Soil microbial activity and community structure as affected by osmotic and matric potential.

A thesis submitted in fulfilment of the degree of Doctor of Philosophy,
Soils division, School of Agriculture Food and Wine, The University of Adelaide.

Nasrin Chowdhury

April, 2011.

Dedicated to my father, Dr. A. B. M. Habibur Rahman Chowdhury

Table of Contents

Abstract

Salinization of soils is a serious land degradation problem, causing poor plant growth and low microbial activity due to osmotic stress, ion toxicity and imbalanced element uptake. In arid, semi arid or seasonally arid (Mediterranean) regions, low or fluctuating matric potential causes further stress to soil microorganisms in saline soil by decreasing the osmotic potential as salts in the soil solution become more concentrated, as well as by reducing diffusion and thus substrate availability. Soil properties such as soil texture, water retention characteristics and organic matter content also influence soil microbial activity and community structure and the effect of salinity and matric potential on soil microorganisms. While the effects of low matric and low osmotic potential on soil microorganisms have been studied separately, little is known about their interaction. The objective of this thesis was to determine the interaction between soil matric and osmotic potential on soil microbial activity and community structure.

Most experiments described in this thesis were carried out with two non-saline soils (sand and sandy loam) differing in nutrient status, microbial biomass and community composition. Osmotic stress was induced by application of different rates of NaCl. In all experiments, pea residues were added to increase substrate availability and thus microbial activity. Respiration was measured throughout the experimental period (usually 14 days); microbial community structure was measured by phospholipid fatty acid (PLFA) analysis and PLFA patterns were compared by multivariate analysis.

The soils were air-dried after collection and an experiment was carried out to determine how quickly microbial activity stabilises after rewetting. Respiration rates in three non-saline and four saline soils stabilised seven to ten days after rewetting of the air dry soil. Therefore the soils used in this study were pre-incubated for 10 days before the experiments were started.

To investigate the effect of adaptation to matric and osmotic stress, the sandy loam was incubated for 14 days at different matric or osmotic potential (adaptation) or at optimal water content (no adaptation). Then matric and osmotic potential were adjusted in the treatments with no adaptation, whereas the potentials were maintained in the adapted

treatments. Cumulative respiration after 14 days decreased with decreasing osmotic or matric potential with no differences between adapted and non-adapted treatments indicating that prior exposure to low matric and osmotic stress does not increase tolerance compared to a sudden decrease in osmotic and matric potential.

The study in which the effect of matric and osmotic stress was compared, both soils showed a greater decrease in cumulative respiration at a given water potential (osmotic + matric) due to matric stress compared to osmotic stress. In the sand, a large proportion of the decrease in cumulative respiration at a given water potential may be due to concomitant low osmotic potential, whereas in the sandy loam the contribution of osmotic potential was small. Decreasing osmotic and matric potential had little effect on microbial biomass (sum of PLFAs), but changed microbial community structure. Compared to bacteria, fungi were less tolerant to decreasing osmotic potential, but more tolerant to decreasing matric potential.

The study on the combined effect of matric and osmotic potential showed that cumulative respiration at a given soil water content decreased with decreasing osmotic potential, but the effect of decreasing water content differed between the two soils, respiration in the sand being more affected. Cumulative respiration decreased with decreasing water potential but was poorly related to EC or water content alone. In both soils, the microbial biomass (sum of PLFAs) was affected by the interaction of EC and water content, with the EC having the greater effect.

To investigate the recovery of microbial activity after rewetting of soil, the two soils were incubated for 14 days at different water content and then adjusted to optimal water content and respiration measured for 65 days. Rewetting of the soils caused a flush in respiration rate, with the flush being greater the lower the water content before rewetting. Cumulative respiration of previously dried soils increased at a greater rate compared to the constant moist treatment, indicating recovery. But even after 50 days, cumulative respiration remained lower in the previously dry soils.

To investigate the effect of drying and rewetting (DRW) in saline soil, the salinised sandy loam was exposed to 1-3 DRW cycles each consisting of 1 week drying and 1 week moist incubation. The size flush in respiration decreased with increasing number of DRW cycles and was negatively related to the EC of the soil. Microbial community structure was affected by DRW and salinity.

To investigate the effect of the length of the dry period on the size of the flush in respiration after rewetting, a non-saline and four saline sandy loam soils from the field differing in EC were maintained dry for 1-5 days, maintained at the achieved water content for 4 days and then rewet. Rewetting induced a flush in respiration only if the WP of the soils was previously decreased at least 3-fold compared to the constantly moist soil.

The study showed that in order to understand microbial biomass and activity in saline soils, both osmotic and matric potential must be considered, particularly at low water contents when the salt concentration in the soil solution increases. Hence, the EC is a poor indicator of the stress microbes are exposed to in saline environments because, as the water content changes, microbes will be subjected to different osmotic and matric potentials even though the measured EC changes little. Low matric potential may be more detrimental than a corresponding low osmotic potential at optimal soil water content because of the reduced diffusion of substrates to the microbes at low matric potential. Thus, they may be unable to synthesise osmoregulatory compounds to maintain cell water content.

Furthermore, microorganisms previously exposed to low potential (either matric or osmotic) do not appear to be more tolerant to low potential than those from optimal conditions. This suggests that the high metabolic burden for synthesis of osmoregulatory compounds does not allow microbes to tolerate further decreases in potential particularly when diffusion of substrates is limited by low water content.

Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary to **Nasrin Chowdhury** 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.

I give consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

The author acknowledges that copyright of published works contained within this thesis (as listed below*) resides with the copyright holder(s) of those works.

1. Chowdhury, N., Marschner, P., Burns, R.G., 2011. Response of microbial activity and community structure to decreasing soil osmotic and matric potential. Plant Soil, in press.
2. Chowdhury, N., Marschner, P., Burns, R.G., 2011. Soil microbial activity and community composition: impact of changes in matric and osmotic potential. Soil Biology and Biochemistry 40,1229-1236.

I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library catalogue and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

Nasrin Chowdhury

Acknowledgements

I would like to extend my special gratitude to my supervisor Dr. Petra Marschner for her invaluable guidance and support throughout my PhD journey. It would not have been possible to finish and shape the research without her guidance. I like to thank my co-supervisor Dr. Robert Murray for his support and help with soil physics.

I would also like to sincerely thank Dr. Richard Burns for his valuable and critical comments and suggestions with preparing the manuscripts.

I would like to thank Mr. Colin Rivers for his help in collection of the soils and his technical assistance with the pressure plates.

I am extremely grateful to the Australian Government for 'Endeavour Postgraduate Award, 2008' for providing financial support.

Many thanks go to my Soil Organic Matter group friends Karen (Germany), Raj (India), Tra (Vietnam), YanNan (China) for their support during the project work. My special thanks go to my forever smiling friend Hasnuri (Malaysia) for her endless help during my stay in Adelaide, Australia.

I would like to express my deep respect to Dr. Khan Towhid Osman for his inspiration and support from Bangladesh.

Most sincerely I would like to thank to my parents and sisters for their support and encouragement. I wish to express my deepest gratitude to my husband, Nazrul for his unconditional love, endless inspiration and support. Finally, I wish to thank my beloved daughter Zaara, who has been a never ending source of encouragement and whose smile, cry and support have really kept me going through my research and who has become a part of my thesis.