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Performance of phosphorus levels and biofertilizers on growth, yield and quality of pigeon pea (*Cajanus cajan* L. MILL SP.) under rainfed condition

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ABSTRACT

The present investigation entitled "Performance of phosphorus levels and biofertilizers on growth, yield and quality of pigeon pea (Cajanus cajan L. Millsp.) under rainfed condition" during Kharif 2024 at the Research Farm of the Department of Agronomy, Faculty of Agriculture Science and Technology, AKS University, Satna (M.P.). The experiment was laid out in a Randomized Block Design (RBD) with twelve treatment combinations, comprising four phosphorus levels [0 (P_0), 30 (P_1), 60 (P_2), and 90 kg P_2O_5 ha^{-1} (P_3)] and three biofertilizer treatments [Rhizobium (B_1), PSB (B_2), and Rhizobium + PSB (B_3)], replicated three times. The results revealed that application of 90 kg P_2O_5 ha^{-1} (P_3) along with dual seed inoculation of Rhizobium + PSB (B_3) significantly improved growth parameters, yield attributes, seed yield (1988.52 kg/ha), stover yield (4477.41 kg/ha), protein content (22.82%), and economic returns (net return ₹71,644.33/ha and B:C ratio 2.58) over the control. The treatment combination P_3B_3 (90 kg P_2O_5 ha^{-1} + Rhizobium + PSB) was found significantly superior than the other treatments. The lowest values for most parameters were recorded in control (P_0B_1). The study concluded that the integrated use of phosphorus at 90 kg P_2O_5 ha^{-1} and combined inoculation with Rhizobium + PSB is highly effective in improving the productivity and profitability of pigeon pea under rainfed conditions.

Keywords: B:C, Pegionpea, Phosphorus, PSB, Rhizobium.

INTRODUCTION

Pigeon pea (*Cajanus cajan* L.) nutritionally rich, containing approximately 22.3% protein, 1.7% fat, 3.5% minerals, 1.5% fiber, and 57.6% carbohydrates (Dash and Debbarma, 2024). On a global scale, pigeon pea is cultivated across 6.02 million hectares, yielding 5.32 million tonnes with an average productivity of 883 kg/ha (FAO, 2023). In India, it is grown on about 4.06 million hectares, producing 3.31 million tonnes with a productivity of 814 kg/ha (GOI, 2023). In Madhya Pradesh, it is cultivated in about 2.19 lakh ha which contributes to the production of 2.86 lakh tonnes with a productivity of 1305 kg/ha (Anonymous, 2021). Among legumes, pigeon pea ranks sixth globally in area and production, and it is consumed in more diverse forms than many other pulses like beans and chickpeas. Phosphorus is an essential nutrient that plays a vital role in the growth and metabolic processes of pulse crops. Despite its importance, only a small fraction of the phosphorus applied through fertilizers is actually absorbed by plants. A significant portion becomes fixed in the soil in insoluble forms, making it unavailable for uptake. As a result, the phosphorus use efficiency in crops typically ranges between 10 to 30% (Swarup, 2002). Biofertilizers contribute to improved soil fertility and yield by transforming unavailable forms of nitrogen and phosphorus into forms accessible to plants. Rhizobium bacteria, for example, can fix between 4–200 kg N ha^{-1} in pigeon pea, enhancing nodulation, nitrogen fixation, and overall crop performance. PSB can substitute 15–20% of the phosphorus fertilizer requirement through the production of organic acids, which help solubilize bound phosphate. Phosphorus solubilizing bacteria (PSB) play a significant role in enhancing phosphorus availability by converting insoluble forms of phosphorus into plant-available forms, thereby improving its uptake (Khan *et al.,* 2007).

MATERIALS AND METHODS

The experiment was conducted during the *Kharif* season of 2024 at the Research Farm, Department of Agronomy, AKS University, Satna, Madhya Pradesh. The soil of the experimental field was sandy loamy in texture, neutral in reaction, and moderately fertile, containing 0.61% organic carbon with adequate

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levels of available nitrogen, phosphorus, and potassium. During the crop period, a total rainfall of 992.50 mm was recorded, accompanied by moderate temperatures and high relative humidity, which were favourable for the growth and development of the pegionpea crop. The field trial was laid out in a Randomized Block Design (RBD) with tweleve treatments and three replications. The treatments included T_1 (Control + Rhizobium), T_2 (Control + PSB), T_3 (Control + Rhizobium + PSB), T_4 (30 kg P_2O_5 ha^{-1} + Rhizobium), T_5 (30 kg P_2O_5 ha^{-1} + PSB), T_6 (30 kg P_2O_5 ha^{-1} + Rhizobium + PSB), T_7 (60 kg P_2O_5 ha^{-1} + Rhizobium), T_8 (60 kg P_2O_5 ha^{-1} + PSB), T_9 (60 kg P_2O_5 ha^{-1} + Rhizobium + PSB), T_{10} (90 kg P_2O_5 ha^{-1} + Rhizobium), T_{11} (90 kg P_2O_5 ha^{-1} + PSB) and T_{12} (90 kg P_2O_5 ha^{-1} + Rhizobium + PSB). The variety of Pegionpea used for the study was Kalyani, which was sown manually using a spacing of 60 × 20 cm and a seed rate of 20 kg/ha at about 4-5 cm depth. Fertilizers were applied as full dose of Nitrogen and Potassium @ 20 kg/ha was applied as a basal dressing at the time of sowing. Similarly, phosphorus was also applied as per the treatments. It was applied as a basal dose. All other recommended agronomic practices including irrigation, weed control, pest and disease management, and harvesting were performed uniformly across all treatment plots.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads for both ends phosphorous and biofertilizer**:**

Growth Parameters

Effect of Phosphorus Levels

The application of phosphorus significantly influenced the growth parameters of pigeon pea. The highest dose, P_3 (90 kg P_2O_5 ha^{-1}), consistently outperformed lower doses and the control in all measured growth characters—plant height, number of branches, root nodules, chlorophyll content, and flowering duration. At harvest, the tallest plants (162.96 cm) were recorded under P_3, while the control (P_0) had the shortest plants (140.43 cm), confirming phosphorus's pivotal role in vegetative growth. Similarly, number of branches per plant peaked at 13.89 in P_3 at 90 DAS, owing to better nutrient uptake and assimilates distribution. Additionally, higher root nodulation (31.58 nodules/plant under P_3) suggests that phosphorus availability encouraged robust Rhizobium activity, which is essential in legume crops for biological nitrogen fixation.

Table 1: Performance of phosphorus levels and biofertilizers on growth, yield and quality of pigeon pea at 90 DAS

Treatment	Plant height (cm)	Number of root Nodules/Plant	Number of Branches/Plant	Pods/ Plant	Pod Length (cm)	Seeds/ Pod	Grain Yield ($kgha^{-1}$)	Protein Content (%)
P_0 B_1	128.02	24.20	11.33	148.67	4.44	4.13	724.26	17.81
P_0 B_2	122.96	23.93	10.27	147.00	4.03	3.53	609.09	17.64
P_0 B_3	127.41	24.73	11.13	150.00	4.92	4.27	906.55	17.87
P_1 B_1	132.02	26.27	11.00	153.53	5.37	4.53	981.78	18.45
P_1 B_2	127.17	24.60	10.87	153.67	5.22	4.33	877.90	18.18
P_1 B_3	136.21	28.27	11.33	156.13	6.07	4.53	1041.10	18.59
P_2 B_1	143.03	29.87	13.73	169.73	7.36	5.00	1196.19	20.03
P_2 B_2	136.85	30.33	12.40	166.33	6.56	4.73	1086.53	18.92
P_2 B_3	146.57	31.13	13.27	170.40	7.60	5.07	1209.50	20.11
P_3 B_1	151.60	32.40	13.93	173.13	7.99	5.13	1591.74	21.94
P_3 B_2	137.16	29.47	13.20	167.00	6.89	4.87	1190.98	19.02
P_3 B_3	157.28	32.87	14.53	176.20	8.19	6.07	1617.20	22.10
SEm±	2.12	0.42	0.17	0.95	0.10	0.15	40.16	0.40
CD (p=0.05)	6.22	1.23	0.50	2.79	0.29	0.44	117.79	1.17

Effect of Biofertilizers

The application of biofertilizers significantly influenced the growth parameters of pigeon pea, with the combined treatment of

Table 2: Performance of phosphorus levels and biofertilizers on economic parameter of pigeon pea

Treatment	Cost of cultivation (₹ ha^{-1})	Gross monetary returns (₹ ha^{-1})	Net monetary returns (₹ ha^{-1})	B:C Ratio
P_0 B_1	30387.00	57206.51	26819.51	1.88
P_0 B_2	30387.00	47986.32	17599.32	1.58
P_0 B_3	30387.00	71014.34	40627.34	2.34
P_1 B_1	31801.38	76932.85	45131.47	2.42
P_1 B_2	31805.38	68956.83	37151.45	2.17
P_1 B_3	31806.38	81442.51	49582.13	2.56
P_2 B_1	33160.75	93237.47	60076.72	2.81
P_2 B_2	33164.75	84901.64	51736.89	2.56
P_2 B_3	33219.75	94289.25	61069.50	2.84
P_3 B_1	34520.13	123258.44	88738.31	3.57
P_3 B_2	34524.13	92831.17	58307.04	2.69
P_3 B_3	34579.13	125290.74	90711.61	3.62
SEm±		3029.38	3029.38	0.08
CD (p=0.05)		8884.87	8884.87	0.23

P_0B_1 (Control + Rhizobium), P_0B_2 (Control + PSB), P_0B_3 (Control + Rhizobium +PSB), P_1B_1 (30 kg P_2O_5 ha^{-1} + Rhizobium), P_1B_2 (30 kg P_2O_5 ha^{-1} + PSB), P_1B_3 (30 kg P_2O_5 ha^{-1} + Rhizobium +PSB), P_2B_1 (60 kg P_2O_5 ha^{-1} + Rhizobium), P_2B_2 (60 kg P_2O_5 ha^{-1} + PSB), P_2B_3 (60 kg P_2O_5 ha^{-1} + Rhizobium +PSB), P_3B_1 (90 kg P_2O_5 ha^{-1} + Rhizobium), P_3B_2 (90 kg P_2O_5 ha^{-1} + PSB), P_3B_3 (90 kg P_2O_5 ha^{-1} + Rhizobium +PSB)

Rhizobium + PSB consistently outperforming sole applications of either Rhizobium or PSB. This synergistic treatment resulted in the highest values for plant height, number of branches, root nodules, chlorophyll content, and earliness in flowering. At harvest, the tallest plants (156.15 cm) were recorded under Rhizobium + PSB, followed by Rhizobium alone (153.46 cm). The number of branches per plant also peaked under Rhizobium + PSB (12.57 at 90 DAS), indicating enhanced vegetative growth. Higher nodulation (29.25 nodules/plant under Rhizobium + PSB) also confirms the improved symbiotic interaction, which plays a pivotal role in nitrogen supply and shoot development. Similar findings were reported by Kumar *et al.,* (2012), Ade *et al.,* (2018), Ahirwar *et al.,* (2018) and Dash and Debbarma (2024).

Yield Attributes and Yield

Effect of Phosphorus Levels

Yield attributes and grain yield of pigeon pea were significantly improved by phosphorus application, with the best results from P_3 (90 kg P_2O_5 ha^{-1}). The number of pods per plant, pod length, seeds per pod, and test weight all showed a marked increase under P_3. For instance, P_3 recorded the highest number of pods per plant (172.11), pod length (7.69 cm), and seeds per pod (5.36), in contrast to the respective values under P_0 (148.56, 4.46 cm, and 3.98). Grain yield per hectare was highest under P_3 (1466.64 kg/ha) compared to the control (746.63 kg/ha), stover yield was also higher under P_3 (3062.05 kg/ha), indicating robust biomass accumulation and better structural growth, which also adds to the economic value. The harvest index was also highest in P_3 (32.23%), reflecting more efficient conversion of biomass into economic yield.

Effect of Biofertilizers

Biofertilizer application had a profound impact on yield attributes and yield, with the best results consistently observed under the Rhizobium + PSB treatment. The number of pods per plant (163.18), pod length (6.70 cm), seeds per pod (4.99), and test weight (110.66 g) were all significantly higher in this treatment compared to Rhizobium or PSB alone. Grain yield per hectare was maximum under Rhizobium + PSB (1193.59 kg/ha), followed by Rhizobium (1123.49 kg/ha) and PSB (941.13 kg/ha), stover yield also followed a similar pattern, highest under Rhizobium + PSB (2893.36 kg/ha), supporting the observation of robust overall plant growth. The harvest index (28.86%) under this treatment was superior to other biofertilizer treatments, suggesting more efficient partitioning of biomass toward economic yield.

Quality Parameters

Effect of Phosphorus Levels

Protein content in pigeon pea seeds was significantly influenced by phosphorus levels. The maximum protein content (21.02%) was observed under P_3 (90 kg P_2O_5 ha^{-1}), compared to the lowest in P_0 (17.77%). This improvement is due to the synergistic effect of phosphorus on nitrogen metabolism.

Effect of Biofertilizers

The protein content in pigeon pea seeds was also significantly affected by biofertilizer treatments. The highest protein content (19.67%) was recorded under Rhizobium + PSB, followed by Rhizobium (19.56%), and the lowest under PSB (18.44%).

Economic

Effect of Phosphorus Levels

With increasing phosphorus application, there was a gradual rise in the cost of cultivation due to the added input of phosphorus fertilizer, with the maximum cost (₹33,263.33/ha) observed under P_3 (90 kg P_2O_5 ha^{-1}). However, this increased investment was offset by a corresponding and substantial rise in economic returns. The highest gross return (₹1, 13,793.45/ha) and net return (₹79,252.32/ha) were recorded under P_3, which also resulted in the maximum B:C ratio of 3.29, indicating superior profitability.

Effect of Biofertilizers

Among the treatments, the highest cost of cultivation (₹32,057.00/ha) was observed with Rhizobium + PSB, due to the use of both microbial inoculants. However, this additional investment was economically justified, as the same treatment recorded the maximum gross return (₹93,009.21/ha) and net return (₹60,497.65/ha). It also resulted in the highest B:C ratio (2.84), indicating greater profitability compared to individual biofertilizer treatments.

CONCLUSION

The highest dose, P_3 (90 kg P_2O_5 ha^{-1}), consistently recorded the best performance across plant height, number of branches, nodulation, chlorophyll content, yield components, grain yield (1466.64 kg/ha), stover yield (3062.05 kg/ha), harvest index, and protein content (21.02 %). Furthermore, Net return and Benefit cost ratio was also higher under the same treatment. With respect to biofertilizers, the combined application of Rhizobium + PSB was superior to individual inoculation with either Rhizobium or PSB. The dual inoculation significantly enhanced vegetative and reproductive traits, leading to the highest grain (1193.59 kg/ha) and stover yield (2893.36 kg/ha) and improved protein content (19.67 %). Moreover, higher net return and B:C ratio was also obtained under dual inoculation (Rhizobium + PSB).

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REFERENCES

Ade, U. K., Dambale, A. S., and Jadhav, D. B. (2018) Effect of phosphorus and biofertilizer on growth, yield and economics of pigeonpea (*Cajanus cajan* L. Millsp.) under rainfed condition. *International Journal of Current Microbiology and Applied Sciences, Special Issue-**6**, 1408–1416.*

Ahirwar*, R. P.,* Mishra*, U. S.,* Sirothia*, P.,* and Mitra*, N. G. (2018)* Effect of phosphorus and biofertilizer on root nodulation and yield of pigeonpea (*Cajanus cajan* L.). *Journal of Pharmacognosy and Phytochemistry, SP1, 3059–3061.*

Anonymous (2023) Crop-wise Area, Production and Productivity of Pulses from 2010-11

to 2022- 2, DPD, GoI, Bhopal, Pp 8.

Dash, S., and Debbarma, V. (2024) Effect of different biofertilizers and phosphorus on growth and yield of Pigeon pea. *International Journal of Research in Agronomy, **7**(5), 260– 264.*

Food and Agriculture Organization (FAO). (2022) Ministry of Agriculture and Farmers Welfare. *Domestic and International Area, Production and Yield of Pigeon peas. Retrieved from https://www.fao.org*

Garaniya, N.H., Bambhaneeya, S.M., Patel, S.G., and Bambharolia, R.P. (2023) Comparing anti-nutritional factors in pigeon pea: seeds vs. Seed coats. *Annals of Plant and Soil Research **25**(4): 614-619.*

Government of India (GOI). (2023) Agricultural statistics at a glance: *Ministry of Agriculture and Farmers Welfare, Government of India. Retrieved from http://www.agricoop.nic.in*

Khan, M. S., Zaidi, A., and Wani, P. A. (2007) Role of phosphate-solubilising microorganisms in sustainable agriculture – *A review. Agronomy for Sustainable Development, **27**, 29– 43*.

Kumar, P., Rana, K. S., and Rana, D. S. (2012) Effect of planting systems and phosphorus with bio-fertilizers on the performance of sole and intercropped pigeonpea (*Cajanus cajan*) under rainfed conditions. *Indian Journal of Agronomy, **57**(2), 127–132.*

Nadaf, A. A., Mansur, C. P, Salakinkop, S. R. and Pattar, P. S. (2015) Effect of broad bed and furrow cultivation of pigeonpea varieties on growth, yield and uptake of nutrients. *Annals of Plant and Soil Research **17** (Special Issue): 13-16.*

Rajesh, N., Paulpandi, V.K., and Pandian, B.J. (2015) New agronomic practices for enhancement of pigeonpea productivity. *Annals of Plant and Soil Research **17** (Special Issue): 10-12.*

Swarup, A. (2002) Lessons from long-term fertilizers experiments in improving fertilizer use efficiency and crop yields. *Fertilizer News, **47**(12), 59–73.*