, the effect of green manure was examined with and without the addition of gypsum, while for the surface non-sodic soils, green manure only was added.

Because green manuring requires the addition of a considerable amount (mass) of plant material, plants to be used had to be selected largely on this basis. Pilot experiments were thus conducted to determine the production of biomass from the following green manure plants: common vetch *(Vicia sativa)*, alfalfa *(Medicago sativa)*, cowpea *(Vigna sinensis)* and white clover *(Trifolium repens)* as influenced by soils with different previous management histories. Without its breakdown by microorganisms, the incorporated organic matter is of little value to the soil. Because succulence is related to the efficiency of plant matter decomposition, estimates of the quality of green manure produced were carried out via a subjective index of succulence. Of the above mentioned plant species, the common vetch was found to be the most succulent, whilst achieving more biomass in these soils.

In the main experiments, common vetch was chosen as a green manure plant. For the sodic soils with gypsum treatment, gypsum (20 t/ha) was added initially to ameliorate sodicity, where four cycles of wetting and drying allowed exchange of Na^+ with subsequent leaching. Green manure crops were then planted in the sodic soils. After the growth and harvesting, soils, both sodic and non-sodic, were incubated with green manure (20 t/ha equivalent) by incorporating fresh plant material throughout the soil mass in the pots at 25^o C in a sealed cabinet under the following water regimes: (1) alternate wet and dry, (2) field capacity (3) 80% field capacity.

Soil structural stability of non-sodic soils was assessed by wet sieving, water retention at -100 kPa potential and saturated hydraulic conductivity (K_S). These measurements were chosen for the following reasons: (1) Organic materials in general have been observed to maintain pore openings in soils by holding aggregates intact and thereby reducing dispersion which results in the filling of small pores with clay particles. (2)The stability of aggregates to wetting helps to determine the speed at which water flows through a column of soil. (3) The amount of water retained at various potentials depend on texture and structural characteristics of a soil, indicating that at the lower potentials a fine texture and good structure increases the amount of water retained by soils and available for plant use.

In sodic soils, spontaneous and mechanical dislocation of clay particles facilitate their mobility in the soil solution, thereby blocking pores and microchannels. Low permeability in clayey soils such as sodic subsoils, is the main problem. Additional measurements for sodic soils thus included clay dispersion, electrophoretic mobility of clays and particle size analysis.

In non-sodic Urrbrae soils, the improvements due to green manuring on water stable macroaggregation (WSMA), and water retention at -100 kPa potential were not statistically significant. However, these measurements showed a significant soil structural improvement in the Urrbrae soil which had previously been under permanent pasture. Further, green manure when incubated at 80% field capacity substantially improved the structural features in this soil. Saturated hydraulic conductivity values were improved by green manuring in all soils under all conditions due to the increasing trend in macroaggregation.

In sodic soils, generally, the improvements in soil structure was in the following order of treatments: gypsum + green manure > gypsum > green manure > control. The K_S increased in the same order. The soils incubated at 80% field capacity showed highest increases. The differences in water retention and water stable macroaggregation measurements were not statistically significant. In sodic soils, green manure increased the cations Ca^{++} and Mg^{++} in solution and the electrical conductivity, and pH was reduced. A marked decrease in pH was observed in Strathalbyn soil containing 15% $CaCO_3$, due to the dissolution of native $CaCO_3$ by the protons and CO_2 produced by green manure. The combination of these changes reduced the sodium absorption ratio (SAR) of these soils considerably.

Green manure did not improve macroaggregation in sodic soils, although in non-sodic soils, a slight improvement was observed. However, in sodic soils, stabilisation occurred at the microstructure level. The average size of dispersed materials in control soils were < 0.5µm, whereas after green manuring, the average particle size increased up to 30µm. The products of decomposition of green manure were both organic compounds and the release of Ca^{++}, which aggregated the clay particles and stabilized the domains. Thus, the effect of green manure on sodic soils containing $CaCO_3$ markedly differs from non-sodic soils. The results of this experiment promise the use of green manure as an economic ameliorant for sodic soils with $CaCO_3$ and high pH.

DECLARATION

This disssertation contains no material which has been accepted for the award of any other degree or diploma in any University. To the best of the author's knowledge and belief, this dissertation contains no material previously published or written by another person, except where due reference is made in the text.

I consent to this dissertation being made available for photocopying and loan.

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M. A. Harris

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