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Effect of Phosphorous Application on Yield and its Uptake by Soybean (*Glycine max* L.) in Different Cropping Systems

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ABSTRACT

Background: Soybean-wheat is the most dominant soybean based cropping system and it also fits well in soybean-spring maize and soybean-gobhi sarson cropping systems. Soybean being a highly nutrient-exhaustive crop requires higher amounts of nutrients, particularly phosphorus for its optimum production. Thus, the present investigation was undertaken.

Methods: A field experiment was conducted for three years to study the effect of phosphorous application on yield and P uptake by soybean in different cropping systems. There were three cropping systems which were kept in main plots and five P levels *viz.*, 0, 20, 40, 60 and 80 kg P_2O_5 ha^{-1} applied to soybean which were kept in the sub plot.

Result: Application of 80 kg P_2O_5 ha^{-1} resulted in highest mean seed yield of soybean (20.9 q ha^{-1}) but significant response was observed up to 40 kg P_2O_5 ha^{-1} (19.8 q ha^{-1}) only. Highest mean seed P uptake of soybean was observed under application of 80 kg P_2O_5 ha^{-1}. The mean seed yield, stover yield and P uptake of soybean was not affected significantly under different cropping systems. The interaction effects of cropping system and applied P levels were however non-significant. A significant build-up of available P in surface soil over control was observed under 80 kg P_2O_5 ha^{-1} level.

Key words: Available P, Cropping systems, P uptake, Phosphorous, Soybean, Yield.

INTRODUCTION

Soybean [*Glycine max* (L.) Merril] is an important oilseed and pulse crop rich in essential amino acids and is enriched with high-quality proteins. Besides improving soil health by nitrogen fixation from the atmosphere, this leguminous crop helps increasing productivity of succeeding crop.

Being a high nutrient exhaustive crop (Hasan, 1994), soybean demands higher fertilization doses as compared to other legumes. The imbalanced fertilization leads to low dry matter production, poor nutritional quality and less crop productivity (Arbad *et al*., 2014). Thus, to sustain the crop productivity, balanced and adequate supply of inorganic fertilizers is needed. Soybean is highly responsive to phosphorous application owing to its key role as an essential element responsible for photosynthesis in legumes (Sivak and Walker, 1986). Each part of soybean plant responds well to P application, although excessive application might supress the plant growth (Cai *et al*., 2004). Since phosphorous is not readily available to plants, it is replenished through additional phosphatic fertilizers. Inadequate phosphorous supply is considered as one of the major factors leading to low yields of soybean (Jason and Antonio, 2005). Although soybean can better adapt to low P soils, but for sustained yields, it is necessary to apply sufficient phosphorous (Liu *et al*., 2014) to harmonize production (Kamprath and Miller, 1958), improving physiological characteristics along with enhanced plant biomass and nutrient uptake (Hinsinger, 2001). Improving phosphorous use efficiency alleviate chemical over usage also (Noushahi *et al*., 2019).

Phosphorous occurs in soils both as organic and inorganic forms and the relative amount of each form of phosphorous vary greatly among soils. Organic P is generally unavailable for plant uptake as it is tightly held with soil colloids, unless it is decomposed and released through mineralization process (Filippelli, 2002) Inorganic form of phosphorous ($H_2PO_4^-$ and HPO_4^{2-}) is available to plants, but it is found in soil solution in very low quantities (Weil and Brady, 2017). The chemistry of P cycling in soils is very complex and this is influenced mainly by moisture and temperature. Out of many possible forms of phosphorous, Labile P has to be replenished consistently to meet the plant nutrition needs at every growth stage of a plant's life. Phosphorous concentration in soil solution is amplified by addition of inorganic P fertilizers (Pierzynski *et al*., 2005). Soils that have not received sufficient phosphorous for long time could mark much of the P fertilizer applied unavailable (Antonangelo *et al*., 2018). So it is better to uphold proper phosphorous application to soils and not to excavate them of their P. Else the soils may continue accumulating phosphorous (Hansen *et al*., 2004) until the labile P fractions

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replenished through appropriate phosphatic fertilization. Generally soybean is grown in rotation with wheat,gobhi sarson and spring maize. But soybean, because of its high P needs, requires to be sufficiently supplemented with phosphorous. Keeping in view the variable P fertilization of these crops and cropping systems, an experiment was conducted to find out the phosphorous requirement of soybean in soybean-wheat, soybean-gobhi sarson and soybean-spring maize cropping systems.

MATERIALS AND METHODS

A field experiment was conducted at the research farm of Department of Soil Science, Punjab Agricultural University for three years (2015-2018) under irrigated conditions to find out the P requirement of soybean in soybean-wheat, soybean-gobhi sarson and soybean-spring maize cropping systems. The soil of the experimental field was sandy loam in texture, low in available N (134.6 kg ha^{-1}), low in available P (10.8 kg ha^{-1}), low in available K (178.4 kg ha^{-1}) and low in organic carbon (0.38%), neutral in reaction (pH 7.42). Soybean variety SL 525 was sown during second fortnight of June and harvested in the second fortnight of October during three years. The experiment was laid out in split plot design with three cropping systems *viz*; soybean-wheat, soybean-gobhi sarson and soybean-spring maize in main plots and five P levels comprising 0, 20, 40, 60 and 80 kg P_2O_5 ha^{-1} in sub plots with total of fifteen treatments which were replicated thrice on a fixed layout. All recommended package of practices were followed to raise wheat, gobhi sarson and spring maize. The phosphorous recommendation to wheat (60 kg P_2O_5 ha^{-1}), gobhi sarson (30 kg P_2O_5 ha^{-1}) and spring maize (60 kg P_2O_5 ha^{-1}) is variable. Whereas, soybean was raised with recommended dose of nitrogen and variable levels of P (0, 20, 40, 60 and 80 kg P_2O_5 ha^{-1}) were superimposed. The nutrient elements N and P were applied through urea, DAP/SSP, respectively. Entire dose of N and P were applied at the time of sowing to soybean, soybean seed was treated with *Bradyrhizobium japonicum* culture before sowing. The soybean crop was sown at a row spacing of 45 cm and the crop was irrigated as and when required. All the recommended cultural operations other than phosphorous treatments were practised to raise the crop. For determination of changes in available P and to determine the P uptake in soybean, soil and plant samples of different treatments were collected. Soil samples were collected from 0 to 15 cm layer, dried in shade and ground to pass through 2 mm sieve. Soil samples were then analysed for available P (Olsen *et al*. 1954). At the time of harvest, seed and straw samples of soybean were collected and oven-dried at a temperature of 70°C. The dried samples were ground in a stainless steel Willey mill. For the determination of P in soybean seed and straw, a known weight of grain and straw samples were digested in diacid mixture of HNO_3 and $HClO_4$ in the ratio of 3:1. The uptake of P by seed and straw was calculated by multiplying the P content with the respective oven dried seed and straw yield of soybean. The data were analysed in split plot design to determine the significance among different treatments.

RESULTS AND DISCUSSION

Effect of P levels on yield of soybean

The yield of soybean was significantly affected by graded levels of P (Table 1). The minimum soybean seed yield was observed in control where no P was applied (12.2 q ha^{-1}) and highest mean soybean seed yield (20.9 q ha^{-1}) was observed where 80 kg $P_2O_5ha^{-1}$ was applied. Though there was successive and linear increase in the soybean seed yield (Table 1) with all levels of applied P but the increase was non-significant among 40, 60 and 80 kg $P_2O_5ha^{-1}$ treatments. Pauline *et al*. (2010); Aise *et al*. (2011) and Samia *et al*., 2011 also reported that different levels of phosphorous application caused a significant increase in soybean yield. Soybean seed yield was not influenced under various cropping systems. However, Borges and Mallarino (2000) reported positive response in soybean grain yield with an increasing rates of P application in soil under soybean-wheat cropping system. The interaction effects of P levels and cropping systems also remained non-significant. The stover yield was also significantly affected by P levels (Table 2). Maximum mean stover yield (31.2 q ha^{-1}) was recorded in the treatment where 80 kg $P_2O_5ha^{-1}$ was applied which was significantly more than 0 and 20 kg P_2O_5 ha^{1} treatment but

Table 1: Average seed yield of soybean as influenced by cropping systems and P levels.

P levels (kg P_2O_5/ha)	Soybean-wheat	Soybean-gobhi sarson	Soybean-spring maize	Mean
		Yield (q/ha)		
0	11.4	12.3	12.5	12.2
20	14.1	15.1	15.8	15.0
40	19.0	20.2	20.2	19.8
60	20.1	20.7	21.3	20.7
80	21.1	20.1	21.5	20.9
Mean	17.2	17.7	18.3	

CD 5% Cropping system: NS; P level: 2.7; P × cropping systems: NS.

Table 2: Average stover yield of soybean as influenced by cropping systems and P levels.

P levels (kg P_2O_5/ha)	Soybean-wheat	Soybean-gobhi sarsons	Soybean-pring maize	Mean
		Yield (q/ha)		
0	21.4	22.5	23.2	22.0
20	25.4	23.4	25.8	24.9
40	29.2	30.6	30.2	30.0
60	30.4	30.6	31.3	30.7
80	31.1	30.4	32.2	31.2
Mean	27.9	27.7	28.6	

CD 5% Cropping system: NS; P level: 4.2; P × cropping systems: NS.

statistically at par with 40 kg (30.0 q ha^{-1}) and 60 kg (30.7 q ha^{-1}) P_2O_5 ha^{-1} levels. Though there was a linear increase in seed and stover yield of soybean at all levels of applied P than the control (22.0 q ha^{-1}) but the increase was not significant beyond 40 kg P_2O_5 ha^{-1} levels. Luikham *et al.* 2018 earlier reported a similar significant increase in stover yield of soybean with the application of different phosphorous levels. As was observed for soybean seed yield, no influence of cropping systems was observed for stover yield also. Mean stover yield of 27.9, 27.7 and 28.6 q ha^{-1} of soybean was observed in soybean-wheat, soybean-gobhi sarson and soybean-spring maize cropping systems, respectively. The interaction effects of different cropping systems and P level also remained non-significant. The yield of succeeding crops (Table 3) wheat, gobhi sarson and spring maize remained statistically similar in the treatments where different levels of P were applied to soybean, indicating no residual effect of higher application rates of P to soybean. This may be due to the fact that the succeeding crops after soybean were raised with recommended cultural practices including application of phosphorous (Anonymous, 2014b). Where phosphorous-fixing capacity is grossly unsaturated, optimum crop yields will likely require additions that considerably exceed plant uptake. However, as the excess phosphorous begins to saturate fixation sites, rates of application should be lowered to supply no more than what plants take up so as to prevent excessive phosphorous accumulations which may cause environment pollution (Weil and Brady, 2017).

Correlation study revealed that seed yield was positively and significantly correlated with seed P uptake (Fig 1).

Effect of P levels on P uptake by soybean

The mean seed P uptake of soybean was significantly affected by different P levels and it ranged from 14.0 kg ha^{-1} in control to 18.2, 25.3, 24.7 and 29.9 kg P ha^{-1} at 20, 40, 60 and 80 kg P_2O_5 ha^{-1} application rates, respectively. The maximum mean seed P uptake (29.9 kg ha^{-1}) was recorded at 80 kg P_2O_5 ha^{-1} which was significantly superior to all the P levels applied but the same was not reflected towards increasing the seed yield of soybean (Yan *et al*., 1995; Mustafa *et al*., 2004). The interaction effects of different cropping systems and P level also remained non-significant for seed P uptake. As was observed for seed and stover yield, different cropping systems did not influence seed P uptake significantly. The mean stover P uptake was also significantly affected by different P levels (Table 5) and it ranged from 23.6 kg ha^{-1} in control to 25.2, 29.1, 32.9 and 35.0 kg ha^{-1} at 20, 40, 60 and 80 kg P_2O_5 ha^{-1} application rates, respectively. The maximum mean stover P uptake (35.0 kg ha^{-1}) was recorded at 80 kg P_2O_5 ha^{-1} which was significantly superior to all other P levels except 60 kg P_2O_5 ha^{-1} treatment. Tiwari *et al*. (2019) also reported similar findings that supplementation of fertilizer P enhanced the phosphorous uptake in soybean. The stover P uptake also remained statistically similar in different cropping systems and no interaction effect was found.

Table 3: Yield of wheat, gobhi sarson and spring maize as influenced by P application to soybean.

P to soybean (kg P_2O_5/ha)	Wheat	Gobhi sarson	Spring maize
		Yield (q/ha)	
0	55.2	16.4	72.4
20	54.8	15.2	75.6
40	56.1	16.8	70.5
60	55.2	18.2	72.4
80	56.8	16.4	74.6
Mean	55.3	16.5	72.8
CD	NS	NS	NS

Table 4: Seed P uptake of soybean as influenced by cropping systems and P levels.

P levels (kg P_2O_5/ha)	Soybean-wheat	Soybean-gobhi sarson	Soybean-spring maize	Mean
		P uptake (kg/ha)		
0	13.4	15.1	13.5	14.0
20	16.3	19.4	18.5	18.2
40	23.9	26.0	25.6	25.3
60	23.6	24.5	26.5	24.7
80	26.7	31.5	31.4	29.9
Mean	20.8	23.3	23.0	

CD 5% Cropping system: NS; P level: 1.93; P × cropping systems: NS

Table 5: Stover P uptake of soybean as influenced by cropping systems and P levels.

P levels (kg P_2O_5/ha)	Soybean-wheat	Soybean-gobhi sarson	Soybean-spring maize	Mean
		P uptake (kg/ha)		
0	23.2	24.1	23.5	23.6
20	25.3	24.4	25.8	25.2
40	28.9	26.0	32.5	29.1
60	30.6	31.5	36.5	32.9
80	32.7	33.5	38.4	35.0
Mean	28.5	27.3	30.4	

CD 5% Cropping system: NS; P level: 3.9; P × cropping systems: NS

Table 6: Available P content of soil as influenced by cropping systems and P levels.

P levels (kg P_2O_5/ha)	Soybean-wheat	Soybean-gobhi sarson	Soybean-spring maize	Mean
		Available P (kg/ha)		
0	13.3	13.1	13.5	13.3
20	14.3	13.4	15.5	14.4
40	15.9	16.0	15.5	15.8
60	15.5	14.3	16.0	15.3
80	16.7	21.5	18.4	18.9
Mean	15.2	15.7	15.8	

CD 5% Cropping system: NS; P level: 1.3; P × cropping systems: NS.

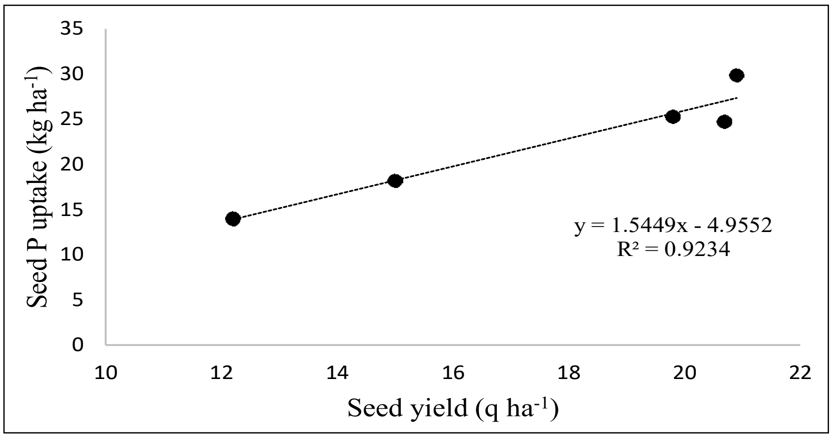

Fig 1: Correlation between mean seed yield and seed P uptake of soybean.

Effect of P levels on available soil P

The available P content of the soil (Table 6) ranged from 13.3 kg ha^{-1} in control to 14.4, 15.8, 15.3 and 18.9 kg ha^{-1} in 0, 20, 40, 60 and 80 kg P_2O_5 ha^{-1} levels, respectively. The increase in available P over control was significant at all applied P levels except for 20 kg P_2O_5 ha^{-1} levels. There was a marginal increase in available P from initial 10.8 kg ha^{-1} to 13.3 kg ha^{-1} in control. Whereas, at 40, 60 and 80 kg P_2O_5 ha^{-1} levels, the available P increased linearly. At higher levels excess P leaches down through soil profile and pollutes fresh water sources (Aulakh *et al*., 2009) making excess P unavailable (Mills and Jones, 1996).

CONCLUSION

It may be concluded that soybean responded upto 40 kg P_2O_5 per hectare and resulted in enhanced productivity of soybean and that the performance of soybean in different cropping systems remained statistically at par. No residual response of soybean applied P was observed on succeeding crops, although there was some increase in the available P content of the soil.

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