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Response of vermicompost and NPK fertilizer on soil properties growth and yield of cluster bean (*Cyamopsis tetragonoloba*) var. Radha

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Abstract

An experiment was carried out at the soil science and agricultural chemistry research farm 2025. It is situated at 25°57' N latitude, 81°59' E longitude and at the altitude of 98 meter above the sea level. The objectives were response of vermicompost and N P K fertilizers application on soil properties, growth and yield of cluster bean. The design applied was RBD having 3 factors with three levels of VC @ 0, 50, & 100% ha⁻¹ and NPK @ 0, 50, & 100% ha⁻¹ respectively. The study revealed that application of @ 100% recommended dose of NPK along with VC recorded the highest values for growth and yield attributes in T₉ [@N₂₀P₄₀K₄₀ kg ha⁻¹ + @VC₀ t ha⁻¹] 53.78 q ha⁻¹, resulting in superior crop productivity. However, economic analysis indicated that application of @ 100% NPK alone produced the highest benefit ratio 2.79 in T₇ [@N₂₀P₄₀K₄₀ kg ha⁻¹ + @VC₀ t ha⁻¹] due to lower input cost compared to integrated treatments involving vermicompost. The sole application of recommended NPK fertilizers provides greater economic efficiency.

Keywords: Vermicompost, NPK, soil fertility, cluster bean etc.

Introduction

Soil is one of the most important natural resources because it supports agriculture, maintains environmental balance, and sustains life (Hou *et al.*, 2024) ^[10]. It contains minerals, organic matter, water, air, and living organisms that work together to support plant growth and ecological processes (Jackson, 1973) ^[11]. Besides serving as a medium for crops, soil helps in nutrient cycling, water storage, carbon sequestration, and maintaining biodiversity (Hou *et al.*, 2024) ^[10]. However, due to intensive farming, population pressure, excessive tillage, and improper land management practices, soil degradation has become a major issue, especially in regions like the Indo-Gangetic Plains and Prayagraj (Yadav *et al.*, 2023) ^[44]. Problems such as nutrient depletion, erosion, salinity, soil compaction, and decline in organic matter have negatively affected soil fertility and productivity (Hou *et al.*, 2024) ^[10].

In recent years, the concept of soil health has gained importance because healthy soil is essential for sustainable agriculture (Yadav *et al.*, 2023) ^[44]. Soil health depends on balanced physical, chemical, and biological properties such as good structure, nutrient availability, organic carbon content, microbial activity, and water-holding capacity (Jackson, 1973) ^[11]. Among these factors, soil organic carbon is especially important because it improves soil fertility, aggregation, moisture retention, and microbial growth (Walkley & Black, 1947) ^[40]. Unfortunately, continuous cropping and excessive dependence on chemical fertilizers have reduced soil health in many agricultural areas (Meena *et al.*, 2021) ^[20].

The excessive and imbalanced use of chemical fertilizers, particularly NPK fertilizers, has increased crop production but has also created several environmental and soil-related problems (Kumar *et al.*, 2015) ^[14]. Nitrogen promotes vegetative growth, phosphorus supports root development and energy transfer, while potassium improves stress tolerance and crop quality (Yadav *et al.*, 2012) ^[12]. Although these nutrients are essential, overuse of fertilizers has led to nutrient imbalance, reduced fertilizer efficiency, micronutrient deficiencies, groundwater pollution, and greenhouse gas emissions (Kumar *et al.*, 2020) ^[15]. Therefore, balanced and sustainable nutrient management has become necessary (Meena *et al.*, 2019) ^[19].

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Vermicompost has emerged as an effective organic amendment for improving soil fertility and sustainability (Edwards & Burrows, 1988; Joshi *et al.*, 2015) ^[7, 12]. It is produced through the decomposition of organic wastes by earthworms and contains nutrients, beneficial microbes, enzymes, and plant growth hormones (Edwards & Burrows, 1988) ^[7]. Vermicompost improves soil structure, aeration, porosity, water-holding capacity, and nutrient availability (Azarmi *et al.*, 2008; Parthasarathi & Ranganathan, 1999) ^[1, 24]. It also enhances microbial activity and helps in the gradual release of nutrients, reducing nutrient losses compared to chemical fertilizers (Joshi *et al.*, 2015) ^[12].

Research has shown that the combined use of vermicompost and NPK fertilizers gives better results than using either alone (Patel *et al.*, 2019; Swaroop *et al.*, 2023) ^[26, 37]. Chemical fertilizers provide immediate nutrients for crop growth, while vermicompost improves long-term soil fertility and biological activity (Azarmi *et al.*, 2008) ^[1]. This integrated nutrient management approach increases nutrient use efficiency, improves soil organic carbon, enhances microbial activity, and reduces environmental damage caused by excessive chemical fertilizer use (Sharma *et al.*, 2012; Yadav *et al.*, 2023) ^[30, 44]. Cluster bean (guar) is an important leguminous crop widely grown in arid and semi-arid regions of India (Rathore *et al.*, 2009) ^[28]. It is valued for its use as a vegetable, fodder, green manure, and for guar gum production (Patel *et al.*, 2014) ^[25]. Being a legume, cluster bean can fix atmospheric nitrogen through Rhizobium bacteria, which improves soil fertility (Sharma *et al.*, 2018) ^[32]. However, balanced nutrition, especially phosphorus and potassium, is still necessary for proper growth, nodulation, and yield (Yadav *et al.*, 2012) ^[42]. In regions like Prayagraj, declining soil fertility and low organic carbon are major challenges for sustainable crop production (Yadav *et al.*, 2023) ^[44]. The integrated application of vermicompost along with balanced NPK fertilizers can improve soil properties, nutrient availability, crop growth, and yield while maintaining environmental sustainability (Choudhary *et al.*, 2024; Patel *et al.*, 2022) ^[6, 27]. Such practices not only restore soil productivity but also support long-term agricultural sustainability, farmer profitability, waste recycling, and ecological balance (Meena *et al.*, 2024; Swaroop *et al.*, 2023) ^[21, 37].

Materials and Methods

The current study was set up using a randomised block design (RBD), which consists of nine treatment combinations that are replicated three times with different treatment allocations in each replication. This creates twenty-seven plots at the research site (Fisher, 1950) ^[8]. In this study, Vermicompost and NPK was applied in three different doses as RDF. The cluster bean crop was manually sown on August 5th, 2025. At a pace of 10 kg ha⁻¹, with a row-to-row distance of 45-50 cm and a plant-to-plant distance of 10-15 cm, the seed variety Radha was planted.

Table 1: Treatment Combinations

Treatment	Treatment combinations	Symbol
T ₁	Absolute control	R ₀ F ₀
T ₂	@N ₀ P ₀ K ₀ kg ha ⁻¹ + @VC ₅ tha ⁻¹	R ₀ F ₁
T ₃	@N ₀ P ₀ K ₀ kg ha ⁻¹ + @VC ₁₀ tha ⁻¹	R ₀ F ₂
T ₄	@N ₁₀ P ₂₀ K ₂₀ kg ha ⁻¹ + @VC ₀ tha ⁻¹	R ₁ F ₀
T ₅	@N ₁₀ P ₂₀ K ₂₀ kg ha ⁻¹ + @VC ₅ tha ⁻¹	R ₁ F ₁
T ₆	@N ₁₀ P ₂₀ K ₂₀ kg ha ⁻¹ + @VC ₁₀ tha ⁻¹	R ₁ F ₂
T ₇	@N ₂₀ P ₄₀ K ₄₀ kg ha ⁻¹ + @VC ₀ tha ⁻¹	R ₂ F ₀
T ₈	@N ₂₀ P ₄₀ K ₄₀ kg ha ⁻¹ + @VC ₅ tha ⁻¹	R ₂ F ₁
T ₉	@N ₂₀ P ₄₀ K ₄₀ kg ha ⁻¹ + @VC ₁₀ tha ⁻¹	R ₂ F ₂

Soil Analysis

Physical Analysis

The physical analysis was done with the help of Bouyoucos Hydrometer method for texture class, RD bottle method for bulk and particle density and use of measuring cylinder method for pore space and water holding capacity.

Chemical Analysis

The chemical analysis of was done for pH, Electrical conductivity, organic carbon (%), Available Nitrogen, Available Phosphorus and Available Potassium.

Results and Discussion

The results indicated that integrated application of NPK fertilizers and vermicompost significantly influenced soil physical and chemical properties of post-harvest soil. Bulk density and particle density decreased with increasing levels of vermicompost and NPK fertilizers. The lowest bulk density (1.17 Mg m⁻³) and particle density (2.48 Mg m⁻³) were recorded under T₉ [@N₂₀ P₄₀K₄₀ kg ha⁻¹+ @VC₁₀ t ha⁻¹], whereas the highest values were observed in T₁ [Absolute Control]. Pore space and water holding capacity increased significantly under integrated nutrient management treatments. The maximum pore space (48.75%) and water holding capacity (46.59%) were observed in T₉ [@N₂₀ P₄₀K₄₀ kg ha⁻¹+ @VC₁₀ t ha⁻¹]. Chemical properties of soil were also significantly improved under integrated nutrient management. Organic carbon content and available nitrogen, phosphorus and potassium increased with application of vermicompost and NPK fertilizers. The highest nutrient availability was recorded in T₉ due to balanced nutrient supply and enhanced microbial activity. Growth and yield attributes of cluster bean were significantly affected by different treatments. The maximum plant growth, pod development and seed yield were recorded under T₉ [@N₂₀ P₄₀K₄₀ kg ha⁻¹+ @VC₁₀ tha⁻¹]. The highest seed yield (53.78 q ha⁻¹) obtained under integrated nutrient management. Economic analysis revealed that T₇ [@N₂₀ P₄₀K₄₀ kg ha⁻¹+@VC₀ t ha⁻¹], recorded the highest benefit-cost ratio (1:2.79) because of lower input cost compared to integrated treatments. Although integrated nutrient management produced higher yield, the additional cost of vermicompost reduced net economic return.

Table 2: Influence of Vermicompost and NPK on Bulk density, Particle density, Pore space and Water holding capacity

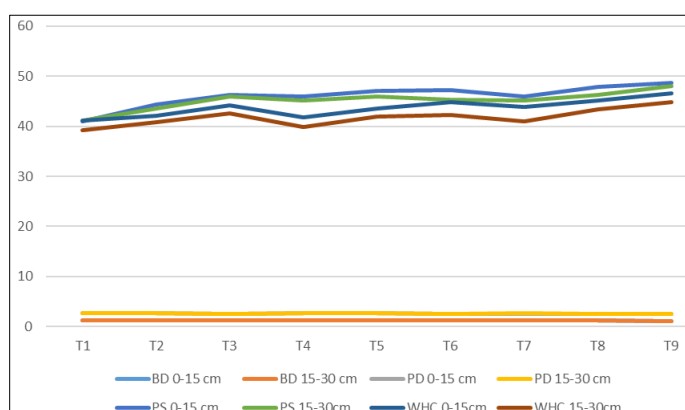
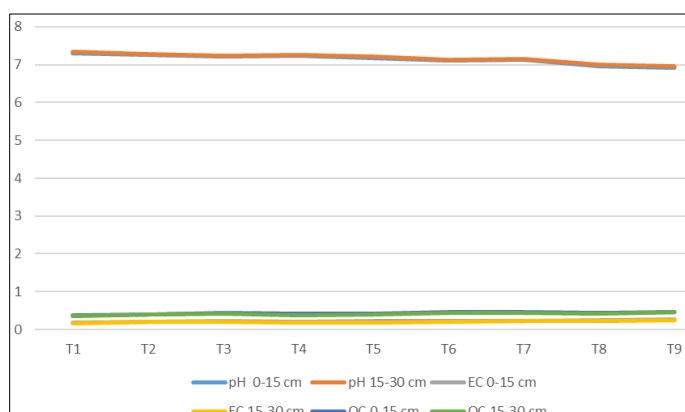
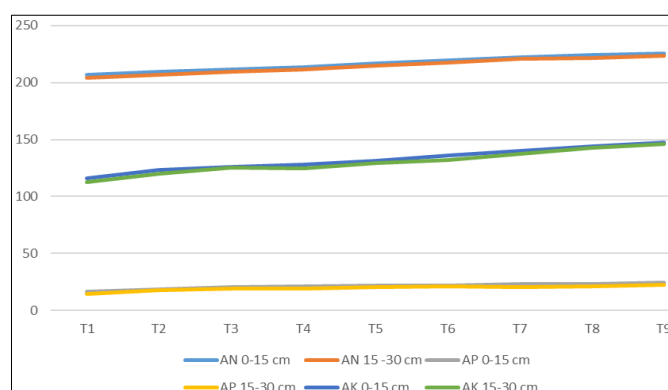
Treatment	Treatment combinations	Bd (Mg m ⁻³)		Pd (Mg m ⁻³)		Pore space (%)		WHC (%)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T ₁	Absolute control	1.23	1.25	2.66	2.68	41.05	41.21	41.21	39.21
T ₂	@N ₀ P ₀ K ₀ kg ha ⁻¹ + @VC ₅ tha ⁻¹	1.20	1.23	2.61	2.62	44.30	43.51	42.03	40.78
T ₃	@N ₀ P ₀ K ₀ kg ha ⁻¹ + @VC ₁₀ tha ⁻¹	1.21	1.22	2.53	2.55	46.31	45.98	44.13	42.56
T ₄	@N ₁₀ P ₂₀ K ₂₀ kg ha ⁻¹ + @VC ₀ tha ⁻¹	1.20	1.21	2.59	2.62	45.88	45.10	41.74	39.88
T ₅	@N ₁₀ P ₂₀ K ₂₀ kg ha ⁻¹ + @VC ₅ tha ⁻¹	1.22	1.19	2.57	2.59	47.06	45.94	43.52	41.92
T ₆	@N ₁₀ P ₂₀ K ₂₀ kg ha ⁻¹ + @VC ₁₀ tha ⁻¹	1.19	1.15	2.49	2.51	47.26	45.38	44.86	42.32
T ₇	@N ₂₀ P ₄₀ K ₄₀ kg ha ⁻¹ + @VC ₀ tha ⁻¹	1.21	1.20	2.56	2.58	46.02	45.11	43.88	40.98
T ₈	@N ₂₀ P ₄₀ K ₄₀ kg ha ⁻¹ + @VC ₅ tha ⁻¹	1.18	1.14	2.50	2.52	47.83	46.34	45.07	43.36
T ₉	@N ₂₀ P ₄₀ K ₄₀ kg ha ⁻¹ + @VC ₁₀ tha ⁻¹	1.17	1.12	2.48	2.51	48.75	47.99	46.59	44.76
	F-test	S	S	S	S	S	S	S	S
	S.Em. (±)	0.006	0.007	0.03	0.02	0.44	0.41	0.42	0.38
	C.D. (5%)	0.019	0.022	0.09	0.07	1.33	1.24	1.27	1.15

Table 3: Influence of Vermicompost and NPK on pH EC and OC

Treatment	Treatment Combinations	pH 1:2.5 (w/v)		EC (dS m ⁻¹)		OC (%)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T ₁	Absolute control	7.31	7.34	0.18	0.16	0.38	0.36
T ₂	@N ₀ P ₀ K ₀ kg ha ⁻¹ + @VC ₅ tha ⁻¹	7.25	7.29	0.21	0.20	0.40	0.39
T ₃	@N ₀ P ₀ K ₀ kg ha ⁻¹ + @VC ₁₀ tha ⁻¹	7.21	7.24	0.22	0.21	0.43	0.41
T ₄	@N ₁₀ P ₂₀ K ₂₀ kg ha ⁻¹ + @VC ₀ tha ⁻¹	7.23	7.26	0.21	0.19	0.41	0.38
T ₅	@N ₁₀ P ₂₀ K ₂₀ kg ha ⁻¹ + @VC ₅ tha ⁻¹	7.17	7.22	0.23	0.19	0.42	0.40
T ₆	@N ₁₀ P ₂₀ K ₂₀ kg ha ⁻¹ + @VC ₁₀ tha ⁻¹	7.11	7.14	0.23	0.21	0.45	0.43
T ₇	@N ₂₀ P ₄₀ K ₄₀ kg ha ⁻¹ + @VC ₀ tha ⁻¹	7.13	7.15	0.23	0.22	0.45	0.43
T ₈	@N ₂₀ P ₄₀ K ₄₀ kg ha ⁻¹ + @VC ₅ tha ⁻¹	6.96	7.01	0.25	0.23	0.43	0.41
T ₉	@N ₂₀ P ₄₀ K ₄₀ kg ha ⁻¹ + @VC ₁₀ tha ⁻¹	6.91	6.97	0.26	0.24	0.47	0.45
	F- test	S	S	S	S	S	S
	S. Em. (±)	0.03	0.02	0.004	0.003	0.006	0.005
	C.D. (5%)	0.09	0.08	0.012	0.009	0.018	0.015

Table 4: Influence of Vermicompost and NPK on Available N, P, and K

Treatment	Treatment Combinations	Available N (kg ha ⁻¹)		Available P (kg ha ⁻¹)		Available K (kg ha ⁻¹)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T ₁	Absolute control	207.17	204.19	16.13	14.67	115.98	112.86
T ₂	@N ₀ P ₀ K ₀ kg ha ⁻¹ + @VC ₅ tha ⁻¹	209.48	206.56	18.61	17.98	123.05	120.03
T ₃	@N ₀ P ₀ K ₀ kg ha ⁻¹ + @VC ₁₀ tha ⁻¹	211.49	209.67	20.45	19.32	125.83	125.11
T ₄	@N ₁₀ P ₂₀ K ₂₀ kg ha ⁻¹ + @VC ₀ tha ⁻¹	213.48	211.34	21.12	19.02	128.11	124.81
T ₅	@N ₁₀ P ₂₀ K ₂₀ kg ha ⁻¹ + @VC ₅ tha ⁻¹	217.19	215.17	21.98	20.11	131.57	129.11
T ₆	@N ₁₀ P ₂₀ K ₂₀ kg ha ⁻¹ + @VC ₁₀ tha ⁻¹	219.48	217.76	22.03	21.09	135.87	132.09
T ₇	@N ₂₀ P ₄₀ K ₄₀ kg ha ⁻¹ + @VC ₀ tha ⁻¹	222.17	220.98	22.96	20.51	139.95	137.34
T ₈	@N ₂₀ P ₄₀ K ₄₀ kg ha ⁻¹ + @VC ₅ tha ⁻¹	224.2	221.37	23.18	21.32	144.27	142.49
T ₉	@N ₂₀ P ₄₀ K ₄₀ kg ha ⁻¹ + @VC ₁₀ tha ⁻¹	225.22	223.54	24.20	22.12	147.57	145.84
	F- test	S	S	S	S	S	S
	S. Em. (±)	0.72	0.68	0.41	0.36	0.23	0.25
	C.D. (5%)	2.16	2.04	1.24	1.08	0.69	0.75

**Fig 1:** Influence of Vermicompost and NPK on Bulk density [BD] (Mg m⁻³), Particle density [PD] (Mg m⁻³), Pore space [PS] (%) and Water holding capacity [WHC] (%)**Fig 2:** Influence of Vermicompost and NPK on pH, Electrical Conductivity (dS m⁻¹), Organic carbon (%)**Fig 3:** Influence of Vermicompost and NPK on Available Nitrogen (kg ha⁻¹), Phosphorus (kg ha⁻¹), Potassium (kg ha⁻¹)

Conclusion

It is concluded from the trial that integrated application of vermicompost and recommended dose of NPK fertilizers significantly improved soil physical and chemical properties, growth and yield of cluster bean. Treatment T₉ [@N₂₀P₄₀K₄₀ kg ha⁻¹ + @VC₁₀ t ha⁻¹] proved superior in improving soil health and crop productivity. However, treatment T₇ recorded the highest economic return due to lower cultivation cost. Therefore, integrated nutrient management may be recommended for sustainable cluster bean production and soil fertility improvement.

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