Changes in soil P pools during legume residue decomposition

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Abstract
There is a growing interest to find effective management systems to utilise the large unavailable soil P bank resulting from the excess use of P fertiliser and to overcome the associated financial and environmental problems. It has been suggested that legume residues can play a significant role in mobilising soil P forms which are unavailable to many crops. The aim of our experiment is to study the changes in soil P pools during legume residue decomposition. Legume residues with varying P concentrations were added to a sandy loam soil with low P availability and changes in various soil P pools were determined after 14 days. Residue addition increased available P. Residues with lowest C/P ratio (46.9) increased the $NaHCO_3$ extractable inorganic P 4.82 fold compared to the control (22.9 mg /kg). Cumulative respiration over 14 days was higher in soil treated with young residues compared to control and mature residues.

Key Words
P availability, P pools, decomposition rate.

Introduction
Due to low P availability and low fertiliser use efficiency, farmers often apply P fertilisers in excess of plant requirements. Only 10-20% of applied P fertilisers is used by plants in the year of application, hence the majority of applied P is rapidly fixed or precipitated into poorly available forms (Vu *et al.* 2008). Application of P fertilisers in excess of plant needs has resulted in a largely unavailable soil P bank in Australian soils (Holford 1997). Environmental and economic problems associated with over-use of P fertilisers such as diffuse losses of P from agricultural soils and surface water eutrophication (Barberis *et al.* 1995) and the diminishing reserves of P for fertilisers have led to a renewed interest in alternative management systems, including the substitution of chemical fertilisers with manures, composts and crop residues.

Legumes play an important role in agricultural systems and the incorporation of legumes as green manure in cropping systems not only positively affects soil properties and increases nitrogen (N) supply, but also increases P supply to the main crop (Kabir and Koide 2002). Residue decomposition and nutrient release are affected by residue chemistry (nutrient content, concentration of easily available and recalcitrant compounds) as well as by environmental factor such as soil moisture. Generally, residues high in P decompose faster and release more P within a shorter period (Tian *et al.* 1992) because these residues contain sufficient P (and N) to satisfy the P and N demand of the microbes which have low C/N and C/P ratios. Due to the greater capacity of legumes to utilise soil P, it is expected that legume residues contain more P and have lower C/P ratios than cereal residues, favouring net P mineralisation. Much information exists on the effects of residue quality on rates of decomposition and N mineralisation; but fewer studies have evaluated the relationship between residue quality and P release during decomposition. Moreover, soil P and fertiliser P can be mobilised during legume residue decomposition. Organic acid anions and phenolics released during residue decomposition mobilise P and decrease P fixation capacity (Ayaga *et al.* 2006; Schefe *et al.* 2008), but there is no published data on the impact of legume residues on P pools and P fixing capacity in Australian soils. The aim of this experiment is to determine the changes in soil P pools during decomposition of legume residues which differ in P content.

Methods
Sandy loam soil from Monarto, South Australia with low P availability was used in the experiment. The pH of the soil is 8.82 (1:5 water) with a bulk density of 1.63 (g/cm^3).The soil moisture was adjusted to optimum water content for microbial activity (70% WHC as determined in preliminary experiments). A range of residues from different legume species and different plant parts and growth stages were chosen to represent a wide range of P concentrations and other chemical properties which may affect decomposability. Total P content of the residues ranged from 0.56 g P /kg to 8.32 g P /kg with the C/P ratio ranging from 46.9 to 687.6 (Table 1).The residues were finely ground and sieved to 0.25 to 2 mm, added at a rate of 2% (w/w) and

mixed thoroughly into the soil. The decomposition and P release from residues and changes in soil P pools were evaluated by incubating soil with residues for 8 weeks at constant temperature of 25^0C with sampling after 7, 14, 28 and 56 days. Decomposition rate was measured by respiration with a food-pack gas analyser (Servomex 1450 series). The size of various P pools during residue decomposition were determined according to (Vu *et al.* 2008). Data presented here are from samples after 14 days incubation.

Table 1. Nutrient concentrations of different legume residues.

Residue	Total P g /kg	Total N g /kg	Total C g /kg	C/N	C/P
White Lupin mature shoot from field	0.6	9.7	384.3	39.6	687.6
Faba bean young shoot waite campus	6.6	34.5	417.2	12.1	63.7
Faba bean young root waite campus	8.3	30.9	390.0	12.6	46.9
White lupin young shoot Mt. Bold	1.1	38.3	441.8	11.5	392.5
White lupin young shoot Monarto	3.3	34.5	438.2	12.7	134.1

Statistical analysis

Statistical analyses of data were performed by one way ANOVA using PASW Statistics 17 for windows. Means were compared by using DMRT at alpha = 0.05.

Results

Respiration

Compared to the control, residue addition increased cumulative respiration over 14 days (Figure 1). Microbial activity was higher in soil treated with young residues compared to mature residues. There was a positive correlation between total C content of residues and cumulative respiration (r=0.79). Cumulative respiration was higher in residues with lower C/P ratio, thus cumulative respiration was negatively correlated with C/P ratio (r=0.71).

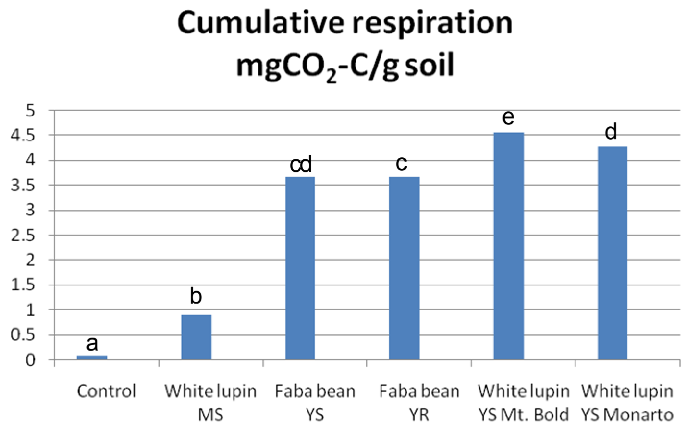

Figure 1 Cumulative respiration of soil treated with legume residues over 14 days.

Changes in P pools

The amount of P added with residue and concentrations of different P pools in control soil and soil treated with residues after 14 days of incubation are shown Table 2. Residue addition increased the $NaHCO_3$ extractable P (0.09 to 4.82 fold) compared to the control With greatest increases after addition of faba bean young shoots and roots which had the highest total P content. This is probably due to the fact that residues high in P decompose faster and release more P within a shorter period (Tian *et al.* 1992). In terms of resin P, mature and young shoot of white lupin with the highest C/P ratio caused the immobilisation of available P. This result confirms the suggestion of (Brady and Weil 2002) that net immobilisation of P is most likely to occur if residues added to the soil have a C/P ratio greater than 300:1, while net mineralisation is likely if the ratio is below 200:1. A portion of added P was taken up by microorganisms as indicated by increase on microbial P (2.08 to 7.38 fold) compared to control. The strong increase in microbial P with white lupin young shoots indicates that microbial P immobilisation is very strong in residues with high decomposition rates Addition of faba bean young roots and shoots also increased NaOH Pi and HCl Pi, suggesting that P from these P-rich residues had been converted in relatively poorly available P pools within 14 days after residue addition.

Table 2. Amount of P added (mg /kg) by residue addition and concentrations of different P pools (mg /kg) in control soil and soil treated with residues after 14 days of incubation.

Treatments	Amount of P added by residues	Resin Pi	Microbial P	$NaHCO_3$ Pi	NaOH Pi	HCl Pi	Residual P
Control	-	3.20a	2.59a	22.89a	16.11ab	17.19a	76.83a
White lupin MS	112.00	1.99a	7.90ab	24.85a	15.34a	17.13a	73.67a
Faba bean YS	131.00	76.73c	12.85bc	91.81bc	21.86c	19.95c	85.71a
Faba bean YR	166.40	114.29d	18.61cd	133.11c	21.89c	21.14c	80.44a
White lupin YS Mt. Bold	22.60	0.73a	17.38cd	67.15ab	16.57ab	18.44ab	113.63b
White Lupin YS Monarto	65.40	10.43b	21.70d	63.19ab	18.89b	19.80bc	82.39a

*Values containing same letter don't differ significantly from each other at alpha = 0.05.

Conclusion

The results of the experiment indicate that P released from the decomposition of legume residues can increase the available P pools which would benefit the subsequent crop. Addition of high P residues also increased the size of NaOH and HCl Pi, suggesting that P from these residues moved into less available P pools. This research will help in better understanding of the beneficial effect of incorporation of legumes into legume-wheat cropping systems.

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