Growth, P uptake in grain legumes and changes in soil P pools in the rhizosphere

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Abstract
Legumes can increase the growth and P (phosphorus) uptake of the following cereals which may be related to mobilization of P during the growth of the legumes. This study is part of a project to investigate the mechanisms by which legumes increase growth and P uptake of the following wheat. In a pot experiment, faba bean, chick pea, narrow-leafed lupin, yellow lupin and white lupin were grown in a loamy sand soil with low P availability (resin P 4.5 mg P/kg) with addition of 80 mg P/kg as KH_2PO_4 and harvested at flowering and maturity. At maturity, growth decreased in the following order: faba bean > chickpea > narrow-leafed lupin > white lupin > yellow lupin. The depletion of labile P pools (resin P and $NaHCO_3$-Pi) was greatest in the rhizosphere of faba bean, while sparingly available P pools, particularly residual P, were most strongly depleted in the rhizosphere of white lupin. The results suggest that these legumes could differentially affect the dynamics of organic and inorganic P pools and the capacity of the following wheat to utilise these pools.

Key Words
P pools, P fractionation, P uptake, rhizosphere soil, legumes.

Introduction
Legumes can mobilise more P from poorly soluble P compared to non-legumes (Kamh *et al.* 1999, Nuruzzaman *et al.* 2005). A glasshouse study found that several legumes showed less response to increasing P fertilizer addition than cereals due to the capability of the legumes to utilise native soil P (Bolland *et al.* 1999).Previous studies have shown that some legumes increase growth and P uptake of the following cereal (Vanlauwe *et al*. Carsky *et al*. 2001, Nuruzzaman *et al*. 2005). It has been suggested that the positive pre-crop effect of legumes on cereals is due to P mobilization or P release from legume residues. However, there are few studies on the changes in soil P pools during the growth of the legumes and the following wheat. This experiment was a part of the project to understand the mechanisms by which legumes increase growth and P uptake of the following wheat.

Methods
Soil
Soil was collected from the top of 10 cm in Monarto, South Australia. The soil had following properties: clay 7.5%, sand 82.5%, silt, 10%, pH 8.82, available P (resin P) 4.5 mg/kg, total P 229.6 mg/kg, nitrate 31.2 mg/kg, ammonium 28.1 mg/kg, bulk density 1.63 g/cm^3. Since the aim was to maximize the growth and thus capacity to mobilize soil P pools of the legumes, a preliminary experiment was conducted with faba bean over six weeks to determine the optimum supply of P which was found to be 80 mg P/kg as KH_2PO_4.This P addition rate was used for the experiment described here.

Plant growth and maintenance
The experiment was carried out in a glasshouse between October and January 2008. Four pre-germinated seeds of faba bean (*Vicia faba L.*), chickpea (*Cicer arietinumL.*), narrow-leafed lupin (*Lupinus angustifolius L.*) yellow lupin (*Lupinus luteus L.*) and white lupin (*Lupinus albus L.*) were sown in 2 kg pots lined with a polyethylene bag. Each legume was inoculated with the appropriate rhizobium strain 4 days after sowing. Two weeks after sowing, plants were thinned out to 2 plants per pot. The soil was kept at 70% field capacity using deionized water throughout the experiment. Basal nutrients except P were added once as nutrient solution as described in Nuruzzaman (2005). Unplanted pots served as controls received the same amount of water and nutrients. Plants were harvested at two growth stages: flowering and maturity. There were four replicate pots per legume species for each harvest. The pots were arranged in a complete randomised design.

Plant and soil analyses

Shoots and roots were oven-dried at 80ºC for two days before further analyses were carried out. Ground plant samples were digested in nitric and perchloric acid mixture (6:1) and total P was measured using vanado-molybdate method. Rhizosphere soil (soil adhering to the roots) was collected by gently brushing the roots and kept in the freezer for P fractionation. For determination of soil P pools, sequential fractionation was carried out using the method described by Tiessen and Moir (1993) The P concentration in each extractant was determined by the molybdenum blue method (Murphy and Riley 1962).

Results

Plant growth and P uptake

Shoot (including pods) dry weight increased considerably from flowering to maturity for all species (Figure 1). Shoot and root dry weight were highest in faba bean and lowest in white lupin and yellow lupin. Shoot P concentration and root P concentration were greatest in narrow-leafed lupin and chick pea and lowest in yellow lupin. Plant P uptake was greatest in chickpea and lowest in yellow lupin. The poor growth of yellow and narrow-leaf lupin is probably due to their sensitivity to high pH (Tang *et al*. 1995).

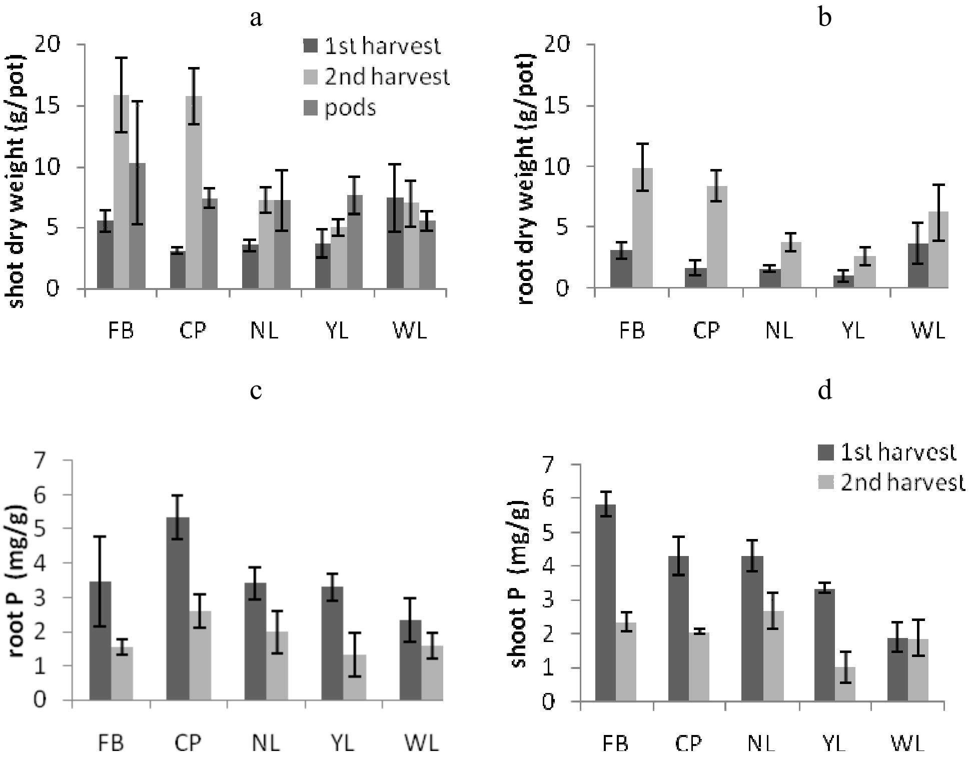

Figure 1. Shoot (a), root (b) dry weight, P concentration in shoots (c) and roots (d) of five legumes grown in loamy sand soil at flowering (1st Harvest) and maturity (2nd harvest). (FB= faba bean, CP= chickpea, NL= narrow-leafed lupin, YL=yellow lupin, WL= white lupin).

Size of P pools in the rhizosphere soil

Generally, the changes of P fractions compared to control soil were more pronounced at maturity, therefore only the P pools at this growth stage will be described here. Compared to the unplanted control soil, the labile fractions, resin P and $NaHCO_3$-Pi, were most strongly depleted in the rhizosphere of faba bean with a decrease of 57% and 42 % respectively. NaOH-Pi and NaOH-Po as well as residual P were most strongly depleted in the rhizosphere of white lupin with a decrease of 25%, 50% and 30% respectively. This suggests that white lupin can mobilize P from sparingly available P which is probably due to carboxylate exudation (Nuruzzaman *et al.* 2005). The concentrations of microbial P and HCl-Pi in the rhizosphere were similar as those in the control soil.

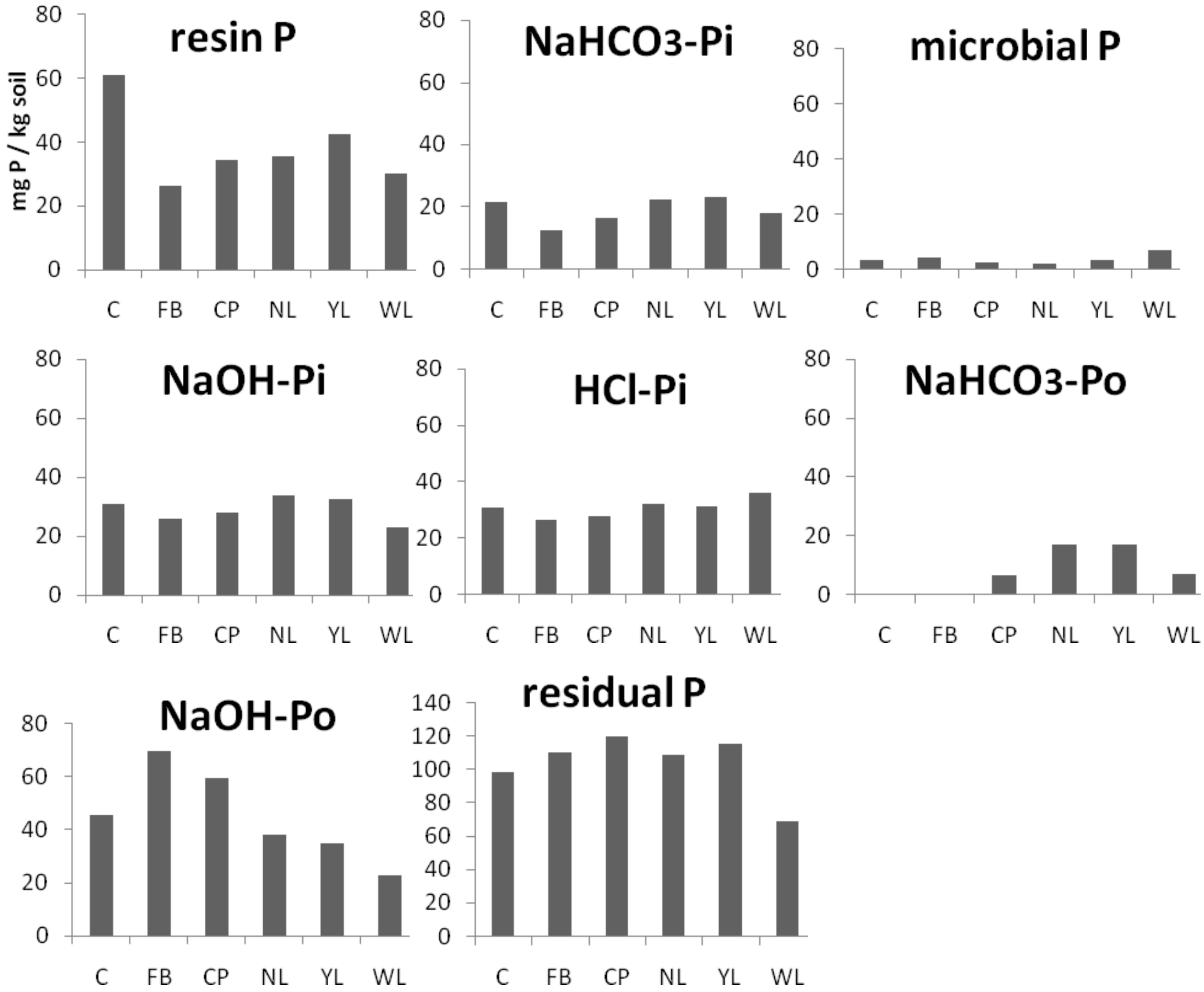

Figure 2. Concentration of different fractions (mg/kg)of Pi (inorganic P) and Po (organic P) and total P (mg/kg soil) in the rhizosphere of faba bean (FB), chickpea (CP), narrow-leafed lupin (NL), yellow lupin (YL), and white lupin (WL) at maturity.

Conclusion

The results show the differential capacity of the legumes tested to grow and take up P and have access to different P pools in the soil. Faba bean showed the greatest growth and utilization of labile P pools compared to other species, whereas white lupin was able to mobilize P from poorly available P forms. In subsequent experiments, we will investigate how the changes in soil P pools induced by the legumes are related to the ability of wheat to take up P and access the soil P pools.

References

Bolland MDA, Siddique KHM, Loss SP, Baker MJ (1999) Comparing responses of grain legumes, wheat and canola to applications of superphosphate. *Nutrient Cycl. Agroecosyst* ***53***, 157-175.

Carsky RJ, Oyewole B, Tian G (2001) Effect of phosphorus application in legume cover crop rotation on subsequent maize in the savanna zone of West Africa. *Nutrient Cycl. Agroecosyst* ***59***, 151-159.

Kamh M, Horst WJ, Amer F, Mostafa H, Maier P (1999) Mobilisation of soil and fertilizer phosphate by cover crops. *Plant Soil* ***211***, 19-27.

Nuruzzaman M, Lambers H, Bolland MDA, Veneklaas EJ (2005) Phosphorus uptake by grain legumes and subsequently grown wheat at different levels of residual phosphorus fertiliser. *Austr. J. Agricult. Res.* ***56***, 1041-1047.

Murphy J, Riley JP (1962).A modified single solution for determination of phosphate in natural waters. *Anal. Chim. Acta.* ***27***, 31-36.

Tang C, Robson AD, Longnecker NE, Buirchell BJ (1995) The growth of lupines species on alkaline soil. *Austr. J. Agricult. Res*. **446**, 255-268.

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

Tiessen H, Moir JO (1993) Characterization of available P by sequential extraction. In 'Soil sampling and method of analysis'. (Eds MR Carter) pp. 75-86. (Lewis publisher).

Vanlauwe B, Diels J, Sanginga N, Carsky RJ, Deckers J, Merckx R (2000) Utilisation of rock phosphate by crops on a representative toposequence in the Northern Guinea savanna zone of Nigeria: response by maize to previous herbaceous legume cropping and rock phosphate treatments. *Soil Biol. Biochem.* ***32***, 2079-2090.