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Effect of phosphorus and phosphate solubilizing bacteria on growth, yield and quality of chickpea (*Cicer arietinum*)

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ABSTRACT

A field experiment was conducted during the winter (rabi) seasons of 2012-13 and 2013-14 at Jalalpur village of Morena district (M.P.) to study the effect of phosphorus and phosphate solubilizing bacteria on growth, yield and quality of chickpea (Cicer arietinum). The experiment was laid out in randomiged block design with seven treatments and three replications. Results revealed that combined application of 60 kg P_2O_5 ha^{-1} + PSB inoculation significantly increased the growth attributes (plant height, branches/plant, number and dry weight of root nodule and root and shoot dry weight/plant) yield attributes and yield (pods/plant, 1000 seed weight) and yield of chickpea over control. Chickpea crop responded significantly up to 90 kg P_2O_5 ha^{i1} alone and increased the seed and stover yield by 42.7 and 38.3 per cent, respectively over control. The maximum seed (23.55q ha^{-1}) and straw (64.48q ha^{-1}) yields were recorded with 60 kg P_2O_5 ha^{-1} + PSB inoculation. The maximum values of protein content (22.5%) in grain and straw (8.0%) and protein yield (534.6 kg ha^{-1}) were also recorded with 90 kg P_2O_5 ha^{-1}. The uptake of N and P by chickpea grain and straw improved significantly with phosphorus and PSB. Inoculations with Pseudomonas striate alone and in combination with phosphorus levels also improved the growth and yield of chickpea over control.

Keywords: Phosphorus, PSB, quality, yield, nutrient uptake, chickpea

INTRODUCTION

Chickpea (Cicer arietinum L.) is one of the most important winter (rabi) pulses of India. Phosphorus fertilization to legumes is more important than that of nitrogen. The cultivation of pulses without phosphatic fertilizer is one of the important factors responsible for their low productivity. Phosphorus nutrient in legumes simulates a greater attention in increasing the productivity, as it encourages healthy root growth and promotes rhizobial activity resulting in increased nodulation that exemplify nitrogen fixation. Phosphorus plays a vital functional role in energy transfer and metabolic regulation and it is an important structural component of many molecules. Efficiency of soil applied phosphatic fertilizers is around 10-25%, as these are converted readily to less available forms by the process of P-fixation. Phosphate solubilizing bacteria (PSB) play an important role in enhancing phosphorus availability to plants by lowering soil pH and by microbial production of organic acids and mineralization of organic phosphorus. Introduction of PSB in the rhizosphere of crop also increases the efficiency of phosphatic fertilizers (Gaur, 1990). Thus, adopting proper nutrient management practices in conjunction with PSB will help to improve the yield and quality of chickpea besides maintaining the soil fertility (Singh and Singh, 2014). Since data are lacking regarding combined effect of phosphorus and PSB inoculation on chickpea. Therefore, a field experiment was conducted to study the effect of phosphorus along with PSB inoculation on growth, yield and quality of chickpea.

MATERIALS AND METHODS

A field experiment was conducted at Jalalpur village of Morena district (M.P.) during winter season of 2012-13 and 2013-14. The soil was sandy loam and alkaline (pH 7.6) in reaction. It was low in organic carbon (3.7 g kg^{-1}) and available N (170 kg ha^{-1}) available P (10 kg ha^{-1}) and potassium (190 kg ha^{-1}). Seven treatments (T_1, control, T_2, PSB, T_3, 30 kg P_2O_5 ha^{-1}, T_4, 30 kg P_2O_5 ha^{-1} + PSB, T_5, 60 kg P_2O_5 ha^{-1}, T_6, 60 kg P_2O_5 ha^{-1} + PSB and T_7, 90 kg P_2O_5 ha^{-1}) were replicated thrice in randomized block design. Chickpea cultivar Jaki 9218 was sown in rows, 45 cm apart, with seed rate of 100 kg ha^{-1} in last week of October during both the years. The crop was fertilized with basal dose of 20 kg N ha^{-1} and 40 kg K_2O ha^{-1} as urea and muriate of potash, respectively at the time of sowing. Phosphorus as per treatments was

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applied as triple superphosphate at the time of sowing. PSB was inoculated with seeds one hour prior to sowing and then dried in shade. Growth and yield attributes were recorded at maturity. Seed and straw yields were recorded at harvest. Seed and straw samples collected at harvest were analysed for their nitrogen and phosphorus content. Nitrogen was determined by modified Kjeldahl method. Phosphorus was determined by vanadomolybdate yellow colour method in diacid (HNO_3 : $HClO_4$) digest (Jackson 1973). Protein content was calculated by multiplying N content by a factor of 6.25. The protein yield was calculated by multiplying grain yield with protein content. The nutrient content was multiplied with yield data (grain and straw) for calculating uptake of nutrients. The data on growth, yield and quality parameters of chickpea were statistically analysed as per analysis of variance procedure outlined for randomized block design (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Growth characters

Growth characters, viz., plant height and primary branches/plant were maximum with the application of 90 kg P_2O_2 ha^{-1}. The application of 60 kg P_2O_5 ha^{-1} + PSB being at par with 90 kg P_2O_5 $ha^{=1}$ resulted in significantly superior plant height to rest of the treatments. The application of 60 kg P_2O_5 ha^{-1} + PSB being at par with 90 kg P_2O_5 ha^{-1} also recorded significantly more number of primary branches/plant than the remaining treatments (Table 1). The increase in plant height and number of primary branches/plant of chickpea may be owing to the improvement in vigour of the plants possibly by balanced supply and higher uptake of nitrogen and phosphorus. Singh and Singh (2014) also reported similar results in chickpea. With regard to nodules/plant, 90 kg P_2O_5 and 60 kg P_2O_5 + PSB were significantly superior to remaining treatments Singh and Singh (2014) also reported that phosphorus is an essential nutrient for grain legumes, as it helps in improving nodulation and nitrogen fixation (Gaur, 1990). Growth promotional activities of PSB through production of growth promoting substances and proliferation of beneficial organisms in the rhizosphere might have also improved these growth characters and nodulation (Gupta, 2006).

Table 1: Growth and yield attributes of chickpea as affected by various treatments (mean of 2 years)

Treatments	Plant height (cm)	Primary branches/plant	Nodules/ plant	Pods/ plant	Seeds/ plant	Test weight (g)
T_1 Control	46.0	5.9	17.0	31.5	1.2	170.0
T_2 Phosphate solubiling bacteria	47.1	6.3	17.5	32.9	1.2	171.2
T_3 30 kg P_2O_5 ha^{-1}	48.5	6.7	18.6	33.5	1.3	173.7
T_4 30 kg P_2O_5 ha^{-1} + PSB	50.4	6.9	19.1	34.1	1.3	174.8
T_5 60 kg P_2O_5 ha^{-1}	51.9	7.2	19.7	34.8	1.4	179.5
T_6 60 kg P_2O_5 ha^{-1} + PSB	52.5	7.5	20.4	36.0	1.4	182.0
T_7 90 kg P_2O_5 ha^{-1}	53.0	7.6	20.7	36.2	1.4	182.5
SEm±	0.38	0.08	0.22	0.49	0.07	0.69
CD (P=0.05)	1.12	0.23	0.65	1.45	NS	2.03

Yield attributes and yield

Application of 90 kg P_2O_5 ha^{-1} being at par with 60 kg P_2O_5 ha^{-1} + PSB recorded significantly more pods/plant, seeds/pod and test weight over remaining treatments. However, maximum pods/plant (36.2), seeds/pod (1.4) and test weight (182.5g) were recorded with 90 kg P_2O_2 ha^{-1}. Seeds/pod were not affected significantly by the application of phosphorus alone or in combination with PSB. This behavior of treatments may be attributed to differential availability of phosphorus under different treatments. This might be the result of improved supply of phosphorus by Pseudomonas striata at the later stages of crop growth. Khan *et al.* (2007) and Singh *et al.* (2014) reported significant increase in yield attributes with bio-fertilizers. Pooled data showed that seed and stover yield of chickpea increased with PSB which might be owing to increase in P availability through solubilization of insoluble native P and production of plant growth promoting substances (Singh *et al.* 2014). Application of phosphorus had significantly influenced the seed and straw yield of chickpea over control. The increases in seed and straw yields with 90 kg P_2O_5 ha^{-1} alone over the control were recorded to the tune of 42.7 and 38.3%, respectively. The increase in yield with P levels can be attributed to the effective metabolic activities coupled with increased rate of photosynthesis, leading to better translocation of nutrients and expression of development characters. Singh and Singh (2012), Singh *et al.* (2017) and Singh (2017) also reported similar results in chickpea, lentil and pea, respectively. Seed and straw yields of chickpea also increased significantly with combined use of P levels and PSB and relatively higher yields were recorded with 60 kg P_2O_5 ha^{-1} + PSB. Improved environment in rhizosphere coupled with more balanced nutritional environment inside the plant owing to P and PSB inoculation increased the plant growth resulting in higher seed and straw yield. These results are in agreement with the findings of Singh and Singh (2017).

Table 2: Effect of treatments on yield, quality and nutrient uptake in chickpea (mean of 2 years)

Treatments	Yield (q ha^{-1})		Protein (%)		Protein yield ($kg\ ha^{-1}$)	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})	
	Seed	Straw	Seed	Straw		Seed	Straw	Seed	Straw
T_1 Control	16.65	46.71	19.9	6.6	331.3	53.1	49.0	5.8	8.8
T_2 PSB	18.04	51.95	20.3	6.8	366.2	58.6	56.6	6.7	10.9
T_3 30 kg P_2O_5 ha^{-1}	20.05	54.18	20.6	7.1	413.0	66.1	61.7	7.8	12.5
T_4 30 kg P_2O_5 ha^{-1} + PSB	21.75	58.46	20.9	7.4	454.5	72.6	69.0	8.7	14.0
T_5 60 kg P_2O_5 ha^{-1}	22.40	61.05	21.2	7.6	474.8	76.2	73.8	9.4	15.8
T_6 60 kg P_2O_5 ha^{-1} + PSB	23.55	64.48	21.6	7.8	508.7	81.2	80.6	10.1	17.4
T_7 90 kg P_2O_5 ha^{-1}	23.76	64.61	22.5	8.0	534.6	85.5	82.7	10.7	18.1
SEm±	0.70	0.95	0.19	0.10	10.3	1.77	1.54	0.08	0.17
CD (P=0.05)	2.10	2.81	0.56	0.29	30.6	5.27	4.58	0.23	0.50

Quality

Different treatments significantly increased the protein content in chickpea seed and straw (Table 2). Inoculation of seeds with PSB improved the protein content over control but the improvement was statistically non-significant. Application of phosphorus also improved the protein content in seed and straw of chickpea and higher values of protein content in seed (22.5%) and straw (8.0%) were recorded with 90 kg P_2O_5 ha^{-1}. This increase in protein content with P application might be due to higher N absorption as a result of N_2 fixation by nodules (Singh and Singh 2017). The maximum protein content in chickpea seed and stover was recorded with combined use of 60 kg P_2O_5 ha^{-1} + PSB inoculation. The protein yield ranged from 331.3 kg ha^{-1} at control to 534.6 kg ha^{-1} at 90 kg P_2O_5 ha^{-1}. Since protein yield is mainly the function of seed yield and its protein content in seeds protein yield increased with increase in P levels. The increase in protein yield with P application has also been reported by Singh and Singh (2017).

Nutrient uptake

The mean uptake of nitrogen by chickpea crop improved markedly with all the treatments over control. The nitrogen uptake by seed ranged from 53.1kg ha^{-1} at control to 85.5 kg ha^{-1} at 90 kg P_2O_5 ha^{-1}. The corresponding range of N uptake by straw was from 49.0 to 82.7 kg ha^{-1}. PSB inoculation improved the N uptake non-significantly over control but application of P increased N uptake significantly over control (Singh *et al.* 2014). Inoculation with P. striata amended with 60 kg P_2O_5 ha^{-1} enhanced the uptake of nitrogen by chickpea seed and straw over P alone. PSB inoculation augmented the amount of phosphorus assimilated by grain and straw which may be due to both the higher content of phosphorus and seed and straw yield of chickpea (Singh *et al.* 2014). Phosphorus application increased the uptake of phosphorus by chickpea crop over control and relatively higher values of P uptake by seed (10.7 kg ha^{-1}) and straw (18.1 kg ha^{-1}) were recorded with 90 kg P_2O_5 ha^{-1}. This might be owing to increased P availability and yield of chickpea seed and straw. The maximum uptake of P was recorded with 60 kg P_2O_5 ha^{-1} + PSB inoculation which differed significantly from most of the treatments. The higher P utilization by chickpea crop could be attained because of increased microbial activity in improving the availability of soil nutrients for their absorption. Singh *et al.* (2014), Singh and Singh (2017) also reported similar results.

Based on two years of field study, it may be concluded that application of P along with PSB inoculation increased productivity and quality of chickpea crop. Application of 90 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 ha^{-1} + PSB proved statistically at par with respect to yield and quality of the crop.

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