THE UNIVERSITY OF ADELAIDE

Response of microbial activity and biomass to changes in soil salinity and water content

Nan Yan

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School of Agriculture, Food and Wine

Faculty of Sciences

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I dedicate this thesis to my grandmother Yueying Wang

my greatest ever incentive for completing this work

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ABSTRACT

Salinization is a serious land degradation problem because osmotic stress and toxic ions cause poor plant growth and low soil microbial activity. The effect of salinity on soil microbes has been studied previously, but usually at constant salinity. However, in the field salinity may vary over time. Another factor influencing the effect of salinity on soil microbes is the soil water content. The osmotic potential, which is a measure of the salt concentration in the soil solution, increases as soils dry. The aim of the experiments described in this thesis was to assess how soil microbial activity and microbial biomass respond to changes in soil salinity and soil water content. One non-saline and four saline soils from Monarto, South Australia (35° 05´ S and 139° 06´ E) were used in the experiments. Soils were air-dried after collection. In some experiments, salinity was induced by adding certain amount of NaCl (dissolved in RO water), or decreased by leaching. Preliminary experiments were carried out to quantify the salts or water needed to reach the desired salinity. Pea (*Pisum sativum L.*) straw (C/N=26) was used as available substrate in most experiments except for experiments in Chapter four, where glucose was used. Soil CO_2 release (respiration as measure of microbial activity) was measured daily throughout each experimental period, microbial biomass was determined at different times in each experiment by fumigation extraction.

The experiments described in Chapter 2 (Soil Biology and Biochemistry 53, 50-55, 2012) were conducted to investigate the response of soil microbial activity and biomass to increasing salinity. The electrical conductivity of the saturation extract (EC_e) of five different soils was adjusted to 3 to 119 dS m^{-1} by adding NaCl. After 15 days, cumulative respiration and microbial biomass were negatively correlated with EC. Irrespective of the original soil EC, cumulative respiration at a given adjusted EC was similar, suggesting that microbes from originally saline soils are not more tolerant to increases in salinity than those from originally non-saline soils.

The experiment described in Chapter 3 (Biology and Fertility of Soils 49, 367-371, 2013) was designed to investigate the response of soil microbial activity and biomass to decreasing salinity. Three

saline soils were used, the EC_e was decreased by leaching to EC_e 6 to 32 dS m^{-1}. At a given adjusted EC, irrespective of the original EC, cumulative respiration recovered to the same level as in the soils which had originally lower EC. This was also true for microbial biomass C, except for the soil with the highest original EC, where microbial biomass C did not fully recover.

The aim of the two experiments in Chapter 4 (Soil Biology and Biochemistry 65, 322-328, 2013) was to investigate the response of soil microbial activity and biomass to changes of salinity. In both experiments, one non-saline soil and two saline soils were used. Every 5 days, soil cores were dipped into a salt solution (contained glucose as available substrate) to increase or maintain the EC or salinity was decreased by leaching. In Experiment 1, soil salinity was increased or reduced between EC 1, 11, and 31 dS m^{-1} repeatedly over six 5-day cycles. In Experiment 2, soil salinity was increased over four 5-day cycles from 1 or 11 to 31 dS m^{-1} either abruptly (within one cycle) or gradually (over at least 2 cycles). The results showed that soil microbes can respond quickly to changes in EC with respect to activity and growth when they are supplied with easily available C. A previous exposure to high EC did not limit the ability of the soil microbes to respond to a subsequent decrease in salinity. Compared to the originally saline soils, microbial activity and biomass in the originally non-saline soil were higher, less affected by EC increases and recovered more quickly after the EC was decreased. A gradual EC increase did not result in greater respiration or microbial biomass compared to an abrupt increase.

In semi-arid and Mediterranean ecosystems, surface soils frequently experience dry and rewet events. The experiment in Chapter 5 (Soil Biology and Biochemistry 43, 2265-2272, 2011) aimed to determine the effect of the length of the dry period on the size of the flush in respiration after rewetting. One non-saline and four saline soils were used. The length of the dry period varied between 1 and 5 days which resulted in different water contents, being lowest with the longest dry period. At the end of the dry period, soils were rewet to optimal water content. The experiment showed that rewetting induced a flush in respiration only if the water potential of the soils was previously decreased at least 3-fold compared to optimal water content.

Chapter 6 (submitted Biology and Fertility of Soils) includes three experiments with the aim to test the hypotheses that: (i) the osmotic potential to which the microbes were previously exposed influences their activity at a different osmotic potential and (ii) the response is modulated by the speed of the changes in osmotic potential were tested. Three soils were used, a non-saline soil and two saline soils where the EC_e was adjusted to 10 and 30 dS m^{-1}. In Experiment 1, the relationship between soil water content and respiration was determined. Water contents for optimal, medium and low respiration were chosen for the following experiments. There were five treatments for each soil In Experiment 2, and each treatment included two periods: maintained at optimum water content; from optimum to medium water content; maintained at medium water content; slow change from low to medium water content; rapid change from low to medium water content. In Experiment 3, the effect of the speed by which the water content was changed on soil respiration was further investigated. In both Experiments 2 and 3, respiration at the target water content was higher at medium or high water content when the soils had a low water content before, indicating that the response of microbial activity to a certain water content (osmotic potential) is influenced by the previous water content. However, microbial activity was less related to the speed of changes, as cumulative respiration was not consistently different between rapid and slow drying.

DECLARATION

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Signed:

Nan Yan April 2014

PUBLICATIONS ARISING FROM THIS THESIS

1. Yan, N., Marschner, P., 2012. Response of microbial activity and biomass to increasing salinity depends on the final salinity, not the original salinity. Soil Biology & Biochemistry 53, 50-55.

2. Yan, N., Marschner, P., 2013. Microbial activity and biomass recover rapidly after leaching of saline soils. Biology and Fertility of Soils 49, 367-371.

3. Yan, N., Marschner, P., 2013. Response of soil respiration and microbial biomass to changing EC in saline soils. Soil Biology & Biochemistry 65, 322-328.

4. Chowdhury, N., Yan, N., Islam, M.N., Marschner, P., 2011. The extent of drying influences the flush of respiration after rewetting in non-saline and saline soils. Soil Biology & Biochemistry 43, 2265-2272.