Original Research Article

Influence of Biofertilizers and Phosphorus on growth, yield and economics of field pea (Pisum sativum, Fabaceae)

ABSTRACT

The field experiment was conducted during *Rabi* season, 2022 at Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India. The objective was to study the influence of Biofertilizers and Phosphorous application on growth and yield of field- pea (*Pisum sativum* L.). The results showed that treatment 9 [Phosphate-solubilizing bacteria (PSB) + Rhizobium along with (70 kg/ha) Phosphorus (P_2O_5)] recorded significantly higher plant height (54.75 cm), more number of branches/plant (5.15), maximum plant dry weight (8.99 g/plant), maximum pod length (8.05), maximum number of pods/plant (24.97), higher number of grain/pod (7.24), maximum test weight (44.74 g), higher seed yield (16.25 q/ha), higher stover yield (37.11 q/ha) compare to other treatment. The maximum gross return (141133.00 INR/ha), maximum net return **(**101262.45 INR/ha) and the highest Benefit cost ratio (2.53) was also recorded in treatment 9 as compared to other treatments. Thus the best combination to get maximum growth, yield attributes and economics in field-cultivated Pea (*Pisum sativum*) was found [PSB + Rhizobium inoculation + 70 kg/ha (P_2O_5)].

Keywords: Field pea, Biofertilisers, Phosphorus, Growth, Yield and Economics.

1. Introduction

Field pea (*Pisum sativum* L.) is herbaceous, annual in habit and self-pollinated vegetable crop. This cultivated pulse is grown for its green pods and seeds. The immature green seeds are consumed fresh, canned or in dehydrated jars and is leading frozen vegetable food. It is one of the most important vegetables in the world and ranks among top ten vegetable crops. India is second largest producer of pea in the world and accounts for 21% of the world production. Punjab is fifth largest producer of pea in the country and accounts for 6.7% of India's production. It is second important vegetable crop of Punjab and is grown on an area of 31.3 thousand hectare with annual production of 315.87 thousand tonnes. **(Singh *et al.* 2019)**

Pulses occupy a unique position in agriculture and are rich in protein, the protein content of field pea ranges from 15.5-39.7%. Fresh peas contain (per 100g) 44 calories, 75.6% water, 6.2g protein, 0.4 g fat, 16.9 carbohydrate, 2.4 g crude fiber, 0.9 g ash, 32 mg Ca, 102 mg P, 1.2 mg Fe, 6 mg Na and 350 mg K **(Gowher *et al.*, 2013),** Pea belongs to the family Fabaceae (Leguminosae) which is characterised by maintaining soil fertility through biological nitrogen fixation in soil and thus play a vital role in furthering sustainable agriculture. The field pea is a cool-season legume crop that is grown on over 25 million acres of all over worldwide. Pea is also known as dun (grey-brown) pea, and it is one of the oldest domesticated crops, cultivated for at least 7,000 years. Field peas are now grown in many countries for both human consumption and stock feed. There are several cultivars and colors including blue, dun (brown), maple and white. The total area of pulses was 28.83 million/ha. The total production of pulses 25.72 million tonnes and yield was 892 kg/ha. The production of field pea in India 2020 - 21 was 7.92 lakh/ha. Uttar Pradesh having the highest production of field pea in 2020 - 21 by producing 4.953 lakh/ha, the 49% of total production in India **(GOI. 2021).**

Fertilizer being vital agriculture input to increase the production but the main drawbacks in the use and manufacture of chemical fertilizer viz., energy crises and unavailability of indigenous material like neptha, sulphur etc. at the national level and hazardous effect of chemical fertilizer on our health and environment. All these thing have led to research of alternative renewable source of nutrients to the crop though fertilizer of biological origin (bio-fertilizer) **(Rather *et al.* 2010).** In early growth stage, hairy vetch plants sometimes show very poor plant growth and exhibit nutritional disorder that the leaves and stems turn to red color. From the results we investigated, the poor plant growth and the nutritional disorder is caused by nitrogen deficiency. For that reason, hairy vetch cannot easily utilize soil nitrogen under low temperature conditions. On the other hand, it is considered that nitrogen deficiency is related to the poor nodule formation and low nitrogen fixation activity of the rhizobia in the nodules. (**Siddiqui and Debbarma, 2022).**

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 nitrogen, may help in boosting up production and consequently more nitrogen fixation. Being a legume crop, major portion of N requirement of the crop is met through biological nitrogen fixation **(Bhat *et al.* 2013)**.

Rhizobium belongs to family Rhizobiaceae and is symbiotic in nature. *Rhizobium* has ability to fix atmospheric nitrogen in symbiotic association with legumes and certain non-legumes like *Parasponia* Miq. (Cannabaceae).

Rhizobium incorporated in pea rhizosphere through seed treatment probably induced more amount of nitrogen fixation in nodules of pea and solubilisation of fixed nitrogen from non-available to exchangeable pool which imparts more vegetative growth **(Singh *et al*. 2019).**

Phosphate-solubilizing bacteria (PSB) may also improve P availability and crop growth by promoting biological nitrogen fixation, through releasing growth promoters such as indoleacetic acid, gibberellic, and cytokinin's. Inoculation of PSB has been found to improve the yield and Phosphorus nutrition of crops such as rice, maize, and other cereals. Thus, inoculation of PSB can be an efficient, environmentally friendly and economically beneficial substitute for expensive P fertilizers. However, the potential of PSB in soils of a calcareous nature and with an alkaline reaction has not been well documented **(Krishnaraj *et al*. 2014).**

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 **(Bhat *et al.* 2013)**. Keeping in view the above fact, the experiment was conducted to assess the influence of phosphorus and bio-fertilizers on the growth and yield of field pea (*Pisum sativum*).

2. MATERIALS AND METHODS

This experiment was laid out during the *Rabi* season of 2022 at Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj (U.P.), India. The soil of the field constituting a part of central gangetic alluvium is neutral and deep. The soil of the experimental field was sandy loam in texture, nearly neutral in soil reaction (pH 8.0), low level of organic carbon (0.62%), available N (225 kg/ha), P (38.2 kg/ha) and K (240.7 kg/ha). The treatment consisted of three (3) different levels of Biofertilizers (PSB, Rhizobium and PSB + Rhizobium) with combination of three (3) different levels of Phosphorus (50, 60 and 70 kg/ha P_2O_5). The experiment was laid out in randomized block design (RBD) with 10 treatments each replicated thrice. The treatment combination are T_1 – PSB + 50 kg/ha P_2O_5, T_2 – PSB + 60 kg/ha P_2O_5, T_3 – PSB+ 70 kg/ha P_2O_5, T_4 – Rhizobium + 50 kg/ha P_2O_5, T_5 – Rhizobium + 60 kg/ha P_2O_5, T_6 – Rhizobium + 70 kg/ha P_2O_5, T_7 – PSB + Rhizobium + 50 kg/ha P_2O_5, T_8 – PSB + Rhizobium + 60 kg/ha P_2O_5, T_9 – PSB + Rhizobium + 70 kg/ha P_2O_5, T_{10} - Control. The Data recorded on different aspects of crop, *viz.*, growth parameters, yield attributes were subjected to statistically analysis by analysis of variance method (**Gomez and Gomez, 1976).**

3. RESULT AND DISCUSSION:

3.1 Growth parameters

3.1.1 Plant height (cm)

The data revealed that a significantly higher plant height (54.75cm) was recorded in treatment 9 (PSB+ Rhizobium+ 70 kg/ha P_2O_5) as compared to rest of the treatments (Table 1). However, treatment-8 (PSB+ Rhizobium+ 60 kg/ha P_2O_5) was found to be statistically at par with treatment 9 (Table 1). Significant and higher plant height was recorded with the application of PSB along with Rhizobium which may be due to seed inoculation which improved soil N and P status hence also subsequently boosted N and P uptake, increasing plant growth particularly plant height. Similar result was also reported by **Singh *and Yadav* (2008).** Further significant and higher plant height was recorded with the application of 70kg/ha P□O□ might be due to higher phosphorus levels which may have cause plants to grow taller, which could have a positive effect of phosphorus on root multiplication, nodulation, and the speeding up the height of plant. Similar results were also reported by **Ade *et al.* (2018).**

3.1.2 Number of branches/ plant

The data revealed that a significantly maximum number of branches/plant (5.15) was recorded in treatment 9 (PSB + Rhizobium + 70 kg/ha P□O□) as compare to rest of treatments (Table 1). However, the treatment 8 (PSB + Rhizobium + 60 kg/ha P□O□) was found to be statistically at par with treatment 9 (PSB + Rhizobium + 70 kg/ha P□O□). in (Table 1). Significant and higher number of branches/plant was recorded with the application of PSB along with Rhizobium which may be a result of PSB's enhancement of phosphorus availability to the plant and its ability to mitigate the negative effects of excessive nitrogen in the soil which may help to improve number of branches. Similar results were also reported by **Rather *et al*. (2010).** Further significant and maximum number of branches/plant was recorded with the application of 70kg/ha P□O□ because phosphorus boosts Rhizobium activity, which improves N fixation in the root nodules as well as promotes better plant growth and development which lead to the enhanced cell division in addition to growth brought on by higher phosphorus levels which showed the production of more apical bud primordia and ultimately, more branches. Similar results were also reported by **Bhat *et al*. (2013).**

3.1.3 Plant dry weight

The data revealed that significantly maximum dry weight (8.99) was recorded in treatment 9 (PSB + Rhizobium + 70 kg/ha P□O□) as compare to rest of treatments. However, the treatment 8 (PSB + Rhizobium + 60 kg/ha P□O□) was found to be statistically at par with treatment 9 (PSB + Rhizobium + 70 kg/ha P□O□)in (Table 1). Significant and maximum dry weight was recorded with the application of PSB along with Rhizobium, this could be a result of symbiotic and non-symbiotic nitrogen fixation, which enhances the availability of phosphorus to the plant through PSB and reducing the negative effects of excessive nitrogen in the soil. Similar results were also reported by **Rather *et.al.* (2010)**. Further significant and maximum dry weight was recorded with the application of 70 kg/ha P□O□ which could be attributable to the favourable effect of phosphorus application on root growth and phosphorus availability which results in more root surface for bacterial infection and improved biological nitrogen fixation which helps in better dry matter production. Similar results were also reported by **Jayshree and Umesha (2021).**

3.1.4 Crop growth rate (g/m^2/day)

The data revealed that significantly higher crop growth rate (6.54) was recorded in treatment 9 (PSB + Rhizobium + 70 kg/ha P□O□) as compare to rest of treatments. However, the treatment 8 (PSB + Rhizobium + 60 kg/ha P□O□) was found to be statistically at par with treatment 9 (PSB + Rhizobium + 70 kg/ha P□O□) in Table 1.Significant and higher crop growth rate was recorded with the application of PSB along with Rhizobium which might be due to better accumulation of dry matter throughout the plant's vegetative and reproductive phase that enhances the physiological and metabolic activity and growth by assimilating the available nutrients at exponential rate and ease more photosynthesis, which results into higher crop growth rate. Similar results were also reported by **Jayshree and Umesha (2021).**

3.1.5 Relative growth rate (g/g/day)

The data revealed that significantly higher relative growth rate (0.0285) was recorded in treatment 9 (PSB + Rhizobium + 70 kg/ha P□O□) as compare to rest of treatments. However, the treatment 8 (PSB + Rhizobium + 60 kg/ha P□O□) was found to be statistically at par with treatment 9 (PSB + Rhizobium + 70 kg/ha P□O□) in Table 1.

3.2 Yield attributes

3.2.1 Pods length (cm)

The data revealed that significantly and higher pod length (8.05) was recorded in treatment 9 (PSB + Rhizobium + 70 kg/ha P_2O_5) as compare to rest of treatments. However, the treatment 8(PSB + Rhizobium + 60 kg/ha P_2O_5) was found to be statistically at par with treatment 9 (PSB + Rhizobium + 70 kg/ha P_2O_5) in Table 2. Significant and higher pod length was recorded with application of Rhizobium along with PSB which might be brought on by more nitrogen being available that promotes more vegetative growth, higher vegetative growth may be caused by inoculation in the pea rhizosphere through seed treatment, which likely increase the amount of nitrogen fixation in the pea nodules and cause the fixed nitrogen to be released from the exchangeable pool causing increased vegetative growth particularly pod length. Similar results were also reported by **Singh *et al*. (2019).**

Number of pods/plant

The data revealed that significantly and maximum number of pods/ plant (24.97) was recorded in treatment 9 (PSB + Rhizobium + 70 kg/ha P_2O_5) as compare to rest of treatments. However, the treatment 8(PSB + Rhizobium + 60 kg/ha P_2O_5) was found to be statistically at par with treatment 9 (PSB + Rhizobium + 70 kg/ha P_2O_5) (Table 2). Significant and maximum number of pods were with application of Rhizobium along with PSB may be because rhizobium introduced into the pea rhizosphere by seed treatment most likely increase nitrogen fixation in pea nodules and solubilization of fixed nitrogen from the non-available to the exchangeable pool results in increased number of pods/plant. Similar results were also reported by **Singh *et al*. (2019)**. Further significant and maximum number of pods/plant was recorded with the application of 70kg/ha P_2O_5 which may be because of the essential role of phosphorus in photosynthesis, fast energy transfer may have enhanced photosynthetic efficiency and consequently photosynthesis availability which further resulted in an increase in overall biomass production and plant part translocation. Similar results were also reported by **Hangsing *et al*. (2020).**

Number of grains/pod

The data revealed Significant and maximum number of grains/pod (7.24) was recorded in treatment 9 (PSB + Rhizobium + 70 kg/ha P_2O_5) as compare to rest of the treatments. However, the treatment 8(PSB + Rhizobium + 60 kg/ha P_2O_5) was found to be statistically at par with treatment 9 (PSB + Rhizobium + 70 kg/ha P_2O_5) in Table 2. Significant and maximum number of grains/pod was recorded with the application of 70kg/ha P_2O_5 which can be due to high phosphorus availability resulting in increased photosynthetic activity because phosphorus is a major constituent of ATP, and ATP is used in the dark reactions of photosynthesis which also increases the production of carbohydrates, sugars, starch, amino acids, and proteins, resulting in increase of the number of pods/ plant and seed yield, which eventually plays a role in increasing biological yield. Similar results were reported by **Kumar *et al*. (2022).**

Test weight (g)

The data revealed significantly and higher test weight (44.74) was recorded in treatment 9 (PSB + Rhizobium + 70 kg/ha P_2O_5) as compare to rest of treatments. However, the treatment 8(PSB + Rhizobium + 60 kg/ha P_2O_5) was found to be statistically at par with treatment 9 (PSB + Rhizobium + 70 kg/ha P_2O_5) in Table 2. Significant and higher test weight was recorded with the application of 70kg/ha P_2O_5 due to phosphorus, which was brought about by increased photosynthesis, respiration, energy storage, cell division, and elongation, all of which ultimately improved the weight of seeds. Similar results were also reported by **Dey *et al*. (2021).**

Seed yield (q/ha)

The data revealed significant and higher grain yield (16.25). It was recorded in treatment 9 (PSB + Rhizobium + 70 kg/ha P_2O_5) as compare to rest of treatments. However, the treatment 8(PSB + Rhizobium + 60 kg/ha P_2O_5) was found to be statistically at par with treatment 9 (PSB + Rhizobium + 70 kg/ha P_2O_5), see in Table 2. Significant and higher seed yield was recorded with application of Rhizobium along with PSB which may be due to the combined effect of biofertilizers seed inoculation might have improved yield attributes specially number of pods/plant and number of seeds/pod than Rhizobium or PSB inoculation alone. Similar results were also reported by **Abisha** and **Singh (2022).** Further, significant and maximum grain yield was recorded with the application of 70kg/ha P_2O_5 which may be caused by improved root proliferation, higher development of roots, increased nutrient availability and uptake energy conversion along with plant metabolic activities. Similar results were also reported by **Yadav *et al.* (2017).**

Stover yield (q/ha)

The data revealed significant and higher stover yield (37.11). It was recorded in treatment 9 (PSB + Rhizobium + 70 kg/ha P_2O_5) as compare to rest of treatments. However, the treatment 8(PSB + Rhizobium + 60 kg/ha P_2O_5) was found to be statistically at par with treatment 9 (PSB + Rhizobium + 70 kg/ha P_2O_5) see in Table 2. Significant and higher stover yield was recorded with application of Rhizobium along with PSB which may be determined by the genetically influenced yield traits rather than the external environmental influences. Similar results were also reported by **Siddiqui and Debbarma (2022).** Further, significant and higher stover yield was recorded with the application of 70kg/ha P_2O_5 which may have enhanced fixation of nitrogen along with nodulation and greater amount of nitrogen fixation will boost crop yield. Similar results were also reported by **Singh *et al.* (2011).**

Harvest Index (%)

At harvest, there was non-significant difference between the treatments and maximum harvest index (30.45 %) was observed the applications of PSB + Rhizobium + 70 kg/ha P_2O_5 (treatment 9), whereas the lowest value (31.06) was observed in treatment 10 (Control) see in Table 2. Significant and higher harvest index was recorded with application of Rhizobium along with PSB that might be due to increased and balanced availability of both N and P in dual inoculation which could be attributable to seed inoculation with bio-fertilizers, because of the increased nitrogenase activity and accessible P status of the soil, the synergistic effect of Rhizobium and PSB may have increased growth, yield characteristics, and eventually higher harvest index values observed with dual inoculation indicated increased photosynthate production and translocation to the sink. Similar reports were also recorded by **Bhat *et al.* (2013**).

3.3 Economic

The result showed that, maximum gross return (141133.00 INR/ha), maximum net return **(**101262.45 INR/ha) and highest B: C ratio (2.53) was recorded in treatment 9 (PSB + Rhizobium + 70 kg/ha P□O□) in (Table 3). Higher benefit cost ratio was recorded with PSB along with rhizobium which might be due to higher grain and stover yield with combine doses of biofertilizer inoculation with seeds. Further, higher gross return and net return was with application of phosphorus(70kg/ha) which might be due to phosphorus, by means of energy transfer plays a fundamental role in photosynthesis, increasing photosynthetic efficiency and thus the availability of photosynthates which helps to obtain higher benefit cost ratio. Similar report was also recorded by **Adjei-Nsiah *et al*. (2018).**

CONCLUSION

Based on the above findings it is concluded that in field pea, application of Phosphate-solubilizing bacteria (PSB) along with Rhizobium and 70 kg/ha P□O□ (Treatment 9) was observed with higher seed yield and benefit cost ratio.

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Table 1: Influence of biofertilizers and phosphorus on the growth attributes of field Pea (*Pisum sativum*).

S.no	Treatments combination	Plant height(cm) (80DAS)	Number of branches/plant (80DAS)	Plant Dry weight (g/plant) (80DAS)	CGR ($g/m^2/day$) (60-80)	RGR (g/g/day) (60-80)
1.	PSB inoculation + 50 kg/ha P□O□	42.77	3.27	5.26	3.42	0.0248
2.	PSB inoculation + 60 kg/ha P□O□	45.13	3.42	5.59	3.80	0.0262
3.	PSB inoculation + 70 kg/ha P□O□	46.32	3.66	5.86	3.97	0.0261
4.	Rhizobium inoculation + 50 kg/ha P□O□	48.16	4.04	6.16	4.05	0.0251
5.	Rhizobium inoculation + 60 kg/ha P□O□	49.54	4.36	6.62	4.27	0.0245
6.	Rhizobium inoculation + 70 kg/ha P□O□	50.80	4.54	7.29	4.91	0.0258
7.	PSB inoculation + Rhizobium inoculation + 50 kg/ha P□O□	51.90	4.64	8.09	5.93	0.0290
8.	PSB inoculation + Rhizobium inoculation + 60 kg/ha P□O□	53.37	4.86	8.72	6.75	0.0319
9.	PSB inoculation + Rhizobium inoculation + 70 kg/ha P□O□	54.75	5.15	8.99	6.54	0.0285
10.	Control	39.15	3.02	5.01	3.19	0.0161
	F-test	S	S	S	NS	NS
	SEm (±)	2.06	0.36	0.39	0.43	0.0019
	CD (P=0.05)	6.15	1.08	1.67	-	-

Note: CGR= crop growth rate; DAS= Days after sowing; **PSB=** Phosphate-solubilizing bacteria; RGR= relative growth rate.

Table 2: Influence of biofertilizers and phosphorous on yield and yield attributes of field pea (*Pisum sativum*).

S.no	Treatments combination	Pod length (cm)	Number of pod/ plant	Number of grain/pod	Test weight (g)	Seed yield (q/ha)	Stover yield (q/ha)	Harvest index (%)
1.	PSB inoculation + 50 kg/ha P□O□	5.29	17.24	3.73	36.36	12.37	27.69	30.89
2.	PSB inoculation + 60 kg/ha P□O□	5.52	17.80	4.03	37.32	12.78	29.28	30.39
3.	PSB inoculation + 70 kg/ha P□O□	5.78	18.82	4.44	38.17	13.22	31.18	29.78
4.	Rhizobium inoculation + 50 kg/ha P□O□	6.17	19.98	5.08	39.53	13.62	32.57	29.49
5.	Rhizobium inoculation + 60 kg/ha P□O□	6.51	21.36	5.47	40.65	14.00	33.49	29.48
6.	Rhizobium inoculation + 70 kg/ha P□O□	6.90	22.51	6.03	41.91	14.46	34.35	29.63
7.	PSB inoculation + Rhizobium inoculation + 50 kg/ha P□O□	7.33	23.43	6.35	42.65	15.15	35.06	30.18
8.	PSB inoculation + Rhizobium inoculation + 60 kg/ha P□O□	7.66	23.94	6.78	43.56	15.69	36.23	30.22
9.	PSB inoculation + Rhizobium inoculation + 70 kg/ha P□O□	8.05	24.97	7.24	44.74	16.25	37.11	30.45
10.	Control	5.06	16.22	3.35	33.95	10.58	23.48	31.06
	F-test	S	S	S	S	S	S	NS
	SEm (±)	0.39	1.11	0.36	1.87	0.78	1.64	0.66
	CD (P=0.05)	1.16	3.29	1.07	5.55	2.31	4.89	-

Note: **PSB=** Phosphate-solubilizing bacteria.

Table 3: Influence of biofertilizers and phosphorus on economics of field pea (*Pisum sativum*).

Sr. No.	Treatment combination	Economic			
		Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	B:C
1.	PSB inoculation + 50 kg/ha P□O□	38969.55	107267.00	68297.45	1.75
2.	PSB inoculation + 60 kg/ha P□O□	39532.05	111024.00	71491.95	1.80
3.	PSB inoculation + 70 kg/ha P□O□	40094.55	115114.00	75019.45	1.87
4.	Rhizobium inoculation + 50 kg/ha P□O□	38521.55	118731.00	80209.45	2.08
5.	Rhizobium inoculation + 60 kg/ha P□O□	39084.05	122047.00	82962.95	2.12
6.	Rhizobium inoculation + 70 kg/ha P□O□	39646.55	125985.00	86338.45	2.17
7.	PSB + Rhizobium inoculation + 50 kg/ha P□O□	38745.55	131718.00	92972.45	2.39
8.	PSB + Rhizobium inoculation + 60 kg/ha P□O□	39308.05	136389.00	97080.95	2.46
9.	PSB + Rhizobium inoculation + 70 kg/ha P□O□	39870.55	141133.00	101262.45	2.53
10.	Control	35517.05	91684.00	56166.95	1.58

Note: B: C= benefit cost ratio; **PSB=** Phosphate-solubilizing bacteria.