



Impact of Biofertilizers and Phosphorus Application on Growth 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 was conducted during the Rabi season of 2023–24 at FASAI, Rama University Agricultural Farm, Kanpur (Uttar Pradesh). The soil of the experimental site was sandy loam, neutral in reaction (pH 7.40), low in organic carbon (0.45%), low in available nitrogen (163.02 kg ha⁻¹), medium in phosphorus (21.3 kg ha⁻¹), and low in potassium (130.6 kg ha⁻¹). The study comprised 10 treatment combinations: T₁ (Control), T₂ (Rhizobium + 15 kg P/ha), T₃ (PSB + 15 kg P/ha), T₄ (Rhizobium + PSB + 15 kg P/ha), T₅ (Rhizobium + 30 kg P/ha), T₆ (PSB + 30 kg P/ha), T₇ (Rhizobium + PSB + 30 kg P/ha), T₈ (Rhizobium + 45 kg P/ha), T₉ (PSB + 45 kg P/ha), and T₁₀

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(Rhizobium + PSB + 45 kg P/ha), laid out in a Randomized Block Design (RBD) with three replications. The chickpea variety KPG-59 (Uday) was sown manually using a kudal. Weather conditions during the crop season included a maximum temperature of 40.51°C, a minimum of 6.74°C, and total rainfall of 9.73 mm across 10 rainy days. Results indicated that while plant population did not differ significantly among treatments, plant height, dry matter accumulation, and branching were significantly enhanced with combined applications of Rhizobium, PSB, and 45 kg P/ha (T₁₀). T₁₀ also recorded the highest nodulation, biomass, and delayed flowering.

Keywords: Biofertilizer; phosphorus; rhizobium; PSB; chickpea.

1. INTRODUCTION

Pulses are the key component of the Indian agriculture system. In India, key pulses such as pigeon pea, green gram, chickpea, black gram, kidney bean, cow pea, lentil, and white pea are widely cultivated and consumed. Historically, pulses have been deeply integrated into the country's farming practices, as farmers could grow them using their own seeds and family labor, with minimal reliance on external inputs. These crops continue to be grown primarily on marginal and sub-marginal lands, mostly under rain fed conditions. Rich in protein (21-25%), pulses are often referred to as the "poor man's meat. Every pulse plant functions as a "mini fertiliser factory" because of their symbiotic relationship with Rhizobium and their capacity to fix atmospheric nitrogen. This helps to enrich soil organic nitrogen and gives them an advantage over chemical fertilisers, which leach nutrients as ammonia. Pulse crops' deeply penetrating root structure substantially aids in top soil loosening and enables them to take advantage of the soil's restricted moisture supply more effectively than other crops. Pulses can be grown as a catch crop, green manure crop, intercrop, primary crop, or sequence crop because of their short growing season (Uddin et al., 2014; Moinuddin et al., 2014). Chickpeas are an important source of protein for millions of people in developing countries, especially in South Asia, where many people are vegetarians by choice or necessity. Chickpeas are packed with nutrients, containing 18-22% protein, 61-63% carbohydrates, 4.5% fat, and important minerals like calcium (280 mg/100 g), iron (12.3 mg/100 g), and phosphorus (301 mg/100 g). They also have amino acids such as lysine, leucine, isoleucine, valine, and phenylalanine (Mukherjee et al., 2020).

"Bio fertilizers are living microorganisms which colonizes the Rhizosphere and promotes growth by increasing the availability and supply of nutrients and/or growth stimulus to crop" (Singh et al., 2016). "Bio fertilizers are carrier

based preparations containing beneficial microorganisms in a viable state intended for seed or soil application to improve soil fertility and plant growth by increasing the number and biological activity of beneficial microorganisms in the rhizosphere. They improve soil fertility level by fixing atmospheric nitrogen, solubilizing insoluble soil phosphates and releasing plant growth substances in the soil" (Vahideh, 2015). "Biofertilizers are cost effective, ecofriendly, and renewable sources of plant nutrition" (Ali et al, 2024). "These are also known as microbial inoculants. There are different types of microbial inoculants. Some important inoculants are Rhizobium inoculants, Azotobacter inoculants, Arbuscular mycorrhiza (AM), blue green algae inoculants, azolla, phosphate solubilizing bacterial (PSB) inoculants etc. Rhizobium inoculants are widely used as biofertilizer to enhance Chickpea growth & yield as they fix atmospheric nitrogen symbiotically. Rhizobium inoculation increased nodulation and seed yields upto 35%" (Bhagat 2022). Gupta (2022) found that seed inoculation with Rhizobium increased chickpea seed yields by 9.6-27.9%. Singh et al., (2017) was told that "the biofertilizers are cheap and eco- friendly source for nutrient supply that can substitute a part of chemical fertilizers resulting reduce the soil, water and air pollution. Generally, Indian soils are lacking in effective and specific strains of Rhizobium which are responsible for symbiotic nitrogen fixation. Some important strains are mentioned as plant growth promoting rhizobacteria (PGPR) and that can be used as biofertilizer".

"Phosphorus is essential for plant growth as it stimulates growth of young plants, giving them a good and vigorous start" (Das et al., 2022). "It is among the important elements needed for crop growth and production in many tropical soils. However, many tropical soils are P- deficient. Phosphorus is vital to plant growth and is found in every living plant cell. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and

starches, nutrient movement within the plant” (Dwivedi et al., 2021). “It is a component of important substances such as nucleic acids, phospholipids, and ATP, and as a result, plants cannot grow properly without an adequate supply of this important nutrient. It is an important plant macronutrient, making up about 0.2% of a plant’s dry weight. In addition, P is involved in controlling key enzyme reactions and in the regulation of metabolic pathways. Phosphorus also plays an important role in the buildup and maintenance of soil productivity by legumes through its effect on host plant growth and through its specific effect on Rhizobium growth, survival, and nodulation capability” (Kanaujia et al., 2023). However, irrespective of the fact that the effect of P is closely associated with the stimulation of host plant growth, P is a vital requirement for N₂ fixation.

2. MATERIALS AND METHODS

A field experiment was conducted during the Rabi season of 2023–24 at FASAI, Rama University Agricultural Farm, Kanpur (Uttar Pradesh). The soil of the experimental site was sandy loam, neutral in reaction (pH 7.40), low in organic carbon (0.45%), low in available nitrogen (163.02 kg ha⁻¹), medium in phosphorus (21.3 kg ha⁻¹), and low in potassium (130.6 kg ha⁻¹). The study comprised 10 treatment combinations: T₁ (Control), T₂ (Rhizobium + 15 kg P/ha), T₃ (PSB + 15 kg P/ha), T₄ (Rhizobium + PSB + 15 kg P/ha), T₅ (Rhizobium + 30 kg P/ha), T₆ (PSB + 30 kg P/ha), T₇ (Rhizobium + PSB + 30 kg P/ha), T₈ (Rhizobium + 45 kg P/ha), T₉ (PSB + 45 kg P/ha), and T₁₀ (Rhizobium + PSB + 45 kg P/ha), laid out in a Randomized Block Design (RBD)

with three replications. The chickpea variety KPG-59 (Uday) was sown manually using a kudal. Weather conditions during the crop season included a maximum temperature of 40.51°C, a minimum of 6.74°C, and total rainfall of 9.73 mm across 10 rainy days.

3. RESULTS AND DISCUSSION

3.1 Growth Characters

3.1.1 Plant population (m⁻²)

The data on plant height as impacted by various treatments are summarized in the Table 1.

The data on plant population recorded at 25 days after sowing (DAS) ranged from 34.50 to 37.21 plants m⁻², with the highest population observed under the treatment Rhizobium + PSB + Phosphorus 45 kg/ha (37.21), followed closely by Rhizobium + Phosphorus 45 kg/ha (37.13) and PSB + Phosphorus 45 kg/ha (37.10). However, all treatments remained statistically at par with the control (34.51 plants m⁻²). Similar result reported by Kumar et al. (2019), Machehour (2017).

Similarly, at harvest, plant population varied between 32.27 and 36.60 plants m⁻². The maximum population was again observed with Rhizobium + PSB + Phosphorus 45 kg/ha (36.60), while the minimum was recorded in the control (32.27). Despite numerical differences, all treatments were statistically at par at harvest as well. Similar result reported by Aditya et al. (2012), Badini (2015).

Table 1. Effect of various treatments on Plant population (m⁻²) in chickpea

Treatments	Treatments Combinations	Plant population (m ⁻²)	
		25 DAS	At harvest
T ₁	Control	34.51	32.27
T ₂	Rhizobium + Phosphorus 15 kg/ha	34.50	32.71
T ₃	PSB + Phosphorus 15 kg/ha	35.10	33.16
T ₄	Rhizobium + PSB + Phosphorus 15 kg/ha	35.12	33.41
T ₅	Rhizobium + Phosphorus 30 kg/ha	35.16	33.66
T ₆	PSB + Phosphorus 30 kg/ha	35.66	33.66
T ₇	Rhizobium + PSB + Phosphorus 30 kg/ha	36.10	35.10
T ₈	Rhizobium + Phosphorus 45 kg/ha	37.13	35.90
T ₉	PSB + Phosphorus 45 kg/ha	37.10	36.32
T ₁₀	Rhizobium + PSB + Phosphorus 45 kg/ha	37.21	36.60
	SEm±	1.13	3.21
	CD(p=0.05)	N.S.	N.S.

Table 2. Effect of various treatments on Plant height (cm) in chickpea

Treatments	Treatments Combinations	Plant height (cm)			
		30 DAS	60DAS	90 DAS	At harvest
T ₁	Control	14.00	22.00	32.55	34.55
T ₂	Rhizobium + Phosphorus 15 kg/ha	15.60	26.55	35.32	38.10
T ₃	PSB + Phosphorus 15 kg/ha	16.00	26.66	35.77	38.66
T ₄	Rhizobium + PSB + Phosphorus 15 kg/ha	16.10	27.43	36.10	39.32
T ₅	Rhizobium + Phosphorus 30 kg/ha	16.66	27.66	36.66	39.66
T ₆	PSB + Phosphorus 30 kg/ha	17.10	29.66	36.80	40.10
T ₇	Rhizobium + PSB + Phosphorus 30 kg/ha	17.66	30.32	37.19	41.32
T ₈	Rhizobium + Phosphorus 45 kg/ha	18.21	30.66	37.45	41.66
T ₉	PSB + Phosphorus 45 kg/ha	18.46	31.06	40.32	42.20
T ₁₀	Rhizobium + PSB + Phosphorus 45 kg/ha	19.26	32.01	43.10	44.32
	SEm	1.10	0.92	1.34	1.03
	CD	3.31	2.75	4.01	3.10

Table 3. Effect of various treatments on Dry matter accumulation at different growth stages of chick pea crop

Treatments	Treatments Combinations	Dry matter production plant ⁻¹			
		30 DAS	60 DAS	90 DAS	At harvest t
T ₁	Control	1.125	3.72	6.72	9.77
T ₂	Rhizobium + Phosphorus 15 kg/ha		3.47	7.16	9.98
T ₃	PSB + Phosphorus 15 kg/ha	1.128	3.53	7.76	10.28
T ₄	Rhizobium + PSB + Phosphorus 15 kg/ha	1.130	3.61	7.86	10.55
T ₅	Rhizobium + Phosphorus 30 kg/ha	1.131	3.66	7.93	11.13
T ₆	PSB + Phosphorus 30 kg/ha	1.132	3.66	8.01	11.86
T ₇	Rhizobium + PSB + Phosphorus 30 kg/ha	1.134	3.70	8.17	11.97
T ₈	Rhizobium + Phosphorus 45 kg/ha	1.135	3.78	8.57	12.43
T ₉	PSB + Phosphorus 45 kg/ha	1.137	3.96	9.88	12.52
T ₁₀	Rhizobium + PSB + Phosphorus 45 kg/ha	1.139	4.22	6.72	13.56
	SEm±	0.00 2	0.10	0.4	0.7
	CD(P =0.05)	NS	0.3	1.3	2.1

3.1.2 Plants height (cm)

The data pertaining to plant height recorded at 30 DAS, the highest plant height (19.26 cm) was recorded with the treatment Rhizobium + PSB + Phosphorus 45 kg/ha, which was significantly superior to all other treatments except PSB + Phosphorus 45 kg/ha (18.46 cm) and Rhizobium + Phosphorus 45 kg/ha (18.21 cm). Treatments receiving 15 kg and 30 kg P ha⁻¹, either with Rhizobium or PSB or both, remained statistically at par with each other but were significantly taller than the control (14.00 cm). Similar result reported by Malik *et. al.*,(2023), Nawange *et. al.*, (2021)

The data pertaining to plant height recorded at 60 DAS, the tallest plants (32.01 cm) were again recorded under Rhizobium + PSB + Phosphorus

45 kg/ha, which was significantly higher than the control (22.00 cm) and most other treatments. However, PSB + Phosphorus 45 kg/ha (31.06 cm) and Rhizobium + Phosphorus 45 kg/ha (30.66 cm) were statistically at par with the highest treatment. Similar result reported by Pal *et. al.*,(2021), Raghwendra *et. al.*, (2022)

The data pertaining to plant height recorded at 90 DAS, maximum plant height (43.10 cm) was observed with Rhizobium + PSB + Phosphorus 45 kg/ha, which was significantly higher than all other treatments. The treatments PSB + Phosphorus 45 kg/ha (40.32 cm), Rhizobium + Phosphorus 45 kg/ha (37.45 cm), and Rhizobium + PSB + Phosphorus 30 kg/ha (37.19 cm) were statistically at par with each other but significantly superior to lower phosphorus treatments and the

control (32.55 cm). Similar result reported by Pingoliya et al.(2024), Neenu et. al, (2024)

The data pertaining to plant height recorded at harvest, the trend continued with Rhizobium + PSB + Phosphorus 45 kg/ha showing the tallest plants (44.32 cm), significantly outperforming all other treatments. However, treatments with 30 kg P ha⁻¹ and 45 kg P ha⁻¹ in combination with either Rhizobium or PSB were statistically at par with each other but significantly taller than the control (34.55 cm). Similar result reported by Rajput et. al,(2024), Sapatnekar et. al, (2022)

3.1.3 Dry matter accumulation/plant

The data pertaining to dry matter accumulation/plant recorded at 30 DAS, dry matter production ranged from 1.125 g in the control to 1.139 g in Rhizobium + PSB + Phosphorus 45 kg/ha. However, the differences among treatments were statistically non-significant, and all treatments were at par with each other. Similar result reported by Sharma et. al,(2023), Singh et. al, (2021)

The data pertaining to dry matter accumulation/plant recorded at 60 DAS, dry matter production increased noticeably, with the highest value (4.22 g) recorded under Rhizobium + PSB + Phosphorus 45 kg/ha, which was significantly higher than the control (3.72 g) and several lower phosphorus treatments. However, treatments receiving 30 kg and 45 kg phosphorus along with either Rhizobium or PSB (T₅ to T₉) were statistically at par with each other. Similar result reported by Srivastav et. al, (2024), Singh et. al, (2024)

The data pertaining to dry matter accumulation/plant recorded at 90 DAS, the maximum dry matter accumulation (9.88 g) was observed in PSB + Phosphorus 45 kg/ha, followed closely by Rhizobium + Phosphorus 45 kg/ha (8.57 g) and Rhizobium + PSB + Phosphorus 30 kg/ha (8.17 g). These treatments were significantly superior to the control (6.72 g) and were statistically at par with one another. Similar result reported by Tewari et. al, (2022), Yadav et. al, (2022)

The data pertaining to dry matter accumulation/plant recorded at harvest, dry matter production ranged from 9.77 g in the control to 13.56 g in Rhizobium + PSB + Phosphorus 45 kg/ha. This treatment significantly outperformed all others. Treatments receiving 30

kg and 45 kg P ha⁻¹ (T₅ to T₉), either alone or in combination with Rhizobium and/or PSB, were statistically at par with each other but significantly higher than the control and 15 kg P ha⁻¹ treatments. Similar result reported by Yakardi et. al,(2022), Singh et. al, (2018)

4. CONCLUSION

The combined application of *Rhizobium*, PSB (Phosphate Solubilizing Bacteria), and 45 kg/ha phosphorus significantly enhanced plant growth parameters in terms of plant population, height, and dry matter accumulation. Plant height and dry matter accumulation showed marked improvement with increasing phosphorus levels, particularly when combined with biofertilizers. The treatment *Rhizobium* + PSB + Phosphorus 45 kg/ha consistently produced superior results across all growth stages, indicating its effectiveness in promoting plant vigor and productivity compared to lower phosphorus doses or control treatments.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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