Growth, Yield and Economics of Field pea (*Pisum sativum* L.) as Influenced by Phosphorus and Bio-fertilizers under Subtropical Conditions of Jammu

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A field study was conducted in *Rabi* season of year 2009-10 at the Agronomy Farm of SKUAST-J to studygrowth, yield and economics of field pea (*Pisum sativum* L.) as influenced by phosphorus and bio-fertilizers under subtropical conditions of Jammu. Results revealed that among various levels of phosphorus and bio-fertilizers, 100 *per cent* recommended dose of phosphorus and dual inoculation of *Rhizobium* + PSB recorded significantly higher values of growth and yield attributes studied. Recommended dose of phosphorus recorded seed yield of 15.85 q ha^{-1} with a benefit cost ratio of 1.86 than other phosphorus levels and control. Among seed inoculation treatments, dual inoculation of *Rhizobium* + PSB produced significantly higher seed yield of 15.01 q ha^{-1} and benefit cost ratio of 1.77 than inoculation of *Rhizobium* and PSB alone, but significantly superior over control. The interaction effect of phosphorus and bio-fertilizers was significant on number and dry weight of root nodules and seed yield.

Key words: Field pea, Phosphorus, Bio-fertilizers, Growth and yield.

Field pea (*Pisum sativum* L.) 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. 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[1]. 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[2]. 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* and PSB in soil, which is poor in

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nitrogen, may help in boosting up production and consequently more nitrogen fixation[3]. Being a legume crop, major portion of N requirement of the crop is met through biological nitrogen fixation. Therefore, the present study was designed to assess the influence of phosphorus and bio-fertilizers on the growth and yield of field pea.

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°402 N latitude and 74° 532 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 11th 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 sugarin 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 15March. 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 °C, respectively.

Plant height, number of branches $plant^{-1}$were recorded from ten randomly selected marked plants in each plot and then average number was calculated. Two plants in each plot from penultimate rows were uprooted. After sun drying for 4-5 days, the plant samples were dried in the oven at 60-65° C for 72 hours till constant weight and dry weight of the plant samples were recorded in grams. No. of nodules $plant^{-1}$ were counted by carefully uprooted three plants with the help of spade by digging a soil core of 150 mm around the plant and 200 mm in depth from the penultimate rows and were kept in plastic buckets full of water just to loosen the adhering soil from the roots of the plant. Thereafter, plants were separated into roots and shoots by cutting from the first unable node. The roots were then brought to laboratory, followed by washing of roots under running water with a screen underneath to catch the detached nodules. Nodules excised from the roots with a scalpel were counted and nodules which were counted for nodule number $plant^{-1}$ were oven dried at 60° C for 48 hours till constant weight and then average nodule weight was calculated in terms of g $plant^{-1}$. Economics were calculated by considering prevailing sale price of field pea and the cost of cultivation.The data collected was subjected to analysis of variance technique as described by Cochran and Cox[4].

RESULTS AND DISCUSSIONS

Growth parameters

The data in (Table 1) revealed that maximum plant height (22.56 and 64.24 cm) was recorded at 60 days after sowing (DAS) and at maturity with 100 % recommended dose of P_2O_5 ha^{-1} which marked an increase of 6.88, 5.13 and 2.00 % over control, 50 and 75 *per cent* recommended dose of P_2O_5 ha^{-1},respectively.Dry matter accumulation per plant was found to enhance significantly with each successive increase in dose of phosphorus at 60 DAS and at maturity. At harvest, 100 *per cent*recommended dose of P_2O_5 ha^{-1} recorded highest dry matter $plant^{-1}$ (19.57 g) andthe magnitude of increase was 35.33, 20.80 and10.06 % over control, 50 and 75 *per cent* recommended dose of P_2O_5 ha^{-1}, respectively.Maximum branches $plant^{-1}$ (16.91and 48.46) were recorded with 100 *per cent* recommended dose of P_2O_5 ha^{-1}at 60 DAS and at maturity with a superiority of 42.15, 25.02 and 10.74 % over control, 50 and 75 *per cent* recommended dose of P_2O_5 ha^{-1}, respectively as compared to control, 50 and 75 *per cent* recommended dose of P_2O_5 ha^{-1}. Significant increase in plant height, dry matter accumulation $plant^{-1}$ and number of branches $plant^{-1}$ with increasing levels of phosphorus might be due to increased availability of phosphorus which encourages the cell division and cell elongation of the plants, besides helping in nitrogen fixation and thus increases availability of nitrogen in soil[5]. Phosphorus enhances the activity of *Rhizobium* and thus increases N-fixation in the root nodules, thereby improving plant growth and development. The increased cell division and development due to increasing levels of phosphorus probably resulted in more meiotic

Table 1. Effect of phosphorus levels and bio-fertilizers on plant height, dry matter $plant^{-1}$ and number of branches $plant^{-1}$ of field pea

Treatments	Plant height (cm)		Dry matter $plant^{-1}$(g)		Number of branches $plant^{-1}$	
	60 DAS	Maturity	60 DAS	Maturity	60 DAS	Maturity
Phosphorus levels						
Control	20.23	60.10	4.08	14.46	12.10	34.09
50% recommended dose of P	21.43	61.10	5.42	16.20	13.86	39.36
75% recommended dose of P	21.92	62.98	5.76	17.78	14.75	43.76
100% recommended dose of P	22.56	64.24	6.12	19.57	16.91	48.46
S.Em ±	0.12	0.29	0.06	0.45	0.20	1.42
C D (p=0.05)	0.37	0.91	0.21	1.56	0.69	4.20
Bio-fertilizers						
Control	20.67	60.04	5.00	13.45	10.05	35.66
Rhizobium	21.79	62.20	5.33	16.96	15.02	40.32
PSB	21.27	61.70	5.17	15.57	14.02	38.30
Rhizobium+PSB	22.44	63.90	5.92	22.30	18.62	44.12
S. Em ±	0.17	0.25	0.05	0.47	0.34	0.80
CD (p=0.05)	0.51	0.73	0.16	1.39	1.01	2.35
Interaction	N.S	N.S.	N.S.	N.S.	N.S.	N.S.

Table 2. Effect of phosphorus and bio-fertilizers on number and dry weight (g) of root nodules of field pea

Treatments	No. of nodules $plant^{-1}$		Dry weight of nodules (g)	
	Pre flowering	Post flowering	Pre flowering	Post flowering
Phosphorus levels				
Control	24.69	22.15	5.97	5.36
50% recommended dose of P	30.51	24.90	6.73	5.72
75% recommended dose of P	33.16	27.70	6.84	6.08
100% recommended dose of P	36.61	30.41	6.91	6.28
S.Em ±	0.27	0.90	0.01	0.05
C D (p=0.05)	0.94	2.71	0.02	0.16
Bio-fertilizers				
Control	25.24	19.32	6.35	5.54
Rhizobium	31.94	24.05	6.65	5.90
PSB	31.54	22.48	6.64	5.82
Rhizobium+PSB	36.21	27.31	6.79	6.17
S.Em ±	0.38	1.08	0.02	0.04
CD (p=0.05)	1.12	3.14	0.06	0.11
Interaction	2.31	N.S	0.12	N.S.

activities, thus the development of more apical bud primordia took place which produced more number of branches[5].

Among the bacterial strains combined inoculation of *Rhizobium* + PSB recorded maximum plant height at 60 DAS (22.44 cm) and at maturity (63.90 cm) as compared to *Rhizobium* or PSB alone which were at par with each other but significantly superior over control.Dual inoculation of *Rhizobium* and PSB recorded the highest dry matter plant^{-1} (5.92, and 22.30 g) at 60 DAS and at maturity as compared to control, *Rhizobium* and PSB. Number of branches plant^{-1} recorded a significant increase with seed inoculation andhighest number of branches per plant (18.62and 44.12) at 60 DAS and maturity were recorded with combined inoculation of *Rhizobium* + PSB andthe increase was 23.72, 9.42 and 15.19 % over control, *Rhizobium* and PSB at maturity compared to seed inoculation with *Rhizobium* or PSB and control. Seed inoculation alone with *Rhizobium* or PSB were at par with each other but significantly superior to control. Increase in the vegetative growth of pea crop with bio-fertilizers application may be due to their role in increasing soil fertility, increasing availability and uptake of nutrient elements (N, P and K) which ultimately led to improved vegetative growth of pea crop[1]. Also bio-fertilizers causes biological N fixation by *Rhizobium*,greater release of P by phosphate

Table 3. Effect of phosphorus levels and bio-fertilizers on yield attributes, seed yield and harvest index of field pea

Treatments	Number of Pods plant^{-1}	No. of seeds pod^{-1}	Test weight (g)	Seed yield (q ha^{-1})	Harvest Index (%)
Phosphorus levels					
Control	6.01	4.91	165.24	10.06	25.91
50% recommended dose of P	7.54	5.36	177.19	12.64	31.22
75% recommended dose of P	8.45	5.80	188.75	14.50	31.70
100% recommended dose of P	9.10	6.22	200.13	15.85	32.33
SEm ±	0.10	0.13	3.09	0.16	0.14
CD (p=0.05)	0.35	0.39	10.67	0.55	0.45
Bio-fertilizers					
Control	6.78	4.83	177.40	10.81	28.58
Rhizobium	7.75	5.60	183.40	13.87	30.27
PSB	7.50	5.56	181.42	13.14	30.11
Rhizobium + PSB	9.07	6.30	189.07	15.01	32.62
SEm ±	0.09	0.23	0.96	0.29	0.39
CD (p=0.05)	0.27	0.69	2.80	0.87	1.20
Interaction	N.S.	N.S.	N.S.	1.77	N.S.

Table 4. Relative economics of field pea (hectare basis) as affected by levels of phosphorus and bio-fertilizers

Treatments	Cost of cultivation (₹ha-1)	NetReturns (₹ha-1)	Net B: C ratio
Phosphorus levels			
Control	15562.5	14617.5	0.93
50% recommended dose of P	16090.5	22609.5	1.40
75% recommended dose of P	16354.5	27145.5	1.65
100% recommended dose of P	16618.5	30931.5	1.86
Bio-fertilizers			
Control	16106.5	16323.5	1.01
Rhizobium	16156.5	25453.5	1.57
PSB	16156.5	24043.5	1.48
Rhizobium + PSB	16206.5	28823.5	1.77

solubilizing bacteria and synthesis of growth promoting hormones by these microbes[6].

Nodulation

Increasing phosphorus application significantly increased number and dry weight of nodules plant^{-1} at pre and post flowering stages (Table 2). Full recommended dose of P_2O_5 ha^{-1} recorded maximum number and dry weight of root nodulesplant^{-1} both at pre flowering (36.61 and 6.91 g) and at post flowering stages (30.41 and 6.28 g), respectively. With application of full recommended dose of P_2O_5 ha^{-1},increase in number of nodules plant^{-1} was higher to the extent of 43.46 and 41.35 % at pre and post flowering stage over control

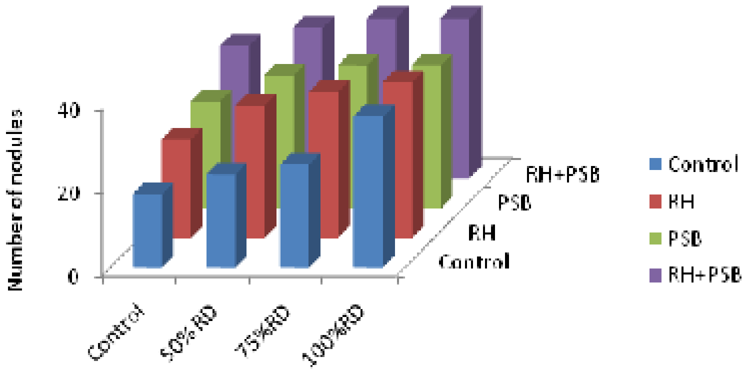

Fig. 1. Interaction effect between levels of Phosphorus and biofertilizers on number of nodules/plant at pre-flowering stage of field pea

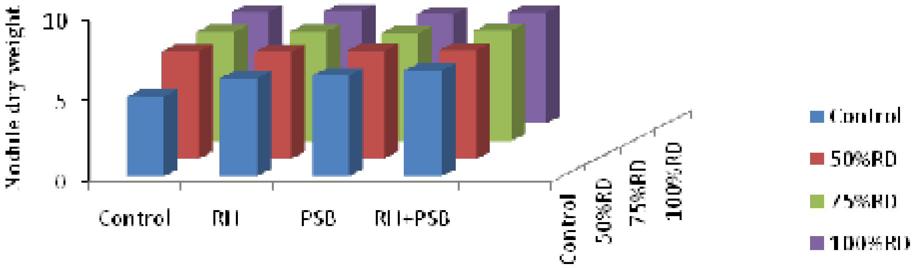

Fig. 2. Interaction effect between levels of Phosphorus and biofertilizers on nodule dry weight (g) at pre-flowering stage of field pea

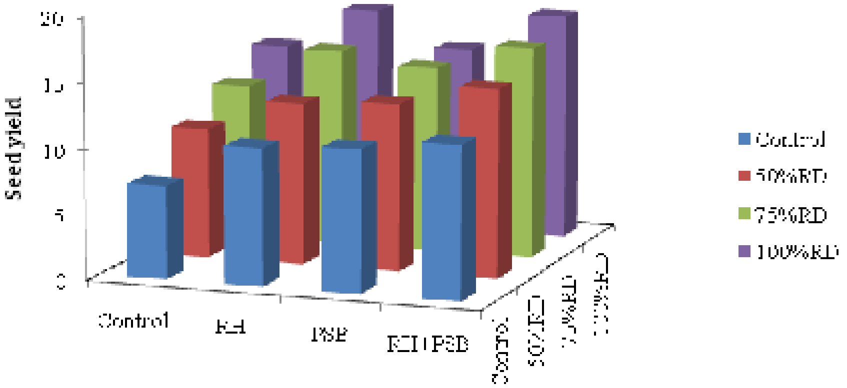

Fig. 3. Interaction effect between levels of phosphorus and biofertlizers on seed yield (q/ha)of field pea

whereas, dry weight of root nodules plant^{-1} showed an increase of 15.74 and 17.16 % at pre and post flowering stage over control. The significant increase in number and dry weight of nodules at higher phosphorus levels might be due to the fact that phosphorus is required for the normal functioning of nitrogen fixing bacteria and has favourable effect on number and weight of effective nodule formation on the root system[7]. At all the phosphorus levels, number as well as dry weight of nodules plant^{-1} was found higher at pre flowering than at post flowering stage. There was decline in nodulation after flowering because the nitrogenase activity in the nodules reaches its maximum at flowering stage and declines thereafter, possibly due to assimilates being unavailable for continued nodule activity as the photosynthates were directed to reproductive parts for grain development[8,9]. Phosphorus plays a key role in nodule activity through increased formation and availability of Adenosine Tri-phosphate (ATP), a resource material for the energy intensive for the N reduction process *via* nitrogenase enzyme activity.

Dual inoculation with *Rhizobium* + PSB recorded highest number and dry weight of root nodules plant^{-1} at pre flowering (36.21 and 6.79 g) and at post flowering stages (27.31 and 6.17 g) compared to control, *Rhizobium* or PSB. The magnitude of increase with dual inoculation of *Rhizobium* + PSB on number of root nodules plant^{-1} was 43.46 and 41.35 % at pre and post flowering stage over control and on dry weight of root nodules plant^{-1} was 6.90 and 11.37 % at pre and post flowering stage over control. However, application of *Rhizobium* or PSB alone remained at par with each other but significantly superior over control. This is attributed to increased number of Rhizobia and PSB in the rhizosphere due to inoculation, which synergistically increased the number and dry weight of nodules plant^{-1}[10].

Yield attributes and yield

Yield attributes *viz*. number of pods plant^{-1}, number of seeds pod^{-1}, seed yield and 1000-seed weight were significantly influenced by phosphorus application and seed inoculation (Table 3). 100 *per cent* recommended dose of P_2O_5 recorded highest number of pods plant^{-1} (9.10), seeds pod^{-1} (6.22) and 1000-seed weight (200.13 g). The magnitude of increase with 100 *per cent* recommended dose of P_2O_5 ha^{-1} was to the extent of 51.41, 20.68 and 7.60 % (no. of pods plant^{-1}), 26.68, 16.04 and 7.24 % (no. of seeds pod^{-1}) and 21.11, 12.94 and 6.02 % (1000-seed weight) as compared to control, 50 and 75 recommended dose of P_2O_5 ha^{-1}. Seed yield exhibited a discernable increase as a result of increased phosphorus application. The highest seed yield was recorded with 100 *per cent* 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 per cent recommended dose of P_2O_5 ha^{-1}. Application of 100 *per cent* recommended dose of phosphorus recorded maximum harvest index (32.33 %) and the extent of increase was 24.77 % over control. The improvement in yield attributes and yield by P application may be attributed to profuse nodulation leading to increased N fixation, which in turn had positive effect on photosynthetic organs and rate[1]. Adequate supply of phosphorus along with starter dose of nitrogen play a vital role in metabolic process of photosynthesis, thereby improving number of pods plant^{-1}, seeds pod^{-1} and test weight[11]. The increase in seed yield at higher levels of phosphorus may also be attributed to the role of phosphorus in the energetisation processes 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 in turn favours better yield of the crop [12]. The significant increase in harvest index may be attributed to the fact that proportionate increase in seed yield was higher as compared to the stover yield due to translocation of more photosynthates from source to sink at the ripening stage [12].

Combined inoculation with *Rhizobium* + PSB recorded highest number of pods plant^{-1} (9.07), seeds pod^{-1} (6.30) and 1000-seed weight (189.07) and marked a superiority of 33.77, 17.03 and 20.93 % (no. of pods plant^{-1}), 30.43, 12.50 and 13.30 % (no. of seeds pod^{-1}) and 6.57, 3.09 and 4.21 % (1000-seed weight) as compared to control, *Rhizobium* and PSB, respectively. Dual inoculation of *Rhizobium* + PSB recorded highest seed yield (15.01 q ha^{-1}) and the magnitude of increase was 38.85, 8.21 and 13.91 % as compared to control, *Rhizobium* and PSB alone. Inoculation with *Rhizobium* and PSB marked an increase of 28.30 and 23.95 %, respectively over control. Seed inoculation with *Rhizobium* or PSB alone remained at par with each other but significantly superior over control.Seed inoculation significantly increases harvest index over control. Combined inoculation with *Rhizobium* + PSB recorded maximum harvest index (32.62 %) as compared to control, *Rhizobium* or PSB inoculation.The significant improvement in yield attributes, seed yield and harvest index due to seed inoculation with bio-fertilizers could be attributed to increased and balanced availability of both N and P in dual inoculation. 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[13]. Higher values of harvest index recorded with dual inoculation meant the synthesis of more photosynthates and their translocation to the sink[13].

Interaction effect of phosphorus and bio-fertilizers

The interaction effect of phosphorus levels and seed inoculation on number and dry weight (g) of root nodules at pre and post-flowering and seed yield (q ha^{-1}) was significant (Fig. 1, 2 and 3). A significant increase up to 100 *per cent* recommended dose of P_2O_5 ha^{-1} was recordedwhen seeds are sown without inoculation and when inoculated with *Rhizobium*, whereas significant increase was detectable up to 75 *per cent* recommended dose of P_2O_5 ha^{-1} when inoculated with *Rhizobium* +PSB which was at par with 100 *per cent* 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 *per cent* recommended dose of P_2O_5 ha^{-1} when inoculated with PSB which was at par with 75 and 100 *per cent* recommended dose of P_2O_5 ha^{-1}. Interaction effect of 100 *per cent* 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 *per cent* recommended dose of phosphorus (16.30 q 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[14].

Relative economics

Among different phosphorus levels, 100 *per cent* recommended dose of $P_2O_5$$ha^{-1}$ gave highest net returns (₹ 30931.5) which resulted in highest benefit cost ratio (1.86) whereas, control gave lowest net returns (14617.5) and benefit cost ratio (0.93) than other phosphorus levels (Table 4). Dual inoculation with *Rhizobium*+ PSB recorded highest net returns (28823.5) which resulted in highest benefit cost ratio (1.77) over no inoculation which gave lowest net returns (16323.5) and benefit cost ratio (1.01). This might be due to higher growth and yield attributes resulting in more seed and stover yield with full recommended dose of phosphorus[15] and dual inoculation with *Rhizobium* + PSB[16].

CONCLUSION

Full recommended dose of phosphorus (88 kg ha^{-1}) and dual seed inoculation with *Rhizobium* + PSB resulted in highest growth and yield attributes and consequently maximum benefit cost ratio. Therefore, integrated management with phoshorus application and combined inoculation with *Rhizobium* + PSB can be used to boost the production of field pea (*Pisumsativum* L.).

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