Effects of legumes on arbuscular mycorrhizal colonisation and phosphorus uptake by the following wheat

Habullah, Petra Marschner, Ann McNeill

Soils, Faculty of Science, University of Adelaide, Adelaide, Australia. Email hasbullah@adelaide.edu.au; petra.marschner@adelaide.edu.au; ann.mcneill@adelaide.edu.au

Abstract

It has been shown that biomass and P uptake in cereals following legumes are higher than in cereals following cereals. This may be due to soil chemical and biological changes induced by the legumes and/or their residues. However, the relative importance of legume pre-crops and their residues on P uptake and arbuscular mycorrhizal colonisation of wheat has not been investigated. The aim of the overall project is to separate the two effects by comparing the following treatments: legume pre-crops with or without residue incorporation and legume residues added without pre-growth of legumes in the soil on P uptake and AM colonisation of wheat. Here we present the results of three short experiments that provide important data for the main experiments.

Key Words

Legume residues; AM fungi; P uptake

Introduction

A number of studies have shown that biomass and P uptake in cereals following legumes are higher than in cereals following cereals (Armstrong *et al.,* 1997; Asseng *et al.,* 1998; Nuruzzaman *et al.,* 2005). The positive effect of legumes to the following wheat may be due to the growth of legumes prior to wheat and/or due to nutrients released during decomposition of legume residue that are utilised by the subsequent wheat (Nuruzzaman *et al.,* 2005). However, information about the effect of legumes as a pre-crop and their residues on P availability and P uptake is very limited.

In African soils, legume as a pre-crop also affects the biological properties: legume pre-crops result in earlier colonisation of cereal roots by AM fungi (Bagayoko *et al.,* 2000). However, it is not known if such biological changes also occur in Australian soils and how AM fungal colonisation is linked to legumes as pre-crop and legume residue application.

The aim of this study is to determine the effect of legumes as a pre-crop and also their residues on colonisation of arbuscular mycorrhiza and P uptake by the subsequent wheat. To do so, three short experiments were carried out to provide basic information about the effects of available P concentration on AM colonisation and the relationship between additions of different legume residues on available P.

Methods

Experiment 1: Relationship between addition of inorganic P and available P in Monarto soil

The aim of this experiment was to determine the relationship between rate of inorganic P addition and available P. Inorganic P was added as KH_2PO_4 at 2.5 to 60 mg P/kg to soil from Monarto (South Australia) . The soil was incubated at 70% WHC for 5 days and then available P was determined as resin P.

Experiment 2: Available P and AM colonisation

The aim of this experiment was to investigate the relationship between P availability and AM colonisation in wheat. Wheat was grown in a soil with low available P (Monarto) over 6 weeks at 11 different rates of inorganic P addition (0, 2.5, 5, 7.5, 10, 12.5, 15, 20, 25, 30, and 40 mgP/kg as KH_2PO_4). AM colonisation was determined after weeks 6 using gridline intersection method (Brundrett *et al.,* 1996; Giovannetti and Mosse, 1980).

Experiment 3: The relationship between legume residue addition and available P in soil

This experiment was conducted to investigate the relationship between rate of residue addition and available P. Four rates (0.5, 1, 1.5 and 2% w/w) and four types of residues (chickpea (CP), faba bean mature shoot (FMS), faba bean young shoot (FYS) and faba bean young root (FYR) were added to the soil and incubated for 5 days and the available P of the soil was determined.

Main experiment
Germinated seeds of wheat, faba bean, chickpea and white lupin will be sown at 2 cm depth and thinned after 2 weeks to 2 plants per pot; unplanted pots will serve as controls. After 8 weeks, three treatments will be imposed: to determine the effect of legumes as pre-crop and their residues, shoots of each legume will be removed, while roots will remain in the soil. In order to determine the pre-crop effect alone, both roots and shoots will be removed completely. To investigate the effect of root and shoot residues in absence of a pre-crop effect, shoot and root residues will be added to previously unplanted soil.

The following wheat will be planted immediately without a fallow period. During wheat growth, P availability in soils will be determined after 1, 2, 4 and 6 weeks. AM colonisation, wheat growth and P uptake will be assessed after 6 weeks.

Results
Experiment 1
Figure 1a shows that available P increased with increasing amount of inorganic P added. At 2.5 mg P/kg added P, only a small percentage (less than 20%) was recovered as available P. At 5 mg P/kg about 50% remained available. At higher rates of P addition, nearly all P remained available. This suggests that the buffering capacity of the soil is saturated at P addition ≥15 mg/kg.

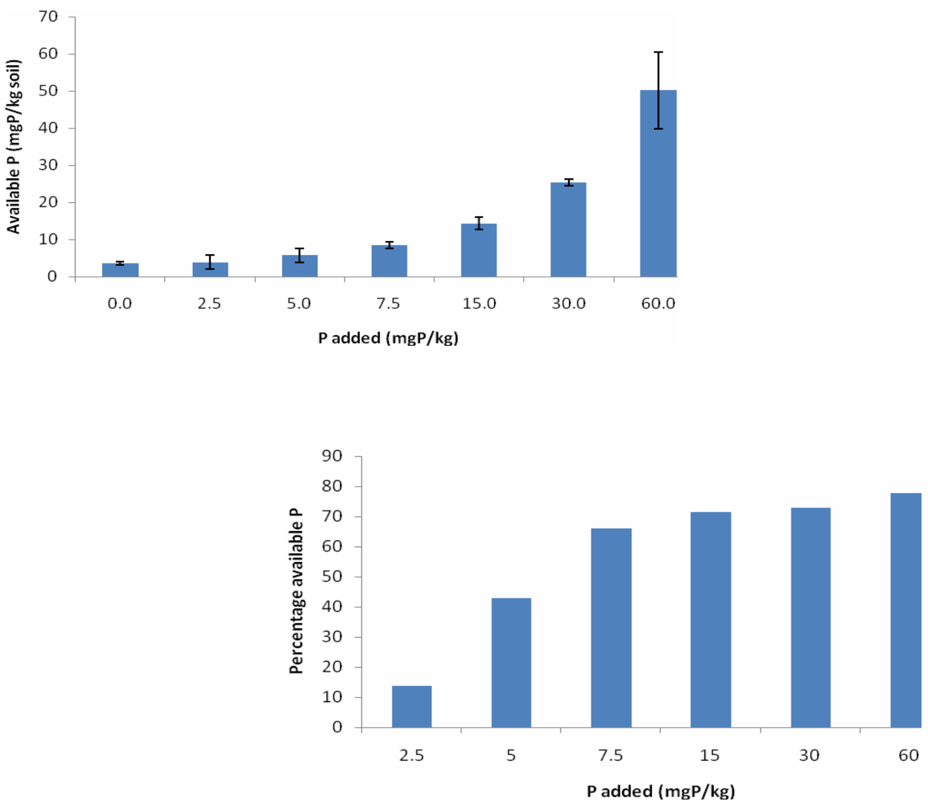

Figure 1. Relationship between P addition and available P expressed as mg/kg (a) and percentage of added P (b).

Experiment 2
After 6 weeks, AM colonisation was highest (20% colonisation) in soil with no P addition (Figure 2). Inorganic P addition significantly decreased the percentage of colonisation compared with the control soil without added P. The addition of ≥ 12.5 mgP/kg, decreased the colonisation to less than a half of the control; only around 5-7%.

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

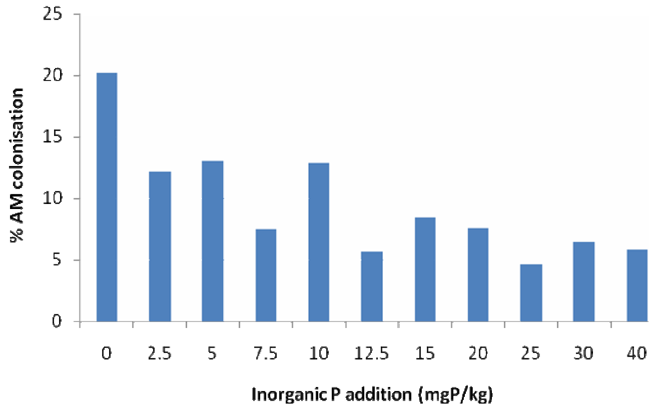

Figure 2. Percentage of AM colonisation of wheat in different rate inorganic P.

Experiment 3

The total P concentration in the residues was 0.67171, 2.08904 mg/kg in chickpea (CP), 6.553 mg/kg in faba bean mature shoot (FMS), 6.553 mg/kg in faba bean young shoot (FYS) and 8.31976 mg/kg in faba bean young root. For chickpea and faba bean mature shoot available P was very low and not significantly different between the rates of residue addition (Figure 3) . For faba bean young shoot and roots, available P increased with increasing residue addition rate with the greatest increase between 0.5 and 1% addition rate. As expected, available P nearly doubled. The increase between 1 and 1.5 % and 1.5 to 2% was smaller and did not match the increased amount of P added with the residues. This could be due to a smaller percentage of residues being decomposed at higher rates of residue addition.

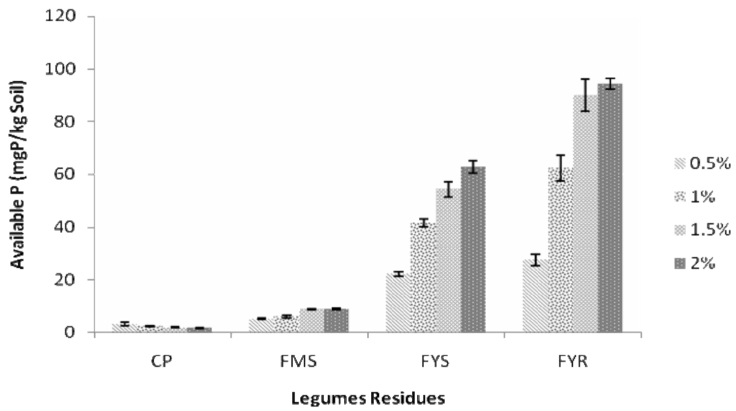

Figure 3. Available P in four different residue types and rates.

Conclusion

From these experiment, it is clear that the addition inorganic P lowered the AM colonisation particularly at more than 10 mg/kg available P. Hence, both chickpea and faba bean mature shoots will be used in the main experiment as sources of low available P because addition of these residues resulted in available P ≤10mgP/kg soil. On the other hand, faba bean young shoots and roots which had high total P concentrations resulted in > 20 mgP/kg soil available P even at 0.5% addition rate. Based on the increase in available P, these two residues may have a negative effect to AM colonisation. However, these residues may have a different effect if compared with inorganic P addition, e.g. addition of organic matter and/or stimulation of microbial activity via the residues may also stimulate AM colonisation despite the high concentrations of available P.

The study will provide important information about the link between legumes, AM colonisation and P uptake by wheat in an Australian soil. The finding of this research will contribute to the development of farming systems with increased growth and yield of wheat and less reliance on inorganic P fertilisers.

References

Armstrong EL, Heenan DP, Pate JS, Unkovich MJ (1997) Nitrogen benefits of lupins, field pea, and chickpea to wheat production in south-eastern Australia. *Australian Journal of Agriculture Research* **48**, 39-47.

Asseng S, Fillery IRP, Gregory PJ (1998) Wheat response to alternative crops on a duplex soil. *Australian Journal of Experimental Agriculture* **38**, 481-488.

Bagayoko M, Buerkert A, Lung G, Bationo A, Roemheld V (2000) Cereal/legume rotation effects on cereal growth in Sudano-Sahelian West Africa: Soil mineral nitrogen, mycorrhizae and nematodes. *Plant and Soil* **218**, 103-116.

Brundrett M, Bougher N, Dell B, Grove T, Malajczuk N (1996) 'Working with mycorrhizas in forestry and agriculture.' (Australian Centre for International Agricultural Research).

Giovannetti M, Mosse B (1980) An evaluation of techniques for measuring vesicular arbuscular mycorrhizal infection in roots. *New Phytologist* **84**, 489-500.

Nuruzzaman M, Lambers H, Bolland MDA, Veneklaas EJ (2005) Phosphorus benefits of different legume crops to subsequent wheat grown in different soils of Western Australia. *Plant and Soil* **271**, 175-187.