Effects of legume growth and residue decomposition on growth and phosphorus uptake in following wheat

A thesis submitted to The University of Adelaide in fulfilment of the requirements for the degree of Doctor of Philosophy.

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Dedicated to my father, Mat Hassan Mohamad and mother, Wan Limah Wan Abdullah

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Abstract

In phosphorus (P) deficient soils, several legumes have been shown to mobilise less labile P pools and to have a greater capacity to take up P than cereals. In conditions where N was not limiting, some legumes can increase the growth and P uptake of the following cereals which may be related to P mobilisation by the legumes. There is little information about the size of various soil P pools in the rhizosphere of legumes in soil fertilised with P although P fertiliser is often added to legumes to improve N_2 fixation. The aims of this study were to (i) compare the growth, P uptake and the concentration of rhizosphere soil P pools of different grain legumes, (ii) compare the decomposition rate of grain legume and wheat residues, and (iii) determine the effect of legume pre-crops and residue addition on growth, P uptake and concentrations of rhizosphere P pools of the following wheat.

A series of plant growth experiments were carried out in a glasshouse to compare the growth of the different grain legumes and wheat and the concentrations of P pools of the rhizosphere soil. The soil pH determines the dominant P forms, therefore, two soils which were low in available P and contrasting pH (a loamy sand soil pH 8.8 and a sandy loam pH 5.4) were used in separate experiments to which soluble P was added to ensure good plant growth. Additionally, another experiment was conducted in the alkaline soil with lower P supply. Nodulated chickpea (*Cicer arietinum* L.), faba bean (*Vicia faba* L.), white lupin (*Lupinus albus* L.), yellow lupin (*Lupinus luteus* L.) narrow-leafed lupin (*Lupinus angustifolius* L.) and wheat were grown until maturity. Plant dry weight and P uptake were measured, sequential P fractionation was employed to determine the concentrations of P pools in the rhizosphere of the legumes and wheat.

Irrespective of soil pH and P supply, growth and P uptake were greatest in faba bean whereas the less labile P pools were most strongly depleted in the rhizosphere of white lupin despite its lower growth and P uptake compared to faba bean. In the alkaline soil with high P supply, compared to the unplanted control soil, the depletion of labile pools (resin P and

$NaHCO_3$) were greater in the rhizosphere of faba bean whereas in the alkaline soil with low P supply and the acidic soil, white lupin depleted most of the labile pools more strongly than the other legumes.

An incubation study was carried out to compare the decomposition rate and the available N and P concentrations after addition of the legume and wheat residues. Shoots, roots and the combination of shoots and roots of wheat, faba bean, chickpea and white lupin were mixed into the loamy sand soil. The decomposition rate was measured over 42 days by determining soil CO_2 release and the concentrations of available P and N in the soil were measured on days 0 and 42. Chickpea shoot residue decomposed faster than the other residues. Compared to the control soil without residue addition, resin P concentration was increased with legume residue addition but not with wheat residue addition. Inorganic N was increased significantly with addition of faba bean and white lupin residues compared to the un-amended control whereas wheat residue addition had no effect.

In order to differentiate between the effect of the legume pre-crop alone and that of legume pre-crop and their residue on the following wheat, soil grown with legumes from which root and shoot residues were removed or added back were planted with wheat. Growth, P uptake and concentrations of rhizosphere P pools of the following wheat were measured. Generally, growth was greater in wheat grown in the previously unplanted soil than in the pre-cropped soils. Among the pre-crops, in the alkaline and acidic soils with high P supply, the growth of the following wheat was greater in legume pre-crop soil without residue than with residue addition. The reverse was true for plant P concentration in the alkaline soil whereas in the acidic soil, plant P concentration was similar among the treatments. Varying results with residue addition on the growth of following wheat were observed in the alkaline soil with low P supply, but residue addition consistently increased wheat P concentration. In the loamy sand (pH 8.8) with high P supply, regardless of the pre-crops, wheat depleted the less labile residual P, NaOH-Pi and particularly NaOH-Po, whereas in the sandy loam (pH 5.4), the

depletion was greatest in resin P. Similarly, in the loamy sand soil with low P supply, wheat after legumes depleted labile and less labile pools more than wheat after wheat. Generally, the addition of pre-crop residues increased the size of organic P pools in the rhizosphere of wheat grown in pre-crop soils.

The results of this study showed that in the alkaline loamy sand, among the legumes only those with the greatest depletion of either labile or less labile pools (faba bean at high P and white lupin at low P supply) enhanced the growth of the following wheat. At high P supply, the pre-crop faba bean with greatest depletion of labile pools resulted in a greater depletion of less labile pools by the following wheat than the other legumes. At low P supply, the pre-crop white lupin with greatest depletion of labile and less labile pools induced a greater depletion of the less labile pools in the rhizosphere of wheat. On the other hand, in the acidic sandy loam, the legumes with the greatest depletion of most pools (labile and less labile) did not increase the growth of the following wheat compared to legumes with little depletion. Furthermore, the addition of legume pre-crop residues increased the concentration of organic P pools in the rhizosphere of the following wheat compared to pre-crop alone but generally decreased wheat growth.

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 **Hasnuri Mat Hassan** 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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