Microbial activity and dissolved organic matter dynamics in the soils are affected by salinity and sodicity

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Abstract
A laboratory incubation experiment was conducted to assess changes in microbial activity, dissolved organic matter (DOM) and nutrients dynamics in response to salinity and sodicity. We hypothesised that salinity would decrease microbial activity due to osmotic stress, whereas sodicity would increase microbial activity as a result of increased organic matter solubility. A non-saline non-sodic soil was repeatedly leached using a combination of 1M NaCl and 1M $CaCl_2$ solutions to reach $EC_{1:5}$ 0.4, 1.2, 2.5 and 4.0 dS/m combined with SAR < 3, 10 and 20. Two percent finely ground wheat straw residue was added as an amendment. The results indicate that cumulative respiration on day 64 was more strongly affected by EC than SAR. Cumulative respiration was highest at low $EC_{1:5}$ (0.4) and high SAR (20) and lowest at high $EC_{1:5}$ (4.0) and high SAR (20). Increasing salinity adversely affected the microbial activity in the soil, whereas increased the microbial activity in response to sodicity was only observed at $EC_{1:5}$ (0.4).

Key Words
Microbial activity, dissolved organic matter, salinity, sodicity.

Introduction
High concentrations of salt in soils constraint crop production and have enormous influence on soil organic matter (SOM) content. Salinity has been found to negatively influence the size and activity of soil microbial biomass and biochemical processes essential for maintenance of soil organic matter (Rietz and Haynes 2003; Tripathi *et al.* 2006). Sodicity, i.e. a high percentage of Na on the adsorption sites, can lead to increased SOM solubility and thus loss of C and N (Peinemann *et al*. 2005) from soils. Dissolved organic matter (DOM) is the most mobile and dynamic non-living organic matter fraction. It comprises only a small part of soil organic matter (< 1 % of soil organic C); nevertheless, it is a primary source of mineralizable C, N and P and affects many processes in soil such as nutrient translocation and leaching (Qualls and Haines 1991), microbial activity, mineral weathering and plant nutrient availability (Kuiters and Mulder 1993). Leaching of DOM can reduce the amount of DOM available for microbial mineralization and therefore, may influence soil nutrient cycling and soil fertility. In spite of the extent of salt affected soils in Australia, studies on the magnitude and mechanisms of changes in dissolved organic matter dynamics in these degraded environments are fragmentary. DOM losses in salt affected soils are expected to be high due to solubilization of organic matter in sodic soils and decreased microbial activity in saline soils. The aim of the present experiment was to study the effect of salinity and sodicity and their combination on microbial activity, dissolved organic matter and nutrient dynamics in soil.

Materials and Methods
A non-saline and non-sodic sandy soil (95% sand, 1.3% silt and 3.7% clay, pH (1:5) 6.5, 49 mg/kg organic carbon was collected from Monarto located 80 km east of Adelaide in South Australia. The area experiences hot, dry summers and mild winters with the mean annual rainfall of 352 mm. The soil was thoroughly mixed to ensure uniformity, air dried, sieved to 2mm and stored at room temperature.

Soil preparation
Twelve salt solutions of known EC and SAR were prepared using a combination of 1M NaCl and 1M $CaCl_2$. The soil was leached repeatedly with these solutions to achieve $EC_{1:5}$ 0.4, 1.2, 2.5 and 4.0 dS/m combined with SAR < 3, 10 and 20. These EC values were chosen because previous experiments in our group (unpublished data) had shown that soil respiration was not affected at $EC_{1:5}$ <1 and negligible above $EC_{1:5}$ >4. Soils with SAR <3 are non-sodic, soils with SAR 10 are considered to be sodic according to the Australian soil classification system (Isbell 1998), whereas soils with SAR >13 are considered sodic in most other countries (Soil survey staff 1999). After adjustment of EC and SAR, the soils were air-dried.

Incubation
Before the start of the experiment, the soil water content of the prepared soils was adjusted to 85 % water holding capacity (WHC) which in this soil is optimal for microbial activity, and kept at 25°C for 10 days in the dark before amendment with residues. This is done to avoid the flush of activity that occurs after rewetting at the start of the experiment since this could mask the treatment effects. After the preincubation, wheat straw (C: N ratio 120:1), ground and sieved to 0.25-2 mm, was thoroughly mixed into the soil. Twenty five grams of soil with residues were placed into polyvinyl cores fitted with a nylon mesh at the bottom was and then transferred into individual incubation jars. Respiration was quantified by measuring headspace CO_2 concentrations using a Servomex 1450 infra-red gas analyser (Servomex, UK) at different intervals. Samples were harvested at different times during the 90 days experiment and analysed for microbial biomass, DOM (DOC, DON and DOP), SUVA, inorganic N, EC, SAR and pH.

Results and discussion
Since the experiment is still in progress at the time of the writing of the manuscript, only soil respiration data up to day 64 is shown here. On day 64, cumulative respiration was highest in the low-salinity and high sodicity (EC 0.4, SAR 20) treatment, whereas it was lowest in the high-salinity and high sodicity (EC 4.0, SAR 20) treatment (Examples for EC 0.4 and 4.0 are shown in Figure 1a, b). Cumulative respiration on day 64 was more strongly affected by EC than SAR. It decreased by 43-59% as EC values increased from 0.4 to 4.0, whereas SAR 20 increased cumulative respiration by 8% and 1.5% at EC 0.4 and 1.2, respectively (Figure 2) However, at EC 2.5 and 4.0, there was no increase in cumulative respiration with increasing SAR. The differences in cumulative respiration among various treatments became more evident after 28days.

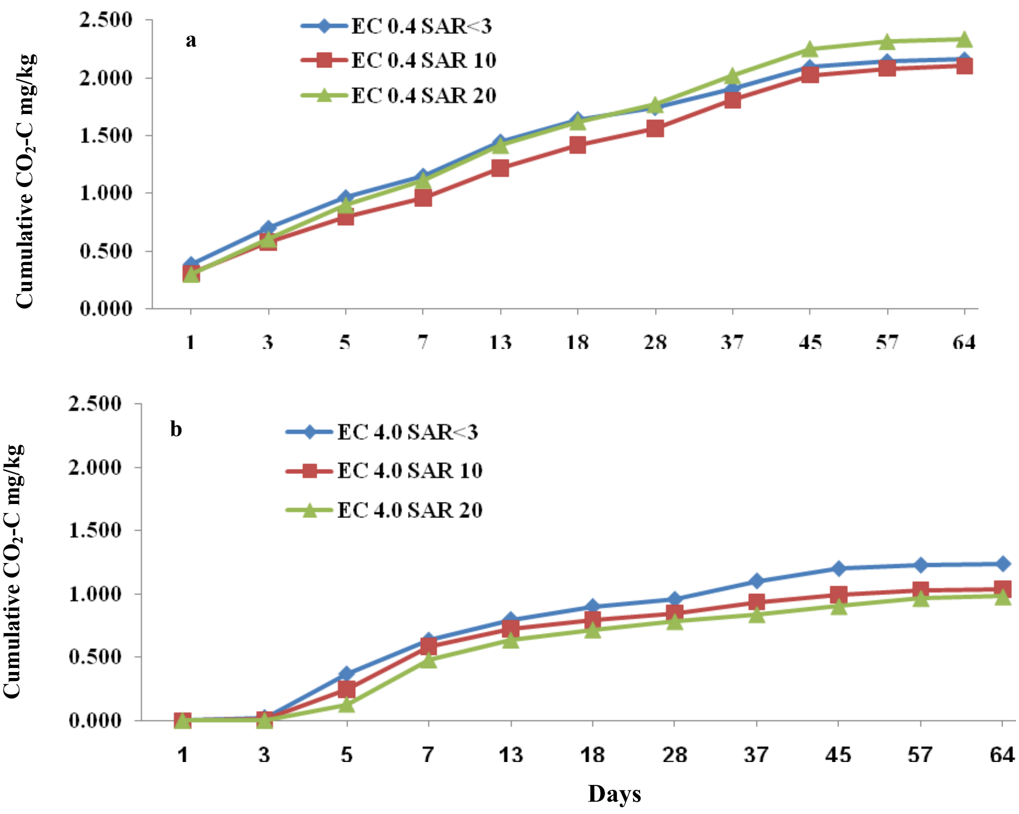

Figure 1. Cumulative respiration with increasing SAR at EC 0.4 (a) and EC 4.0 (b).

Increasing salinity causes an increase the osmotic potential in the soil adversely affecting the microbial activity, whereas high SAR results in increased organic matter solubility; thus, the increase in the soil microbial activity at high-sodicity and low-salinity (EC 0.4, SAR 20) can be explained by solubilisation of soil organic matter which provided additional substrate for decomposition by microbes. This pattern is similar to what was found by Nelson *et al.* (1996) in laboratory incubation study. Jandl and Sollins (1997) have also suggested that soluble carbon can provide a large proportion of the microbial substrate. The lack of effect of high SAR on respiration at higher EC can be explained by the flocculation caused by high EC which counteracts the increased solubility induced by high SAR.

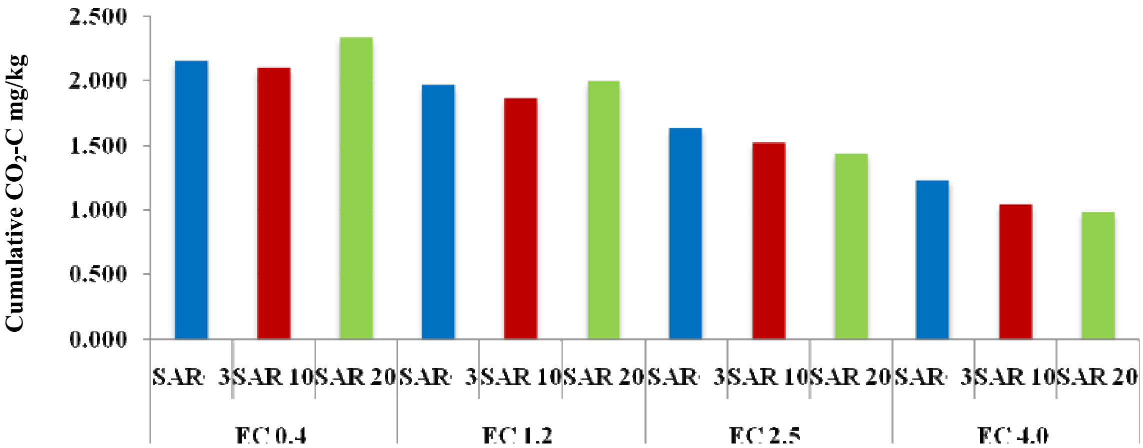

Figure 2. Cumulative respiration on day 64 at EC 0.4, 1.2, 2.5 and EC 4.0 in combination with SAR <3, 10, 20.

Conclusions

Increasing salinity adversely affects the microbial activity in the soil, whereas the effect of sodicity was only observed at $EC_{1:5}$ (0.4) where it increased the microbial activity in the soil. Further analysis of the soil samples harvested at different intervals is in progress to assess the effects of EC and SAR on microbial biomass, dissolved organic carbon, nitrogen, phosphorous and nutrients.

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