Influence of Bio-fertilizers and Plant geometry on growth, yield and economics of field pea (*Pisum sativum L.*)

ABSTRACT

A field experiment was conducted during *Rabi* 2022 at Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P) to determine the "Influence of Bio-fertilizers and Plant geometry on growth, yield and economics of field pea (*Pisum sativum L.*)", The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 8.0), low in organic carbon (0.62 %), available N (225 kg/ha), available P (38.2 kg/ha) and available K (240.7 kg/ha),to study the response of plant geometry (20x20cm,30x10cm,40x10cm) with the combination of biofertilizers such as, rhizobium (20g), PSB (20g) and rhizobium (20g) + PSB (20g). The experiment laid out in RBD with 10 treatments each replicated thrice .the results showed that treatment 9 recorded significantly higher plant height (44.57cm), maximum number of nodules/plant (7.12), higher plant dry weight (15.32g), maximum number of pods/plant (20.13), maximum number of seeds/pod (4.00), higher seed index (18.57g), higher seed yield (1243.67kg), maximum straw yield (2656.21kg), higher harvest index (32.93%), maximum gross returns (1,19,838), maximum net returns (85,504) and highest Benefit cost ratio of (2.49) was recorded.

Keywords: Bio-fertilizers, Plant geometry, Growth, Yield and Economics.

INTRODUCTION

"Field pea (*Pisum Sativum L.*) occupying a unique position in agriculture and are rich in protein, ranging from 17-27%. Besides being a rich source of protein, they maintain soil fertility through biological nitrogen fixation in soil and thus play a vital role in furthering sustainable agriculture. It is important pulse crop after chickpea and pigeon pea, cultivated throughout India for its multipurpose uses as vegetable, pulse and fodder. It is also known as dun (grey-brown) pea, and it is one of the oldest domesticated crops, cultivated for at least 7,000 years, 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" **(Siddiqui and Debbarma 2022)**. "It is 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 and it is not only rich in protein but also have essential amino acid compared to cereal protein. They provide energy to the tune of 372K Cal/100g. They also contain other nutrients such as C, Fe and vitamins viz.,β-carotene, thiamine, riboflavin and niacin" **(Bhat *et al.* 2013)**.

"Field pea ranks Seventh in area and second in terms of production and is grown in all most cool weather conditions of different countries. Globally, field pea covers an area about 10.59 million hectares with production of 21.99 million tonnes and the productivity of 955 kg/ha" **(USDA, 2022)**. "In India fieldpea grown cover an area about 28.33 million hectares with production of 25.72 million tonnes and productivity of 892kg/ha under 2021, During 2020-2021 total area coverage under field pea in Madhya Pradesh 4.89 million hectares with production of 5.30 million tonnes and productivity of 1084 g/ha" **(GOI, 2021). "**According to government third advance estimates field pea production in 2021-2022 is
26.95 million tonnes" **(GOI, 2022)**.

"In order to meet out the nutritional demand of the increasing population, efforts are being made at the national and international level to increase the per hectare production. Fertilizers being vital agricultural inputs to increase the production but the main drawbacks in the use and manufacture of chemical fertilizers viz., energy crises and in availability of indigenous materials like neptha, Sulphur at the national level and hazardous effect of chemical fertilizers on our health and environment **Rather *et al.* (2010)**, and also Due to constant decrement in soil fertility status, its production and productivity is low in the country. The deficiency of macro and micro nutrient in soil leads to poor quality produce (lower oil and protein content). Persistent nutrient depletion is posing a greater threat to the sustainable

Agriculture". "Although, chemical fertilizers are playing crucial role but various constraints viz., short in supply, rising price and harm to the soil fertility and productivity increased the awareness to adopt a technology which can support developing sustainable, green and non-polluted agriculture" **Singh *et al*. (2018)**.

"Planting spacing has significant effect on growth and development of Field pea. Closer spacing enhances the disease development and lower yield of crop. Optimum spacing ensures the proper growth, development and Quality of seed also depends on proper spacing of crop, it is a major determinant of crop yield and population density mostly depends on management of plant spacing. In fact, the yield of plant is the result of the competition within and outside of the plant on the environmental factors and the maximum yield will be obtained when, this competition has decreased and the plant has the maximum using of these environmental factors. Increasing the excessive density, prevent the light penetrating into the canopy and increase competition" **Rahman *et al*. (2020)**.

"Field pea inoculated with the appropriate strain of Rhizobium bacteria is able to fix a large protein of its nitrogen requirement from air in the soil. Field peas can be met their N needs between 30-80% trout biological fixation. For this to occur, the seed or the soil surrounding the seed must be inoculated. The rhizobia enter the root hairs and induce nodule formation. The plant provides energy for the bacteria living inside the nodules and, in return, the rhizobia convert atmospheric nitrogen inti plant useable forms. Biological nitrogen fixation is an important nitrogen source due to the fact that it requires less energy and causes less environmental pollution" **Erman *et al*. (2009)**.

"Biofertilizer is a natural product carrying living microorganisms derived from root or cultivated soil. These preparations in strict terms are called as microbial inoculants. Biofertilizer application has shown bright results in case of leguminous crops especially exclusive results have been obtained in case of Field Pea being a leguminous crop, it can fix atmospheric nitrogen in symbiosis with Rhizobium and thus has low nitrogen requirement. 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. It is useful for legumes like pea, beans, chick pea, lentil, red gram etc. It colonizes the roots of specific legumes to form tumor like growths called nodules which act as factories of ammonia production" **Singh *et al*. (2019)**.

"Plant spacing is one of the important factors which play a vital role in enhancing the production and productivity of Field pea. It is an efficient management tool for maximizing grain yield by increasing capture of solar radiation within the canopy thereby increasing land use efficiency" **Yeswanth and Debbarma (2022)**. "There is a need to manipulate the spacing competition and to increase plant productivity. Optimum spacing can ensure proper growth of the aerial and underground parts of the plant through efficient utilization of solar radiation, nutrients, water, land as well as air spaces. Spacing for line sowing is recommended to maintain the required number of plant population and to undertake intercultural operations for harvesting a higher yield" **Swargiary *et al*. (2021)**. Keeping in view the above fact, the experiment was conducted to find out the "Influence of Bio-fertilizers and Plant geometry on growth, yield and economics of field pea (*Pisum sativum L.*)".

Materials and Method

A field experiment was conducted during *Rabi* 2022 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P) on the topic "Influence of Bio-fertilizers and Plant geometry on growth, yield and economics of field pea (*Pisum sativum L.*)", The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 8.0), low in organic carbon (0.62 %), available N (225 kg/ha), available P (38.2 kg/ha) and available K (240.7 kg/ha). There were 10 treatments, each being replicated thrice and laid out in Randomized Block Design. The treatment combinations are treatment 1 (*Rhizobium* + 20x20 cm), treatment 2 (PSB + 20x20 cm), treatment 3 (*Rhizobium* + PSB + 20x20cm), treatment 4 (*Rhizobium* + 30x15cm), treatment 5 (PSB + 30x15cm), treatment 6 (*Rhizobium* + PSB + 30x15cm), treatment 7 (*Rhizobium* + 40x10cm), treatment 8 (PSB + 40x10cm), treatment 9 (*Rhizobium* + PSB + 40x10cm),treatment 1 (Control). "Data was collected on growth parameters [Plant height (cm) , Number of nodules/plant , Plant dry weight (g), Crop Growth Rate (g/m^2/day), Relative growth rate(g/g/day)], yield attributes [Number of pods/plant, Number of Seeds/pod, Seed yield(kg/ha),Stover yield(kg/ha),Harvest index(%)] and Economics data were subjected to statistical analysis of variance method" **(Gomez and Gomez , 1976).**

Results and Discussion

Growth attributes of Field pea

Plant height (cm)

The results showed that, significant and highest plant height of (44.57cm) was recorded in treatment 9 [Rhizobium + PSB + Spacing (40×10cm)] [Table 1]. Significant and higher plant height was observed with application of PSB might be due to increasing availability of phosphorous to the plant by PSB on one hand and on the other hand countering the ill effects of excessive nitrogen in the soil, thereby helping in improving the aforesaid. Similar results were also reported by **Rather *et al*. (2010).** Further increased with plant height was Spacing (40×10cm) may be due to availability of free access of environmental resources like light, water, and nutrients for the plants in wider spacing, resulted increased in plant height. Similar results were also reported by **Sibhatu *et al*. (2016).**

Number of nodules/plant

The data showed that, significant and highest number of nodules/plant (7.89) was recorded in treatment9 [Rhizobium + PSB + Spacing(40×10cm)] [Table 1]. Significant and higher number of nodules/plant was observed with application of Rhizobium along with PSB might be due to increase number of rhizobia and PSB in the rhizosphere due to inoculation, which synergistically increase the amount of nodules/plant, in the fact that PSB in plant system enhances growth attributes. Similar results was also reported by **Siddiqui and Debbarma, (2022).**

Plant dry weight (g)

The data revealed that, significant and significantly higher plant dry weight (15.32) was found in treatment 9 [Rhizobium + PSB + Spacing (40×10cm)]. However, treatments 8 [PSB + Spacing (40×10cm)] was found to be statistically at par with treatment 9 [Rhizobium + PSB + Spacing (40×10cm)] [Table 1]. Significant and higher plant dry weight (g) was observed with Rhizobium might be due to it increases the availability of enzymes and vitamins in soil to this enzyme activity the number of microbial population increases and this increased population of bacteria, and actinomycetes recharge the soil with conditioner, ultimately increased in plant dry weight. Similar results were also reported by **Yadav *et al*. (2021),** in chickpea. Further increased in plant dry weight, with application of Spacing (40x10cm) may be due to availability of free access of environmental resources like water, nutrients, and light for the plants in the wider spacing resulted increased in plant dry weight. Similar results were also reported by **Bishnoi *et al*. (2021)** in Cluster bean.

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

The results revealed that, significant and higher Crop growth rate (5.03 g/m^2/day) was recorded in treatment 9 [Rhizobium + PSB + Spacing(40×10cm)]. However, treatment1 [*Rhizobium* + Spacing(20×20cm)] Was found to be statistically at par with treatment 9 [Rhizobium + PSB + Spacing(40×10cm)] [Table 1]. Significant and higher crop growth rate (g/m^2/day) was observed with application of PSB might be du better accumulation of dry matter throughout the plant's vegetative and reproductive phase, which enhances the physiological and metabolic activity and growth by assimilating the available nutrients at higher rate and facilitating more photosynthesis, resulting in higher crop growth rate . Similar results were reported by **Jayshree and Umesha, (2021).** Further increased in crop growth rate with Spacing (40x10cm) may be due to higher plant spacing all the natural resources including water, sunlight, nutrients, and minerals were efficiently utilized by the plants and their by enhanced individual plant performance was observed. Similar results were reported by **Swargiary *et al*. (2021).**

Relative growth rate (g/g/day)

The data revealed that, there was no significant difference among the treatments. However, highest relative growth rate (0.0256 g/g/day) was observed in treatment 1 [Rhizobium + Spacing(20×20cm)] [Table 1].

Yield and yield attributes of filed pea

Number of Pods/plant

The data showed that, significantly maximum number of pods/plant (20.13) were recorded in treatment9 [Rhizobium + PSB + Spacing (40x 10cm)]. However, treatment 8[PSB + Spacing (40×10cm)] was found to be statistically at par with treatment 9 [Rhizobium + PSB + Spacing (40x 10cm)] [Table 2]. Significant and maximum number of pods/plants was recorded with application of Rhizobium might be due to it is incorporated in pea rhizosphere through seed treatment probably induced more amount of nitrogen fixation in nodules of pea and solubilization of fixed nitrogen from non-available to exchangeable pool which imparts more vegetative growth resulted increased in number of pods/plant. Similar results were reported by **Singh *et al.* (2019).** Further, increase in number of pods/plants with Spacing (40x10cm) may be due to plants grew vigorously and produced more branches/plant which leads to produce maximum number of pods/plant. Similar results were reported by **Bitew *et al.* (2014).**

Number of seeds/pod

The data revealed that, significantly highest number of seeds/pod (4.00) were recorded in treatment 9 [Rhizobium + PSB + Spacing (40x10cm)]. However, there was no significant difference among the treatments [Table 2].

Seed index (g)

The data revealed that, significantly higher seed index (18.57g) was recorded in treatment 9 [Rhizobium+ PSB + Spacing (40x 10cm)]. However, treatment 8[PSB + Spacing (40×10cm)] Was found to be statistically at par with treatment 9 [Rhizobium + PSB + Spacing (40x 10cm)] [Table 2]. Significant and higher seed index (g) was observed with application of rhizobium might be due to it is ascribed to the greater availability and uptake of phosphorus due to additive effect of these two bio-fertilizers in improving nutritional environment enhanced the growth in terms of branches and dry matter, photosynthetic area, production of assimilates and their translocation to reproductive structures, thereby increasing the seed index ultimately. Similar results were reported by **Yadav *et al.* (2017)** in black gram. Further, increased in seed index with Spacing (40x10cm) may be due to wider plant spacing which intercepted more photosynthetically active radiation owing to better geometric situation resulted in vigorous plant growth, higher accumulation and assimilation food reserves and better source to sink relationship, ultimately increased in seed index. Similar results were reported by **Mohanta and Singh, (2021)** in chickpea.

Seed yield (kg/ha)

The data revealed that, significantly higher seed yield (1243.67 kg) was recorded in treatment 9 [Rhizobium + PSB + Spacing (40x10 cm). However, treatment 8[PSB + Spacing (40×10cm)]. Was found to be statistically at par with treatment 9 [Rhizobium + PSB + Spacing (40x 10cm)] [Table 2]. Significant and higher seed yield (kg/ha) was observed with application of PSB might be due to use of biofertilizers has been linked to the production of additional plant growth hormones particularly auxin, cytokinin, gibberellins resulted increase in Seed yield. Similar results were reported by **Abhishali *et al*. (2023)** in green gram. Further, increase in seed yield with spacing (40x10cm) may be due to this spacing helped plant to receive sufficient amount of heat, water and nutrients from soil which increased number of pods/plant, seeds/pod and test weight which directly helped in increase of seed yield. Similar results were reported by **Yeswanth and Debbarma, (2022)** in groundnut.

Stover yield (kg/ha)

The data showed that, significantly maximum stover yield (2656.21 kg/ha) was recorded in treatment 9[Rhizobium +PSB+ Spacing (40x10cm)]. However, treatment 8[PSB + Spacing (40×10cm)] Was found to be statistically at par with treatment 9 [Rhizobium + PSB + Spacing (40x 10cm)] [Table 2]. Significant and maximum stover yield (kg/ha) was recorded with application of PSB might be due to by the inoculation there is increase of Organic acids, such as gluconic acid, oxalic acid, and citric acid, secreted by PSB can directly solubilize mineral phosphate as a result of anion exchange or indirectly chelate both Fe and Al ions associated with phosphate. This leads to increased P availability, which ultimately increases plant P uptake, resulted increase in stover yield. Similar results were reported by **Walpola and Yoon (2013**) in mung bean. Further, increase in stove yield with spacing (40x10cm) might be due to efficient availability of suitable plant nutrients in adequate quantities, better partitioning of metabolites and adequate translocation of photosynthates to developing reproductive structures, resulted increase in straw yield. Similar results were reported by **Priyadarshini *et al*. (2017**) in cluster bean.

Harvest index (%)

The data revealed that, significantly higher harvest index (32.93%) was recorded in treatment 9 [Rhizobium +PSB+ Spacing (40x10cm)]. However, treatment 8[PSB + Spacing (40×10cm)] Was found to be statistically at par with treatment 9 [Rhizobium + PSB + Spacing (40x 10cm)] [Table 2]. Significant and higher harvest index was recorded with PSB might be due to the phosphate solubilization was attributed to the production of non-volatile organic acids, such as (malic acid, lactic acid, pyruvic acid etc.). These organic acids were effective chelating agents and form stable complexes with Ca, Mg, Fe and Al and thus render P available to the plants, resulted increase in harvest index. Similar results were reported by **Kumar and Singh (2019)** in groundnut. Further, increase in harvest index with spacing (40x10 cm) may be due to significantly increased in vegetative characters such as growth and yield attributes and enhanced the plant capability to produce carbohydrates, sugar starch formation of amino acid and protein and thus helping in fruiting and seed production, these all had played great roles in enhancing seed and stover yield, resulted increase in harvest index. Similar results were reported by **Shukla *et al*. (2017)** in chickpea.

Economic Analysis

Economics

The results showed that maximum gross returns (1,19,838), maximum net returns (85,504) and highest Benefit cost ratio (2.49) were observed in the treatment 9 with application of Rhizobium + PSB along with spacing (40x10cm) [Table 3]. Maximum gross return, net return and highest benefit cost ratio was recorded with Rhizobium and PSB inoculation might be due to higher growth and yield attributes resulting in more seed yield and stover yield, which increased benefit cost ratio. Similar results were reported by **Bhat *et al.*(2013)**.

CONCLUSION

Based on the above findings it is concluded that, Rhizobium and PSB along with Spacing (40x10 cm) has performed better in growth parameters and yield attributes of field pea and also proven profitable .

Table 1 Effect of Bio-fertilizers and Plant geometry on growth attributes of field pea

		Growth attributes				
S. No.	**Treatment combinations**	**Plant height (cm) (100 DAS)**	**Number of nodules/plant (60 DAS)**	**Plant dry weight (g) (100 DAS)**	**CGR ($g/m^2/day$) (60-80 DAS)**	**RGR (g/g/day) (20-40 DAS)**
1.	*Rhizobium* + Spacing (20×20cm)	42.07	15.33	14.52	4.60	0.0256
2.	PSB + Spacing (20×20cm)	42.30	16.67	14.66	4.08	0.0246
3.	*Rhizobium* + PSB + Spacing (20×20cm)	42.23	17.00	14.71	4.10	0.0249
4.	*Rhizobium* + Spacing (30×15cm)	42.23	16.78	14.69	3.61	0.0245
5.	*PSB*+ Spacing (30×15cm)	42.77	17.11	14.81	3.59	0.0251
6.	*Rhizobium* + PSB + Spacing (30×15cm)	43.63	17.33	15.03	3.59	0.0250
7.	*Rhizobium* + Spacing (40×10cm)	43.67	17.22	14.78	4.00	0.0251
8.	PSB + Spacing (40×10cm)	43.50	17.89	15.24	4.17	0.0249
9.	*Rhizobium* + PSB + Spacing (40×10cm)	44.57	18.67	15.32	5.03	0.0252
10.	Control	42.02	14.55	13.52	4.02	0.0242
	F test	S	S	S	S	NS
	S Em (±)	0.10	0.47	0.31	0.28	0.0001
	CD (p =0.05)	0.31	1.39	0.10	0.85	-

Table 2 Effect of Bio-fertilizers and Plant geometry on yield and yield attributes of field pea

S. No.	Treatment combinations	Number of Pods/plant	Number of seeds/pod	Seed Index(g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest Index (%)
1.	*Rhizobium* + Spacing (20×20cm)	16.13	3.22	16.30	700.90	1672.89	29.44
2.	PSB + Spacing (20×20cm)	16.50	3.33	16.43	736.77	1755.59	29.61
3.	*Rhizobium* + PSB + Spacing (20×20cm)	17.10	3.44	17.30	881.53	2025.32	30.43
4.	*Rhizobium* + Spacing (30×15cm)	17.03	3.33	17.13	839.53	1960.46	30.08
5.	*PSB*+ Spacing (30×15cm)	18.57	3.67	18.17	1053.33	2319.07	31.37
6.	*Rhizobium* + PSB + Spacing (30×15cm)	18.77	3.78	18.27	1095.67	2396.66	31.47
7.	*Rhizobium* + Spacing (40×10cm)	17.87	3.55	17.93	1069.80	2169.50	32.00
8.	PSB + Spacing (40×10cm)	19.37	3.89	18.33	1136.67	2481.09	31.51
9.	*Rhizobium* + PSB + Spacing (40×10cm)	20.13	4.00	18.57	1243.67	2656.21	32.93
10.	Control	18.30	3.92	18.30	1043.33	2269.25	31.52
	F test	S	NS	S	S	S	S
	S Em (±)	0.29	0.19	0.50	48.65	98.25	0.66
	CD (p=0.05)	0.85	-	1.48	144.55	291.90	1.96

Table 3 Effect of Bio-fertilizers and Plant geometry on economics of production of field pea

S. No.	Treatment Combination	Cost of cultivation (INR/ha)	Gross returns (INR/ha)	Net returns (INR/ha)	B:C ratio (INR/ha)
1.	*Rhizobium* + Spacing (20×20cm)	33161	68033	34299	1.01
2.	PSB + Spacing (20×20cm)	33176	71506	37352	1.09
3.	*Rhizobium* + PSB + Spacing (20×20cm)	33169	85365	51031	1.48
4.	*Rhizobium* + Spacing (30×15cm)	33161	81391	47657	1.41
5.	*PSB*+ Spacing (30×15cm)	33176	101727	67573	1.97
6.	*Rhizobium* + PSB + Spacing (30×15cm)	33169	105739	71405	2.07
7.	*Rhizobium* + Spacing (40×10cm)	33161	102718	68984	2.04
8.	PSB + Spacing (40×10cm)	33176	109683	75529	2.21
9.	*Rhizobium* + PSB + Spacing (40×10cm)	33169	119838	85504	2.49
10.	Control	33154	100677	63123	1.88

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