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Article

Yield, Soil Health and Nutrient Utilization of Field Pea (*Pisum sativum* L.) as Affected by Phosphorus and Bio-fertilizers under Subtropical Conditions of Jammu

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Abstract: A field study was conducted in *Rabi* season of year 2009-10 at the Agronomy Farm of SKUAST-J to evaluate the response of field pea (*Pisum sativum* cv. Rachna) to levels of phosphorus and bio-fertilizers under sun-tropical conditions of Jammu. Recommended dose of phosphorus recorded seed and stover yield of 15.85 q ha^{-1} and 33.63 q ha^{-1}, respectively higher than other phosphorus levels and control. Among seed inoculation treatments, dual inoculation of *Rhizobium* + PSB produced significantly higher seed and stover yield of 15.01 q ha^{-1} and 33.90 q ha^{-1} than inoculation with *Rhizobium*, PSB and control. The effect of recommended dose of phosphorus and dual inoculation on soil available NPK, NPK uptake in crop as well as protein content in seed was found significantly higher as compared to other treatments. Besides, the interaction effect of phosphorus and bio-fertilizers on soil available was found significant.

Key words: Field pea, phosphorus, bio-fertilizers, growth and yield

1. Introduction

Field pea (*Pisum sativum*) is a popular pulse crop of India. India is the second largest producer of pea in the world after Russia. Pea is rich in protein, carbohydrates, vitamin A and C, calcium and phosphorus. It is commonly used throughout the world in human diets and has high levels of amino acid**s**, lysine and tryptophan, which are relatively low in cereal grains and contains approximately 21-25% protein. Besides, maintaining soil fertility through nitrogen fixation in association with symbiotic *Rhizobium* prevalent in their root nodules, it plays a vital role in furthering sustainable agriculture. Thus apart from meeting its own nitrogen requirement, pea crop is known to add 50-60 kg residual nitrogen ha^{-1} in soil (Erman *et al*., 2009). Phosphorus is known to play an important role in growth and development of the crop and have direct relation with root proliferation, straw strength, grain formation, crop maturation and crop quality. The requirement of P, which is essential for root growth and nodulation has to be largely fulfilled through inorganic fertilizers. Enhancing P availability to crop through phosphate-solubilizing bacteria (PSB) holds promise in the present scenario of escalating prices of phosphatic fertilizers in the country and a general deficiency of P in Indian soils (Alagawadi and Gaur, 1988). Bio-fertilizers are known to play an important role in increasing availability of nitrogen and phosphorus besides improving biological fixation of atmospheric nitrogen and enhance phosphorus availability to crop. Therefore, introduction of efficient strains of *Rhizobium* in soil, which is poor in nitrogen, may help in boosting up production and consequently more nitrogen fixation (Gill *et al*., 1987).

2. Materials and Methods

Field experiment was conducted during *rabi* season 2009-10 at Research Farm of Sher-e-Kashmir University of Agricultural Sciences and Technology Jammu (SKUAST-J). The experimental site is located at 32^o 40′ N latitude and 74^o 53′ E longitude at a height of 300 m amsl. The soil of the experimental area was sandy loam with alkaline pH (7.8); low in organic carbon (0.45%), available N (229 Kg ha^{-1}), medium in available P (17.40 Kg ha^{-1}) and K (179.37 Kg ha^{-1}). Field pea cv. Rachna was chosen for the study. The experiment was laid out in split-plot design comprising of 16 treatments in three replications on gross plot size of 5 x 3 m and net plot size of 4.4 x 2.4 m with crop geometry of 30 x 10 cm. The crop was sown on 11^{th} November. In main plots, four phosphorus levels {control (no P), 50% recommended dose of P (44 kg ha^{-1}), 75% recommended dose of P (66 kg ha^{-1}) and 100% recommended dose of P (88 kg ha^{-1})} and in sub-plots, four levels of seed inoculation {control (no inoculation), *Rhizobium*, PSB and *Rhizobium* + PSB} were assigned. Full dose of N (15 kg N ha^{-1}) and P_2O_5 (as per treatment) was applied as basal dose through diammonium phosphate (DAP). Field pea seeds were pre-treated with fungicide tabucanazole (Raxil) @ 1g kg^{-1} of seed. The jaggery was prepared by dissolving 120 g of sugar in 1000 ml of water, the solution was boiled, cooled and then divided into two. The *Rhizobium* and PSB inoculant were mixed in their respective cooled solution. The seeds were then treated with *Rhizobium leguminosarum* (@ 20 g kg^{-1} seed and PSB (*Pseudomonas striata*) (@ 10 g kg^{-1} seed. The inoculated seeds were dried under shade and sown immediately after drying. All the agronomic practices were carried out uniformly to raise the crop. The crop was harvested on 15th March. The total rainfall during the crop season was 36.5 mm. Mean maximum and minimum temperatures varied from 13.6-34.2 ^{0}C and 4.2-15.3 ^{0}C, respectively. The data collected was subjected to analysis of variance technique using method given by Cox and Cochran (1963).

3. Results and Discussions

3.1. Seed and Stover Yield

Seed and stover yield exhibited a discernable increase as a result of increased phosphorus application. The highest seed yield was recorded with 100 *percent* recommended dose of P_2O_5 ha^{-1} (15.85 q ha^{-1}) which was superior by 57.55, 25.39 and 9.31 % as compared to control, 50 and 75 percent recommended dose of P_2O_5 ha^{-1} (Table 1). Maximum stover yield (33.63 q ha^{-1}) was recorded with full recommended dose of P_2O_5 ha^{-1} and marked an increase of 41.54 % over control. The improvement in seed and stover yield at higher levels of phosphorus may be attributed to the role of phosphorus in the energetisation processes, profuse nodulation and being the constituent of ribonucleic acid, deoxyribonucleic acid and ATP which regulate vital metabolic processes in the plant, helping in root formation and nitrogen fixation which had positive effect on photosynthetic organs and rate which in turn favours better growth and yield of the crop. The results are in conformity with that of Erman *et al.,* (2009), Tomar *et al.* (2006).

Table 1: Effect of phosphorus levels and bio-fertilizers on yield attributes, seed yield, stover yield and harvest index of field pea

Treatments	**Seed yield** (q ha^{-1})	**Stover yield** (q ha^{-1})
Control	10.06	23.76
50% recommended dose of P	12.64	27.45
75% recommended dose of P	14.50	31.24
100% recommended dose of P	15.85	33.63
SEm ±	0.16	0.78
CD (p=0.05)	**0.55**	**2.34**
Control	10.81	27.01
Rhizobium	13.87	31.89
PSB	13.14	30.09
Rhizobium + PSB	15.01	33.90
SEm ±	0.29	0.66
CD (p=0.05)	**0.87**	**1.98**
Interaction	1.77	N.S.

Dual inoculation of *Rhizobium* + PSB recorded highest seed yield (15.01 q ha^{-1}) and stover yield (33.90 q ha^{-1}) and the magnitude of increase was 38.85, 8.21 and 13.91 % as compared to control, *Rhizobium* and PSB alone in case of seed yield whereas magnitude of increase was 25.50, 6.30 and 12.66 % as compared to control, *Rhizobium* and PSB in case of stover yield (Table 1). Seed inoculation with *Rhizobium* or PSB alone remained at par with each other but significantly superior over control. Significant increase in seed and stover yield due to seed inoculation could be attributed to increased and balanced availability of both N and P in dual inoculation (*Rhizobium* + PSB). The synergistic effect of *Rhizobium* and PSB might have increased the growth, yield attributes and ultimately the yield due to increased nitrogenase activity and available P status of soil. Similar findings were reported by Negi *et al.* (2006).

3.2. Effect on Soil Available N, P and K

Significant increase in soil available N, P and K was recorded with increased application of phosphorus and seed inoculation (Table 2). Application of 100 *percent* recommended dose of P_2O_5 ha^{-1} recorded highest soil available N (253.67 kg ha^{-1}), P (23.28 kg ha^{-1}) and K (144.90 kg ha^{-1}), respectively. Soil available N marked a superiority of 11.33, 3.75 and 1.30 % as compared to control, 50 and 75 *percent* recommended dose of P_2O_5 ha^{-1}. Similarly in case of soil available P, 100 *percent* recommended dose of P_2O_5 ha^{-1} recorded an increase of 68.94, 42.90 and 22.14 % as compared to control, 50 and 75 percent recommended dose of P_2O_5 ha^{-1} whereas in case of available K, the magnitude of superiority was 11.26, 7.07 and 3.19 % as compared to control, 50 and 75 *percent* recommended dose of P_2O_5 ha^{-1}. The increase in soil available N, P and K could be attributed to greater biological nitrogen fixation with adequate P supply. The status of soil P improved firstly due to direct application of P to soil, and secondly through organic acids released by legume roots capable of solubilizing soil P. The results are in close conformity with Dadhich *et al*., 2011 and Son *et al.* (2001).

Dual inoculation with *Rhizobium* +PSB recorded significantly highest available N (247.13 kg ha^{-1}), available P (19.64 kg ha^{-1}) and K (140.80 kg ha^{-1}) than no-inoculation which recorded 238.88, 16.21 kg ha^{-1} and 128.14 kg ha^{-1} soil available N, P and K, respectively (Table 2). This increase in available nitrogen content of soil was due to favourable effect of Rhizobium and PSB on root nodulation and thereby, nitrogen fixation. Likewise, the available phosphorus content of soil in plots treated with dual inoculation of *Rhizobium*+ PSB and individual inoculation of PSB improved significantly over non inoculated plot which may be attributed to the solubilization of insoluble phosphate into available phosphate in the soil by the PSB. Latif *et al.* (1992) also found similar improvement in soil fertility due to use of biofertilizers.

Table 2: Effect of phosphorus levels and bio-fertilizers on available soil and total nitrogen, phosphorus, potassium and protein content after crop harvest

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Total N, P and K uptake (kg ha^{-1})			Protein content (%)
				N	P	K	
Phosphorus levels							
Control	227.85	13.78	130.23	46.60	8.48	26.89	20.25
50% recommended dose of P	244.50	16.29	135.33	60.11	10.83	33.20	20.50
75% recommended dose of P	250.40	19.06	140.42	69.40	12.53	38.42	20.62
100% recommended dose of P	253.67	23.28	144.42	78.17	14.11	41.87	20.75
SEm ±	0.49	0.69	1.61	1.26	0.36	1.08	0.03
CD (p=0.05)	3.05	2.39	4.40	4.36	1.27	3.24	N.S.
Bio-fertilizers							
Control	238.88	16.21	128.14	49.65	9.34	29.06	20.12
Rhizobium	246.53	18.00	137.31	66.53	11.68	37.06	20.50
PSB	244.36	19.59	136.77	61.78	12.31	36.04	20.37
Rhizobium + PSB	247.13	19.64	140.80	76.83	14.05	41.90	21.12
SEm ±	0.92	0.35	1.67	1.87	0.30	1.10	0.04
CD (p=0.05)	2.69	1.06	3.58	5.48	0.95	4.44	0.16

3.3. NPK Uptake and Protein Content of Field Pea

Increasing phosphorus application and seed inoculation significantly increased total N uptake. 100 *percent* recommended dose of P_2O_5 ha^{-1} recorded highest total N uptake (78.17 kg ha^{-1}) and the magnitude of increase was to the tune of 67.74, 30.04 and 12.63 % as compared to control, 50 and 75 percent recommended dose of P_2O_5 ha^{-1}. Total P uptake increased significantly with increased phosphorus levels and the highest total P uptake was recorded with the application of 100 *percent* recommended dose of P_2O_5 ha^{-1} (14.11 kg ha^{-1}) and the extent of increase was 66.39, 30.28 and 12.60 % as compared to control, 50 and 75 *percent* recommended dose of P_2O_5 ha^{-1} (Table 2). Total K also recorded significant increase with increased phosphorus levels. The application of 100 *percent* recommended dose of P_2O_5 ha^{-1} recorded highest total K uptake (41.87 kg ha^{-1}) and the extent of increase was to the tune of 55.70, 26.11 and 8.97 % as control, 50 and 75 *percent* recommended dose of P_2O_5 ha^{-1} (Table 2). This might be due to greater availability of these nutrients with extended root system, coupled with increased seed and straw yield resulting in higher uptake of these nutrients. The results are in accordance with Dubey and Agarwal (1999). However, phosphorus application did not significantly influence protein content of seed.

Combined inoculation of *Rhizobium* +PSB recorded highest total N uptake (76.83 kg ha^{-1}), P uptake (14.05 kg ha^{-1}) and K uptake (41.90 kg ha^{-1}) which marked a superiority of 54.74, 50.42 and 44.18 percent over no-inoculation in case of N, P and K uptake, respectively. Dual inoculation of *Rhizobium* + PSB recorded highest protein content (21.12 %) and the extent of increase was 4.90, 3.02 and 3.68 % as compared to control, *Rhizobium* and PSB inoculation (Table 2). Seed inoculation alone with *Rhizobium or* PSB were statistically at par with each other but significantly superior over no-inoculation. This may be due to increased availability of phosphorus resulting in more nitrogen fixation by the bacteria which in turn helped in better absorption and utilization of the entire plant nutrient thus resulting in more uptake of N, P and K. The increased protein content with seed inoculation thus might be due to increased N uptake in grains. Similar results have also been reported by Shabir *et al*., (2010).

3.4. Interaction Effect of Phosphorus and Bio-fertilizers

The interaction effect of phosphorus levels and seed inoculation on available soil nitrogen (kg ha^{-1}) after the harvest of field pea was significant (Fig. 1). A significant increase up to 100 *percent* recommended dose of P_2O_5 ha^{-1} was recorded when seeds are sown without inoculation and when inoculated with *Rhizobium*, whereas significant increase was detectable up to 75 *percent* recommended dose of P_2O_5 ha^{-1} when inoculated with *Rhizobium* + PSB which was at par with 100 *percent* recommended dose of P_2O_5 ha^{-1}. The interaction effect of phosphorus levels and seed inoculation showed a significant increase only up to 50 *percent* recommended dose of P_2O_5 ha^{-1} when inoculated with PSB which was at par with 75 and 100 *percent* recommended dose of P_2O_5 ha^{-1}. This may be due to favourable effect of phosphorus and nitrogen by improved biological nitrogen fixation which in turn have promoted higher growth and yield attributes and resulted in increased seed yield (Srivastava and Ahalawat, 1995). Interaction effect of 100 *percent* recommended dose of phosphorus and combined inoculation with *Rhizobium* + PSB recorded highest seed yield (17.58 q ha^{-1}) which was at par with 75 *percent* recommended dose of phosphorus (16.30 q ha^{-1}).

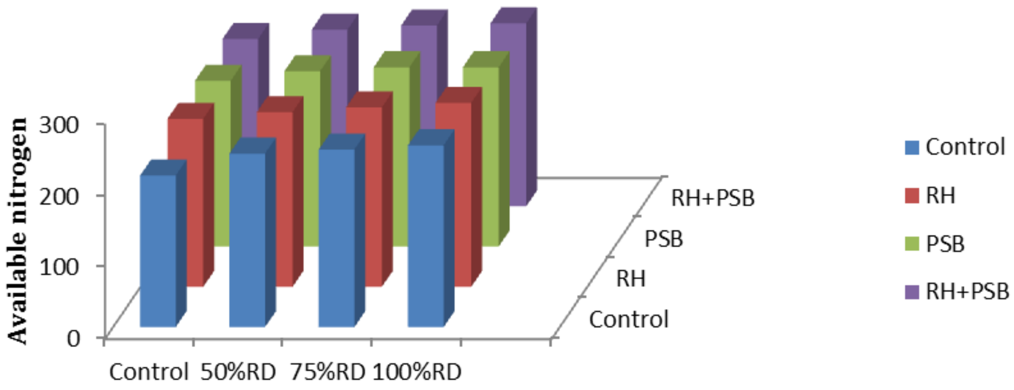

Fig. 1 Interaction effect between levels of phosphorus and biofertlizers on available nitrogen (kg/ha) after crop harvest

4. Conclusion

Full recommended dose of phosphorus (88 kg ha^{-1}) and dual seed inoculation with *Rhizobium* + PSB resulted in highest seed yield besiding increasing soil available and total N, P and K in plants, respectively. The quality of crop in terms of protein content is also enhanced with seed inoculation. Therefore, integrated management with phoshorus application and combined inoculation with *Rhizobium* + PSB can be used to boost the production of field pea (*Pisum sativum* L.) and at the same time enriching the soil with residual nutrients so as to benefit the succeeding crop, thus helps in maintaining the soil fertility.

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