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Effect of bio-fertilizers and phosphorus on growth and yield of garden pea (*Pisum sativum* L.)

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Abstract
The field experiment entitled "Effect of Bio-fertilizers and Phosphorous on growth and yield of Garden pea" was conducted during *Rabi* 2023 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P). The experiment was laid out in Randomized block design with ten treatments replicated thrice with the treatment combination of T_1: P 50 kg/ha + Rhizobium 20 g/kg, T_2: VAM 20 g/kg + P 50 kg/ha, T_3: Rhizobium 20 g/kg + VAM 20 g/kg + P 50 kg/ha; T_4: Rhizobium 20 g/kg + P 60 kg/ha, T_5: VAM 20 g/kg + P 60 kg/ha; T_6: Rhizobium 20 g/kg + VAM 20 g/kg + P 60 kg/ha, T_7: Rhizobium 20 g/kg + P 70 kg/ha, T_8: VAM 20 g/kg + P 70 kg/ha; T_9: Rhizobium 20 g/kg + VAM 20 g/kg + P 70 kg/ha; T_{10}: NPK - 50:60:60 kg/ha (Control). The important findings of the experiment have been significant here under the objectives taken. The application of "P" 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg recorded significantly higher Plant height (44.7 cm), number of nodules per plant (18.9), Plant dry weight (40.83 g/plant), Significantly maximum number of pods per plant (22.8), number of seeds per pod (7.4), Test weight (29.67 g), Seed yield (2112.54 kg/ha), Green fodder yield (3905.10 kg/ha), Harvest index (35.17%), were recorded with the treatment of P 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg. Higher gross returns (Rs. 1,16,189.69/ha), net return (Rs. 85.339.69/ha) and benefit cost ratio (2.77) was obtained in the treatment of P 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg. It was concluded that for obtaining higher yield components with better quality of Garden pea application of P 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg was recorded significantly higher number of pods per plant (22.8), number of seeds per pod (7.4), Seed yield (2112.54 kg/ha), and benefit cost ratio (2.77) as compared to other treatments. Since, the finding based on the research done in one season.

Keywords: Garden pea, rhizobium, VAM, growth, yield and economics

Introduction
Garden Pea (*Pisum sativum* L.) is a commonly grown leguminous vegetable in the world. The pea is most commonly the small spherical seed or the seed-pod of the pod fruit. It can be grown also in mild climate of the tropics. In India pea is a extensively cultivated in Uttar Pradesh, Bihar and Madhya Pradesh. The important producers of pea in the world are USA, China, France, U.K., Holland, Russia, Egypt and Australia. Pea output and area in world average area 1835.56 ha, average production 2381.51 thousand metric tons (MT) and with an average productivity of 12.97 MT/ha. Pea is used as a fresh or processed vegetable. Pea is a also used for dehydration (sun dried) canning and freezing.

Pisum sativum L., known as green pea, dry pea, or field pea, is an important legume crop that provides a good source of protein, vitamins, minerals, and bioactive compounds that are beneficial to human health (Fahmi 2019, Han 2023, Kumari 2021) [6, 10, 11]. Peas are cultivated in almost all countries around the world and regarded as an essential part of the human diet (Liu 2018) [7]. Canada is the biggest producer of peas around the world, followed by China, Russia, and India (Raghunathan 2017) [9]. Vegetable productivity was calculated at 18 t/ha, and the average production of vegetables from 2016-17 to 2020-21 was 186893 thousand MT. Pea output and area in India ranged from 551.4 thousand hectares (ha) to 5604.6 thousand metric tons (MT), with an average productivity of 11.12 MT/ha. Uttar Pradesh, Madhya Pradesh, Jharkhand, Punjab, Himachal Pradesh, West Bengal, Haryana, Bihar, Uttarakhand, Orissa, and Karnataka are the major pea-growing state.

Usually, peas have two phenotypes, namely, the smooth pea and the wrinkled pea, and their seed

coats are cream yellow, chartreuse, light green, green, army green, dark green, brown, or orange-brown (Gao 2022) [8]. The difference observed in the colors of the pea coat is associated with the biosynthesis of flavonoids, which can be affected by different cultivars and grow environment. The content of flavonoids in dark seed coat samples is generally higher than that in light color samples (Devi 2019) [5]. Peas have a large content of lysine but lack of amino acids with thiol, therefore, they are often consumed together with grains for a full set of essential amino acids. Furthermore, peas can also be consumed as sprouts and microgreens after germination (Wojdylo 2020, Avezum 2022) [1]. Pea protein is commonly classified into four categories, namely, globulin, albumin, prolamin, and glutenin, of which globulin is the main storage protein, accounting for about 55-65% of the total protein in field peas.

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 pea. Pea being a leguminous crop, it can fix atmospheric nitrogen in symbiosis with Rhizobium and thus has low nitrogen requirement.

Phosphorus is an element that one will under no circumstances find freely in our environment. It is extremely reactive. Phosphorus is a chemical element with an atomic number of 15, which means that the atomic structure includes 15 protons and 15 electrons. For Phosphorus, the chemical symbol is P.

Bio fertilizers is a substance which contains living microorganisms, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. Bio-fertilizers add nutrients through the natural processes of nitrogen fixation, Solubilizing phosphorus, and stimulating plant growth through the synthesis of growth-promoting substances.

Rhizobium is a soil habitat bacterium (which can able to colonize the legume roots and fixes the atmospheric nitrogen symbiotically). The morphology and physiology of Rhizobium will vary from free-living condition. They are the most efficient biofertilizer as per the quantity of nitrogen fixed concerned. They have seven genera and highly specific to form nodule in legumes, referred as cross inoculation group. 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.

Vesicular-arbuscular mycorrhiza (VAM) is formed by the symbiotic association between certain phycomycetous fungi and angiosperm roots. The fungus colonizes the root cortex forming a mycelial network and characteristic vesicles (bladder-like structures) and arbuscules (branched finger-like hyphae). The mycelia are aseptate or septate ramifying intercellular thus causing little damage to tissues. The arbuscules are the most characteristic structures, formed intracellular and probably having an absorptive function. The vesicles are terminal swellings of hyphae formed inter and intracellular having a storage function A VAM fungus grows in close relation to the roots and increases the amount of soil phosphorous around it.

Materials And Methods

Experiments on the effect of biofertilizers and phosphorus along with recommended rate of fertilizer (RDF) on growth and yield enhancement of garden pea were conducted in the 2023 Rabi season at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, located at 250 24 42 north latitude, 810 50 56 east longitude and 98 m altitude above mean sea level. This area is located on the right side of the river Yamuna by the Prayagraj Rewa Road about 5 km from Prayagraj town. A composite soil sample was collected at a depth of 0-30 cm. It was air-dried, crushed and tested for physical and chemical properties.

The soil was sandy loam texture with soil reaction (pH 7.3), 0.57 organic matter (0.63%), available nitrogen (152.6 kg/ha), phosphorus (9.27 kg/ha), potassium (149 .40 kg/ha), sulfur (6.6 mg/kg), Zn (0.45 mg/kg) and available B (0.36 mg/kg). Garden peas (GS - 10) were selected for sowing. The seeds were sown by hand in the line in 2023. The seeds were covered with soil immediately after sowing. Spacing adopted was 10 cm between plant and 45 cm row to row 45 cm as per treatment details and seeds were sown at 3 to 4 cm depth.

Results and Discussion

Growth parameters

Plant height (cm)

The significant and highest plant height observed within 60 DAS. Phosphorus 70 kg/ha along with Rhizobium 20 g/kg along with VAM 20 g/kg produced the maximum plant height (44.72 cm), while the control treatment (39.14 cm) showed the lowest plant height and the treatment of Phosphorus 70 kg/ha along with Rhizobium 20 g/kg was found to be statistically comparable to T_9.

Plant dry weight (gm) highest plant dry weight (40.67 g) was recorded with the application of Phosphorus 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg, whereas treatment Phosphorus 70 kg/ha + Rhizobium 20 g/kg (40.57 g) and Phosphorus 70 kg/ha + VAM 20 g/kg (40.01 g) were found to be statistically at par with T9, and minimum was reported in control (35.41 cm).

Number of nodules per plant: At 60 DAS there was significant difference among the treatments. However, highest number of nodules per plant (18.87) was recorded with the application of Phosphorus 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg, whereas treatment Phosphorus 70 kg/ha + Rhizobium 20 g/kg (18.0) were found to be statistically at par with T9, and minimum was reported in control (10.93).

Crop Growth Rate: ($g/m^2/day$) There was significant difference in CGR values between treatments at 45 to 60 DAS. The treatment containing 20 g/kg of Rhizobium and Phosphorus 60 kg/ha produced the highest CGR value (10.47 $g/m^2/day$). In contrast, the treatment Phosphorus 70 kg/ha + Rhizobium 20 g/kg + VAM 20 g/kg (8.03 $g/m^2/day$) had the lowest reported minimum.

Relative Growth Rate: (g/g/day) There was no significant different between the treatments during 45-60 DAS. However, the treatment of phosphorus 50 kg/ha along with rhizobium 20 g/kg and also along with VAM 20 g/kg produced the highest relative growth rate (0.006 g/g/day).

Application of bio-fertilizer leads to higher biomass accumulation in mustard plants and helped to achieve higher vegetative growth. Further, the application of sulphur had significant effect on relative growth rate of plants. This may be high rate of photosynthesis, chlorophyll content and more leaf

expansion, while at maturity the aging of the leaves decreases photosynthesis hence RGR declines.

Yield Attributes

Number of pods per plant: There was significant difference among the treatments. However, highest number of pods per plant (22.8) was recorded with the application of Phosphorus 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg, whereas treatment Phosphorus 70 kg/ha + Rhizobium 20 g/kg (21.9) and Phosphorus 70 kg/ha + VAM 20 g/kg (21.6) were found to be statistically at par with T9, and minimum was reported in control (19.1).

Number of seeds per pod

There was significant difference among the treatments. However, highest number of seeds per pod (6.9) was recorded with the application of Phosphorus 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg, whereas treatment Phosphorus 70 kg/ha + Rhizobium 20 g/kg (6.7) and Phosphorus 70 kg/ha + VAM 20 g/kg (6.6) were found to be statistically at par with T9, and minimum was reported in control (4.9).

Test weight (g): There was significant difference among the treatments. However, highest test weight (29.67 g) was recorded with the application of Phosphorus 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg, whereas treatment Phosphorus 70 kg/ha + Rhizobium 20 g/kg (28.68 g) and Phosphorus 70 kg/ha + VAM 20 g/kg (29.67 g) were found to be statistically at par with T9, and minimum was reported in control (24.37 g).

Seed yield (t/ha): There was significant difference among the treatments. However, highest seed yield (2.11 t/ha) was recorded with the application of Phosphorus 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg, whereas treatment Phosphorus 70 kg/ha + VAM 20 g/kg (1.85 t/ha) were found to be statistically at par with T9, and minimum was reported in control (1.02 t/ha).

Harvest Index: (%) Significant difference among the treatments. However, highest harvest index (35.17%) was recorded with the application of Phosphorus 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg, whereas treatment Phosphorus 70 kg/ha + VAM 20 g/kg (32.52%) were found to be statistically at par with T_9, and minimum was reported in control (21.48%).

Economics

The data on the economics of different treatments presented in Table 3 showed that the maximum gross return (INR.116189.69/ha), net return (INR.85339.69 /ha) and benefit-cost ratio (2.77) was recorded treatment-9 with the application (Phosphorus 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg)and the minimum gross return (INR.56145.52 /ha), net return (INR.26445.52 /ha) and benefit-cost ratio (0.89) was found to be in control as compared to other treatments.

Discussion

Kokani *et al.* (2015) [4] evaluated the effect of FYM, phosphorus and sulfur on summer blackgram yield and postharvest soil nutrient status and reported that the highest available sulfur (21.25 ppm) was recorded with soil application of P_2O_5 @ 40 kg/ha. Garb *et al.* (2007) reported that inoculation of pea seeds with any type of biofertilizer used significantly increased all studied vegetative growth characteristics and yield components (plant height, number of leaves, number of branches, plant fresh weight, plant dry weight, yield of green pods fed', number of pod plants, number of seed pods and shelling%). Also, the contents of N, K and chlorophyll in the leaves were increased compared to the non-inoculated control in both seasons. The mixed biofertilizer was the most effective of all studied vegetative growth characteristics and yield components. Bunker *et al.* (2022) [2] reported that in RBD with 11 treatments in 3 replications at different levels of nitrogen and phosphorus and combined with biological fertilizers compared to the control. The treatment of 20 kg/ha N, 40 kg/ha P, + Rhizobium PSB (T) showed a significant increase in growth and yield attributes compared to the control, but statistically at the level of 20 kg/ha N, + 40 kg/ha P, Rhizobium (T1) and 20 kg/ha N, + 40 kg/ha P, + PSB (T4), while the yield of green pods (kg/area and q/ha) was found at a maximum of 15, which is statistically at par with the trend. Bunker *et al.* (2022) [2] reported that nitrogen, phosphorus and biofertilizers on the protein content of garden pea (*Pisum sativum* L) seeds. Significant increase in protein content from 15.60% to 22.06% when applying 20 kg/ha N 40 kg/ha Rhizobium + PSB (T), maximum nitrogen concentration in plants was 20 kg/ha N + 40 kg/ha P + Rhizobium + PSB (T) (2 30 percent) T was statistically comparable to 20 kg/ha N, 40 kg/ha P + Rhizobium (TJ and 20 kg/ha N, 40 kg/ha, P + PSB (T.).

Table 1: Evaluation of bio-fertilizers and phosphorus on plant height of Garden pea, At 60 DAS

S. No.	Treatments	Plant Height (cm)	Plant dry weight (gm)	No. of nodules /plant	Crop Growth Rate (g/m^2/day)	Relative Growth Rate (g/g/day)
1.	Phosphorus 50 kg/ha + Rhizobium 20 g/kg	40.03	36.71	11.67	8.96	0.005
2.	Phosphorus 50 kg/ha + VAM 20g/kg	39.57	36.31	11.73	9.78	0.006
3.	Phosphorus 50 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg	41.05	38.02	13.40	9.93	0.006
4.	Phosphorus 60 kg/ha + Rhizobium 20 g/kg	42.43	39.95	14.20	10.47	0.006
5.	Phosphorus 60 kg/ha + VAM 20g/kg	41.94	38.64	14.13	8.77	0.005
6.	Phosphorus 60 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg	43.16	39.58	16.60	9.23	0.005
7.	Phosphorus 70 kg/ha + Rhizobium 20 g/kg	44.11	40.57	18.00	9.36	0.005
8.	Phosphorus 70 kg/ha + VAM 20g/kg	42.76	40.01	16.60	8.04	0.004
9.	Phosphorus 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg	44.72	40.67	18.87	8.03	0.004
10.	NPK – 50:60:60 Kg/ha	39.14	35.41	10.93	8.08	0.005
	F – Test	S	S	S	S	NS
	SEm±	0.48	0.51	0.15	0.94	0.0005
	CD (p=0.05)	1.42	1.53	0.46	1.11	-

Table 2: Evaluation of bio-fertilizers and phosphorus on yield attributes and yield of Garden pea, Yield attributes

S. No.	Treatments	Post-harvest observations					
		Number of Pods per plant	Number of seeds per pod	Test weight	Seed yield (Kg/ha)	Green fodder yield	Harvest index
1.	Phosphorus 50 kg/ha + Rhizobium 20 g/kg	19.7	4.9	25.08	1097.40	3811.88	22.41
2.	Phosphorus 50 kg/ha + VAM 20g/kg	19.7	4.9	24.13	1057.44	3852.50	21.58
3.	Phosphorus 50 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg	20.8	5.8	25.74	1396.47	3801.90	26.91
4.	Phosphorus 60 kg/ha + Rhizobium 20 g/kg	21.1	5.9	27.31	1536.71	3856.70	28.55
5.	Phosphorus 60 kg/ha + VAM 20g/kg	21.0	5.9	27.14	1521.03	3859.50	28.32
6.	Phosphorus 60 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg	21.8	6.5	27.77	1780.41	3856.76	31.62
7.	Phosphorus 70 kg/ha + Rhizobium 20 g/kg	21.9	**6.7**	28.68	1905.46	3886.65	32.98
8.	Phosphorus 70 kg/ha + VAM 20g/kg	21.6	6.6	29.01	1859.50	3873.30	32.52
9.	Phosphorus 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg	22.8	6.9	29.67	2112.54	3905.10	35.17
10.	NPK – 50:60:60 Kg/ha	19.1	4.9	24.37	1020.83	3737.80	21.48
	F – Test	S	S	S	S	S	S
	SEm±	0.34	0.09	0.43	42.76	24.92	0.57
	CD (p=0.05)	1.02	0.27	1.28	127.05	74.06	1.69

Table 3: Evaluation of bio-fertilizers and phosphorus on Economics of Garden pea

Treatments	Cost of Cultivation	Gross Return	Net Return	Benefit cost ratio	B:C ratio
Phosphorus 50 kg/ha + Rhizobium 20 g/kg	30,060	60,356.91	30,296.91	1.01	1.01
Phosphorus 50 kg/ha + VAM 20g/kg	30,000	58,159.02	28,159.02	0.94	0.94
Phosphorus 50 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg	30,350	76,806.07	46,456.07	1.53	1.53
Phosphorus 60 kg/ha + Rhizobium 20 g/kg	30,260	84,519.03	54,259.03	1.79	1.79
Phosphorus 60 kg/ha + VAM 20g/kg	30,200	83,656.56	53,456.56	1.77	1.77
Phosphorus 60 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg	30,550	97,922.60	67,372.60	2.21	2.21
Phosphorus 70 kg/ha + Rhizobium 20 g/kg	30,560	1,04,800.39	74,240.39	2.43	2.43
Phosphorus 70 kg/ha + VAM 20g/kg	30,500	1,02,272.77	71,772.77	2.35	2.35
Phosphorus 70 kg/ha + Rhizobium 20 g/kg + VAM 20g/kg	30,850	1,16,189.69	85,339.69	2.77	2.77
NPK – 50:60:60 Kg/ha	29,700	56,145.52	26,445.52	0.89	0.89

Conclusion

From the results, it is concluded that application of Phosphorus 70 kg/ha along Rhizobium 20 g/kg along with VAM 20 g/kg of Garden pea has recorded that better production and economics return.

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