International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(5): 260-264
Received: 01-03-2024
Accepted: 05-04-2024

Sahil Dash
M.Sc. Scholar, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj, Uttar Pradesh, India

Victor Debbarma
Assistant Professor, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj, Uttar Pradesh, India

Corresponding Author:
Sahil Dash
M.Sc. Scholar, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj, Uttar Pradesh, India

Effect of different biofertilizers and phosphorus on growth and yield of Pigeon pea

Sahil Dash and Victor Debbarma

DOI: https://doi.org/10.33545/2618060X.2024.v7.i5d.685

Abstract
A field experiment was conducted during *Kharif* 2023 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India. The objective was to determine the “Effect of Different Biofertilizers and Phosphorus on Growth and Yield of Pigeon Pea”. The results revealed that treatment 4 [Rhizobium + Phosphorus (60 kg/ha)] recorded significantly higher plant height (249.77 cm), higher plant dry weight (77.72 cm), maximum number of nodules/plant (10.60), maximum number of seeds/pod (4.11), higher test weight (93.80g), higher seed yield (1988.52 kg/ha), higher stover yield (5633.33 kg/ha), higher harvest index (26.09%). Maximum gross return (99425.93 INR/ha), maximum net return (71644.33 INR/ha) and the highest B:C ratio (2.58) was also recorded in treatment 4 [Rhizobium + Phosphorus (60 kg/ha)].

Keywords: Pigeon pea, biofertilizers, phosphorus, growth, yield and economics.

1. Introduction

Pigeon pea (Cajanus cajan) is the world’s most widely cultivated pulse crop providing adequate protein for more than million peoples in the world. After chickpea, pigeon pea is the second most important pulse crop in India. Pigeon pea has a high nutritional value because of its 22.3% Protein, 1.7% Fat, 3.5% Minerals, 1.5% Fiber and 57.6% Carbohydrate content. Apart from cooked preparations, fresh pigeon peas can also be served in salads as a diet food or can be eaten raw. Pigeon pea is one of the important pulse crop which ranks sixth in terms of area and production in the world as compared to other legumes such as beans, chickpeas and it is consumed in different ways than others.

Globally, pigeon pea covers an area of 6.02 million hectares with the production of 5.32 million tonnes and the productivity of 883 kg/ha (FAO, 2022) [7]. In India, pigeon pea is grown over an area of about 4.06 million hectares with the production of 3.31 million tonnes and productivity of 814 kg/ha. Total area coverage under pigeon pea in Uttar Pradesh is 0.35 million hectares with the production of 0.36 million tonnes and the productivity of 1039 kg/ha (GOI, 2022) [8].

In early growth stage, plants may show very poor growth and exhibit nutritional disorder that make leaves and stems to change their colour. Poor plant growth and the nutritional disorder is caused by nitrogen deficiency. For that reason, plant 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. Here, 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 biofertilizers such as Rhizobium, PSB through doing seed inoculation with them, may help in boosting up of production and consequently more nitrogen fixation for the crop in the soil which is poor in nitrogen. Being a legume crop, major portion of nitrogen requirement of the crop is met through biological nitrogen fixation (Khajuria and Debbarma, 2023) [11].

In addition to improvement of plant growth, Plant growth promoting rhizobacteria (PGPR) is an another biofertilizer which is applied to the crop to enhance growth, seed emergence and crop yield. PGPR colonize plant roots and exert beneficial effects on plant growth and development in a suitable manner (Rani *et al*., 2012) [14].

The low yield of this crop is mainly due to its inadequate and imbalanced fertilization which decreases productivity and can create problem to plant as well as soil health, which also inhibits shoot growth and leaves may turn dark or dull. For all these things fertilizers especially phosphorus should be applied in sufficient amount as it is a major plant nutrient which is referred to as the key element in crop production. It improves seed germination, cell division, flowering, fruiting, synthesis of fat, and in fact mostly all bio-chemical activities (Singh *et al*., 2017) [18].

Rhizobium belongs to family Rhizobiaceae and is symbiotic in nature. It is a gram negative and motile bacterium with non sporulating rods. Rhizobium incorporated in plant rhizosphere through seed treatment probably induced more amount of nitrogen fixation in nodules of plants and solubilisation of fixed nitrogen from non-available to exchangeable pool which imparts more vegetative growth (Khajuria and Debbarma, 2023) [11].

Phosphate solubilizing bacteria (PSB) may also improve phosphorus 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 different crops (Khajuria and Debbarma, 2023) [11].

Plant growth promoting rhizobacteria (PGPR) is a biofertilizer in which inoculation of seeds with it may further helps in improved nutrient availability, crop growth, yield and quality. The modes of action of PGPRs include nitrogen fixation, increasing the availability of nutrients in the rhizosphere, positively influencing root development and morphology and promoting other beneficial plant microbe symbiosis (Choudhary *et al*., 2013) [6].

Phosphorus is an important plant nutrient for pulse crop in which it improves the seed germination, cell division, flowering, fruiting, synthesis of fat, starch and other most biochemical activities in plant. It induces root proliferation and nodulation, also the higher values of yield of the crop may be increased due to the effect of phosphorus on root development, energy transformation and metabolic processes, which in term resulted in greater translocation of photosynthates towards the sink development (Singh and Singh, 2012) [17]. Keeping in view of the above fact, the experiment was conducted to find out "Effect of Different Biofertilizers and Phosphorus on growth and yield of Pigeon Pea".

2. Materials and Methods

The experiment was conducted during Kharif season 2023 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P). The soil of the experimental field was sandy loam in texture, nearly neutral in soil reaction (pH 7.8), low level of organic carbon (0.62%), available N (225 Kg/ha), P (38.2 kg/ha), K (240.7 kg/ha) and zinc (2.32 mg/kg). The treatments consisted of 3 Different Biofertilizers (Rhizobium-20g, Phosphate Solubilizing bacteria (PSB)-20g and Plant growth promoting rhizobacteria (PGPR)-20g) with 3 levels of phosphorus (50, 60 and 70 kg/ha). The experiment was laid out in a Randomized Block Design with 10 treatments and replicated thrice. The treatment combinations are T_1- Rhizobium + Phosphorus (50 kg/ha), T_2- PSB + Phosphorus (50 kg/ha), T_3- PGPR + Phosphorus (50 kg/ha), T_4- Rhizobium + Phosphorus (60 kg/ha), T_5- PSB + Phosphorus (60 kg/ha), T_6- PGPR + Phosphorus (60 kg/ha), T_7- Rhizobium + Phosphorus (70 kg/ha), T_8- PSB + Phosphorus (70 kg/ha), T_9- PGPR + Phosphorus (70 kg/ha), T_{10}- Control N:P:K (20:60:20 kg/ha). Data recorded on different aspects of crop, *viz*., growth, yield attributes and yield were subjected to statistically analysed by analysis of variance method as described by Gomez and Gomez, (1976) [9].

3. Results and Discussion

3.1 Growth Attributes

3.1.1 Plant height (cm)

The data revealed that significant and higher plant height (249.77 cm) was recorded in Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. However, Treatment 6 [PGPR + Phosphorus (60 kg/ha)] was found statistically at par with Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. Significant and higher plant height was observed with the application of Rhizobium inoculation may be due to it has the capability to fix atmospheric nitrogen in rhizosphere of plants through the process of nitrogen fixation, resulted in increased plant height. Similar results were reported by Singh *et al*. (2016) [19] in lentil. Further, significantly increased in plant height was observed with the application of Phosphorus (60 kg/ha) may be due to phosphorus is a key element involved in various function in growth and metabolism of plants evolved towards root growth and synthesis of protoplasm, resulted in increased plant height. Similar results were reported by Ade *et al*. (2018) [1].

3.1.2 Plant dry weight (g)

The data revealed that significant and higher plant dry weight (77.72g) was recorded in Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. However, Treatment 6 [PGPR + Phosphorus (60 kg/ha)] was found statistically at par with Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. Significant and higher plant dry weight was observed with the application of Rhizobium inoculation may be due to it enhances the availability of nutrients like nitrogen and phosphorus, increased nutritional availability led to increase in physiological processes which improved growth indices, resulted in increased plant dry weight. Similar results were reported by Singh *et al*. (2023) [16] in chickpea. Further, significantly increased in plant dry weight was observed with the application of Phosphorus (60 kg/ha) may be due to Phosphorus helps in cell division which leads to increase the plant vigorous, resulted in increased plant dry weight. Similar results were reported by Turuko and Mohammed (2014) [22] in common bean.

3.1.3 Number of nodules/plant

The data revealed that significant and maximum number of nodules/plant (10.60) was recorded in Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. However, Treatment 7 [Rhizobium + Phosphorus (70 kg/ha)] was found statistically at par with Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. Significant and maximum number of nodules/plant was observed with the application of Rhizobium inoculation may be due to it entangled into the root hairs, break down the cell walls of the plant and form an infection thread through which the bacterium enters into cortical cells and within a certain period of time small sac-like structures called nodules become visible into roots of plants which enclose the bacteroid and are the actual site for nitrogen fixation, resulted in increased number of nodules/plant. Similar results were reported by Singh and Singh (2018) [20] in chickpea.

Further, significantly increased in number of nodules/plant was observed with the application of Phosphorus (60 kg/ha) may be due to it is an important constituent of ATP and plays a crucial role for energy transformation in plants, resulted in increased number of nodules/plant. Similar results were reported by Ro *et al*. (2023) [15] in mungbean.

3.1.4 Crop Growth Rate (g/m^2/day)
The data revealed that at 75-100 DAS intervals, significant and higher crop growth rate (21.05 (g/m^2/day) was recorded in Treatment 6 [PGPR + Phosphorus (60 kg/ha)]. However, Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)] and Treatment 7 [Rhizobium + Phosphorus (70 kg/ha)] were found statistically at par with the Treatment 6 [Rhizobium + Phosphorus (60 kg/ha)]. Significant and higher crop growth rate was observed with the application of Rhizobium inoculation may be due to better accumulation of dry matter throughout the plants 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, resulted in increased crop growth rate. Similar results were reported by Khajuria and Debbarma (2023) [11] in field pea. Further, significantly increased in crop growth rate was observed with the application of Phosphorus (60 kg/ha) may be due to plants absorbed nutrients relatively in large amount because the available phosphorus in the soil may have increased the doses of applied phosphorus which leads to improve plant growth, resulted in increased crop growth rate. Similar results were reported by Singh *et al*. (2017) [18].

3.1.5 Relative Growth Rate (g/g/day)
The data revealed that at 75-100 DAS intervals, there was no significant difference among the treatments. Statistically, highest relative growth rate (0.0153 g/g/day) was recorded in Treatment 2 [PSB + Phosphorus (50 kg/ha)] as compared to other treatments.

3.2 Yield and yield attributes
3.2.1 Number of Seeds/Pod
The data revealed that significant and maximum number of seeds/pod (4.11) was recorded in Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. However, Treatment 7 [Rhizobium + Phosphorus (70 kg/ha)] was found statistically at par with Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. Significant and maximum number of seeds/pod was recorded with the application of Rhizobium may be due increased nodulation, an extensive root system, and increased metabolite production and translocation to various sinks especially in fruiting structures (pods and seeds), also number of pods for each plant may have increased the plants overall growth, resulted in increased number of seeds/pod. Similar results were reported by Wesley and Dawson (2023) [23] in blackgram. Further, significantly increased in number of seeds/pod was recorded with the application of Phosphorus (60 kg/ha) may be due to phosphorus fertilization ensures the availability of other plant nutrients, increasing carbohydrate buildup and their remobilization to reproductive sections of the plant which are the closest sink, it is well known that phosphorus promotes blooming and fruiting in plants, resulted higher in number of seeds/pod. Similar results were reported by Balanarayana *et al*. (2023) [4] in lentil.

3.2.2 Test weight (g): The data revealed that significant and higher test weight (93.80g) was recorded in Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. However, Treatment 7 [Rhizobium + Phosphorus (70 kg/ha)] was found statistically at par with Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. Significant and higher test weight was recorded with the application of Rhizobium may be due to via Rhizobium biologically fixed nitrogen make an enhancement that takes place in 1000 seed weight of crop which might have led to better assimilation of nitrogen for the plants, resulted in increased test weight. Similar results were reported by Solaiman and Rabbani (2006) [21] in pea. Further, significantly increased in test weight was recorded with the application of Phosphorus (60 kg/ha) may be due to phosphorus might have increased photosynthesis, respiration, energy storage, cell division, and elongation, all of which ultimately improved the weight of seeds. Similar results were reported by Khajuria and Debbarma (2023) [11] in field pea.

3.2.3 Seed yield (kg/ha): The data revealed that significant and higher seed yield (1988.52 kg/ha) was recorded in Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. However, Treatment 7 [Rhizobium + Phosphorus (70 kg/ha)] was found statistically at par with Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. Significant and higher seed yield was recorded with the application of Rhizobium may be due to inoculation of seed with Rhizobium increase root development, more nutrient availability resulting in vigorous plant growth with improved flowering and pod formation, resulted in increased seed yield. Similar results were reported by Mehta *et al*. (2011) [13] in fenugreek. Further, significantly increased in seed yield was recorded with the application of Phosphorus (60 kg/ha) may be due to favourable influence of phosphorus fertilizer on plant development as a consequence of greater nutrient uptake, also on efficient partitioning of metabolites and adequate translocation and accumulation of photosynthates towards sink, resulted in increased seed yield. Similar results were reported by Jat and Ahlawat (2003) [10].

3.2.4 Stover yield (kg/ha): The data revealed that significant and higher stover yield (5633.33 kg/ha) was recorded in Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. However, Treatment 5 [PSB + Phosphorus (60 kg/ha)], Treatment 7 [Rhizobium + Phosphorus (70 kg/ha)] and Treatment 8 [PSB + Phosphorus (70 kg/ha)] were found statistically at par with Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. Significant and higher stover yield was recorded with the application of Rhizobium may be due to inoculation of seeds with Rhizobium more number of nodules formed which are responsible for increased in stover yield due to high rate of atmospheric nitrogen fixation by translocating in stover, resulted in increased stover yield. Similar results were reported by Yadav *et al*. (2011) [24] in chickpea. Further, significantly increased in stover yield was recorded with the application of Phosphorus (60 kg/ha) may be due to it plays a major role in stimulation of root development, energy transformation and metabolic processes in the plants which resulted in greater translocation of photosynthates towards the sink development, resulted in increased stover yield. Similar results were reported by Kumar *et al*. (2015) [12].

3.2.5 Harvest Index (%): The data revealed that significant and higher harvest index (26.09%) was recorded in Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. However, Treatment 1[Rhizobium + Phosphorus (50 kg/ha)], Treatment 2 [PSB + Phosphorus (50 kg/ha)], Treatment 3 [PGPR + Phosphorus (50 kg/ha)], Treatment 6 [PGPR + Phosphorus (60 kg/ha)], Treatment 7 [Rhizobium + Phosphorus (70 kg/ha)] and

Treatment 9 [PGPR + Phosphorus (70 kg/ha)] were found statistically at par with Treatment 4 [Rhizobium + Phosphorus (60 kg/ha)]. Significant and higher harvest index was recorded with the application of Rhizobium may be due to inoculation with Rhizobium might have increased the nodulation of the crop that fixed more atmospheric nitrogen which was used by crop for better development, resulted in increased harvest index. Similar results were reported by Bhunia *et al*. (2006) [5] in fenugreek. Further, significantly increased in harvest index was recorded with the application of Phosphorus (60 kg/ha) may be due to improved cell activities, enhanced cell multiplication and luxuriant growth of the crop probably because of more absorption and utilization of available nutrients leading to overall improvement of crop growth, resulted in increased harvest index. Similar results were reported by Akram *et al*. (2022) [2] in wheat.

3.3 Economics

The data revealed that Maximum gross return (99,425.93 INR/ha), maximum net return (71,644.33 INR/ha) and highest benefit cost ratio (2.58) was recorded in treatment 4 [Rhizobium + Phosphorus (60 kg/ha)] as compared to other treatments. Higher benefit cost ratio was recorded with the application of Rhizobium may be due to seed inoculation with Rhizobium obtained higher seed yield with stover yield, resulted in increased benefit cost ratio. Further, increased in benefit cost ratio was recorded with the application of Phosphorus (60 kg/ha) may be due to it is a sufficient essential plant nutrient which may have involved in various physiological process especially seed formation ultimately increased seed yield, resulted higher benefit cost ratio. Similar results were reported by Ganesh and Debbarma (2023) [3, 11] in pearl millet.

Table 1: Effect of different biofertilizers and phosphorus on growth attributes of pigeon pea

S. No.	Treatments	Plant height (cm)	Plant dry weight (g)	Number of nodules/plant	CGR (g/m^2/day)	RGR (g/g/day)
1.	Rhizobium + Phosphorus (50 kg/ha)	220.02	71.08	7.80	19.83	0.0151
2.	PSB + Phosphorus (50 kg/ha)	208.83	67.45	6.07	19.10	0.0153
3.	PGPR + Phosphorus (50 kg/ha)	202.53	67.17	6.27	18.63	0.0150
4.	Rhizobium + Phosphorus (60 kg/ha)	249.77	77.72	10.60	20.90	0.0144
5.	PSB + Phosphorus (60 kg/ha)	228.03	72.12	7.00	19.62	0.0146
6.	PGPR + Phosphorus (60 kg/ha)	239.17	75.75	7.40	21.05	0.0150
7.	Rhizobium + Phosphorus (70 kg/ha)	231.03	74.29	9.40	20.31	0.0147
8.	PSB + Phosphorus (70 kg/ha)	223.17	69.95	6.67	19.32	0.0149
9.	PGPR + Phosphorus (70 kg/ha)	225.63	71.57	7.07	19.74	0.0149
10.	20-60-20 N-P-K kg/ha at Control	210.57	71.86	7.00	19.09	0.0142
	F-test	S	S	S	S	NS
	S.Em (±)	6.17	1.22	0.78	0.49	0.0006
	CD (P=0.05)	10.70	2.12	1.36	0.86	-

Table 2: Effect of different biofertilizers and phosphorus on yield attributes and yield of pigeon pea

S. No.	Treatments	Number of seeds/pod	Test Weight (g)	Seed Yield (kg/ha)	Stover Yield (kg/ha)	Harvest Index (%)
1.	Rhizobium + Phosphorus (50 kg/ha)	3.84	92.53	1722.59	4910.00	25.99
2.	PSB + Phosphorus (50 kg/ha)	3.79	90.53	1649.63	4701.48	25.98
3.	PGPR + Phosphorus (50 kg/ha)	3.68	90.33	1595.56	4616.67	25.69
4.	Rhizobium + Phosphorus (60 kg/ha)	4.11	93.80	1988.52	5633.33	26.09
5.	PSB + Phosphorus (60 kg/ha)	3.95	92.20	1765.56	5351.11	24.87
6.	PGPR + Phosphorus (60 kg/ha)	3.95	92.67	1802.22	5225.93	25.65
7.	Rhizobium + Phosphorus (70 kg/ha)	4.06	93.07	1948.52	5553.70	25.98
8.	PSB + Phosphorus (70 kg/ha)	3.83	91.53	1693.33	5334.81	24.10
9.	PGPR + Phosphorus (70 kg/ha)	3.89	92.20	1749.26	5072.96	25.64
10.	20-60-20 N-P-K kg/ha at Control	3.69	91.00	1618.15	4834.44	25.09
	F-test	S	S	S	S	S
	S.Em (±)	0.03	0.59	24.22	178.15	0.53
	CD (P=0.05)	0.06	1.02	42.01	308.90	0.92

Table 3: Effect of different biofertilizers and phosphorus on economics of pigeon pea

S. No.	Treatments	Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR /ha)	B:C Ratio
1.	Rhizobium + Phosphorus (50 kg/ha)	27709.20	86129.63	58420.43	2.11
2.	PSB + Phosphorus (50 kg/ha)	27693.20	82481.48	54788.28	1.98
3.	PGPR + Phosphorus (50 kg/ha)	27609.20	79777.78	52168.58	1.89
4.	Rhizobium + Phosphorus (60 kg/ha)	27781.60	99425.93	71644.33	2.58
5.	PSB + Phosphorus (60 kg/ha)	27765.60	88277.78	60512.18	2.18
6.	PGPR + Phosphorus (60 kg/ha)	27681.60	90111.11	62429.51	2.26
7.	Rhizobium + Phosphorus (70 kg/ha)	27854.00	97425.93	69571.93	2.50
8.	PSB + Phosphorus (70 kg/ha)	27838.00	84666.67	56828.67	2.04
9.	PGPR + Phosphorus (70 kg/ha)	27754.00	87462.96	59708.96	2.15
10.	20-60-20 N-P-K kg/ha at Control	27561.60	80907.41	53345.81	1.94

4. Conclusion
It is concluded that in pigeon pea (treatment 4) application of phosphorus at 60 kg/ha along with rhizobium (20g) was observed with higher seed yield and benefit cost ratio.

5. Acknowledgement
The authors are thankful to Department of Agronomy, Naini Agricultural Institute, Prayagraj, Sam Higginbottom University of Agriculture, Technology and Sciences, (U.P) India for providing necessary facilities to undertaken the studies.

6. References
1. Ade UK, Dambale AS, Jadhav DB. Effect of Phosphorus and Biofertilizer on Growth, Yield and Economics of Pigeonpea (*Cajanus cajan* L. Millsp.) Under Rainfed Condition. Int J Curr Microbiol App Sci. 2018;Special issue-6:1408-1416.
2. Akram S, Singh R, Tripathi P, Lavanya G. Effect of Phosphorus and Sulphur on yield and economics of Wheat (*Triticum aestivum* L.). The Pharma Innovation Journal. 2022;11(5):599-602.
3. Are G, Debbarma V. Influence of Phosphorus and Plant Growth Regulators on Growth, Yield and Economics of Pearl Millet (*Pennisetum glaucum* L.). Int. J Plant Soil Sci. 2023;35(18):1052-1060.
4. Balanarayana R, Dawson J, Srikanth T. Phosphorus and Sulphur's Impact on Lentil Growth and Yield (*Lens culinaris* Medik.). Int J Plant Soil Sci. 2023;35(19):84-90.
5. Bhunia SR, Chauhan RPS, Yadav BS, Bhati AS. Effect of phosphorus, irrigation and Rhizobium on productivity, water use and nutrient uptake in fenugreek (*Trigonella foenumgraecum* L.). Indian J Agron. 2006;51(3):239-241.
6. Choudhary RL, Kumar D, Shivay YS, Anand A, Nain L. Yield and quality of rice (*Oryza sativa*) hybrids grown by SRI method with and without plant growth promoting rhizobacteria. Indian J Agron. 2013;58(3):430-433.
7. Food and Agriculture Organization (FAO). Ministry of Agriculture and Farmers Welfare, Domestic and International Area, Production and Yield of Pigeon peas. https://www.fao.org; c2022.
8. Government of India (GOI). Agricultural statistics at glance: Ministry of Agriculture and Farmers Welfare, Government of India. http://www.agricoop.nic.in; c2022.
9. Gomez KA, Gomez AA. Three or more factor experiment. In: Statistical Procedure for Agricultural research. 2nd ed. c1976, p. 139-141.
10. Jat HS, Ahlawat IPS. Response of pigeonpea (*Cajanus cajan*) + groundnut (*Arachis hypogaea*) intercropping system to planting pattern and phosphorus management. Indian J Agron. 2003;48(3):156-159.
11. Khajuria S, Debbarma V. Influence of Biofertilizers and Phosphorus on Growth, Yield and Economics of Field Pea (*Pisum sativum*, Fabaceae). Int. J Plant Soil Sci. 2023;35(17):623-631.
12. Kumar S, Tomar T, Tomar S, Singh S. Effect of phosphorus and biofertilizers in pigeon pea and its residual effect on the productivity of wheat under pigeon pea-wheat cropping system. Ann Agric Res. 2015;36(1):38-43.
13. Mehta RS, Godara AS, Meena BS. Effect of nitrogen, phosphorus and biofertilizer levels on yield attributes, yield and economics of fenugreek (*Trigonella foenumgraecum* L.). Progress Hort. 2011;43(2):271-275.
14. Rani UA, A, Reddy G. Screening of Rhizobacteria containing plant growth promoting (PGPR) traits in rhizosphere soils and their role in enhancing growth of pigeon pea. Afr J Biotechnol. 2012;11(32):8085-8091.
15. Ro S, Williams J, Chea L. Effects of Nitrogen and Phosphorus Application on Growth and Root Nodules of Mungbean under Sandy Soil Conditions. Curr Appl. Sci. Technol. 2023;23(2):1-10.
16. Singh A, Umesha C, Uday Kiran V. Effect of Spacing and Biofertilizers on Growth and Yield of Chickpea. Int. J Environ Climate Change. 2023;13(10):809-815.
17. Singh A, Singh RS. Effect of phosphorus and bioinoculants on yield, nutrient uptake and economics of long duration pigeon pea (*Cajanus cajan*). Indian J Agron. 2012;57(3):265-269.
18. Singh A, Singh RS, Singh SP, Kumawat N, Kumar R. Productivity, Profitability and Soil Health of Pigeonpea as Influenced by Phosphorus Levels and Bioinoculants under Eastern Uttar Pradesh. Int. J Curr Microbiol App Sci. 2017;6(6):1723-1732.
19. Singh N, Singh G, Khanna V. Growth of lentil (*Lens culinaris* Medikus) as influenced by phosphorus, rhizobium and plant growth promoting rhizobacteria. Indian J Agric Res. 2016;50(6):567-572.
20. Singh Z, Singh G. Role of Rhizobium in chickpea (*Cicer arietinum*) production - A review. Agric Res Commun Cent. 2018;39(1):31-39.
21. Solaiman ARM, Rabbani MG. Effects of Rhizobium Inoculant, Compost and Nitrogen on Nodulation, Growth and Yield of Pea. Korean J Crop Sci. 2006;51(6):534-538.
22. Turuko M, Mohammed A. Effect of Different Phosphorus Fertilizer Rates on Growth, Dry Matter Yield and Yield Components of Common Bean (*Phaseolus vulgaris* L.). World J Agric Res. 2014;2(3):88-92.
23. Wesley JC, Dawson J. Influence of Biofertilizers and Gibberellic Acid on Growth and Yield of Blackgram (*Vigna mungo* L.). Int. J Environ Climate Change. 2023;13(9):329-335.
24. Yadav J, Verma JP, Rajak VK, Tiwari KN. Selection of Effective Indigenous Rhizobium Strain for Seed Inoculation of Chickpea (*Cicer aritenium* L.) Production. Bacteriology Journal. 2011;1(1):24-30.