DECOMPOSITION OF ADDED ORGANIC MATERIAL IN SALT-AFFECTED SOILS

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INTRODUCTION

Large areas of Australia are affected by salinity, sodicity, or both, with the area predicted to increase in the future (NLWRA 2001). Soil organic carbon (SOC) levels in these degraded areas are expected to be low due to decreasing levels of biomass accumulation and declining health of vegetation already established compared to non-degraded areas. However, carbon (C) stocks and fluxes in salt-affected areas are not known, despite the large areal extent affected, and are classified as abandoned agricultural land by the Australian Greenhouse Office (AGO 2003). The importance of maintaining high levels of soil organic matter (SOM), and hence high levels of SOC has been well established and includes improved soil structure and aggregation (Oades 1988, Tisdell & Oades 1982), higher nutrient levels and greater cation exchange capacity (von Lutzow *et al.* 2002). The effects of salinity and sodicity on the decomposition of SOM can be direct: by influencing microbial organisms which form the soil microbial biomass (SMB), the size of the microbial population and the amount of substrate available; or, indirect via the dispersion or flocculation of inorganic colloids which can influence the availability of substrate.

SOM as a whole exhibits a continuum of decomposition and turnover times and has been traditionally partitioned into discrete (e.g., active, slow and recalcitrant) pools according to the time it takes for turnover (Jenkinson & Raynor 1977). The SMB is frequently partitioned into the active pool due to its rapid turnover time. Whilst the SMB usually only comprises of 1-5% of the total SOC (Sparling 1992), microbially mediated processes are essential in any functioning terrestrial ecosystem as all organic matter passes through the SMB before its redistribution to other pools in the soil. Thus the SMB controls turnover and mineralisation rates of organic substrates in the soil (Killham 1994). The SMB also provides critical functions for plant production in the ecosystem, which include: being a labile source of C, nitrogen (N), phosphorus (P) and sulphur (S); a sink for C, N, P and S; and, an agent of nutrient transformation (Dalal 1998). As the living component of SOM, the SMB responds rapidly to variations in environment and changes to management practices. Therefore trends in the SMB can act as early indicators to SOM dynamics, before such changes can be detected by chemical analysis (Powlson & Brookes 1987).

Previous studies on the effects of salts on microbial processes have yielded contradictory results. Increases in salinity have been shown to decrease soil respiration rates and the SMB (e.g., Laura 1973, Laura 1976, Pathak & Rao 1998) and was attributed to stresses placed on the microbial population due to changes in osmotic potential (Batra & Manna 1997). Similarly, increasing sodicity levels have had slight negative correlations with C mineralisation (Nelson *et al.* 1997), and caused a decrease in the amount of SMB (Chander *et al.* 1994). Conversely, increasing sodicity has increased C mineralisation, possibly due to increased solubilisation of organic matter (Nelson *et al.* 1996). Gypsum ($CaSO_4.2H_2O$) is the most commonly used ameliorant where soils are sodic, or saline-sodic, as it provides a source of Ca^{2+} ions to displace Na^+ ions and increase the electrolyte concentration, thus improving permeability and soil structure (Rengasamy *et al.* 1984). Limited studies have been undertaken on the effects of gypsum on microbial processes in soils. One such study found that, in the short term, the addition of gypsum caused a decrease in microbial activity, but tended to increase SMB, with these effects attributed to changes in the soil chemical environment (Carter 1986). However, results are far from conclusive.

Previous results have shown that very low levels of SMB and soil respiration rates have been found in soils sampled from scalded areas, both with and without gypsum amendment (Wong *et al.* 2004b). These low rates have been attributed to low levels of SOC, which provide little substrate for decomposition and hence low levels of microbial activity. This current study aims to determine over a 12 week period the behaviour of the labile C pool in scalded soils ameliorated with gypsum and organic material. By providing additional organic material which the microbial biomass will rapidly decompose, C fluxes in these degraded soils will be greatly accentuated.

In: Roach I.C. ed. 2005. *Regolith 2005 – Ten Years of CRC LEME.* CRC LEME, pp. 333-337.

MATERIALS AND METHODS

Soil

The soil used for the study was collected from two salt-affected profiles. The first profile was a Yellow Sodosol (Isbell 1996) from a property, "Tarcoola" in Bevendale, approximately 40 km south west of Crookwell (34° 30' 45" S, 149° 05' 00" E), in the Southern Tablelands region of NSW. The second profile was a Red Kurosol (Isbell 1996), located on a property "Avoca," approximately 20 km north west of Young (34° 14' 52.31" S, 148° 24' 37.02" E.) in the South West Slopes region of NSW. Disturbed soil samples and bulk density cores were taken from 0-5, 5-10, 10-20, 20-30, and 30-50 cm depths, and transported back to the laboratory for analysis.

Sample Preparation

Samples were stored at 4°C prior to analysis. Bulk density cores were subsampled for moisture content and oven dried at 105°C for 24 hours. Plant material was added to all samples in the form of kangaroo grass (*Themeda australis*). Following collection, the plant material was allowed to air dry for 72 hours, and coarsely ground with the use of a coffee grinder. Soils that were used for the measurement of microbial biomass and respiration were initially sieved at their field moisture contents through a 5 mm sieve. Sub samples were then placed into 9.6 L buckets with holes drilled through the bottoms and covered with filter paper and had plant material incorporated at a rate of 10 t/ha. The "unamended" soils were supersaturated with water and allowed to equilibrate for 72 hours (termed *Tarcoola* and *Avoca* soils respectively). The "amended" soils (termed *Tarcoola+gypsum* and *Avoca+gypsum* soils respectively) were prepared with an application (10 t/ha) of nursery-grade gypsum ($CaSO_4.2H_2O$) and subjected to the same wetting conditions as for the non-amended soils. The soils were then maintained in a constant temperature environment at 25°C for the duration of the incubation, and analysed for respiration and SMB, as described below. All analyses were undertaken in quadruplicate.

Soil pH and electrical conductivity (EC) measurements were also undertaken in 1:5 soil:water extracts.

Soil Biological Analysis

Analysis of soil respiration and SMB-C was undertaken over a period of 12 weeks according to the method described in Wong *et al.* (2004b). Soil respiration was analysed bi-weekly, and determined gravimetrically using soda lime traps (Edwards 1982). The amount of CO_2 evolved was determined using equation 1.

$$CO_2\ (g) = [(SL_a\text{-}SL_b) - B) * 1.69 \qquad \text{(Equation 1)}$$

Where SL_a = weight of soda lime after incubation,
SL_b = weight of soda lime before incubation
B = mean blank soda lime gain

CO_2 evolution was then expressed per gram of soil, according to equation 2.

$$mg\text{-}CO_2\ g^{-1}\ soil = CO_2\ (mg)\ evolved / weight\ of\ oven\ dried\ soil. \qquad \text{(Equation 2)}$$

Soil microbial biomass was extracted weekly using the chloroform fumigation-extraction procedure described in Vance *et al.* (1987), with the level of SMB-C determined by the difference between fumigated and non-fumigated samples following titration against 0.033 M ferrous ammonium sulfate ($[NH_4]_2SO_4FeSO_4.H_2O$) solution. The amount of SMB-C present in the samples was determined by the difference between the carbon in the fumigated samples and the unfumigated samples (E_C), expressed as mg-C/kg oven dry soil using equation 3.

$$C = 2.64\ E_C \qquad \text{(Equation 3)}$$

All measurements were expressed on oven dry weights of soil.

RESULTS

The pH of the soil (1:5 soil:water extracts) from the different treatments are shown in Figure 1. The soil sampled from Tarcoola was highly alkaline, with pH values between 9.63 and 10.31 through 0-50 cm. The pH of the soil decreased slightly after the addition of organic material, and was further decreased following the addition of gypsum, particularly in the 5-10 and 10-20 cm depths. The soil sampled from Avoca was acidic from 0-50 cm, and showed no distinct change following the addition of organic material, both with and

without gypsum amendment.

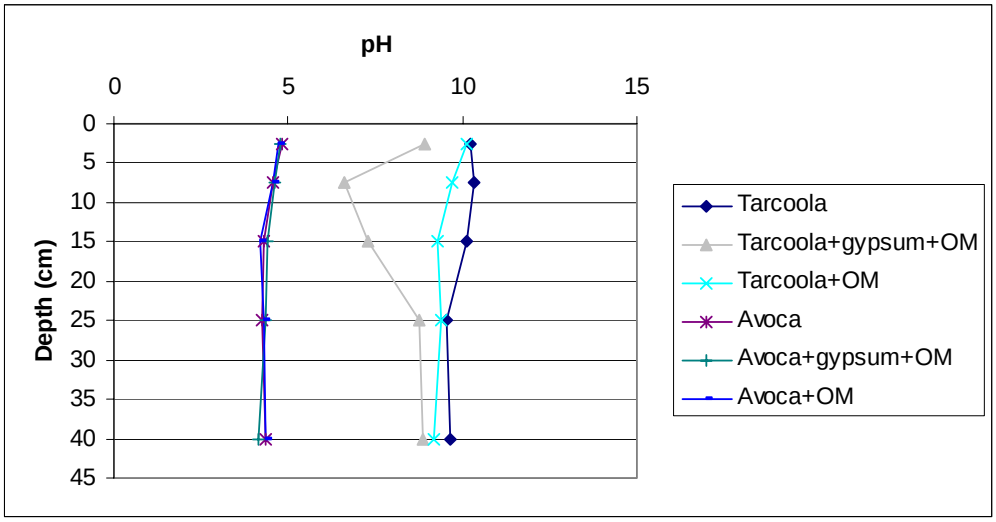


Figure 1: pH profiles for the two soil profiles (Tarcoola and Avoca), with and without gypsum amendment, and with the addition of organic material (OM).

The EC profiles of the two soils from Tarcoola and Avoca are shown in Figures 2a and 2b respectively. Both soils showed the expected increase in EC following the addition of gypsum, however, following the addition of organic material, the EC of the soil solutions was further increased. While the EC profile of the soil from Tarcoola showed no distinct trend following organic material and gypsum addition, there was a general decrease with depth. Similarly in the soil from Avoca, the EC showed no distinct trend, however, decreased with depth following gypsum and organic material addition to the 10-20 cm layer.

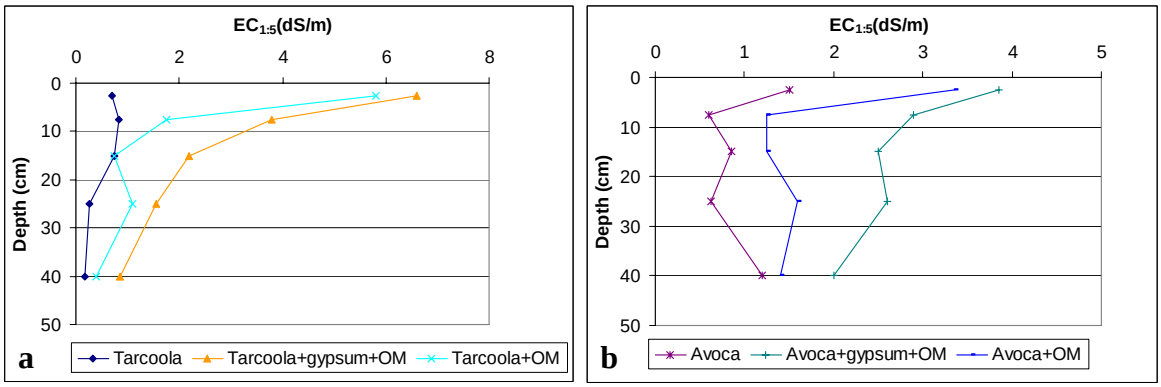
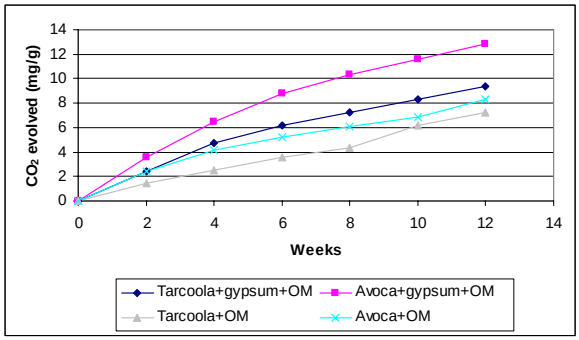


Figure2a (left) and 2b (right): EC profiles of Tarcoola samples (a) and Avoca samples (b) with organic material addition (OM), with and without gypsum.

All treatments showed a steady increase in the cumulative CO_2 evolution over the 12 week period in the 0-5 cm layer (Figure 3). The addition of gypsum appeared to affect soil respiration in both soils. There appeared to be an apparent increase in the rate of CO_2 evolution during the incubation period with addition of gypsum. The Avoca soils displayed higher rates of respiration than the Tarcoola soils with and without gypsum amendment.

In contrast, the addition of gypsum did not appear to have a clear-cut effect on the SMB in the 0-5 cm layer (Figure 4), as its addition did not have an immediate nor obvious effect. The Avoca samples showed an increase in SMB to Week 1 before decreasing, and fluctuating about a mean from Week 5. The Tarcoola samples did not exhibit a clear pattern, and appeared to fluctuate about a mean from Week 6.



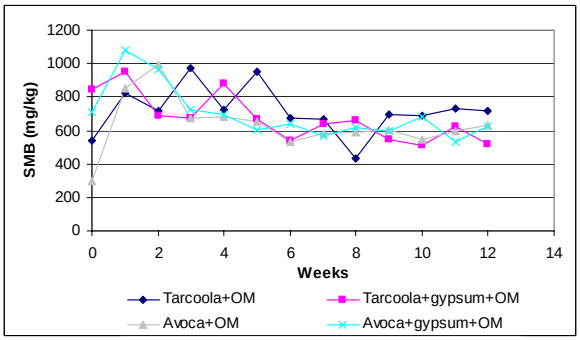


Figure 3 (left): Cumulative CO_2 evolved over the 12 week incubation period in the 0-5 cm layer following the addition of organic material.
Figure 4 (right): Trends in the soil microbial biomass over the 12 week incubation period in the 0-5 cm layer.

DISCUSSION

Despite up to a five-fold increase in EC of both soils following the addition of gypsum, there were no distinct concomitant trends in the SMB in either soil, with and without gypsum addition. This indicated that osmotic stresses were not great enough to affect the microbial population in the short term. Where soils are saline, osmotic stress usually limits microbial growth and activity, while under sodic conditions, ion toxicities and adverse pH conditions may also inhibit microbial growth (Rietz & Haynes 2003). However, this did not occur in the current study, with the addition of gypsum appearing to cause an increase in the rate of respiration in both soils. The addition of gypsum appeared to improve the soil environment without the concomitant increase in osmotic stresses. It has been noted that chloride salts are more toxic to microbial activity, measured in terms of nitrification, than the corresponding sulfate salt (McCormick & Wolf 1980) and this may also apply to C mineralisation. In addition, gypsum is only sparingly soluble in field soils and only causes a slight increase in osmotic potential.

The additional organic material, which, in the short term, provides additional substrates for the microbial population, may also relieve osmotic and pH stress on the microorganisms (Pathak & Rao 1998). The presence of SOM can provide a buffer to the soil solution and to soil microbiological properties, (McCormick & Wolf 1980), particularly where salinity or sodicity levels are high, or in this study, where the EC is increased with gypsum addition. In the absence of pH or aeration effects, sodicity has been found to increase, and salinity decrease decomposition of plant material (Nelson *et al.* 1996). In this study, the continued addition of gypsum and organic matter caused large changes in pH and EC in the Tarcoola soils, particularly in the 5-10 and 10-20 cm depths, and affected the respiration rate but not the SMB. The combined addition of gypsum and organic material in the Avoca increased the EC, but did not alter the pH. The SMB was unchanged by these effects, but there was an increase in respiration rates.

In a previous study (not shown), those soils sampled from scalded areas without organic material addition showed the SMB and respiration rates to be up to five-fold less than that found in this study (Wong *et al.* 2004b). The low levels of SMB were attributed to low levels of SOM, providing little substrate for the SMB to decompose. However, results from this study indicate that where organic material is readily available as substrate for decomposition, the SMB is still active and present, and displayed higher levels of SMB than that found in a non-degraded soil (Wong *et al.* 2004a). Hence, potential exists for these degraded areas to return to functioning soil ecosystems if rehabilitation is successful and plant production re-established.

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Acknowledgements: Thanks to David Little, Karen Fisher and Celina Smith for assistance in the field, and S. Chin Wong and Jan Cheetham for assistance in the laboratory. This project is being funded by CRC LEME and CRC Greenhouse Accounting.