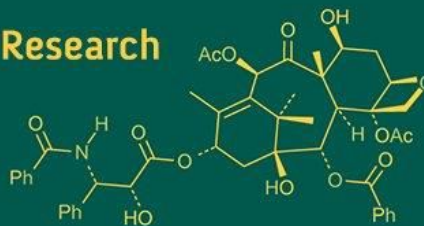
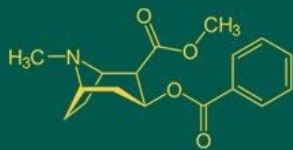


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Influence of phosphorus levels, biofertilizers, and FYM on growth and yield performance of chickpea (*Cicer arietinum* L.)

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Abstract

Chickpea (*Cicer arietinum* L.) is an important pulse crop that plays a vital role in human nutrition and soil fertility improvement through biological nitrogen fixation. However, its productivity is often limited by phosphorus deficiency, low organic matter, and inadequate microbial activity in soils. The present study was conducted to evaluate the influence of varying phosphorus levels, biofertilizers, and farmyard manure (FYM) on growth and yield performance of chickpea under field conditions. The experimental treatments consisted of different phosphorus levels combined with inoculation of *Rhizobium* and phosphate-solubilizing bacteria (PSB) along with or without FYM application. Observations were recorded on growth parameters, yield attributes, seed yield, and nutrient uptake. Results revealed that the combined application of phosphorus at optimum levels (e.g., 60 kg P₂O₅ ha⁻¹) with Rhizobium + PSB inoculation and FYM significantly improved plant height, number of branches, nodulation, and dry matter accumulation compared to control and individual treatments. The integrated use of phosphorus, biofertilizers, and FYM enhanced pod formation, seed yield, and harvest index by improving nutrient availability and utilization efficiency. The synergistic effect of organic and inorganic sources not only increased productivity but also improved soil health parameters such as available nitrogen and phosphorus. It may be concluded that the integrated nutrient management approach involving phosphorus, biofertilizers, and FYM offers a sustainable strategy to enhance growth, yield, and soil fertility in chickpea cultivation.

Keywords: Biofertilizers, farmyard manure, sustainable agriculture

Introduction

Pulses are the second most important group of crops after cereals. India, China, Brazil, Canada, Myanmar and Australia are the major pulse producing countries. About 75% of the global chickpea area falls in India (FAOSTAT, 2010) [4]. India is the largest producer and consumer of pulses in the world. Among the pulses, chickpea is the most important crop growing in every part of India. Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops of the world, valued for its high nutritional content, soil-improving properties, and adaptability to semi-arid regions. It belongs to the family leguminosae and is cultivated in more than 50 countries, with India being the largest producer, accounting for nearly 70% of global production (FAO, 2021) [4]. Chickpea plays a crucial role in human nutrition as it provides an inexpensive source of high-quality protein (18-24%), carbohydrates (52-70%), and essential minerals such as phosphorus, calcium, magnesium, and iron (Jukanti *et al.*, 2012) [5]. In addition, chickpea enriches soil fertility through biological nitrogen fixation, making it a valuable component in sustainable agricultural systems (Ahlawat *et al.*, 2016) [1]. Despite its significance, the average yield of chickpea remains low, particularly in developing countries, due to several constraints such as imbalanced fertilization, poor soil fertility, inadequate organic matter, and limited use of biofertilizers (Singh & Shiva kumar, 2018) [20]. Among the essential macronutrients, phosphorus (P) ranks next to nitrogen (N) in importance for legume growth. It is vital for root development, nodulation, energy transfer (ATP), and seed formation (Khan *et al.*, 2017) [6]. However, the availability of phosphorus in Indian soils is often limited because a large portion of applied phosphorus becomes fixed and unavailable to plants due to interactions with calcium, iron, and aluminium compounds.

Hence, efficient phosphorus management through chemical and biological sources is essential to enhance productivity and nutrient use efficiency in chickpea.

Phosphorus deficiency adversely affects nodulation and nitrogen fixation in legumes, resulting in stunted growth and poor yield (Brahma Prakash & Sahu, 2012) [2]. Application of phosphorus fertilizer has been shown to significantly improve biomass accumulation, root proliferation, nodule number, and seed yield in chickpea (Deshbhratar *et al.*, 2010) [3]. Phosphorus also plays a pivotal role in promoting flowering and pod formation, influencing both yield attributes and total productivity (Kumar *et al.*, 2019) [9]. However, due to high fixation and low mobility of phosphate ions in soil, the efficiency of applied phosphorus fertilizers seldom exceeds 20-25% (Reddy *et al.*, 2018) [17]. Therefore, integrating phosphorus application with organic amendments and biofertilizers can enhance phosphorus availability and uptake by crops.

Farmyard manure (FYM), a widely used organic amendment, not only supplies essential nutrients but also improves soil structure, water-holding capacity, and microbial activity. Regular application of FYM increases the pool of available nutrients and enhances nutrient-use efficiency by reducing losses through leaching and fixation (Sharma *et al.*, 2019) [19]. The decomposition of FYM releases organic acids that help in solubilizing native phosphorus and other nutrients bound in the soil matrix (Mahajan *et al.*, 2008) [10]. Furthermore, FYM enhances microbial biomass and promotes favourable soil biological conditions conducive to nutrient mineralization and plant growth (Sahoo *et al.*, 2017) [18]. Incorporating FYM along with chemical fertilizers is therefore a key component of integrated nutrient management (INM) strategies aimed at sustainable crop production. Biofertilizers, particularly phosphate-solubilizing bacteria (PSB) and Rhizobium inoculants, play a significant role in enhancing nutrient availability to chickpea. Rhizobium bacteria form symbiotic associations with chickpea roots, enabling biological nitrogen fixation that can supply up to 60-80% of the crop's nitrogen requirement (Mandal *et al.*, 2020) [11]. Similarly, PSB produce organic acids and enzymes such as phosphatases that solubilise insoluble phosphates, making them available for plant uptake (Zaidi *et al.*, 2009) [25]. The combined use of PSB and Rhizobium not only enhances the availability of phosphorus but also improves root development, nodule formation, and overall plant vigor (Rana *et al.*, 2014) [16]. Several studies have demonstrated that integrating biofertilizers with phosphorus and FYM can result in synergistic effects, leading to higher growth rates, yield components, and nutrient uptake in chickpea and other legumes (Singh *et al.*, 2021) [22]. Sustainable chickpea production requires balanced nutrient management that combines inorganic and organic sources to maintain soil fertility while minimizing environmental impacts. The concept of integrated nutrient management (INM) emphasizes the judicious use of chemical fertilizers, organic manures, and biofertilizers to achieve long-term soil productivity and crop yield stability (Tandon, 2004) [24]. INM practices not only supply nutrients but also enhance soil microbial diversity, improve nutrient cycling, and sustain soil health (Pathak *et al.*, 2018) [15]. Phosphorus, when used in combination with FYM and biofertilizers, contributes to improved soil physical and biological properties, resulting in enhanced root nodulation, nutrient

uptake, and grain yield in chickpea (Patel *et al.*, 2020) [14].

The interaction among phosphorus levels, biofertilizers, and FYM is particularly important in rainfed and low-input production systems, where resource optimization is essential. In such systems, biofertilizers can reduce dependence on chemical fertilizers, while FYM provides a steady nutrient release and improves soil buffering capacity (Reddy *et al.*, 2018) [17].

Materials and Methods

This field experiment was conducted at the Students' instructional Farm (field no 07) in Nawabganj, part of the Department of Soil Science at Chandra Shekhar Azad University of Agriculture & Technology in Kanpur, during the Rabi season of 2024 and 2025. The soil of experimental field is classified within the soil order of Inceptisols. It is sandy loam in texture and neutral to alkaline in soil reaction. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three factors: phosphorus levels (0, 30, and 60 kg P₂O₅ ha⁻¹), biofertilizer inoculation (control, Rhizobium, PSB and Rhizobium + PSB), and FYM levels (0 and 5 t ha⁻¹), replicated thrice. Chickpea variety [Name of variety] was sown at a spacing of 30 cm × 10 cm using the recommended seed rate. FYM was applied 15 days before sowing, while phosphorus (as single superphosphate) was applied at sowing. All agronomic practices were followed uniformly for all treatments. Plant population, number of pods plant⁻¹, grains pod⁻¹, grain yield, straw yield, biological yield, and harvest index were recorded at respective growth stages. Grain and straw yields were converted to quintals per hectare. The data collected were statistically analyzed using the method of analysis of variance (ANOVA) as outlined by Panse and Sukhatme (1985) [13]. Critical differences (C.D.) at 5% probability level were calculated to determine the significance of treatment effects.

Results and Discussion

Crop Growth Character: The data presented in Table 1 show that the plant population of chickpea (m⁻²) was significantly influenced by different levels of phosphorus, biofertilizers, and farmyard manure (FYM) during both 2023-24 and 2024-25 cropping seasons. The results revealed a consistent increase in plant population with the application of FYM (M₁), phosphorus, and biofertilizers compared to the control (M₀).

During 2023-24, the highest mean plant population (32.60 m⁻²) was recorded under FYM application (M₁), while the lowest (30.82 m⁻²) was observed without FYM (M₀). Among phosphorus levels, P₆₀ kg P₂O₅ ha⁻¹ showed the maximum plant population (32.20 m⁻²), followed by P₃₀ (31.74 m⁻²) and control (31.19 m⁻²). Similarly, biofertilizer inoculation (B₃) resulted in the highest mean population (32.05 m⁻²), while the lowest (31.24 m⁻²) was found in un inoculated control (B₀). A similar trend was observed in 2024-25, with marginally higher plant population values under the same treatments.

The combined application of FYM, phosphorus, and biofertilizers improved soil structure, nutrient availability, and microbial activity, resulting in better germination and crop stand. The interactions between FYM × phosphorus and FYM × biofertilizer were found significant, whereas other interactions were non-significant. These findings align with earlier studies by Singh *et al.* (2019) [21], Kumar *et al.*

(2021) ^[8], and Meena *et al.* (2022) ^[12], who reported that integrated nutrient management enhances early plant establishment and uniform crop stand in chickpea.

Yield and Yield attributes

The data in Table 2 reveal that the number of pods plant⁻¹ in chickpea was significantly influenced by the application of phosphorus, biofertilizers, and farmyard manure (FYM) during both 2023-24 and 2024-25. The results indicated that the combined use of FYM, phosphorus, and biofertilizers markedly improved pod formation compared to the control. During 2023-24, the highest mean number of pods plant⁻¹ (41.45) was recorded with FYM application (M₁), whereas the lowest (39.58) was found in the absence of FYM (M₀). Among phosphorus levels, P₆₀ recorded the maximum number of pods (43.63), followed by P₃₀ (41.03) and P₀ (36.88). Similarly, biofertilizer treatment B₃ (dual inoculation with Rhizobium and PSB) showed the highest mean value (41.12), while the un inoculated control B₀ produced the lowest (39.63). A similar increasing trend was observed in 2024-25, where maximum pod numbers (45.15) were recorded under M₁P₆₀B₃ treatment.

The improvement in pod number may be attributed to better nutrient availability and nodulation through integrated use of FYM, phosphorus, and biofertilizers, which enhanced vegetative growth and reproductive efficiency. The interaction effect of FYM × biofertilizer was found significant in 2024-25, whereas other interactions were non-significant.

Table 3 shows that the number of grains pod⁻¹ also followed a similar pattern. The highest grain count (1.88) was recorded at P₆₀ with FYM (M₁) and biofertilizer inoculation (B₃), compared to the lowest (1.59) under control conditions. These results clearly demonstrate that phosphorus and FYM supplementation improved sink development and grain filling.

The present findings are consistent with the results reported by Singh *et al.* (2019) ^[21], Kumar *et al.* (2021) ^[8], and Meena *et al.* (2022) ^[12], who observed that integrated nutrient management significantly enhanced pod and grain formation

in chickpea by improving soil fertility, nodulation, and nutrient uptake.

Biological Yield and Harvest Index

The data presented in Tables 4,5,6 & 7 indicate that grain yield, straw yield, biological yield, and harvest index of chickpea were significantly influenced by the application of phosphorus, biofertilizers, and farmyard manure (FYM) during 2023-24 and 2024-25.

Grain yield Table 4 the results revealed that integrated application of FYM, phosphorus, and biofertilizers significantly enhanced grain yield compared to the control. During 2023-24, the highest mean grain yield (17.59 q ha⁻¹) was recorded with FYM (M₁) while the lowest (15.57 q ha⁻¹) was obtained without FYM (M₀). Among phosphorus levels, P₆₀ gave the maximum yield (18.76 q ha⁻¹), followed by P₃₀ (17.35 q ha⁻¹) and P₀ (13.62 q ha⁻¹). Biofertilizer inoculation (B₃) also produced the highest mean yield (17.37 q ha⁻¹). A similar trend was observed during 2024-25, where the combination M₁P₆₀B₃ recorded the highest yield (22.90 q ha⁻¹). Straw and biological yield Tables 5 & 6 the straw yield increased consistently with nutrient application. The maximum mean straw yield (32.76 q ha⁻¹ in 2023-24 and 36.88 q ha⁻¹ in 2024-25) was recorded under FYM, while P₆₀ recorded the highest values among phosphorus levels. The biological yield also followed the same pattern, with maximum mean values (50.36 q ha⁻¹ in 2023-24 and 56.87 q ha⁻¹ in 2024-25) under FYM and highest phosphorus level. Harvest index Table 7 the harvest index was only marginally influenced by treatments, ranging from 34.3% to 35.9%, indicating proportional increases in both grain and straw yields.

Overall, the integration of FYM, phosphorus, and biofertilizers improved soil fertility, nutrient uptake, and photosynthetic efficiency, leading to higher productivity. Similar findings were reported by Singh *et al.* (2019) ^[21], Kumar *et al.* (2021) ^[8], and Meena *et al.* (2022) ^[12], who observed synergistic effects of organic and inorganic nutrient sources on yield components and total productivity of chickpea.

Table 1: Influence of Phosphorus Levels, Biofertilizers and FYM on Number of Plant population (m⁻²) at various growth stages of Chickpea during 2023-24 and 2024-25

	Number of Plant population (m ⁻²)											
	2023-24						2024-25					
M ₀	Levels	B ₀	B ₁	B ₂	B ₃	Mean	Levels	B ₀	B ₁	B ₂	B ₃	Mean
	P ₀	29.50	30.20	30.40	30.60	30.18	P ₀	28.60	29.70	30.30	30.70	29.83
	P ₃₀	30.18	30.90	30.98	31.10	30.79	P ₃₀	31.05	31.40	31.60	31.75	31.45
	P ₆₀	31.15	31.40	31.60	31.80	31.49	P ₆₀	31.25	31.50	31.70	31.90	31.59
	Mean	30.28	30.83	30.99	31.17	30.82	Mean	30.30	30.87	31.20	31.45	
M ₁	P ₀	31.80	32.10	32.40	32.55	32.21	P ₀	31.90	32.20	32.50	32.70	32.33
	P ₃₀	32.30	32.60	32.80	33.05	32.69	P ₃₀	32.50	32.75	32.95	33.10	32.83
	P ₆₀	32.50	32.85	33.10	33.20	32.91	P ₆₀	32.70	33.05	33.30	33.60	33.16
	Mean	32.20	32.52	32.77	32.93	32.60	Mean	32.37	32.67	32.92	33.13	
Mean of the mean B				B ₀	B ₁	B ₂	B ₃	B ₀	B ₁	B ₂	B ₃	
				31.24	31.675	31.88	32.05	31.33	31.77	32.06	32.29	
Mean of the mean P					P ₀	P ₃₀	P ₆₀	P ₀	P ₃₀	P ₆₀		
					31.19	31.74	32.20	31.08	32.14	32.37		

Factors	2023-2024			2024-2025		
	SE(m) ±	SE(d)	C.D at 5%	SEm ±	SE (d)	C.D at 5%
Farm yard manure (F.Y.M)	0.061	0.086	0.173	0.061	0.086	0.173
Phosphorus	0.086	0.121	0.245	0.086	0.121	0.244
Biofertilizer	0.074	0.105	0.212	0.074	0.105	0.211
(F.Y.M) × Phosphorus	0.121	0.172	N.S.	0.121	0.171	N.S.
(F.Y.M) × Biofertilizer	0.105	0.149	0.300	0.105	0.148	0.299
Phosphorus × Biofertilizer	0.149	0.210	N.S.	0.148	0.210	N.S.
(F.Y.M) × Phosphorus × Biofertilizer	0.210	0.298	N.S.	0.210	0.297	N.S.

Table 2: Influence of Phosphorus Levels, Biofertilizers and FYM on number of Pods plant⁻¹ at various growth stages of Chickpea during 2023-24 and 2024-25

Number of Pods plant ⁻¹												
	2023-24						2024-25					
	Levels	B ₀	B ₁	B ₂	B ₃	Mean	Levels	B ₀	B ₁	B ₂	B ₃	Mean
M ₀	P ₀	35.00	35.70	36.00	36.40	35.78	P ₀	34.15	34.95	35.30	35.55	34.99
	P ₃₀	39.00	39.90	40.25	40.60	39.94	P ₃₀	40.00	41.05	41.45	41.70	41.05
	P ₆₀	42.10	42.95	43.35	43.70	43.03	P ₆₀	43.00	43.90	44.15	44.55	43.90
	Mean	38.70	39.52	39.87	40.23	39.58	Mean	39.05	39.97	40.30	40.60	
M ₁	P ₀	37.10	37.90	38.30	38.60	37.98	P ₀	38.20	38.95	39.30	39.55	39.00
	P ₃₀	41.20	42.15	42.45	42.70	42.13	P ₃₀	42.30	43.40	43.75	44.05	43.38
	P ₆₀	43.40	44.25	44.55	44.75	44.24	P ₆₀	44.10	45.20	45.50	45.80	45.15
	Mean	40.57	41.43	41.77	42.02	41.45	Mean	41.53	42.52	42.85	43.13	

Mean of the mean B	B ₀	B ₁	B ₂	B ₃		B ₀	B ₁	B ₂	B ₃
	39.63	40.47	40.82	41.12		40.29	41.25	41.58	41.87

Mean of the mean P	P ₀	P ₃₀	P ₆₀		P ₀	P ₃₀	P ₆₀
	36.88	41.03	43.63		37.00	42.22	44.53

Factors	2023-2024			2024-2025		
	SE(m) ±	SE(d)	C.D at 5%	SEm ±	SE (d)	C.D at 5%
Farm yard manure (F.Y.M)	0.250	0.353	0.711	0.250	0.353	0.711
Phosphorus	0.353	0.499	1.005	0.353	0.499	1.005
Biofertilizer	0.306	0.432	0.870	0.306	0.432	0.87
(F.Y.M) × Phosphorus	0.499	0.706	N.S.	0.499	0.706	N.S.
(F.Y.M) × Biofertilizer	0.432	0.611	N.S.	0.432	0.611	1.231
Phosphorus × Biofertilizer	0.611	0.865	N.S.	0.611	0.865	N.S.
(F.Y.M) × Phosphorus × Biofertilizer	0.865	1.223	N.S.	0.865	1.223	N.S.

Table 3: Influence of Phosphorus Levels, Biofertilizers and FYM on Number of grains pod⁻¹ at various growth stages of Chickpea during 2023-24 and 2024-25

Number of grains pod ⁻¹												
	2023-24						2024-25					
	Levels	B ₀	B ₁	B ₂	B ₃	Mean	Levels	B ₀	B ₁	B ₂	B ₃	Mean
M ₀	P ₀	1.50	1.53	1.55	1.57	1.54	P ₀	1.45	1.49	1.51	1.53	1.50
	P ₃₀	1.75	1.80	1.82	1.84	1.80	P ₃₀	1.77	1.81	1.83	1.85	1.82
	P ₆₀	1.78	1.82	1.84	1.86	1.83	P ₆₀	1.80	1.84	1.86	1.88	1.85
	Mean	1.68	1.72	1.74	1.76	1.72	Mean	1.67	1.71	1.73	1.75	
M ₁	P ₀	1.60	1.64	1.66	1.68	1.65	P ₀	1.64	1.68	1.70	1.73	1.69
	P ₃₀	1.80	1.85	1.88	1.91	1.86	P ₃₀	1.82	1.87	1.90	1.93	1.88
	P ₆₀	1.83	1.87	1.90	1.93	1.88	P ₆₀	1.85	1.90	1.92	1.95	1.91
	Mean	1.74	1.79	1.81	1.84	1.79	Mean	1.77	1.82	1.84	1.87	

Mean of the mean B	B ₀	B ₁	B ₂	B ₃	B ₀	B ₁	B ₂	B ₃
	1.74	1.79	1.81	1.84	1.72	1.77	1.79	1.81

Mean of the mean P	P ₀	P ₃₀	P ₆₀	P ₀	P ₃₀	P ₆₀
	1.59	1.83	1.85	1.60	1.85	1.88

Factors	2023-2024			2024-2025		
	SE(m) ±	SE(d)	C.D at 5%	SEm ±	SE (d)	C.D at 5%
Farm yard manure (F.Y.M)	0.25	0.353	0.711	0.250	0.353	0.711
Phosphorus	0.353	0.499	1.005	0.353	0.499	1.005
Biofertilizer	0.306	0.432	0.870	0.306	0.432	0.87
(F.Y.M) × Phosphorus	0.499	0.706	N.S.	0.499	0.706	N.S.
(F.Y.M) × Biofertilizer	0.432	0.611	N.S.	0.432	0.611	1.231
Phosphorus × Biofertilizer	0.611	0.865	N.S.	0.611	0.865	N.S.
(F.Y.M) × Phosphorus × Biofertilizer	0.865	1.223	N.S.	0.865	1.223	N.S.

Table 4: Influence of Phosphorus Levels, Biofertilizers and FYM on Grain Yield (q ha⁻¹) at various growth stages of Chickpea during 2023-24 and 2024-25

	Grain Yield (q ha ⁻¹)											
	2023-24						2024-25					
M ₀	Levels	B ₀	B ₁	B ₂	B ₃	Mean	Levels	B ₀	B ₁	B ₂	B ₃	Mean
	P ₀	12.50	13.15	13.25	13.41	13.07	P ₀	12.15	12.82	13.00	13.15	12.78
	P ₃₀	15.00	16.20	16.45	16.65	16.07	P ₃₀	16.20	17.75	18.00	18.25	17.55
	P ₆₀	16.25	17.80	18.05	18.20	17.57	P ₆₀	17.50	19.45	19.60	19.85	19.10
	Mean	14.58	15.71	15.91	16.08	15.57	Mean	15.28	16.67	16.86	17.08	
M ₁	P ₀	13.25	14.3	14.5	14.7	14.18	P ₀	13.50	14.85	15.05	15.20	14.65
	P ₃₀	16.55	18.7	18.85	20.47	18.64	P ₃₀	18.25	20.05	21.25	21.35	20.22
	P ₆₀	17.90	20.4	20.7	20.85	19.96	P ₆₀	19.05	22.60	22.80	22.90	21.83
	Mean	15.90	17.80	18.01	18.67	17.59	Mean	16.93	19.16	19.70	19.81	

Mean of the mean B		B ₀	B ₁	B ₂	B ₃	B ₀	B ₁	B ₂	B ₃
		15.24	16.75	16.96	17.37	16.11	17.92	18.28	18.45

Mean of the mean P		P ₀	P ₃₀	P ₆₀	P ₀	P ₃₀	P ₆₀
		13.62	17.35	18.76	13.72	18.89	20.47

		2023-2024			2024-2025		
Factors		SE(m) ±	SE(d)	C.D at 5%	SEm ±	SE (d)	C.D at 5%
Farm yard manure (F.Y.M)		0.047	0.067	0.135	0.082	0.115	0.232
Phosphorus		0.067	0.095	0.191	0.115	0.163	0.329
Biofertilizer		0.058	0.082	0.165	0.100	0.141	0.285
(F.Y.M) × Phosphorus		0.095	0.134	0.270	0.163	0.231	0.465
(F.Y.M) × Biofertilizer		0.082	0.116	0.234	0.141	0.200	0.403
Phosphorus × Biofertilizer		0.116	0.164	0.330	0.200	0.283	0.569
(F.Y.M) × Phosphorus × Biofertilizer		0.164	0.232	0.467	0.283	0.400	N.S.

Table 5: Influence of Phosphorus Levels, Biofertilizers and FYM on Straw Yield (q ha⁻¹) at various growth stages of Chickpea during 2023-24 and 2024-25

	Straw Yield (q ha ⁻¹)											
	2023-24						2024-25					
M ₀	Levels	B ₀	B ₁	B ₂	B ₃	Mean	Levels	B ₀	B ₁	B ₂	B ₃	Mean
	P ₀	24.12	24.85	24.91	24.91	24.69	P ₀	23.44	24.35	24.44	24.45	24.17
	P ₃₀	28.80	30.61	30.76	30.80	30.24	P ₃₀	31.10	33.54	33.66	33.76	33.01
	P ₆₀	30.87	33.46	33.57	33.67	32.89	P ₆₀	33.25	36.56	36.65	36.72	35.79
	Mean	27.93	29.64	29.74	29.79	29.27	Mean	29.26	31.48	31.58	31.64	
M ₁	P ₀	25.57	27.07	27.26	27.34	26.81	P ₀	26.05	28.21	28.29	28.42	27.74
	P ₃₀	31.77	35.34	35.43	34.01	34.13	P ₃₀	35.04	38.46	39.73	39.92	38.28
	P ₆₀	34.01	38.35	38.50	38.57	37.35	P ₆₀	37.05	42.48	42.63	42.82	41.24
	Mean	30.45	33.58	33.73	33.30	32.76	Mean	32.71	36.38	36.88	37.05	

Mean of the mean B		B ₀	B ₁	B ₂	B ₃	B ₀	B ₁	B ₂	B ₃
		29.19	31.61	31.73	31.54	30.99	33.93	34.23	34.35

Mean of the mean P		P ₀	P ₃₀	P ₆₀	P ₀	P ₃₀	P ₆₀
		25.75	32.18	35.12	25.96	35.65	38.52

		2023-2024			2024-2025		
Factors		SE(m) ±	SE(d)	C.D at 5%	SEm ±	SE (d)	C.D at 5%
Farm yard manure (F.Y.M)		0.082	0.115	0.232	0.082	0.115	0.232
Phosphorus		0.115	0.163	0.328	0.115	0.163	0.328
Biofertilizer		0.100	0.141	0.284	0.100	0.141	0.284
(F.Y.M) × Phosphorus		0.163	0.231	0.464	0.163	0.231	0.464
(F.Y.M) × Biofertilizer		0.141	0.200	0.402	0.141	0.200	0.402
Phosphorus × Biofertilizer		0.200	0.283	0.569	0.200	0.282	0.568
(F.Y.M) × Phosphorus × Biofertilizer		0.283	0.400	N.S.	0.282	0.399	N.S.

Table 6: Influence of Phosphorus Levels, Biofertilizers and FYM on Biological Yield (q ha⁻¹) at various growth stages of Chickpea during 2023-24 and 2024-25

		Biological Yield (q ha ⁻¹)										
		2023-24					2024-25					
M ₀	Levels	B ₀	B ₁	B ₂	B ₃	Mean	Levels	B ₀	B ₁	B ₂	B ₃	Mean
	P ₀	36.62	38.00	38.16	38.32	37.77	P ₀	35.59	37.17	37.44	37.60	36.95
	P ₃₀	43.80	46.81	47.21	47.45	46.31	P ₃₀	47.30	51.29	51.66	52.01	50.56
	P ₆₀	47.12	51.26	51.62	51.87	50.46	P ₆₀	50.75	56.01	56.25	56.57	54.89
M ₁	Mean	42.51	45.35	45.66	45.88	44.84	Mean	44.54	48.15	48.45	48.72	
	P ₀	38.82	41.37	41.76	42.04	40.99	P ₀	39.55	43.06	43.34	43.62	42.39
	P ₃₀	48.32	54.04	54.28	54.48	52.78	P ₃₀	53.29	58.51	60.98	61.27	58.51
	P ₆₀	51.91	58.75	59.20	59.42	57.32	P ₆₀	56.10	65.08	65.43	65.72	63.08
	Mean	46.35	51.38	51.74	51.98	50.36	Mean	49.64	55.55	56.58	56.87	

Mean of the mean B	B ₀	B ₁	B ₂	B ₃	B ₀	B ₁	B ₂	B ₃
	44.43	48.36	48.70	48.93	47.09	51.85	52.52	52.80

Mean of the mean P	P ₀	P ₃₀	P ₆₀	P ₀	P ₃₀	P ₆₀
	39.38	49.54	53.89	39.67	54.54	58.99

		2023-2024			2024-2025		
Factors		SE(m) ±	SE(d)	C.D at 5%	SEm ±	SE (d)	C.D at 5%
Farm yard manure (F.Y.M)		0.082	0.115	0.232	0.082	0.116	0.233
Phosphorus		0.115	0.163	0.329	0.116	0.163	0.329
Biofertilizer		0.100	0.141	0.285	0.100	0.142	0.285
(F.Y.M) × Phosphorus		0.163	0.231	0.465	0.163	0.231	0.465
(F.Y.M) × Biofertilizer		0.141	0.200	0.403	0.142	0.200	0.403
Phosphorus × Biofertilizer		0.200	0.283	0.569	0.200	0.283	0.570
(F.Y.M) × Phosphorus × Biofertilizer		0.283	0.400	N.S.	0.283	0.400	0.806

Table 7: Influence of Phosphorus Levels, Biofertilizers and FYM on Harvest Index (%) at various growth stages of Chickpea during 2023-24 and 2024-25

		Harvest Index (%)										
		2023-24					2024-25					
M ₀	Levels	B ₀	B ₁	B ₂	B ₃	Mean	Levels	B ₀	B ₁	B ₂	B ₃	Mean
	P ₀	34.13	34.60	34.72	34.99	34.61	P ₀	34.13	34.49	34.72	34.97	34.57
	P ₃₀	34.24	34.60	34.84	35.08	34.69	P ₃₀	34.24	34.60	34.84	35.08	34.69
	P ₆₀	34.48	34.72	34.96	35.08	34.81	P ₆₀	34.48	34.72	34.84	35.08	34.78
M ₁	Mean	34.29	34.64	34.84	35.04	34.70	Mean	34.30	34.62	34.79	35.04	
	P ₀	34.13	34.56	34.72	34.96	34.59	P ₀	34.13	34.48	34.72	34.84	34.54
	P ₃₀	34.25	34.60	34.72	37.57	35.28	P ₃₀	34.24	34.26	34.84	34.84	34.54
	P ₆₀	34.48	34.72	34.96	35.08	34.81	P ₆₀	33.95	34.72	34.84	34.84	34.58
	Mean	34.30	34.60	34.80	35.91	34.90	Mean	34.10	34.49	34.81	34.83	

Mean of the mean B	B ₀	B ₁	B ₂	B ₃	B ₀	B ₁	B ₂	B ₃
	34.29	34.62	34.82	35.47	34.20	34.56	34.80	34.94

Mean of the mean P	P ₀	P ₃₀	P ₆₀	P ₀	P ₃₀	P ₆₀
	34.60	34.98	34.81	34.56	34.62	34.68

		2023-2024			2024-2025		
Factors		SE(m) ±	SE(d)	C.D at 5%	SEm ±	SE (d)	C.D at 5%
Farm yard manure (F.Y.M)		0.250	0.353	N.S.	0.250	0.353	N.S.
Phosphorus		0.353	0.499	N.S.	0.353	0.499	N.S.
Biofertilizer		0.306	0.432	N.S.	0.306	0.432	N.S.
(F.Y.M) × Phosphorus		0.499	0.706	N.S.	0.499	0.706	N.S.
(F.Y.M) × Biofertilizer		0.432	0.611	N.S.	0.432	0.611	N.S.
Phosphorus × Biofertilizer		0.611	0.865	N.S.	0.611	0.865	N.S.
(F.Y.M) × Phosphorus × Biofertilizer		0.865	1.223	N.S.	0.865	1.223	N.S.

Conclusion

The present study clearly demonstrate that the integrated application of farmyard manure (FYM), phosphorus, and biofertilizers had a significant positive effect on growth and yield attributes of chickpea during both 2023-24 and 2024-25. The combination of FYM with higher phosphorus levels (60 kg P₂O₅ ha⁻¹) and dual biofertilizer inoculation

(Rhizobium + PSB) consistently produced higher plant population, number of pods plant⁻¹, grains pod⁻¹, grain yield, straw yield, and biological yield compared to individual applications or control. The improvement can be attributed to enhanced nutrient availability, microbial activity, nodulation, and better soil physical conditions, leading to improved crop growth and yield performance. Although the

harvest index showed only minor variation, the overall productivity increased significantly. Thus, integrated nutrient management involving organic, inorganic, and biological sources proved most effective for sustaining soil fertility and achieving higher chickpea productivity under field conditions.

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