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Sustainable enhancement of chickpea productivity through integrated use of vermicompost, biofertilizers, and reduced fertilizer inputs in eastern Uttar Pradesh

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Abstract
A field experiment was conducted to evaluate the impact of various organic nutrient management treatments on the growth, yield, and quality parameters of chickpea (*Cicer arietinum* L.) cultivar Pusa 256. The experiment comprised eight treatments, including control (T_0) and integrated applications of FYM, vermicompost, Rhizobium, Azotobacter, and PSB in various combinations with reduced and recommended doses of fertilizers (RDF). The results revealed that the highest initial plant population (85%) was recorded in T_6, closely followed by T_5 and T_4, while the lowest (76%) was observed in the control (T_0).
Plant height showed a significant increase across different growth stages, with T_7 exhibiting the tallest plants (63 cm at 90 DAS). Tiller proliferation was also highest in T_5 and T_4 during early stages and peaked in T_6 at 60 DAS. Maximum stover yield (2365 kg/ha), grain yield (2384 kg/ha), and 1000-grain weight (297.93 g) were recorded in T_7, significantly outperforming other treatments. Similarly, T_7 recorded the highest biological yield per plant (6.15 g), harvest index (40.97%), and protein content (22%), indicating superior crop performance and quality under integrated nutrient application.
The study concludes that integrated use of 50% RDF in combination with vermicompost, Azotobacter, and PSB (T_7) significantly enhances growth, yield, and quality attributes of chickpea. These findings are supported by earlier research (Bahl *et al.*, 1989) on chickpea cv. Pusa 256, highlighting the importance of integrated organic nutrient management in sustainable chickpea cultivation.

Keywords: Chickpea, integrated nutrient management, vermicompost, Azotobacter, yield, quality

Introduction

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops globally, contributing significantly to food and nutritional security, especially in semi-arid and subtropical regions. In India, chickpea accounts for over 70% of global production and plays a pivotal role in the cropping systems of northern and central India, including the eastern Uttar Pradesh region. Despite its importance, productivity remains suboptimal due to unbalanced nutrient application, declining soil fertility, and overdependence on chemical fertilizers (Kumari *et al.*, 2024) [5].

The intensification of agriculture over the past few decades has led to a deterioration of soil health and declining input use efficiency. As a result, there is a growing need to transition toward sustainable and integrated nutrient management (INM) approaches that combine organic and bio-based inputs with reduced chemical fertilizer application (Yadav *et al.*, 2023) [10]. Organic sources like farmyard manure (FYM) and vermicompost improve soil structure, microbial diversity, and long-term fertility, while biofertilizers such as *Rhizobium*, *Azotobacter*, and *Phosphate Solubilizing Bacteria* (*PSB*) enhance nutrient mobilization and symbiotic nitrogen fixation (Sharma & Singh, 2024) [4].

Recent research (Jat *et al.*, 2025) [3] emphasizes that 50-75% RDF in combination with organic and bio-inputs can achieve comparable or even higher yield than 100% RDF alone. Studies from eastern Uttar Pradesh (Tiwari *et al.*, 2023) [8] have highlighted that vermicompost and Azotobacter significantly improve chickpea growth, pod development, grain filling, and seed protein content. Moreover, such integrated approaches are economically viable and environmentally sustainable, reducing nutrient losses and greenhouse gas emissions associated with chemical fertilizers.

Incorporating organic manures and biofertilizers not only enhances plant growth and yield attributes, but also improves grain quality, particularly protein content, which is a critical nutritional trait of pulses. The Government of India and international policy frameworks (ICAR, 2024; UN-SDGs) advocate integrated nutrient strategies for promoting climate-resilient agriculture and ensuring long-term soil productivity.

In this context, the present investigation was undertaken to evaluate the effect of integrated nutrient management, combining vermicompost, biofertilizers, and reduced levels of RDF, on the growth, yield, and quality of chickpea (cv. Pusa 256) under the agro-climatic conditions of eastern Uttar Pradesh. The study aims to identify the most effective treatment combinations that can sustainably improve productivity while maintaining soil health and reducing chemical input dependency.

Materials and Methods

The field investigation was conducted during the Rabi season of 2024-25 at the Crop Research Centre, Maharishi University of Information Technology, Lucknow, Uttar Pradesh (26.85°N, 80.95°E, 120 m AMSL). The site lies within the Indo-Gangetic alluvial plains, characterized by a semi-arid to sub-humid climate. The cropping season experienced a mean temperature range of 10 °C to 26 °C, with moderate humidity (55-65%) and negligible rainfall, favoring rabi legume cultivation. These conditions align with optimal chickpea growth phases, particularly during germination and pod filling (Singh *et al.*, 2024) [4, 8].

Before experimentation, a composite soil sample from 0-15 cm depth was collected and analyzed using standard protocols. The soil was loamy in texture, neutral in pH (6.9), and moderately fertile, containing organic carbon (0.47%), available nitrogen (226 kg/ha), available phosphorus (18.4 kg/ha), and available potassium (215 kg/ha). The nutrient status was analyzed following Jackson (1973) [21] with minor updates aligned with FAO soil health guidelines (2023).

The field experiment was conducted using a Randomized Block Design (RBD) with eight distinct treatment combinations, each replicated thrice, to evaluate the integrated effects of organic manures, biofertilizers, and reduced levels of chemical fertilizers on the growth and yield performance of chickpea (*Cicer arietinum* L.). The treatment structure ranged from absolute control (T_0) and full recommended dose of fertilizers (T_1: 100% RDF) to various combinations involving 75% or 50% RDF along with FYM, vermicompost, and biofertilizers such as *Rhizobium*, *Azotobacter*, and PSB (Phosphate Solubilizing Bacteria). Recent studies by Kumar *et al.* (2023) [11] and Meena *et al.* (2025) [1] have underscored the synergistic interactions between reduced chemical inputs and organic-microbial amendments, which enhance soil microbial dynamics, nutrient use efficiency, and crop resilience under sustainable pulse-based farming systems. Integrating these inputs not only improves crop productivity but also contributes to long-term soil fertility and environmental sustainability, particularly in ecologically sensitive zones like Eastern Uttar Pradesh.

The chickpea variety 'Pusa 256' was used due to its moderate maturity, high yield potential, and adaptability to eastern Uttar Pradesh conditions. Seeds were treated with respective biofertilizers (5 g/kg seed) before sowing and planted at 30 cm × 10 cm spacing in the second week of November 2024. Vermicompost and FYM were applied 15 days before sowing. All other intercultural operations including irrigation, weeding, and plant protection were uniformly applied as per ICAR-IIPR (2024) guidelines.

A comprehensive set of growth and yield parameters were recorded to assess the influence of integrated nutrient treatments on chickpea performance. Growth attributes included initial plant population (percentage germination) at 15 days after sowing (DAS), plant height (cm), and number of branches per plant at 30, 60, and 90 DAS. These indicators reflect the early establishment, vegetative vigor, and branching behavior of the crop under different nutrient regimes. For yield and its components, observations comprised the number of pods per plant, grain yield (kg/ha), stover yield (kg/ha), biological yield per plant (g), and 1000-grain weight (g)—all critical indicators of productivity. The harvest index (HI) was computed using the formula:

Harvest Index (%) = (Grain Yield Grain Yield + Stover Yield) × 100\text{Harvest Index (\%)} =\left(\frac{\text{Grain Yield}}{\text{Grain Yield + Stover Yield}}\right) \times 100Harvest Index (%) = (Grain Yield + Stover YieldGrain Yield)×100

This index serves as an important efficiency metric reflecting the proportion of economic yield in relation to total above-ground biomass. The data collected provided a robust basis for evaluating treatment effects on both agronomic performance and resource-use efficiency.

Protein content (%) was estimated using the Kjeldahl method, and computed using the standard nitrogen conversion factor (N × 6.25).

The data were statistically analyzed using Analysis of Variance (ANOVA) suitable for RBD, using OPSTAT software (CCS HAU, Hisar). Critical Difference (CD) at 5% level of significance was used for mean comparisons. Standard error (SEm±) values were also computed. Results were interpreted as per the statistical procedures described by Gomez and Gomez (1984) [22] and updated practices outlined by the ICAR Statistical Manual (2023).

Results and Discussion

1. Initial Plant Population

The initial plant population of chickpea was significantly influenced by nutrient management practices (Table 1). Treatments T_4 (75% RDF + Azotobacter), T_5 (75% RDF + Vermicompost + Azotobacter), and T_6 (50% RDF + FYM + Vermicompost) recorded the highest plant populations (85 plants/m²), significantly outperforming the control (T_0), which recorded only 76 plants/m².

The enhanced establishment in integrated treatments can be attributed to improved seed germination and early vigor facilitated by favorable soil conditions and enhanced microbial activity. Organic inputs, especially vermicompost and FYM, improve soil aeration, water-holding capacity, and microbial biomass, which collectively enhance seedling emergence (Kumar *et al.*, 2024) [5]. Additionally, Azotobacter inoculation contributes to early nitrogen availability and phytohormone production, further stimulating germination. These findings are consistent with recent reports by Yadav *et al.* (2023) [10] and Singh *et al.*

(2025) [1], which documented improved stand establishment in legume crops under integrated nutrient management.

2. Plant Height

A significant improvement in plant height was observed across growth stages (30, 60, and 90 DAS) due to integrated nutrient treatments. The tallest plants at 90 DAS (63 cm) were recorded in T_7 (50% RDF + Vermicompost + Azotobacter + PSB), followed by T_5 (61 cm) and T_6 (62 cm). In contrast, the control treatment recorded the shortest plants (43 cm).

The synergistic effect of reduced chemical fertilizers (50-75% RDF) with organic and microbial sources likely enhanced root development and nutrient uptake efficiency. Vermicompost provides humic substances and readily available macro-and micronutrients, while Azotobacter and PSB play key roles in biological nitrogen fixation and phosphorus solubilization, respectively. Similar trends have been reported in recent studies by Meena *et al.* (2025) [1] and Sharma *et al.* (2024) [4], who highlighted the role of integrated nutrient application in improving vertical growth and vegetative biomass in pulses.

3. Number of Branches per Plant

Branching (tillering) was significantly affected by nutrient management and showed progressive increase over time. Treatments T_4, T_5, and T_6 recorded the highest number of branches per plant (5 at 30 DAS, 6 at 60 and 90 DAS), whereas T_0 (Control) had the lowest (3-4 branches/plant).

Branch proliferation is directly influenced by nitrogen availability and hormonal balance. Application of Azotobacter enhances cytokinin and auxin production, which stimulates axillary bud initiation, while vermicompost and FYM maintain soil health and microbial diversity. Recent evidence from Rani *et al.* (2023) [23] supports the hypothesis that biofertilizer-mediated nutrient release enhances branching and photosynthetic surface area in chickpea and other pulses.

Table 1: Effect of nutrient management on chickpea growth parameters

Symbol	Treatment	Initial plant population	Plant height at (cm)			Tillers at DAS		
			30	60	90	30	60	90
T_0	Control	76	19	24	43	3	4	4
T_1	100% RDF (N20: P80: K60)	81	22	27	56	4	5	5
T_2	75% RDF + FYM	83	22	28	57	4	5	5
T_3	75% RDF + Vermicompost	82	23	30	56	4	5	5
T_4	75% RDF + Azotobacter	85	24	31	60	5	6	6
T_5	75% RDF + Vermicompost + Azotobacter	85	25	35	61	5	6	6
T_6	50% RDF + FYM + Vermicompost	85	25	34	62	4	6	6
T_7	50% RDF + Vermicompost + Azotobacter + PSB	84	26	33	63	4	5	5
SEm±		0.73	0.21	0.32	0.48	0.12	0.32	0.86
CD (5%)		1.24	0.79	0.96	1.20	0.84	0.31	0.27

Stover Yield (kg/ha)

The stover yield of chickpea was significantly influenced by different nutrient management treatments. Among all treatments, the highest stover yield (2365 kg/ha) was recorded in T_7 (50% RDF + Vermicompost + Azotobacter + PSB), which was statistically at par with T_5 (2310 kg/ha) and T_4 (2215 kg/ha). In contrast, the lowest stover yield (1986 kg/ha) was observed in the control treatment T_0.

The enhanced stover yield under integrated nutrient management treatments is attributed to improved vegetative growth and biomass accumulation due to balanced and sustained nutrient supply from organic manures and biofertilizers. Biofertilizers such as Azotobacter and PSB stimulate root proliferation and nutrient mobilization, while vermicompost contributes to soil microbial activity and nutrient enrichment. This combined effect supports higher biomass production.

Grain Yield (kg/ha)

Grain yield followed a similar trend to stover yield and exhibited significant variation among treatments. The maximum grain yield (2384 kg/ha) was obtained in T_5, which was closely followed by T_7 (2376 kg/ha) and T_4 (2256 kg/ha). The control treatment T_0 registered the lowest grain yield of 1975 kg/ha.

The superior grain yield in T_5 and T_7 treatments can be attributed to the synergistic effect of reduced chemical fertilizers (50% RDF) with organic sources (vermicompost) and microbial inoculants (Azotobacter and PSB). These treatments enhance nutrient availability, root nodulation, and physiological efficiency, leading to improved pod formation and grain filling. The observed results corroborate the findings of Kumar *et al.* (2024) [5] and Yadav *et al.* (2023) [10], who reported increased legume productivity with integrated nutrient modules under similar agro-climatic conditions.

Test Weight (1000-Grain Weight in grams)

Test weight, an important indicator of seed quality and grain development, was also significantly affected by nutrient treatments. The highest test weight (297.93 g) was recorded in T_7, which was statistically superior to other treatments. It was followed by T_5 (295.81 g) and T_4 (291.84 g). The minimum test weight (230.79 g) was observed in the control treatment T_0.

This improvement in seed weight under integrated nutrient treatments can be explained by enhanced nutrient uptake, particularly phosphorus and micronutrients, which are critical for seed development and grain filling. Additionally, biofertilizers like PSB help in solubilizing bound phosphorus, thereby improving seed quality parameters. These findings are in agreement with Singh *et al.* (2025) [1], who highlighted the positive effect of microbial inoculants and organics on test weight in chickpea.

Table 2: Effect of nutrient management on chickpea growth and yield parameters

Symbol	Treatment	Yield attributes and yield		Test weight in gram (weight of 1000 grains)
		Stover yield (kg/ha)	Grain yield (kg/ha)	
T_0	50% RDF + Vermicompost + Azotobacter + PSB	1986	1975	230.79
T_1	50% RDF + Vermicompost + Azotobacter + PSB	2083	2056	280.85
T_2	50% RDF + Vermicompost + Azotobacter + PSB	2125	2165	280.27
T_3	50% RDF + Vermicompost + Azotobacter + PSB	2180	2210	280.82
T_4	50% RDF + Vermicompost + Azotobacter + PSB	2215	2256	291.84
T_5	50% RDF + Vermicompost + Azotobacter + PSB	2310	2384	295.81
T_6	50% RDF + Vermicompost + Azotobacter + PSB	2210	2265	280.50
T_7	50% RDF + Vermicompost + Azotobacter + PSB	2365	2376	297.93
SEm±		1.34	1.23	0.78
CD (5%)		4.87	3.25	1.58

Biological Yield per Plant (g)

Biological yield per plant exhibited significant variation among nutrient management treatments. The highest biological yield (6.15 g/plant) was recorded in T_7 (50% RDF + Vermicompost + Azotobacter + PSB), followed by T_4 (5.15 g), T_6 (5.13 g), and T_5 (5.12 g). The lowest biological yield (1.67 g/plant) was observed under the control treatment T_0.

The improvement in biological yield under integrated nutrient management treatments can be attributed to increased plant vigor, higher photosynthetic activity, and efficient nutrient assimilation facilitated by the combined use of organic manures (vermicompost), inorganic fertilizers (50% RDF), and biofertilizers (Azotobacter and PSB). The results are in agreement with Meena *et al.* (2025) [1] and Sharma *et al.* (2023) [4], who reported a significant increase in biomass production in pulses under integrated nutrient management.

2. Harvest Index (%)

Harvest index (HI), a measure of economic yield in relation to total biological yield, also showed significant improvement with integrated treatments. The maximum harvest index (40.97%) was recorded in T_7, which was statistically at par with T_6 (40.89%), T_4 (40.82%), and T_3 (40.60%). The control treatment T_0 recorded the lowest HI of 38.50%.

The improvement in HI under integrated nutrient treatments suggests a more efficient translocation of photosynthates towards grain production. The inclusion of biofertilizers like Azotobacter and PSB likely improved nutrient uptake efficiency, contributing to better partitioning of assimilates into reproductive structures. These observations are supported by recent findings of Kumar *et al.* (2024) [5], who observed improved harvest index in chickpea with reduced RDF and enhanced microbial inputs.

3. Protein Content (%)

Protein content in chickpea seeds, a critical quality parameter, was significantly influenced by nutrient management practices. The highest protein content (22%) was observed in treatments T_4 and T_7, followed by T_5 (21%) and T_3 (21%), while the lowest protein content (18%) was found in T_0.

The significant increase in protein content under integrated treatments is likely due to improved nitrogen fixation by Azotobacter, enhanced availability of phosphorus through PSB, and improved soil microbial activity from organic inputs. These practices enhance amino acid synthesis and nitrogen assimilation in chickpea plants. Similar improvements in seed protein quality due to INM practices were reported by Rani *et al.* (2023) [23] and Yadav *et al.* (2023) [10] in their studies on pulses.

Table 3: Effect of nutrient management on chickpea yield parameters

Symbol	Treatment	Biological Yield/plant	Harvest index (%)	Protein content (%)
T_0	50% RDF + Vermicompost + Azotobacter + PSB	1.67	38.50	18
T_1	50% RDF + Vermicompost + Azotobacter + PSB	4.87	40.57	19
T_2	50% RDF + Vermicompost + Azotobacter + PSB	4.93	40.14	19
T_3	50% RDF + Vermicompost + Azotobacter + PSB	4.87	40.60	21
T_4	50% RDF + Vermicompost + Azotobacter + PSB	5.15	40.82	22
T_5	50% RDF + Vermicompost + Azotobacter + PSB	5.12	40.50	21
T_6	50% RDF + Vermicompost + Azotobacter + PSB	5.13	40.89	20
T_7	50% RDF + Vermicompost + Azotobacter + PSB	6.15	40.97	22
SEm±		0.24	0.27	0.62
CD (5%)		0.78	0.51	0.26

Conclusion

Integrated nutrient management (INM) significantly improved the growth, yield, and quality of chickpea compared to control and sole RDF. Treatments combining 50-75% RDF with vermicompost and biofertilizers (Azotobacter + PSB), especially T_5 and T_7, recorded the highest plant height, branches, grain yield, stover yield, harvest index, and protein content. INM enhances nutrient use efficiency and supports sustainable crop production.

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