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Nutrient management through organic and inorganic sources of nutrition in greengram (*Vigna radiata* L.)

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Abstract

A field experiment was conducted during the kharif season of 2025 to evaluate the effect of integrated nutrient management (INM) on the growth, yield, quality, soil fertility, and economics of greengram (*Vigna radiata* L.). The experiment was laid out in a Randomized Block Design with ten treatments and three replications, involving different combinations of recommended fertilizer dose (RDF), vermicompost, neem cake, and biofertilizers (*Rhizobium* and *Azotobacter*). Among the treatments, 75% RDF + 25% vermicompost + seed treatment with *Rhizobium* produced the highest plant growth, yield attributes, grain yield (1240 kg ha⁻¹), straw yield (2885 kg ha⁻¹), protein content (24.85%), protein yield (307.98 kg ha⁻¹), and improved post-harvest soil fertility. The same treatment also recorded the highest gross return, net return, and benefit-cost ratio (3.06). The study demonstrated that integrating vermicompost and *Rhizobium* with reduced chemical fertilizer effectively enhanced greengram productivity, profitability, and soil health, supporting sustainable crop production.

Keywords: Greengram, integrated nutrient management, vermicompost, *Rhizobium*, soil fertility

Introduction

Pulses are annual leguminous crops that play a special function in Indian agriculture and are known as the "Unique Jewels of Indian crop cultivation". They are derived from the Latin "Puls" and the Ancient Greek "Poltos" for "porridge" (Swaminathan, 1981). Pulses are the diet's primary protein source. An important part of the Indian cuisine, which is heavy in protein and carbs, are pulses. India is the largest pulse producer in the world. Pulses have a protein level of 20-25% by weight, which is twice that of wheat and three times that of rice.

In India, there would be 254 lakh hectares of pulses produced, with a productivity of 903 kg ha⁻¹ and a production of roughly 230.22 lakh tonnes (DA&FW, 2024-2025). India and Myanmar account for about 30% of the 5.3 Mt produced worldwide. With a productivity of 440 kg ha⁻¹ and an area of 3.40 M ha, India generated roughly 1.5 Mt of greengram (DA&FW, 2024-2025). Rajasthan contributes the most to cultivation in terms of both area and production (46% and 45%, respectively), followed by Madhya Pradesh (9% and 14%, respectively) and Maharashtra (9% and 8%, respectively) (AICRP, 2024-2025).

In India, the overall area dedicated to greengram was 3.54 M ha, yielding a production of 1.60 Mt and a productivity of 453 kg ha⁻¹ (DA & FW, 2024). On a dry-matter basis, greengram contains about 24-25% protein, 1.0-1.5% fat, 3.5-4.5% dietary fibre and 60-65% carbohydrates. It is also a good source of micronutrients, with iron content ranging from 4.0 to 7.6 mg 100 g⁻¹ dry weight and zinc from 2.4 to 3.0 mg 100 g⁻¹ dry weight (Dahiya *et al.*, 2015). In addition, 100 g of edible green gram seeds provides approximately 348 kcal of energy, alongwith 49 mg of β -carotene, 4.5 mg of phosphorus, and 75 mg of calcium (Meena *et al.*, 2013; Aslam *et al.*, 2021).

Integrated nutrient management (INM) involves the coordinated use of organic, inorganic and biological nutrient sources (biofertilizers) to sustain soil fertility and ensure optimal nutrient supply for crop productivity (Gupta *et al.*, 2022). In India, greengram and other legumes are often cultivated on marginal and nutrient-deficient soils, and limited access to nutrient inputs contributes to low yields (Kumar *et al.*, 2018) [36, 22, 12, 8, 20, 4, 10, 16]. Inadequate awareness of INM principles, alongwith excessive and improper use of chemical fertilizers, further reduces

productivity and adversely affects soil health and ecosystem sustainability (Shukla *et al.*, 2022).

The use of organic inputs in crop production has a long history in agriculture, with materials such as farmyard manure, compost, neem cake, vermicompost and poultry manure applied either as substitutes for or supplements to chemical fertilizers (Singh *et al.*, 2020). Organic manures supply both macronutrients and micronutrients in balanced proportions, improving soil fertility and stimulating mineralization processes that increase nutrient availability to plants (Dhaliwal *et al.*, 2021). Consequently, their use in conventional farming systems not only provides an environmentally friendly alternative to synthetic fertilizers but also supports long-term soil productivity and sustainable agricultural practices (Meena *et al.*, 2016; Soni *et al.*, 2022).

Vermicomposting involves the interaction of earthworms with decomposer organisms and microbial communities to enhance the biochemical and physical characteristics of organic wastes. During this process, nutrients in organic matter are transformed into more readily available forms. The resulting material is a fine-structured peat-like product with good aeration, porosity, drainage, high water-holding capacity, active microbial populations and rich nutrient content, making it suitable for improving soil and plant health (Pathma & Natarajan, 2012; Hussein *et al.*, 2023; Li *et al.*, 2023; Zhang *et al.*, 2023). The combined application of synthetic fertilizers with vermicompost and compost enhances nutrient availability and crop yields while also improving soil health (Ansari & Sukhraj, 2010; Asghar *et al.*, 2023). Neem cake application enhanced soil organic carbon and the availability of N, P, K and micronutrients, thereby improving the growth and yield of greengram (*Vigna radiata* L.) and suppressing soil-borne pathogens (Murugan *et al.*, 2011). It contains about 5.2% N, 1.0% P and 1.4% K and acts as a nitrification inhibitor, supplying nitrogen to the soil over an extended period (Katyayan, 2012). Additionally, neem cake acts as a natural pest repellent due to its azadirachtin content. It is environmentally friendly and serves as a useful input for sustainable agriculture (Pathak *et al.*, 2024).

Plant biofertilizers improve nitrogen fixation, help convert insoluble phosphorus into available forms, stimulate plant growth, and accelerate the decomposition of plant residues (Itelima *et al.*, 2018). In addition, rhizosphere bacteria promoted root development and nutrient uptake, resulting in a significant increase in nodule formation in greengram (Argaw, 2017; Makwana *et al.*, 2020) [32, 34, 9, 21, 35, 28, 11, 18, 40, 1, 3, 24, 15, 27, 13, 2, 19].

Material and methods

The experiment was conducted in a Randomized Block Design (RBD) with 3 replications and 10 treatments during the kharif season of 2025. Greengram variety Kanika (IPM 302-2) was used with a seed rate of 20 kg ha⁻¹ and spacing of 30 × 10 cm. The recommended dose of fertilizers (20:40:20 kg NPK ha⁻¹) was applied through suitable sources. The crop was sown in August, 2025 and harvested in October, 2025. The field was prepared by tractor ploughing followed by harrowing and levelling to obtain a fine tilth. The experimental soil was well-drained, slightly alkaline and sandy loam in texture with low organic carbon and nitrogen, and medium available phosphorus and potassium. The experiment comprised 10 nutrient management treatments, i.e., control (T₁), 100% RDF (T₂), 75% RDF + 25% neem cake + seed treatment with *Rhizobium* (T₃), 75% RDF + 25% neem cake + seed treatment with *Azotobacter* (T₄), 75% RDF + 25% vermicompost + seed treatment with *Rhizobium* (T₅), 75% RDF + 25% vermicompost + seed treatment with *Azotobacter* (T₆), 50% RDF + 25% neem cake + vermicompost + seed treatment

with *Rhizobium* (T₇), 50% RDF + 25% neem cake + 25% vermicompost + seed treatment with *Azotobacter* (T₈), 33% RDF + 33% neem cake + 33% vermicompost + seed treatment with *Rhizobium* (T₉), 33% RDF + 33% neem cake + 33% vermicompost + seed treatment with *Azotobacter* (T₁₀). The doses of NPK were applied in the form of urea, diammonium phosphate, and muriate of potash, respectively. Nitrogen was applied in split doses, while phosphorus and potassium were applied as basal doses. Organic sources and biofertilizers were applied according to the treatment schedule.

Growth parameters, yield attributes, and yield were recorded based on field observations. The productivity and profitability of greengram were determined by calculating the total cost of cultivation, including field preparation, crop management, harvesting and threshing operations. The economic returns were estimated from grain and straw yield based on the prevailing market prices.

Results and discussion

Growth parameters: The data on growth parameters are presented in Tables 1 and 2. Integrated nutrient management significantly influenced all growth parameters. Among the treatments, T₅: 75% RDF + 25% vermicompost + seed inoculation with *Rhizobium* recorded the highest values for plant height (29.27, 63.93 and 72.13 cm at 25 DAS, 50 DAS and at harvest, respectively), number of branches per plant (3.53 and 4.47 at 50 DAS and at harvest, respectively), trifoliate leaves (5.20, 16.40, 12.67 at 25 DAS, 50 DAS and at harvest, respectively), plant dry weight (4.90, 12.43 and 15.07 g/plant at 25 DAS, 50 DAS and at harvest, respectively), leaf area index (LAI) (2.88, 4.28 and 3.30 at 25 DAS, 50 DAS and at harvest, respectively), crop growth rate (CGR) (10.04 and 4.39 g/m²/day at 25 DAS-50 DAS and 50 DAS-at harvest, respectively) and lowest were recorded with T₁: control. Similar findings were reported by Tripathi *et al.* (2014), Singh *et al.* (2019), Aslam *et al.* (2024) and Sasmal *et al.* (2024) [19, 38, 35, 5, 31].

Yield attributes and yield: Among the integrated nutrient management treatments, T₅: 75% RDF + 25% vermicompost + seed treatment with *Rhizobium* recorded the highest yield attributes, including number of pods plant⁻¹ (13.10), pod length (8.07 cm), grains pod⁻¹ (9.40), and test weight (35.20 g). It was followed by T₆: 75% RDF + 25% vermicompost + *Azotobacter* and treatments receiving T₇: 50% RDF + 25% neem cake + 25% vermicompost with either *Rhizobium*, and T₈: 50% RDF + 25% neem cake + 25% vermicompost with *Azotobacter*, and lowest recorded with T₁: control (Table 3). The superior performance was attributed to the combined effect of inorganic fertilizers, organic nutrient sources, and biofertilizer inoculation, which improved nutrient availability, biological nitrogen fixation, and overall crop growth. These findings are consistent with those reported by Singh *et al.* (2019), Banotra *et al.* (2021), Tripathi & Tiwari (2022), Patel *et al.* (2023), and Sasmal *et al.* (2024) [33, 6, 37, 26, 31].

The same treatment (75% RDF + 25% vermicompost + seed treatment with *Rhizobium*) also produced the highest grain yield (1240 kg ha⁻¹), straw yield (2885 kg ha⁻¹), and biological yield (4125 kg ha⁻¹), followed by 75% RDF + 25% vermicompost + *Azotobacter*, and the lowest recorded with T₁: control (Table 3). The higher yield was attributed to balanced nutrient supply, improved nutrient uptake, and efficient translocation of photosynthates. Similar results have been reported by Pandey *et al.* (2019), Singh *et al.* (2019), Mohit & Kumar (2022), Sahu *et al.* (2020), Patel *et al.* (2023), and Sasmal *et al.* (2024) [25, 33, 23, 29, 26, 31].

Quality parameters

Integrated nutrient management significantly improved the quality parameters of greengram, namely protein content and protein yield (Table 4). The highest protein content (24.85%) and protein yield (307.98 kg ha⁻¹) were recorded with T₅: 75% RDF + 25% vermicompost + seed treatment with *Rhizobium*, followed by T₆: 75% RDF + 25% vermicompost + *Azotobacter*, T₇: 50% RDF + 25% neem cake + 25% vermicompost with *Rhizobium* and T₈: 50% RDF + 25% neem cake + 25% vermicompost with *Azotobacter*, and the lowest recorded with T₁: control. The improvement was attributed to enhanced nitrogen availability and uptake, which promoted protein synthesis and increased protein accumulation in the grains. These findings agree with those of Upperi *et al.* (2011), Barkha *et al.* (2020), and Sasmal *et al.* (2024) [39, 7, 31].

Soil chemical properties

Integrated nutrient management significantly improved the post-harvest soil fertility status of greengram (Table 5). The highest available nitrogen (191.48 kg ha⁻¹), phosphorus (15.65 kg ha⁻¹), potassium (198.89 kg ha⁻¹), and organic carbon (0.49%) were recorded with T₅: 75% RDF + 25% vermicompost + seed treatment with *Rhizobium*, followed by T₆: 75% RDF + 25% vermicompost + *Azotobacter*, and the lowest recorded with T₁:

control. The improvement in soil fertility was attributed to enhanced microbial activity, biological nitrogen fixation, gradual nutrient release from vermicompost, and increased organic carbon, which improved nutrient availability. These results are in agreement with the findings of Singh *et al.* (2019), Sahu *et al.* (2020), Barkha *et al.* (2020), Patel *et al.* (2023), Sahu *et al.* (2023), and Sasmal *et al.* (2024) [33, 29, 7, 26, 30, 31].

Economics

Integrated nutrient management significantly influenced the economics of greengram cultivation (Table 6). Although the highest cost of cultivation (₹41,630 ha⁻¹) was recorded with 33% RDF + 33% neem cake + 33% vermicompost combined with either *Rhizobium* or *Azotobacter*, the maximum gross return (₹1,13,020 ha⁻¹), net return (₹76,132 ha⁻¹), and B ratio (3.06) were obtained with 75% RDF + 25% vermicompost + seed treatment with *Rhizobium*, followed by 75% RDF + 25% vermicompost + *Azotobacter*. The higher profitability was attributed to increased grain and straw yields under these treatments, whereas the control recorded the lowest economic returns due to poor productivity. Similar results have been reported by Singh *et al.* (2019), Barkha *et al.* (2020), Banotra *et al.* (2021), Lal *et al.* (2022), Sahu *et al.* (2023), Jangid *et al.* (2024), and Sasmal *et al.* (2024) [33, 7, 6, 17, 30, 14, 31].

Table 1: Effect of organic, inorganic and biofertilizers on the plant height, no. of branches/plant and no. of trifoliolate leaves/plant of greengram

Treatments		Plant height (cm)			No. of branches/plant		No. of trifoliolate leaves/plant		
		25 DAS	50 DAS	At harvest	50 DAS	At harvest	25 DAS	50 DAS	At harvest
T ₁	Control	18.40	53.60	55.20	2.33	3.07	2.90	11.03	9.47
T ₂	100% RDF (20:40:20)	21.50	60.13	63.10	2.90	3.73	4.27	13.50	11.20
T ₃	75% RDF + 25% N through Neem Cake + Seed treatment with <i>Rhizobium</i>	25.10	61.83	65.60	3.07	4.03	4.63	14.33	11.70
T ₄	75% RDF + 25% N through Neem Cake + Seed treatment with <i>Azotobacter</i>	24.73	61.67	65.43	2.97	3.97	4.43	14.10	11.50
T ₅	75% RDF + 25% Vermicompost + Seed treatment with <i>Rhizobium</i>	29.27	63.93	72.13	3.53	4.47	5.20	16.40	12.67
T ₆	75% RDF + 25% Vermicompost + Seed treatment with <i>Azotobacter</i>	28.40	62.90	69.17	3.23	4.33	5.00	15.80	12.33
T ₇	50% RDF + 25% N through Neem Cake + 25% Vermicompost + Seed treatment with <i>Rhizobium</i>	28.10	62.40	68.93	3.20	4.17	4.80	14.90	12.00
T ₈	50% RDF + 25% N through Neem Cake + 25% Vermicompost + Seed treatment with <i>Azotobacter</i>	26.50	62.00	67.63	3.13	4.07	4.70	14.50	11.80
T ₉	33% RDF + 33% N through Neem Cake + 33% Vermicompost + Seed treatment with <i>Rhizobium</i>	21.07	57.67	59.40	2.80	3.60	3.93	13.27	10.90
T ₁₀	33% RDF + 33% N through Neem Cake + 33% Vermicompost + Seed treatment with <i>Azotobacter</i>	20.13	55.10	57.70	2.50	3.23	3.70	11.13	10.07
SEm(±)		0.84	2.01	2.30	0.15	0.20	0.20	0.65	0.53
C.D. (P=0.05)		2.50	5.98	6.84	0.44	0.59	0.61	1.94	1.57

Table 2: Effect of organic, inorganic and biofertilizers on the plant dry weight, leaf area index and crop growth rate of greengram

Treatments		Plant dry weight (g/plant)			LAI			CGR (g/m ² /day)	
		25 DAS	50 DAS	At harvest	25 DAS	50 DAS	At harvest	25 DAS-50 DAS	50 DAS-At harvest
T ₁	Control	3.73	10.36	12.10	0.25	2.13	1.37	8.83	2.91
T ₂	100% RDF (20:40:20)	4.60	11.44	13.67	0.80	3.20	1.88	9.13	3.71
T ₃	75% RDF + 25% N through Neem Cake + Seed treatment with <i>Rhizobium</i>	4.62	11.49	14.00	0.98	3.48	2.28	9.17	4.18
T ₄	75% RDF + 25% N through Neem Cake + Seed treatment with <i>Azotobacter</i>	4.61	11.45	13.95	0.83	3.25	2.13	9.12	4.17
T ₅	75% RDF + 25% Vermicompost + Seed treatment with <i>Rhizobium</i>	4.90	12.43	15.07	2.88	4.28	3.30	10.04	4.39
T ₆	75% RDF + 25% Vermicompost + Seed treatment with <i>Azotobacter</i>	4.88	12.37	15.00	1.78	4.25	3.13	9.99	4.38
T ₇	50% RDF + 25% N through Neem Cake +	4.87	12.24	14.83	1.52	3.90	2.98	9.83	4.32

	25% Vermicompost + Seed treatment with <i>Rhizobium</i>								
T ₈	50% RDF + 25% N through Neem Cake + 25% Vermicompost + Seed treatment with <i>Azotobacter</i>	4.86	12.23	14.75	1.27	3.53	2.85	9.82	4.20
T ₉	33% RDF + 33% N through Neem Cake + 33% Vermicompost + Seed treatment with <i>Rhizobium</i>	4.45	11.22	13.37	0.67	2.72	1.72	9.02	3.58
T ₁₀	33% RDF + 33% N through Neem Cake + 33% Vermicompost + Seed treatment with <i>Azotobacter</i>	4.32	10.99	13.03	0.43	2.25	1.60	8.89	3.41
	<i>SEm</i> (±)	0.23	0.42	0.43	0.06	0.16	0.11	0.30	0.19
	<i>C.D.</i> (<i>P</i> =0.05)	0.68	1.25	1.27	0.17	0.46	0.33	0.88	0.55

Table 3: Effect of organic, inorganic and biofertilizers on the yield attributes and yield of greengram

Treatments		Yield attributes				Yield			
		No. of pods plant ⁻¹	Pod length (cm)	No. of grains pod ⁻¹	Test weight (g)	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	Harvest index (%)
T ₁	Control	9.90	6.00	7.10	32.17	616	2201	2817	24.00
T ₂	100% RDF (20:40:20)	11.70	6.90	8.23	34.60	938	2752	3690	26.23
T ₃	75% RDF + 25% N through Neem Cake + Seed treatment with <i>Rhizobium</i>	12.10	7.20	8.80	34.87	1068	2796	3864	28.31
T ₄	75% RDF + 25% N through Neem Cake + Seed treatment with <i>Azotobacter</i>	12.00	7.03	8.77	34.80	1035	2753	3788	28.09
T ₅	75% RDF + 25% Vermicompost + Seed treatment with <i>Rhizobium</i>	13.10	8.07	9.40	35.20	1240	2885	4125	30.57
T ₆	75% RDF + 25% Vermicompost + Seed treatment with <i>Azotobacter</i>	12.90	7.90	9.30	35.10	1200	2870	4070	30.11
T ₇	50% RDF + 25% N through Neem Cake + 25% Vermicompost + Seed treatment with <i>Rhizobium</i>	12.60	7.63	9.23	35.00	1166	2818	3983	29.81
T ₈	50% RDF + 25% N through Neem Cake + 25% Vermicompost + Seed treatment with <i>Azotobacter</i>	12.50	7.30	9.20	34.93	1143	2811	3953	29.36
T ₉	33% RDF + 33% N through Neem Cake + 33% Vermicompost + Seed treatment with <i>Rhizobium</i>	11.60	6.70	8.20	34.47	912	2715	3627	25.63
T ₁₀	33% RDF + 33% N through Neem Cake + 33% Vermicompost + Seed treatment with <i>Azotobacter</i>	11.40	6.43	8.13	34.43	888	2668	3555	25.33
	<i>SEm</i> (±)	0.56	0.35	0.43	0.56	49.41	116.78	134.92	1.38
	<i>C.D.</i> (<i>P</i> =0.05)	1.67	1.05	1.29	1.66	146.80	346.98	400.85	4.10

Table 4: Effect of organic, inorganic and biofertilizers on the economics of greengram

Treatments		Protein content (%)	Protein yield (kg ha ⁻¹)
T ₁	Control	21.94	135.09
T ₂	100% RDF (20:40:20)	22.75	213.61
T ₃	75% RDF + 25% N through Neem Cake + Seed treatment with <i>Rhizobium</i>	23.23	247.73
T ₄	75% RDF + 25% N through Neem Cake + Seed treatment with <i>Azotobacter</i>	23.02	238.38
T ₅	75% RDF + 25% Vermicompost + Seed treatment with <i>Rhizobium</i>	24.85	307.98
T ₆	75% RDF + 25% Vermicompost + Seed treatment with <i>Azotobacter</i>	24.38	292.41
T ₇	50% RDF + 25% N through Neem Cake + 25% Vermicompost + Seed treatment with <i>Rhizobium</i>	24.02	279.78
T ₈	50% RDF + 25% N through Neem Cake + 25% Vermicompost + Seed treatment with <i>Azotobacter</i>	23.79	271.91
T ₉	33% RDF + 33% N through Neem Cake + 33% Vermicompost + Seed treatment with <i>Rhizobium</i>	22.40	204.35
T ₁₀	33% RDF + 33% N through Neem Cake + 33% Vermicompost + Seed treatment with <i>Azotobacter</i>	22.06	196.03
	<i>SEm</i> (±)	0.41	11.36
	<i>C.D.</i> (<i>P</i> =0.05)	1.21	35.43

Table 5: Effect of organic, inorganic and biofertilizers on the economics of greengram

Treatments		Available Nitrogen (kg ha ⁻¹)	Available Phosphorus (kg ha ⁻¹)	Available Potassium (kg ha ⁻¹)	Organic Carbon (%)
T ₁	Control	168.08	12.35	175.17	0.37
T ₂	100% RDF (20:40:20)	175.63	13.30	183.65	0.40
T ₃	75% RDF + 25% N through Neem Cake + Seed treatment with <i>Rhizobium</i>	179.93	14.98	187.65	0.43
T ₄	75% RDF + 25% N through Neem Cake + Seed treatment with <i>Azotobacter</i>	176.94	14.60	186.21	0.41
T ₅	75% RDF + 25% Vermicompost + Seed treatment with <i>Rhizobium</i>	191.48	15.65	198.89	0.49
T ₆	75% RDF + 25% Vermicompost + Seed treatment with <i>Azotobacter</i>	188.49	15.50	195.67	0.48
T ₇	50% RDF + 25% N through Neem Cake + 25% Vermicompost + Seed treatment with <i>Rhizobium</i>	186.01	15.46	190.32	0.47
T ₈	50% RDF + 25% N through Neem Cake + 25% Vermicompost + Seed treatment with <i>Azotobacter</i>	181.05	15.40	188.32	0.45
T ₉	33% RDF + 33% N through Neem Cake + 33% Vermicompost + Seed treatment with <i>Rhizobium</i>	174.06	12.92	181.64	0.39
T ₁₀	33% RDF + 33% N through Neem Cake + 33% Vermicompost + Seed treatment with <i>Azotobacter</i>	171.08	12.74	179.15	0.38
<i>SEm</i> (±)		2.24	0.18	2.19	0.01
<i>C.D.</i> (<i>P</i> =0.05)		6.65	0.55	6.50	0.03

Table 6: Effect of organic, inorganic and biofertilizers on the economics of greengram

Treatments		Cost of cultivation (₹ ha ⁻¹)	Gross return (₹ ha ⁻¹)	Net return (₹ ha ⁻¹)	B:C ratio
T ₁	Control	31500.00	57287	25787	1.82
T ₂	100% RDF (20:40:20)	34438.00	86409	51971	2.51
T ₃	75% RDF + 25% N through Neem Cake + Seed treatment with <i>Rhizobium</i>	37513.00	97854	60341	2.61
T ₄	75% RDF + 25% N through Neem Cake + Seed treatment with <i>Azotobacter</i>	37513.00	94874	57361	2.53
T ₅	75% RDF + 25% Vermicompost + Seed treatment with <i>Rhizobium</i>	36888.00	113020	76132	3.06
T ₆	75% RDF + 25% Vermicompost + Seed treatment with <i>Azotobacter</i>	36888.00	109508	72620	2.97
T ₇	50% RDF + 25% N through Neem Cake + 25% Vermicompost + Seed treatment with <i>Rhizobium</i>	39905.00	106439	66534	2.67
T ₈	50% RDF + 25% N through Neem Cake + 25% Vermicompost + Seed treatment with <i>Azotobacter</i>	39905.00	104397	64492	2.62
T ₉	33% RDF + 33% N through Neem Cake + 33% Vermicompost + Seed treatment with <i>Rhizobium</i>	41630.00	84043	42413	2.02
T ₁₀	33% RDF + 33% N through Neem Cake + 33% Vermicompost + Seed treatment with <i>Azotobacter</i>	41630.00	81828	40198	1.97
<i>SEm</i> (±)		-	4367.83	4367.83	0.12
<i>C.D.</i> (<i>P</i> =0.05)		-	12977.50	12977.50	0.35

Conclusion

The present study demonstrated that integrated nutrient management significantly improved the growth, yield attributes, yield, quality, post-harvest soil fertility, and economic returns of greengram. Among the treatments, T₅ (75% RDF + 25% vermicompost + seed inoculation with *Rhizobium*) consistently recorded the highest values for growth parameters, grain yield (1240 kg ha⁻¹), protein content (24.85%), available soil nutrients, and profitability (B:C ratio of 3.06). The combined application of inorganic fertilizer, vermicompost, and *Rhizobium* enhanced nutrient availability, biological nitrogen fixation, and soil health, resulting in superior crop performance and higher economic returns. Therefore, the application of 75% RDF + 25% vermicompost with *Rhizobium* seed inoculation can be recommended as an effective and sustainable nutrient management strategy for improving greengram productivity, soil fertility, and farm profitability.

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