Effect of legume residues on P availability in soil and P uptake by the following wheat

A Thesis submitted to the University of Adelaide

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Doctor of Philosophy

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Dedicated to my family

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Abstract

Phosphorus (P) deficiency is a common constraint to crop growth in many parts of the world. For optimum plant growth, P is often added to soil as inorganic fertiliser or as crop residues. It has been shown that addition of legume residues can increase P availability by supplying P within the residues but also by mobilising native soil P which could reduce the dependence on inorganic P fertilization for crop growth. In soil, P is found in various organic and inorganic pools which vary in availability. The size of these pools is affected by soil properties such as pH; the flux among these pools determines the relative size of pools and also influences P availability. Less is known about how soil properties such as texture and organic matter content affect the size of the various P pools and if this is modulated by addition of residues or inorganic P fertilisers. The aims of this study were to (i) assess the changes in the P pools over time as affected by residue P concentration and plant part (root or shoot) (ii) to compare the effect of different rates of P added as inorganic P or as residues on soil P pools and growth and P uptake by wheat, (iii) assess short and longer term changes in P pools in soils with different physical and chemical properties amended with residues differing in P concentration.

The research conducted involved laboratory experiments as well as glasshouse experiment. In these experiments three South Australian soils with low P availability and a wide range of legume residues were used. The soils were selected to represent different physical and chemical properties that may affect P availability and were collected from Mount Bold (Mt. Bold) (acidic sandy clay loam), Monarto (neutral loamy sand), and Langhorne Creek (alkaline sandy loam). To have a wide range of P concentrations, the following root and shoot residues from field or glasshouse-grown plants differed in C, N, P content, maturity

were used: mature white lupin (*Lupinus albus* L., low P concentration), mature chick pea (*Cicer arietinum* L., medium P concentration) and young faba bean (*Vicia faba* L., high P concentration).

To investigate the changes in P pools during legume residue decomposition legume shoot or root residues with varying P concentrations of faba bean, chickpea and white lupin (high P, medium P and low P) were added to a loamy sand soil at a rate of 20 g residue kg^{-1} soil and the concentration of various P pools were assessed on day 0 and after 14, 28 and 56 days of incubation. The result of this experiment showed that the size of the P pools changed over time and was affected by both residue P concentration and plant part. The differences in soil P pools among residues were greatest in the first 14 days. Later there was an increase in stable organic and inorganic P in the residue amended soils, indicating net conversion of labile into stable P. Differences in P pools between roots and shoots occurred mainly in the initial phase. The concentration of NaOH-Po increased from d0 to d14 with root and shoot residues, but then decreased from d14 to d28 with addition of shoot residues whereas the concentration of this pool increased when root residues were added. The changes over time were generally more pronounced in low-P than in medium-P residues.

In the second experiment, the short term effects (42 days) of different rates of P added either as inorganic P or as legume residues on soil P pools and wheat growth were compared. In this glass house experiment wheat was grown to the flowering stage (42 days) in a loamy sand soil from Monarto amended with shoot residues of faba bean (high P) chickpea (medium P) and white lupin (low P) at a rate of 5 or 15 g residue kg^{-1} soil. Inorganic P was added at four different rates (3, 10, 30 and 100 mg P kg^{-1}) corresponding to the total P added with the different residues at the two residue rates. Soil P pools were

determined at wheat harvest. Compared to inorganic P addition, P added with residues led to a 10-80% greater increase in shoot biomass at the two highest P addition rates. In residue P amended soil, resin P and microbial P were correlated with wheat P uptake whereas in soil amended with inorganic P, resin P and NaOH Pi pools mainly contributed to P uptake.. Over time, the concentration of HCl P decreased in the residue treatments and that of residual P decreased in all treatments suggesting that these so-called non-labile P pools are quite dynamic and could serve as P source for plants.

To assess the impact of soil properties on changes in P pools induced by legume residue addition, three legume different residues differing in P concentration: faba bean (high P) chickpea (medium P) and white lupin (low P), were added at a rate of 20 g kg^{-1} to three soils differing in pH, organic C content and texture from Monarto (pH 7.5), Mount Bold (pH 5.1) and Langhorne Creek (pH 8.1) and incubated for 42 days. In residue-amended soils from day 0 to day 42, the concentration of water soluble and microbial P decreased, whereas the concentrations of $NaHCO_3$ Pi and NaOH Po increased; the magnitude of these changes differed among soils, being greatest in the Mt Bold soil. Residue addition had little or no effect on the concentrations of NaOH Pi, HCl Pi and residual P which also did not change significantly over time. Principal component analysis (PCA) of the data showed that most effects of residue addition to soils on microbial activity and growth and soil P pools can be generalized across the three soil used in this study, but that the size of the P pools is affected by soil properties such as organic carbon content, pH and texture.

To assess longer term temporal changes in P pools in two soils with contrasting physical and chemical properties amended with residues differing in P concentrations, another incubation experiment was carried out with Monarto and Mt Bold soil amended with shoot

residues of faba bean (high P) chickpea (medium P) and white lupin (low P). The concentration of the P pools was measured on days 0, 14, 28, 56, 70 and 98. The PCA plot based on the soil P pools showed a clear separation between the un-amended control soils and those amended with white lupin residues on the one hand and soils amended with faba bean and chickpea residues on the other. The concentrations of most P pools and particularly the labile P pools on days 28 and 56 were higher in soil amended with faba bean and chickpea residues than in the un-amended soil and that with white lupin residues. Despite some differences in temporal changes in P pools between Monarto and Mt. Bold, the PCA showed that the P pool concentrations on day 0 and 98 were quite similar and differed from the P pool concentrations on days 28, 56 and 70 suggesting clear temporal patterns and a limited effect of residue addition on P pool concentrations in the long term. Nevertheless, the temporal changes were more pronounced in the soils amended with faba bean and chickpea residues suggesting that addition of residues with medium or high P concentration has a greater effect on the dynamics among the soil P pools than residues with low P concentration. At the start and the end of the experiment, the concentrations of microbial P and NaOH-Pi were high in both soils, but the concentration of HCl-P was high only in the alkaline Monarto soil whereas the Mt Bold soil was characterized by high resin P concentrations.

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 **Md Alamgir** 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.

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1. **Alamgir M, McNeill A, Tang C, Marschner P (2012) Changes in soil P pools during legume residue decomposition.** ***Soil Biology and Biochemistry*****, 49:70-77. doi:10.1016/j.soilbio.2012.01.031**

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Structure of this thesis

The thesis is organised into 6 chapters and is presented as a combination of papers that have been published, or have been submitted for publication.

Chapter 1 provides an overview of the literature review on P dynamics in soil and characterisation of P.

Chapter 2 comprises a paper published in the *Soil Biology and Biochemistry*. It describes the effect of legume residues with varying P concentration and plant part on changes in soil P pools.

Chapter 3 comprises a paper submitted for publication in the *Journal of Plant Nutrition and Soil Science*. It describes the comparative effect of inorganic P and P added as residues at different rates on soil P pools and growth and P uptake by wheat at flowering.

Chapter 4 comprises a manuscript submitted for publication in the *European Journal of Soil Science*. It describes the changes in P pools in three soils with different physical and chemical properties.

Chapter 5 comprises a manuscript submitted for publication in the *European Journal of Soil Science*. It describes the temporal changes in P pools in two soils induced by residue addition and soil properties.

Chapter 6 contains general conclusions from all chapters and future research suggestions.