Drying/rewetting cycles in southern Australian agricultural soils: effects on turnover of soil phosphorus, carbon and the microbial biomass.

A thesis submitted in fulfilment of the degree of Doctor of Philosophy
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January, 2008

Dedicated to my parents, Robert and Betty Butterly

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Abstract

Phosphorus (P) limitations to agricultural productivity commonly occur in Australian soils and have largely been overcome by the use of inorganic fertilisers. However, studies have shown that most of the P taken up by plants is from native P pools. The turnover of P and native soil organic matter may be strongly affected by drying and rewetting (DRW). Rewetting dry soil results in a pulse of respiration activity and available nutrients. In Mediterranean-type climates surface soils naturally undergo recurrent DRW cycles. In southern Australia, soils experience DRW due to erratic rainfall within the growing season, and short, high intensity thunderstorms also during summer periods. The principal objective of this thesis was to determine the significance of dry-rewet events, for altering P availability and cycling in agricultural soils in Australia.

Soils representing a wide range of soil types and climatic zones of southern Australia, showed large flushes in carbon (C) mineralisation after a single DRW event. For some soils these were comparable with reported values, however large variability in flush size between soils was observed. Soils that commonly experience DRW did not appear to be more resilient to DRW than soils from areas with fewer DRW events. Even when soils had relatively small respiration flushes, as a result of low soil organic matter, a high proportion of the soil C was mineralised after rewetting. Soil physiochemical properties (total C, total N, organic C, humus, microbial biomass P, organic P, sand and silt) were correlated to the size of the flush, hence nutrient availability and soil texture appear to primarily determine flush size. Therefore, the influence of climate on DRW may relate to determining the quantity of organic matter and microbial biomass that is available for turnover.

Different size and composition of the microbial biomass within the same soil matrix were achieved by adding three different C substrates (glucose, starch and cellulose at 2.5 g kg^{-1}) at 5 times over 25 weeks. The treatments showed disparate responses to DRW, due to greater biomass (larger flushes) and effects of community composition, highlighting the central role of the soil microbes in DRW processes. When subjected to multiple DRW events these soils showed smaller rewetting respiration flushes with subsequent rewetting events. In contrast, the amount of P released after rewetting was

the same. This study showed that increases in P after rewetting were transient and rapid immobilisation of P by microbes occurred, which may limit the availability to plants. The composition of the microbial community was changed by DRW with a reduction in fungi and gram negative bacteria, showing that certain species are more susceptible to DRW than others.

Closer investigation at 2 hourly intervals after rewetting confirmed the transient nature of P flushes. The response in microbial respiration after rewetting was immediate, with the highest activity occurring within the first 2 h. Phosphorus availability was increased by DRW but remained stable over the following 48 h incubation period. The study highlights the rapid nature of changes in available nutrients after rewetting. Furthermore, while potentially only a small component of the P flush that occurred, the DRW soil had higher levels of P than most incubated soil at 48 h, this would be potentially available for plant uptake or movement with the soil solution.

Long-term water regimes (continuously moist or air-dry, or DRW occurring at different times during incubation) that were imposed on two soils from different climatic regions over a 14 wk period, did not alter available nutrient (P and C) pools or the size of the microbial biomass. However, these long-term water regimes determined the respiration response of the soils to experimental DRW. The largest flushes occurred in the treatment with the longest dry period, and confirm findings of reported studies that the response of a soil at rewetting is determined by the length of the period that it is dried. Microbial biomass was little affected by experimental DRW, but showed large changes in C:P ratio. Thus, changes in physiological state or community composition may be more affected by DRW than the size of the microbial biomass. Microbial communities were altered by DRW irrespective of climatic history (warm wet summer and temperate Mediterranean), however these changes were not related to specific groups of organisms. In addition, the disparate respiration responses and inhibition of phosphatase by DRW, indicate that functional changes may be induced by DRW but can not be sufficiently explained by quantifying available nutrient pools or the microbial biomass.

The use of wheat seedlings bio-indicators of P availability after the long-term water regimes, confirmed that plant available P was altered by DRW, indicated by differences in growth, although the large variability in seedling growth made it difficult to quantify these differences. However, the distribution of labile P, available at planting, in soil and plant pools at harvest, showed that long-term water regimes increased P allocation in plant tissue in one soil and decreased it in another. Furthermore, only a small fraction of the labile P present at planting was taken up by plants, which confirms the superior ability of soil microbes to immobilise P that is released by DRW. Nevertheless, since the long-term water regimes increased P availability, this may be transported via surface water or leaching.

DRW is important for C and P turnover in soils of southern Australia. However, P flushes occur rapidly after rewetting and are transient. Therefore, DRW appears to have only minor consequences for P availability to plants.

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 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.

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.

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January 2008

Acknowledgements

I would like to thank my supervisors Dr Petra Marschner, Dr Ann McNeill and Dr Jeff Baldock for their invaluable guidance and support. I would also like to thank Dr Else Bünemann for her mentoring and friendship.

I wish to acknowledge the Grains Research and Development Corporation (GRDC) for funding of this work, which was a component of the 'Biological cycling of P in farming systems' project and also to the School of Earth & Environmental Sciences, The University of Adelaide for financial support via a divisional scholarship.

I am extremely grateful for the following awards; GRDC Travel Award, Alf Anderson Award from the Australian Plant Nutrition Trust, Research Abroad Scholarship from The University of Adelaide and also financial assistance from the Australian Society of Soil Science to; conduct a research project at The University of California, Berkeley, USA, attend the '3rd International Symposium - Phosphorus dynamics in the soil-plant continuum', Brazil, the '18th World Congress of Soil Science', USA and to visit Rothamsted Research, UK in 2006.

I would also like to acknowledge the support and friendship of colleagues within the Discipline of Soil and Land Systems at The University of Adelaide, in particular Dr Damien Adcock and Dr Kris Broos. I am indebted for the technical assistance of Rebecca Stonor and Carol Sigston.

I wish to thank my extended 'Adelaide family' who have made my PhD an enjoyable and memorable time, particularly Emily, Laurence and Jean-Patrick for encouragement and support during our PhD studies. Finally, I wish to thank Pete for his assistance, support and unconditional friendship.