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Effect of Phosphorus and Biofertilizers on Yield and Economics of Chickpea (*Cicer arietinum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment to examine the yield and economics of chickpea (*Cicer arietinum* L.) was conducted during the Rabi season of 2022 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj, (U.P. India). The experimental plot's soil had a sandy loam texture, a pH of 7.2, was neutral, had an EC-value of 0.26 (dS/m), organic carbon content of 0.72 percent, and availability of 178.48 kg/ha of available N, 27.80 kg/ha of available P, and 233.24 kg/ha of available K. As biofertilizers, *Rhizobium sp.* (5 g/kg seed), *Pseudomonas striata* (10 g/kg seed), and PSB (20 g/kg seed) were utilized, while phosphorus (40 kg/ha, 50 kg/ha, and 60 kg/ha) was applied in three levels as a fertilizer. Ten treatments were used in the experiment's Randomized Block Design (RBD), which was triple duplicated. Phosphorus treatment (60 kg/ha) + PSB (20 g/kg seed) resulted in highest No. of pods/plant (30.90), No. of seeds/pod (1.53), seed yield (2570.74 kg/ha) and stover yield (3583.33 kg/ha), were all determined to be significant. The treatment (T9) with application of Phosphorus (60 kg/ha) + PSB (20 g/kg seed) also observed maximum gross returns (1, 54,165.87 INR/ha), net returns (1, 13,725.57 INR/ha) and benefit cost ratio (2.81) in chickpea crop.

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1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the third most cultivated legume in the world. India stands out as one of the largest producers and consumers of chickpea seeds (or seed), but its production is insufficient to meet the needs of the domestic market, and chickpea is imported. It is known as a legume with high concentrations of proteins, nutrients, and carbohydrates, is adaptable to wide climatic variation, has low production costs, and encourages biological fixation of a nitrogen cycle [1]. In India, Madhya Pradesh (39%), Maharashtra (14%), Rajasthan (14%), Uttar Pradesh (7%), Karnataka (6%), and Gujarat (5%) are the major chickpea growing states. In India, pulses are produced on roughly 28.83 million ha, producing 25.72 million t of output annually, with a productivity of 0.8 t ha. According to the Ministry of Agriculture and Farmers Welfare, some of the states, including Uttar Pradesh, which is roughly 8.24 million hectares in size with an annual production of 9.97 million tonnes and productivity of 1.08 t ha, are key producers of chickpea in India [2].

Although phosphorus fertilization is one of the primary crop management techniques, it is regarded as complicated in tropical soils because to the high covalent adsorption capability of phosphorus to soil oxides and the poor natural availability of P to plants. It is confirmed that phosphorus fertilization at a rate of 60 kg/ha is adequate to produce the most chickpea seeds in *Vertisols* in India. Application of 60 kg/ha of phosphorus had a favorable impact on relative growth rate, dry matter accumulation, nodulation, yield, and harvest index. By employing the same phosphorus treatment rate, it has also been reported to be economically efficient and rich in protein [1]. The reaction of phosphorus is affected by a number of variables, including climate, soil type, variety, and the availability of nutrients during the growth phase. For the growth of their roots and metabolic processes, legumes like chickpeas require more phosphorus than other types of crops. From the start of seedling growth through the maturation of grain, phosphorus catalyzes a variety of biochemical events and is an essential component of DNA, RNA, ATP, and the photosynthetic system [3].

Biofertilizers are inexpensive, sustainable sources of plant nutrition that are used in addition to chemical fertilizers. Through their actions in the soil or rhizosphere, biofertilizers solubilize plant nutrients like nitrogen and phosphorus and gradually make them accessible to plants. Tricalcium, iron, and aluminium phosphates are among the insoluble types of phosphates that Phosphate Solubilizing Bacteria solubilize into usable forms [4]. Biofertilizers can colonize the rhizosphere and stimulate crop development by boosting the supply and availability of nutrients. Plant growth-promoting rhizobacteria (PGPR) strains such as *Rhizobium, Pseudomonas, Azospirillum, Azotobacter, Bacillus, Burkholdaria, Erwinia, Mycobacterium, Flavobacterium,* etc. are some significant strains that may be employed as biofertilizers [5]. Most soils have microorganisms that may dissolve phosphate. By reducing the soil pH, solubilizing P, activating synthesized phosphatases, mineralizing organic P, and/or chelating P from aluminium, calcium, and iron under in vitro settings, they can increase P bioavailability [6]. When inoculated, phosphorus-solubilizing bacteria secrete acidic compounds that solubilize previously inaccessible soil phosphorus. Thus, the culture can demonstrate broad range biofertilizers that might boost crop yields (such as those of legumes and vegetables) by 10% to 30%. Utilizing PSB culture improves crop growth, nitrogen absorption, nodulation, and yield [7]. It is known that certain microbes in the plant rhizosphere, such as phosphate-solubilizing bacteria and fungi, may transform insoluble inorganic phosphorus (P) into a soluble form that plants can use [8]. As a result, using PSB in combination with good nutrient management practises will assist to preserve soil fertility while also increasing chickpea output and quality [9].

The present study was therefore, carried out to study the effect of phosphorus and biofertilizers on yield and economics of chickpea.

2. MATERIALS AND METHODS

At the Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India, which is situated at 25° 24' 42" N latitude above mean sea level (MSL), the experiment was carried out during the Rabi season of 2022. The soil is sandy loam in texture, with a pH of 7.2, 0.72 percent organic carbon, 178.48 kg/ha of available N, 27.80 kg/ha of available P, and 233.24 kg/ha of available K. Ten treatments, each replicated three times,

Table 1. Treatment combination

S. No.	Treatment combination
1.	Phosphorus 40 kg/ha + *Rhizobium sp.* (5 g/kg seed)
2.	Phosphorus 40 kg/ha + *Pseudomonas striata* (10 g/kg seed)
3.	Phosphorus 40 kg/ha + PSB (20 g/kg seed)
4.	Phosphorus 50 kg/ha + *Rhizobium sp.* (5 g/kg seed)
5.	Phosphorus 50 kg/ha + *Pseudomonas striata* (10 g/kg seed)
6.	Phosphorus 50 kg/ha + PSB (20 g/kg seed)
7.	Phosphorus 60 kg/ha + *Rhizobium sp.* (5 g/kg seed)
8.	Phosphorus 60 kg/ha + *Pseudomonas striata* (10 g/kg seed)
9.	Phosphorus 60 kg/ha + PSB (20 g/kg seed)
10.	Control (20-50-20 NPK kg/ha)

were used in the experiment's Randomized Block Design setup. The experiment used three levels of biofertilizers, including PSB (in the form of *Bacillus mageterium* 20 g/kg seed), *Rhizobium sp.* (5 g/kg seed), *Pseudomonas striata* (10 g/kg seed), and three levels of phosphorus (40 kg/ha, 50 kg/ha, and 60 kg/ha) when applied in combinations as shown in Table 1.

At the third week after germination, five randomly selected plants were tagged in order to record observations. The chickpea crop was collected as the pods reached maturity. Bundles were then produced, dried in the sun, and weighed to determine the biological yield. Following the threshing of plants from each treatment, the seed production was recorded and translated into kg/ha. Each plot's observations, including the number of pods per plant, the number of seeds per pod, the seed yield, and the stover yield, were noted. Based on the cost of cultivation and the current market price, net returns, gross returns, and benefit cost ratio were calculated. Data was statistically analyzed by using Gomez and Gomez [10].

3. RESULTS AND DISCUSSION

3.1 Yield Parameters

In comparison to treatment 10 (Control 20-50-20 NPK kg/ha), treatment 9 (Phosphorus 60 kg/ha + PSB) produced more pods per plant (30.90), seeds per pod (1.53), seeds yield (2570.74 kg/ha), and stover yield (3583.33 kg/ha). One of the main factors restricting development, especially during the reproductive period, might be regarded to be the regulatory role of phosphorus in photosynthesis and carbohydrate metabolism of leaves [7]. The seed output of chickpea above the control has been greatly impacted by the application of phosphorus. With 60 kg of phosphorus alone, the improvements in seed output over the control were measured at 42.7 and 38.3%, respectively. Due to more efficient metabolic processes and faster photosynthesis, which improves nutrient transport and the expression of developmental traits, there is a rise in yield when P levels are present [11]. The application of increasing levels of phosphorus resulted in a significant increase in grain yield, which may be attributable to the active biotic role of phosphorus in plant metabolic processes and photosynthesis. This element also tends to increase flowering, fruiting, and grain formulation, all of which have a positive impact on yield attributes. The increase in grain yield attributed to phosphorus appears to be the consequence of the additive impact of yield characteristics and may be attributable to the plant's intense root system's efficient absorption and utilization of nutrients under conditions of sufficient phosphorus availability [12]. Application of phosphorus hastened photosynthesis and their transfer from source to sink, resulting in larger values of stover output. The use of biofertilizers increased yield primarily because nearly all growth and yield-contributing traits increased, which eventually led to a considerable rise in stover output. This was primarily driven by the increased availability of N and P, which led to well-developed roots with stronger nitrogen-fixing capability, faster plant growth and development, and better photosynthetic diversion towards sinks [13].

Table 2. Influence of phosphorus and biofertilizers on yield attributes and yield of chickpea

S. No.	Treatments	No. of pods/plant	No. of seeds/pod	Seed yield (kg/ha)	Stover yield (kg/ha)
1.	Phosphorus 40 kg/ha + *Rhizobium sp.*	26.27	1.13	1521.34	2606.67
2.	Phosphorus 40 kg/ha + *Pseudomonas striata*	25.90	1.13	1465.56	2570.00
3.	Phosphorus 40 kg/ha + PSB	28.07	1.20	1758.56	2983.33
4.	Phosphorus 50 kg/ha + *Rhizobium sp.*	27.30	1.20	1658.17	2783.33
5.	Phosphorus 50 kg/ha + *Pseudomonas striata*	26.87	1.13	1533.27	2746.67
6.	Phosphorus 50 kg/ha + PSB	28.53	1.47	2276.39	3470.00
7.	Phosphorus 60 kg/ha + *Rhizobium sp.*	28.10	1.33	1975.50	3256.67
8.	Phosphorus 60 kg/ha + *Pseudomonas striata*	27.70	1.20	1701.20	2836.67
9.	Phosphorus 60 kg/ha + PSB	30.90	1.53	2570.74	3583.33
10.	Control (20-50-20 NPK kg/ha)	25.13	1.13	1396.27	2496.67
	F test	S	S	S	S
	SEm(±)	0.93	0.05	101.85	79.42
	CD (p=0.05)	2.77	0.16	302.63	235.99

Table 3. Influence of phosphorus and biofertilizers on economics of chickpea

S. No.	Treatments	Total cost of cultivation (INR)	Gross return (INR/ha)	Net return (INR/ha)	Benefit cost ratio (B:C)
1.	Phosphorus 40 kg/ha + *Rhizobium sp.*	40,208.30	93,610.00	53,401.70	1.32
2.	Phosphorus 40 kg/ha + *Pseudomonas striata*	40,214.30	90,760.00	50,545.70	1.25
3.	Phosphorus 40 kg/ha + PSB	40,220.30	1,08,180.00	67,861.70	1.68
4.	Phosphorus 50 kg/ha + *Rhizobium sp.*	40,318.30	1,01,880.00	61,561.70	1.52
5.	Phosphorus 50 kg/ha + *Pseudomonas striata*	40,324.30	94,840.00	54,515.70	1.35
6.	Phosphorus 50 kg/ha + PSB	40,330.30	1,34,480.00	94,149.70	2.33
7.	Phosphorus 60 kg/ha + *Rhizobium sp.*	40,428.30	1,21,240.00	80,811.70	1.99
8.	Phosphorus 60 kg/ha + *Pseudomonas striata*	40,434.30	1,04,300.00	63,865.70	1.57
9.	Phosphorus 60 kg/ha + PSB	40,440.30	1,54,110.00	1,13,669.70	2.81
10.	Control (20-50-20 NPK kg/ha)	39,624.38	86,700.00	47,075.62	1.18

3.2 Economics

The application of phosphorus 60 kg/ha together with PSB in treatment 9 produced the highest gross returns (1, 54,165.87/- INR/ha), net returns (1,13,725.57/- INR/ha), and benefit cost ratio (2.81), when compared to treatment 10 (Control 20-50-20 NPK kg/ha). The value of the increase in crop production is attributable to the fact that the quantity of fertilizer applied is more than the cost of fertilizer used, making the application of unit fertilizer cheap. The secret to increasing profit is applying vital ingredients in the ideal quantity and balance [14]. This was because the cost of the bio inoculants was less expensive, and the increased yield that was seen with each treatment led to a larger net return [15]. This could be due to increased chickpea crop yields [3].

4. CONCLUSION

The application of Phosphorus 60 kg/ha combined with PSB (Treatment 9) was shown to have the maximum seed yield and benefit-cost ratio in chickpea crop.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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