Effect of co-application of phosphorus and potassium fertilisers on phosphorus uptake by Mungbeans

Kyin Kyin Htwe[1], Chris Guppy[1], Richard Flavel[1], Graeme Blair[1]
[1] Agronomy and Soil Science, University of New England, Armidale NSW, Australia, gblair@une.edu.au

Abstract
Deep placement of phosphorus (P) has been shown to increase the effectiveness of fertiliser application in soils with a long cropping history. This cropping history has also often depleted potassium (K) reserves. Research on co-application of phosphorus and potassium has produces variable results. Factors contributing to these variable results such as placement, pH, and K source have been investigated in a glasshouse trial. ^{32}P labelled P fertiliser was applied alone or mixed with four K sources (nitrate, chloride, sulfate, potassium phosphate) to test if the anion associated with K affected P and K uptake by mungbeans [*Vigna radiata* (L.) Wilczek]. There was no significant difference between treatments in fertiliser P recovery with either surface or deep placement. The only significant effect was higher shoot and root yield and higher fertiliser P and K recovery in most treatments compared with the zero K treatment with the highest values in the $P+K_2SO_4$ surface treatment. This increased uptake was not attributable to increased root growth in the fertiliser band or to a difference in band or rhizosphere pH as these were not significantly different in this treatment from the other K source treatments.

Introduction

Potassium is an essential nutrient for growth and development of plants. Plant requirements are high, and prolonged cropping depletes available and reserve sources of K over time. Replacing harvested K in well buffered, higher CEC soils over the large soil volume exploited is challenging. Whilst replacement of other depleted nutrients, such as P, can often be done through fertiliser bands due to root responses to concentrated patches, there is no evidence of root proliferation by dicots or monocot species in response to bands of K. The effect of enriched K concentration on root architecture is largely unknown. In theory, extra root length stimulated by nutrient patches known to stimulate root responses, such as P and N, may inadvertently also increase K recovery when co-located in a band. However other mechanisms may also contribute to increased K recovery should it occur, including the nature of the counter-ion associated with the K. Separating out the relative contributions of root length and root surface uptake processes when K is located in a band may help identify the best fertilisation strategy for replacing depleted K reserves in agricultural soils.

Legume crops are generally responsive to P fertiliser while the response of mungbean to P is variable (Bell, 1991). Many studies have found positive yield response of mungbean [*Vigna radiata* (L.) Wilczek] to P fertiliser but the required rate of P varies according to soil types and moisture content of the soil in different soil horizons. The optimum rate of P application to mungbean appears to vary between 10 – 100 kg/ha but mostly in the vicinity of 40 kg/ ha (Putland & Parker, 1988; Sathyamoorthi et al. 2013). Singh et al (2015), reported that the application of P fertiliser up to 40 kg/ha to a semiarid tropical soil significantly increased number of pods/plant, number of seed/pod, number of total and effective root nodules, test weight, seed and straw yield, N, P and K content in mungbean seed.

Lester et al. (2009) found that a rate of 10 kg P/ha P applied to Vertosol soils in NSW and SE Queensland increased mungbean grain yield by 15%. On a Vertosol in Central India chickpea did not show any signs of P deficiency growing in a soil with as low as 2 mg of available P/kg (Saxena,1979).

There is a lack of data on the timing and uptake of P and K bymungbean but information is available for another legume, soybean, which might be expected to be similar to mungbean. Gaspar et al. (2017) found distinctly different uptake patterns and rates between P and K. Soybean accumulated greater relative amounts of K by R1 and 91 to 100% of its season-long K total by R5.5, compared with only 68 to 77% of its season-long P total. Removal of P (0.0054 kg P/ kg grain) and K (0.016 kg K/ kg grain) with the seed was consistent across environments and varieties.

Jain et al. (2007) reported that uptake of P by soybean increased up to a low level of K whereas at a higher K level there was decrease in the uptake of P, but it remained higher than the control.

Given that field and incubation studies have found variable results from co-application of P and K a glasshouse study was undertaken to examine the effects of K fertiliser sources on P uptake by mungbean.

Materials and Methods

The experiment was conducted in the glasshouse in 15 cm diameter *50 cm deep tubes. Basal nutrients were uniformly applied to air-dry Vertosol soil. Nutrient rates used were 1.66 mg/kg N as urea, 10 mg/kg S as $CaSO_4.2H_2O$ and 3.34 mg/kg P as $(NH_4)H_2PO_4$, B (0.35 mg/kg) and Mo (0.002 mg/kg) were also applied. Potassium (K) at 28 mg/kg was applied in four different sources (KNO_3, KCl, K_2SO_4 and KH_2PO_4). Supplementary N was applied as urea at 100kg/ha (808 mg/pot) when true leaves were well developed to balance N for all treatments.

Fertiliser $Ca(H_2PO_4)_2$ labelled ^{32}P was applied at 27 mg/kg soil to all treatments except the P_0 controls. ^{32}P activity in the plant shoots was measured with a Geiger counter from days 13 to 24 after sowing to monitor uptake.

K and P fertilisers were applied in 300 g of soil either at the surface or at 20-25 cm depth (designated s and d, respectively). This soil containing the basal nutrients, was added to the pots to a depth to below the respective fertiliser treatment and labelled fertilised soil added. In deep placed treatments the remainder of the soil was added above the treated band. A P_0 treatment was included for each placement depth.

Mungbean seeds (*Vigna radiata* L.) var. Jade Au were planted after fertiliser application and soil moisture adjusted to 80% field capacity which was maintained throughout the growing period. Mungbean shoot and root biomass was measured after 28 days. Roots were removed from the fertilised and non-fertilised areas and biomass and root length measured (data not presented). Soil pH and electrical conductivity measurements were made on these soil samples and on rhizosphere soil (data not presented).

Samples were digested in HNO_3 and analysed for P, K and S using ICP-AES. The ^{32}P activity in digest solutions was determined by liquid scintillation counting.

The use of ^{32}P isotope allows the calculation of the % of P in the plant derived from the labelled fertiliser by comparing the specific activity of the plant to that added in the fertiliser as follows

$$\%\ \text{P in plant from fertiliser} = \frac{\text{Plant specific acitivity (Bq/mgP)}}{\text{Fertiliser specific acitivity (Bq/mgP)}}$$

Fertiliser P recovery is then calculated as $\%\ \text{P in plant from fertiliser} * \text{P content (mg)}$.

Statistics

The experiment was conducted as a randomized complete block design (RCB) with four replications. Variance analysis (ANOVA) was performed with the JMP 13 statistical software. Means were compared by the critical difference (CD) at 5% level of significance.

Results

In-situ counting

In-situ counts of ^{32}P showed that P activity at day 13 was higher in the K_2SO_4, KNO_3 and KCl treatments than in the $Ca(H_2PO_4)_2$ alone treatment. Measurements in the KH_2PO_4 treatment could not be compared because of a lower specific activity (Bq/mg P) in this source. The counts generally reduced below the P control to day 19 before rising to day 22 (Figure 1). By day 24 the counts in the $P+K_2SO_4$ d treatment exceeded the P control treatment.

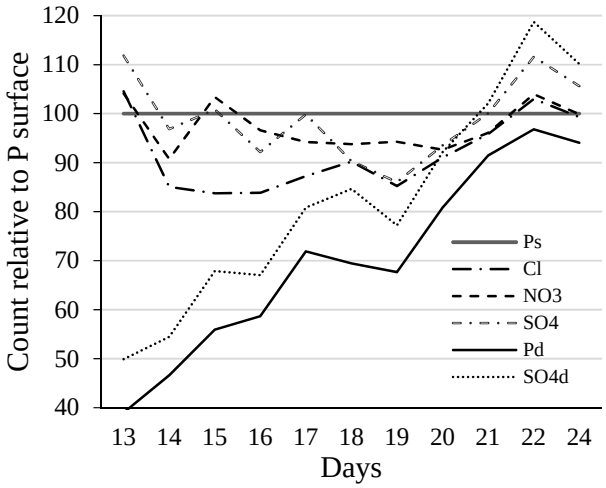

Figure 1. ^{32}P in-situ counts from day 13 to 24

Shoot and root dry weight and plant uptake of P and K

There was a significant response to P in both surface (s) and deep (d) placed treatments (Table 1). Highest shoot and root yields were obtained in the P+K_2SO_4 s treatment in both surface and deep placement although the shoot yield was not significantly different from the P s, P+KNO_3 s and P+KCl s treatments. Root yields showed a similar trend.

Highest plant P uptake was recorded in the P+KNO_3 s treatment (Table 1) but this was not consistently different from the other K treatments. This cannot be explained as a nutrient response to S as tissue concentrations and S uptake in this treatment are not significantly different from the P alone or other K treatments (data not presented).

Table 1. Shoot and root dry weight and plant uptake of P and K by mungbean

Treatment	Shoot DM yield (mg/2 plants)	Root DM yield (mg/ 2plants)	Plant uptake (g/2plants) P	K
0Ps	830 c[1]	416 de	2.3 d	27.3 d
Ps	4445 b	1454 bc	21.6 abc	178.1 c
P+KCl	5273 ab	1809 ab	20.0 abc	241.9 ab
P+KNO_3 s	5085 ab	1469 c	17.8 bc	227.1 bc
P+K_2SO_4 s	5723 a	2207 a	24.2 a	262.4 a
P+KH_2PO4 s	4207 b	993 c	16.0 c	174.2 c
0P d	775 c	330 e	2.1 d	26.5 d
P d	4333 b	1640 b	21.1abc	182.4 bc
P+K_2SO_4 d	4903 ab	1440 c	22.6 ab	199.7 bc
P+KH_2PO_4 d	4598 ab	1527 c	21.1 abc	196.7 bc

[1] Numbers in a column followed by the same letter are not significantly different according to critical difference (CD) at 5% level of significance.

Fertiliser P recovery

Table 2. Fertiliser P recovery

Treatment	Fertiliser P recovery (mg/2 plants)		
	Shoot	Root	Plant
Ps	18.2 ab[1]	2.7 b	20.9 ab
P+KCl s	16.6 ab	2.7 b	19.3 ab
P+KNO_3 s	15.0 ab	2.1 b	17.1 ab
P+K_2SO_4 s	19.4 a	4.1 a	23.4 a
P+KH_2PO_4 s	13.5 b	1.8 b	15.3 b
Pd	17.9 ab	2.5 b	20.4 ab
P+K_2SO_4 d	19.5 a	2.5 b	22.0 a
P+KH_2PO_4 d	18.0 ab	2.2 b	20.2 ab

[1] Numbers in a column followed by the same letter are not significantly different according to critical difference (CD) at 5% level of significance.

Plant yield and fertiliser P recovery was highest in the P+K_2SO_4 treatments but this was not consistently different from the other K source treatments. There was no significant difference between treatments in fertiliser P recovery with either placement depth (Table 2). The only significant effect was on the fertiliser P recovery in the P+K_2SO_4 s treatment. This increased uptake was not attributable to increased root growth in the fertiliser band or to a difference in band or rhizosphere pH as these were not significantly different in this treatment from the other K source treatments.

Conclusions

This study has shown that, unlike dicots, mungbean (monocot) does not respond to high nutrient concentration in the fertiliser band by proliferating roots. Application of K did not alter plant P uptake, soil pH in the fertiliser band or in the root rhizosphere. This research was conducted in an acidic soil with low P buffering capacity and sandy texture and there is a need to repeat the study in a Vertosol soil.

References

Gaspar AP, Laboski CAM, Naeve SL and Conley SP (2017). Phosphorus and Potassium Uptake, Partitioning, and Removal across a Wide Range of Soybean Seed Yield Levels. Crop Scence, 57:2193-2204.

Lester DW, Birch CJ and Dowling CW (2009). Fertiliser N and P applications on two Vertosols in north-eastern Australia. 2. Grain P concentration and P removal in grain from two long-term experiments. Crop and Pasture Science, 60, 218-229

Putland S and Parker D (1988). Mungbean research-Katherine no. 5 phosphate nutrition trial. Technical Bulletin-Northern Territory Department of Primary Industry and Fisheries (Australia). no. 123.

Sathyamoorthi K, Amanullah MM, Vaiyapuri K, Jagathjothi N and Ananthi T (2013). Response of green gram [*Vigna radiata* (L.) Wilczek] to fertilization through soil and foliage. Agricultural Reviews, 34, 71-78.

Saxena M. (1979). Recent advances in chickpea agronomy. pp89-96 in Proceedings of the International Workshop on Chickpea Improvement. Hyderabad, India, 28 Feb - 2 Mar 1979

Singh K, Manohar RS, Choudhary R, Yadav AK and Sangwan R (2015). Response of different sources and levels of phosphorus on yield, nutrient uptake and net returns on mungbean under rainfed condition. Indian Journal Agricultural Research, 35, 263-268.