Effect of Crop Residue Qualities on Decomposition Rates, Soil Phosphorus Dynamics and Plant Phosphorus Uptake

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Thesis submitted for the degree of

Doctor of Philosophy

In the School of Earth and Environmental Sciences

Faculty of Sciences

The University of Adelaide

Discipline of Soil and Land Systems

School of Earth and Environmental Sciences

The University of Adelaide

January, 2009

Dedicated to my parent

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Abstract

Phosphorus (P) is an essential plant nutrient that may limit plant growth and agricultural productivity if not available for crop plant uptake in sufficient quantities at the time required. Many Australian soils are deficient in available P, despite a long history of P fertilizer application, and this is due to fertilizer P rapidly becoming unavailable largely through biochemical fixation. The resulting low P fertilizer efficiency, coupled with rapidly rising cost of fertilizers, has increased interest in biological cycling of P from sources such as crop residues. However, to date, much of the Australian research has focussed on soils with relatively high organic matter content (> 2%) and relatively heavy texture i.e. medium to high clay content. Furthermore, although there is information on pasture residue decomposition and P release for sandy soils with low organic matter in Australia, a recent shift to continuous cropping systems means that information for a range of crop residues is required but is not currently available. Therefore the aims of the work described in this thesis were to (i) increase the efficiency of P use when crop residue P are applied to crops and (ii) determine the effect of crop residue biochemical quality on decomposition rates, soil P dynamics and plant P uptake in light textured sandy soils with low organic matter which are typical of a large proportion of the southern Australian wheat growing area. A further aim was to investigate the effects of combined additions of plant residue and P fertilizer on P cycling in these soils, a scenario highly relevant to farming systems.

A series of soil incubation and plant growth experiments were undertaken to characterize P dynamics in soil following addition of a wide range of crop residues (total 15) collected from agricultural sites throughout South Australia. The residues, differing in age and biochemical quality, were young shoots of canola, lupin, pea, lucerne and lentil; mature shoot residues of canola, lupin, pea and wheat and mature root residues of wheat, canola and lupin. The concentration of total and water soluble P, C, and N in the residues was measured using standard wet chemical analyses and the carbon chemistry was determined by NMR spectroscopy. Decomposition of crop residues was continuously monitored over a period of up to 140 days by measuring soil respiration. Available P and microbial biomass P and C were also assessed at different times during the incubations. The total P in residues ranged from 0.16% to 0.32% and 0.05% to 0.08% in young and mature shoots, respectively. Water-soluble P was related to residue total P and ranged from 29% to 81% and 13% to 29% of total P in young and mature shoots, respectively. The C: P ratio ranged from 133: 1 to 253: 1 and 504: 1 to 858: 1 in young and mature shoots, respectively.

Phosphorus availability and microbial P uptake differed between soils amended with crop residues and soluble P fertilizer as triple super phosphate (TSP). Soil respiration rates were significantly higher in soils amended with crop residues than in the soils amended with TSP or the unamended control in the first 58 days of incubation. In an experiment in which residues and TSP were added at a rate of 10 mg P kg^{-1}, available P was greater for TSP than residue-amended soil, whereas microbial P showed the opposite trend. Respiration rate and microbial P were positively correlated with C addition rate, which was highest in mature wheat residue because it had the lowest P concentration.

In order to assess when P released from the residues is available for plants, wheat was grown over three consecutive crop periods with each period lasting for 4 weeks. Young residues with high content of water soluble P, C, N and amide and low lignin and phenolic content decomposed faster than mature residues. The C type and amount added with residues controlled the dynamics of P availability. Surprisingly, canola mature root increased available P and plant growth as much as young shoot residues while root residues of wheat and lupin resulted in P immobilization and low plant growth. Compared to canola young shoot, canola mature root has a higher total P concentration and a lower C: P ratio. Plant P uptake was positively correlated with residue total and water-soluble P content and negatively correlated with residue C: P and C: N ratio and amount of C added with the residues. In another experiment where residue was added at 2.5 g C kg^{-1} soil and compared with TSP (4 and 10 mg P kg^{-1} soil), available P and plant P uptake decreased in the following order: TSP-10P > canola root ≥ young shoot ≥ TSP-4P > control > mature shoot.

Microbial P was greater with residue addition than with TSP and in the control. Residues with low total P and high C: P ratio resulted in P immobilisation in the microbial biomass. Therefore, residues with high total P and low C: P ratio can be an important source of P for plants. Net P immobilisation of mature wheat residues (0.07% P) was significantly reduced by combining wheat residue (C: P ratio 615: 1) with TSP leading to a C: P ratio of 155: 1 to 310: 1. Furthermore, the combination of wheat residue with TSP increased available P in residue and TSP-amended soils by 3.0 mg P kg^{-1} soil, which was shown to be sufficient to support wheat growth in the early stages of development in the other experiments.

Although water-soluble P fertilizers provide plants with immediately available P, a large proportion becomes unavailable over time. Addition of low C: P residues on the other hand, may not result in high amounts of immediately available P, but the P supply is more sustained due to P release from decomposing residues and turnover of microbial biomass P. Phosphorus immobilization after addition of residues which have high C: P ratio (615: 1) may be offset when residue is applied together with inorganic P fertilizer if the resulting C: P ratio is 300: 1 or less.

Overall, this study has highlighted the potential role that crop residues, either alone or in combination with inorganic P, can play in increasing P availability in the light textured, low organic matter, P-limited soils typical of many southern Australian farming systems. The results provide important quantitative information on the potential of a wide range of crop residues to supply wheat with P, and how additions of inorganic P interact with residue decomposition and influence available P supply. This quantitative information will be valuable for the construction or validation of mechanistic models of residue decomposition relevant to low organc matter light textured soils in farming systems of southern Australia, and will ultimately assist in the development of economic management strategies for minimizing P fertilizer inputs and maximizing the benefits of biological cycling of P.

Declaration

I declare that 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. To the best of my knowledge and belief, this work contains no material previously published or written by another person, except where due reference is made in the text.

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Shahriar Iqbal

January 2009

Acknowledgements

I would like to thank my supervisors Dr. Petra Marschner and Dr. Annie McNeill for their supervision, encouragement and invaluable support throughout the entire period of this research. I enjoyed their constructive comments, criticisms and discussions. I am indebted to them for being always ready to help me, to discuss and read the draft versions of the thesis. I would also like to thank Dr. Else Bünemann for her short-time supervision, valuable support and suggestions in designing and conducting experiments and developing the protocol for phosphorus measurements.

I am indebted to those who have provided great help for my research particularly Colin Rivers, Rebecca Stonor, Carol Sigston, Debbie Miller and Steve Szarvas for their outstanding technical support, Dr. Tony Rathjen for providing wheat seeds and Dr. Damien Adcock for helping me in crop residue collection.

I would like to thank Dr. Therese McBeath for providing information on the soil and her time to read draft chapters 6 and 7 and Dr. Zakaria Solaiman for his encouragement and support during my research. I would also like to thank to all members of Soil Biology Group who gave important feedback during group discussion.

I would like to acknowledge the Grain Research Development Corporation (GRDC) for funding this project, which was a part of the “Biological cycling of P in farming systems: an improved capacity for managing P” and also the School of Earth and Environmental Sciences, The University of Adelaide for financial support through a divisional scholarship. I am also grateful to the Australian Society of Soil Science Incorporation (ASSSI) for financial support to attend the 18th World Congress of Soil Science 2006, Philadelphia, USA.

Finally, I wish to express my deepest gratitude to my wife, Nahid Akter for her encouragement, never-ending patience, assistance in the lab, as well as for understanding and support throughout my study.