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Response of NPK and Neem Cake on Soil Properties, Growth and Yield of Cluster Bean

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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

At the soil science and agricultural chemistry research farm, an experiment was carried out during the 2023–2024 growing season. Nine treatments were arranged in a randomised block design with three replications for the current investigations. The pre-sowing soil sample used for the analysis of the cluster bean was taken for the study. The soil has a sandy loam texture, and the cluster bean responds considerably to the various treatment combinations. Under treatment T9 -, the highest phosphorus was measured at 30.43 kg ha-1 in 0–15 cm deep and 27.65 kg ha-1 in 15–30 cm depth. and in treatment T1, the lowest phosphorus levels were 18.81 kg ha-1 at 0–15 cm depth and 15.74 kg ha-1 at 15–30 cm depth. Treatment T9 produced the highest potassium levels, 252.9 kg ha-1 in 0–15 cm depth and 186.7 kg ha-1 in 15–30 cm depth, while treatment T1 produced the lowest potassium levels, 199.7 kg ha-1 in 0–15 cm depth and 166.8 kg ha-1 in 15–30 cm depth.

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Keywords: Cluster bean; yield attributes; soil; nitrogen; phosphorus; potassium; neem cake.

1. INTRODUCTION

"Soil is a medium for plant growth. Crop production is based largely on soils. Some of the soil properties affecting plant growth include: soil texture (coarse fine), aggregate size, porosity, aeration (permeability), and water holding capacity, pH, bulk density, particle density. The rate of water movement into the soil (infiltration) is influenced by its texture, physical condition (soil structure and tilth), and the amount of vegetative cover on the soil surface. Organic matter tends to increase the ability of all soils to retain water, and also increases infiltration rates of fine textured soils. Bulk density reflects the soil's ability to function for structural support, water and solute movement, and soil aeration. Soil pH directly affects the solubility of many of the nutrients in the soil needed for proper plant growth and development. Soil pH measurement is useful because it is a predictor of various chemical activities within the soil. As such, it is also a useful tool in making management decisions concerning the type of plants suitable for location, the possible need to modify soil pH (either up or down), and a rough indicator of the plant availability of nutrients in the soil. Three elements, carbon, oxygen and hydrogen, are essential to plant growth and are supplied by air and water. The other essential elements are referred to as plant nutrients, and are provided by the soil, or are added as fertilizers, and enter plants almost exclusively through the roots" [1].

"Nutrient balance is the key component to increase crop yields. Excess and imbalanced use of nutrients has caused nutrient mining from the soil, deteriorated crop productivity and ultimately soil health. Replenishment of these nutrients through organic and combination with organic and inorganic has a direct impact on soil health and crop productivity. By keeping in view all the factors related to soil fertility and productivity fertilizers are applied to soil to maintain soil status and crop productivity Greengram highly responsive to fertilizer application. The dose of fertilizer depends on the initial soil fertility status and moisture availability conditions" [2]. "Application of N, P and K to pulses and oilseeds showed greater response than to cereals. Sulphur not only improved grain yield but also improved the quality of crops" [3].

"Nitrogen is an important nutrient for all crops. It increases yield nutrition also increases the protein content. Deficient plants may have stunted growth and develop yellow- green colour. It accelerates photosynthetic behavior of green plants as well as growth and development of living tissues specially tiller count in cereals" [4].

"Phosphorus is the second most important nutrient that must be added to the soil to maintain plant growth and sustain crop yield. It stimulates early root development and growth and there by helps to establish seedlings quickly. Large quantities of Phosphorus are found in seed and fruit and it is considered essential for seed formation. It enhances the activity of rhizobia and increased the formation of root nodules. Thus, it helps in fixing more of atmosphere nitrogen in root nodules" [5].

"Potassium is one of the seventeen elements which are essential for growth and development of plants. Potassium is required for improving the yield and quality of different crops because of its effect on photosynthesis, water use efficiency and plant tolerance to diseases, drought and cold as well for making the balance between protein and carbohydrates" [1].

"Neem cake organic manure protects plant roots from nematodes, soil grubs and termites, probably due to its residual limonoid content. It also acts as a natural fertilizer with pesticidal properties. Neem cake is widely used in India to fertilize paddy, cotton and sugarcane and almost all vegetables. Neem cake improves the organic matter content of the soil, helps improve soil texture, water holding capacity, and soil aeration for better root development" [1].

"Neem cake has an adequate quantity of NPK in organic form for plant growth. Being a totally botanical product it contains 100% natural NPK content and other nutrients as N (Nitrogen 2.0% to 5.0%), P (Phosphorus 0.5% to 1.0%), K (Potassium 1.0% to 2.0%), Ca (Calcium 0.5% to 3.0%), Mg (Magnesium 0.3% to 1.0%), S (Sulphur 0.2% to 3.0%), Zn (Zinc 15 ppm to 60 ppm), Cu (Copper 4 ppm to 20 ppm), Fe (Iron 500 ppm to 1200 ppm), Mn (Manganese 20 ppm to 60 ppm). It is rich in both sulphur compounds" [1].

"Cluster bean (*Cyamopsis tetragonoloba* L.) is an important kharif crop that belongs to

leguminaceae family. It has been emerged in North western India through trans-domestication of Cyamopsis senegalensis and was separated into three species, viz. C. tetragonoloba, C. senegalensis and C. serrata. Among these three species, Cyamopsis tetragonoloba is widely grown. It is a self- pollinated, diploid plant with 14 number of chromosomes (2n = 14). Cluster bean is also being widely known as guar, guwar, gavar or guvar bean and is the source of guar gum having a wide range of industrial applications. It is a drought sufferance leguminous crop because of tap rooting system and has high capacity to recover from water stress. The root ''Guar'' represents it's originated from Sanskrit word ''Gauaahar'' which mean cow fodder of the livestock. It is a drought tolerant crop mainly cultivated in arid and semi- arid regions of the world. It is grown mainly in countries like India, Pakistan, Morocco, USA, Germany, Italy, Greece, and Spain.

India alone accounts for 80% of the world's total production of cluster bean which ranged from 14.24 lakh tonnes to 16.76 lakh tones for year 2017-18" [6].

"In India, vegetable cluster bean is widely cultivated throughout India in both of Zaid and rainy. It is generally cultivated in of urban, rural areas and also in kitchen gardens. India is the world largest producer of guar, contributing about 80 per cent of world production. In India, it is mainly cultivated area under Uttar Pradesh and Maharashtra. The cultivated area under beans in India during 2018-19 was 229 lakh ha with the production of 2324 MT. The cultivated area of gaur in Gujrat is 35.82 thousand ha with a production 365.11 thousand. In Rajasthan, cluster bean is commonly grown in Barmer, Churu, Sriganganagar, Nagaur, Jalore, Sikar, Jaisalmer, Bikaner, Jaipur and Alwar districts. Rajasthan occupies first position in India both in area and production. It accounts nearly 82.1 per cent area and 70 per cent production in India. Haryana and Gujarat have second and third position, respectively. Rajasthan has an area of 30.33 lakh hectare, with production of 17.16 metric tonnes with a productivity of 566 kg ha-1" [7].

"Cluster bean is an important summer annual legume that grows upward that reaches a maximum height of 18 to 40 inches. It develops tap roots that can reach moisture deep below the soil surface and has a single main stem. Cluster bean flowers are of purple to pink colour having a length of about 8 mm and are formed in axillary racemes. Pods of cluster bean are 1.5 to 4 inches long containing 5 to 12 seeds each and seeds are dull-white to pink to light gray or black colored. Guar is a short growing season crop. Its growing season is from July to August and harvesting season lasts from October to November. It grows well on fertile and sandy loam soils with medium texture. Like other legumes, guar is a wonderful soil- building crop with respect to available nitrogen. A large endosperm is found in guar beans that contain galactomannan gum (guar gum) which forms gel when come in contact with water. Guar gum is soluble polysaccharide in cold water, extracted from cluster beans. Guar gum consists of (1→4)-linked β-D- manna units with (1→6)-linked α-D-galactose residues as side chains. Guar gum is composed of galactomannan (75-85%), moisture (8-14%), protein (5-6%), fiber (2-3%) and ash (0.5-1%)" [8].

2. MATERIALS AND METHODS

2.1 Geographical Location of the Experimental Site

The experimental site is located at a latitude of 25.41º North and longitude of 81.84 º.

East, with an altitude of 98 meters above the mean sea level (MSL).

2.2 Climatic Conditions of the Experimental Area

The area of Prayagraj comes under humid sub-tropical climate, which experiences warm humid monsoon, hot dry summer and cold dry winter. The annual mean temperature is 26.1ºC while monthly mean temperatures are 18-29ºC. The daily average maximum temperature is about 22ºC and the minimum temperature is 9ºC. The average annual rainfall received is 1042.2 mm. At this location, the temperature reaches upto 46ºC-48ºC and the minimum temperature recorded is 4ºC-5ºC. The relative humidity ranges in this location ranges between 20-94%.

2.3 Experimental Details

Table 1. Treatment combination

Treatment	Treatment Combination	Symbol
T1	@Absolute control	**R0N0**
T2	@[0% NPK + 50% Neem cake]	**R0N1**
T3	@[0% NPK + 100% Neem cake]	**R0N2**
T4	@[50% NPK + 0% Neem cake]	**R1V0**
T5	@[50% NPK + 50% Neem cake]	**R1V1**
T6	@[50% NPK + 100% Neem cake]	**R1V2**
T7	@[100% NPK + 0% Neem cake]	**R2V0**
T8	@[100% NPK + 50% Neem cake]	**R2V1**
T9	@[100% NPK + 100% Neem cake]	**R2V2**

3. RESULTS AND DISCUSSION

3.1 Effect of NPK, and Neem Cake on Physical Properties of Post-harvest Soil of Cluster Bean

The maximum bulk density was recorded 1.35 Mg m^{-3} in 0-15 cm depth and 1.39 Mg m^{-3} in 15-30 cm depth under treatment T1 and minimum bulk density was recorded 1.17 Mg m^{-3} in 0-15 cm depth and 1.21 Mg m^{-3} in 15-30 cm depth in treatment T9. The maximum particle density was recorded 2.40 Mg m^{-3} in 0-15 cm depth and 2.54 Mg m^{-3} in 15-30 cm depth under treatment T1 and minimum particle density was recorded 2.23 Mg m^{-3} in 0-15 cm depth and 2.35 Mg m^{-3} in 15-30cm depth in treatment T9. The application of treatment T9 recorded the highest porosity (48.78 %) among all the treatments, while lowest porosity was found in control in 0-15 cm depth. Application of T9 recorded the highest porosity (46.20 %) in 15- 30 cm soil, which was significantly superior to other treatments. Minimum porosity content in soil was recorded under control (41.57 %).

The maximum water holding capacity was recorded 45.18 % in 0-15 cm depth and 42.97% in 15-30 cm depth in treatment T9 - and minimum water holding capacity was recorded 42.79% in 0-15 cm depth and 40.33 % in 15-30 cm depth in treatment T1. Soil pH of this experiment ranged from 7.15 to 7.55 and it was maximum for T9 and minimum under T1 i.e. for 0-15 cm depth. In case of 15-30 cm depth it was maximum for T9 and minimum under T1 7.44 and 7.0 respectively. The application of NPK fertilizers can increase soil organicmatter and improve soil structure, leadingto a decrease in soil bulk density. This is because the organic matter helps to bind soil particles together, creating pore spaces that allow for better water and air movement. Additionally, the improved soil structure can lead to better root development and plant growth [9], Kumar et al. [10]. Increased organic matter can improve soil structure and increase soil pore space the retention of dissolved O.M. leading to change in physical propertiesof soil. Similar results were also reported by Awad et al. [11]. Increasing the rate of organic fertilizers increases the soil organic carbon these organic carbon releases organic acid and organic acid increases the soil pH. When increases soil depth soil pH increases due to increase in alkalinity. These results indicated that the soil pH was decreased by N application at different stages. N application could increase the N contents of leaf and stem. Similar findings were recorded by Verma and Baigh, (2012) and Takase et al. [12].

3.2 Effect of NPK, and Neem Cake on Chemical Properties of Post-harvest Soil of Cluster Bean

The treatment T9 - recorded the highest organic carbon is 0.530 %in 0-15 cm soil, which was significantly superior to other treatments. Minimum organic carbon content in soil was recorded under in T1 (0.470 %). Significantly higher O.C attributed to bulk posting of organic matter. Available Nitrogen of soil as influenced by N, P, K, The maximum nitrogen was recorded 182 kg ha^{-1} in 0-15 cm depth and 168 kg ha^{-1} in 15-30 cm depth under treatment T9 and minimum nitrogen was recorded 113 kg ha^{-1} in 0-15 cm depth and 92.5 kg ha^{-1} in 15-30 cm depthin treatment T1. The maximum phosphorus was recorded 19.8kg ha^{-1} in 0-15 cm depth and 17.7kg ha^{-1} in 15-30 cm depth under treatment

and minimum phosphorus was recorded 14.3 kg ha^{-1} in 0-15 cm depth and 11.2 kg ha^{-1} in 15-30 cm depth in treatment T1. The maximum potassium wasrecorded 140 kg ha^{-1} in 0-15 cm depth and 133 kg ha^{-1} in 15-30 cm depth under treatment T9 and minimum potassium was recorded 126 kg ha^{-1} in 0-15 cm depth and 125 kg ha^{-1} in 15-30 cm depthin treatment T1. Similar findings were reported by Moharana et al. (2012), Katkar et al. (2011), Patel et al. (2018) and Rathore et al. (2007).

3.3 Effect of NPK, and Neem Cake on Plant Growth and Yield Parameter of Cluster Bean

Treatment T9 attained the maximum plant height as 26.43 cm, 69.09 cm and 69.71 cm at 30, 60 and 90 DAS at harvest stage, respectively. Among the various treatments, control plot recorded the minimum plant height to the tune 13.5 cm, 41.2 cm and 48.5 cm at 30, 60 and 90 DAS at harvest stage, respectively. The maximum number of leaves per plant 8.31, 18.60 and25.11 at 30, 60 and 90 DAS was found in T9 and minimum number of leaves plant-1 7.61,16.22 and 21.11 at 30, 60 and 90 DAS was found in T1 respectively. The maximum number of pod plant- 1 was recorded 77.2 in treatment T9 - and minimum 39.06 in T1 respectively which was higher than number of pod plant-1 any other treatment combination. The maximum pod yield was recorded 48.22 q ha^{-1} in treatment T9 and minimum 29.25 qha^{-1} in T1 respectively which was higher than pod yield any other treatment. Similar finding was observed by Ali et al., 2011, Chaudhari et al. (2013), Deshmukh et al. [13], Biswas et al. (2014) and Masih et al. (2020).

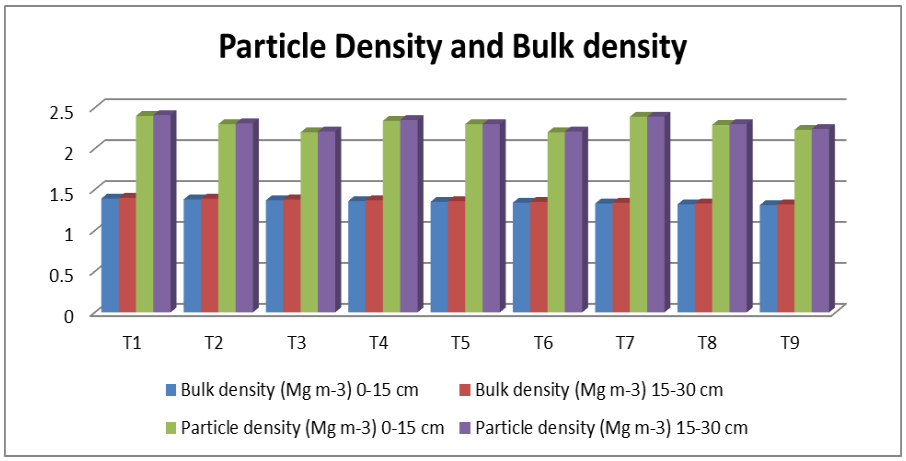

Fig. 1. Effect of NPK, and Neem cake on physical properties of post-harvest soil of cluster bean

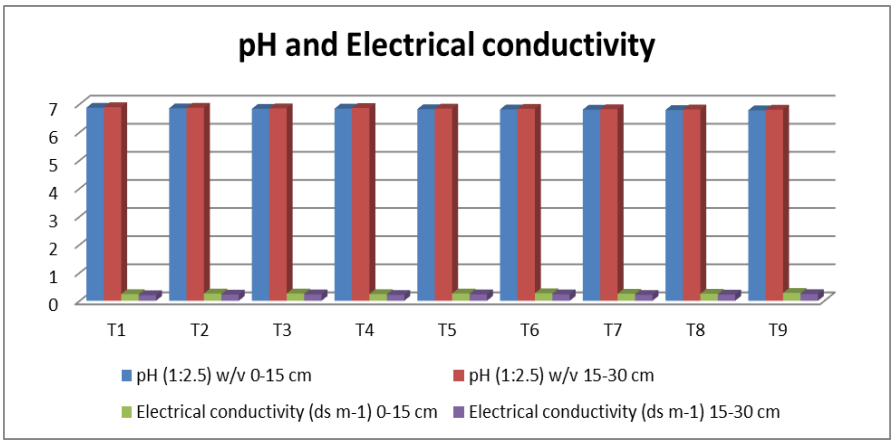

Fig. 2. Effect of NPK, and Neem cake on physical properties of post-harvest soil of cluster bean

Table 2. Effect of NPK, and neem cake on physical properties of post-harvest soil of cluster bean

Treatment	Bulk density (Mg m-3)		Particle density (Mg m^{-3})		Pore space (%)		Water retaining capacity (%)		pH (1:2.5) w/v		Electrical conductivity (ds m^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T1	1.39	1.40	2.40	2.41	43.56	43.85	40.3	42.79	6.87	6.89	0.24	0.20
T2	1.38	1.39	2.30	2.31	44.45	43.65	43.0	44.14	6.85	6.87	0.26	0.22
T3	1.37	1.38	2.20	2.21	45.67	43.26	43.8	46.93	6.83	6.85	0.26	0.23
T4	1.36	1.37	2.34	2.35	43.65	41.25	40.7	42.15	6.84	6.86	0.24	0.21
T5	1.35	1.36	2.30	2.30	45.03	43.61	41.1	43.96	6.82	6.84	0.26	0.23
T6	1.34	1.35	2.20	2.21	44.66	42.60	43.2	45.16	6.81	6.83	0.27	0.23
T7	1.33	1.34	2.39	2.39	43.98	41.69	41.3	43.00	6.80	6.82	0.25	0.21
T8	1.32	1.33	2.29	2.30	44.66	42.61	41.6	43.16	6.79	6.81	0.25	0.22
T9	1.31	1.32	2.23	2.24	46.01	45.69	42.4	45.18	6.78	6.80	0.28	0.24
C.D. at 5%	-	-	-	-	0.064	0.050	0.7	0.555	-	-	-	-
S.Em. (±)	-	-	-	-	0.021	0.017	2.1	1.67	-	-	-	-
F-Test	NS	NS	NS	NS	S	S	S	S	NS	NS	NS	NS

Table. 3. Effect of NPK, and Neem cake on Chemical properties of post-harvest soil of cluster bean

Treatment	Organic carbon (%)		Available nitrogen (Kg ha^{-1})		Available phosphorus (Kg ha^{-1})		Available potassium (Kg ha-1)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T1	0.35	0.33	264.04	262.04	17.3	15.99	166.3	164.5
T2	0.36	0.34	266.87	264.17	17.9	16.59	167.4	165.6
T3	0.38	0.36	269.28	267.28	18.4	17.09	169.1	167.3
T4	0.36	0.34	271.48	269.98	17.6	16.29	168.6	166.8
T5	0.38	0.36	273.14	271.64	18.1	16.79	171.1	169.3
T6	0.39	0.37	275.87	273.87	18.9	17.59	174.3	172.5
T7	0.37	0.35	277.56	275.16	17.9	16.59	176.7	174.9
T8	0.39	0.37	281.76	279.76	20.4	19.09	181.1	179.3
T9	0.41	0.39	283.43	281.36	22.8	21.49	183.2	181.4
C.D. at 5%	0.014	0.003	10.01	4.01	0.99	0.733	0.947	0.56
S.Em. (±)	0.005	0.001	3.27	4.01	1.294	1.044	1.247	1.119
F-Test	S	S	S	S	S	S	S	S

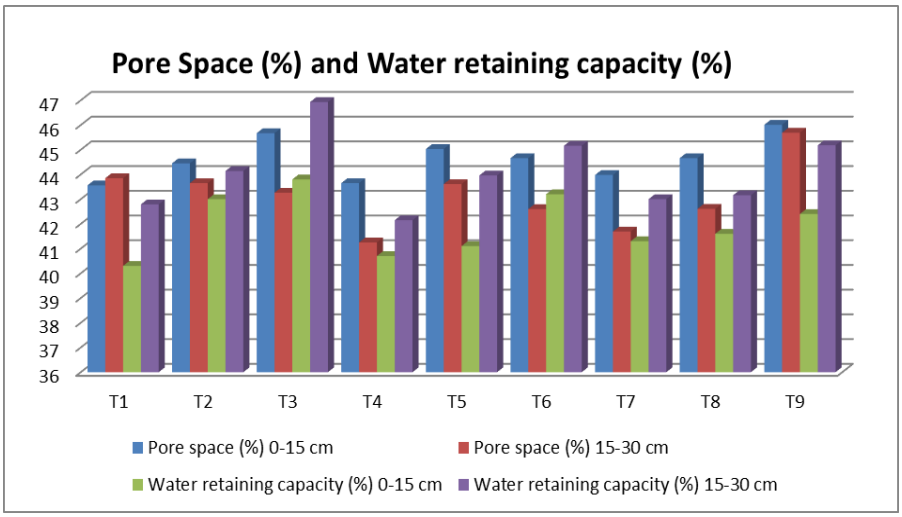

Fig. 3. Effect of NPK, and Neem cake on physical properties of post-harvest soil of cluster bean

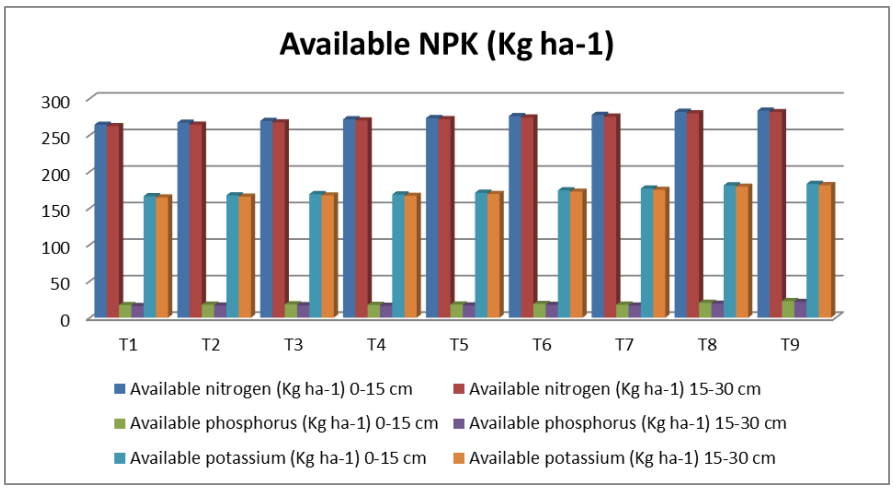

Fig. 4. Effect of NPK, and Neem cake on Chemical properties of post-harvest soil of cluster bean

Table 4. Effect of NPK, and Neem cake on plant growth and yield parameter of cluster bean

Treatment	Plant height (cm)			No. of Branches plant-1	Number of leaves			No. of pod plant-1	Pod yield (qha-1)
	30 DAS	60 DAS	90 DAS		30 DAS	60 DAS	90 DAS		
T1	13.56	41.22	48.5	4.100	7.61	16.22	21.11	39.06	29.25
T2	16.56	53.74	58.44	5.033	7.78	17.47	21.98	41.50	31.74
T3	17.86	55.15	60.04	5.267	7.91	17.62	23.11	43.60	33.44
T4	19.46	58.89	65.61	6.167	8.09	17.78	23.6	46.80	36.12
T5	21.03	58.30	66.36	6.433	8.13	18.04	23.85	59.13	38.58
T6	22.13	61.53	71.28	6.233	8.16	18.14	23.91	61.76	40.33
T7	24.03	68.49	77.22	6.233	8.20	18.31	24.44	73.63	43.11
T8	24.96	67.38	78.02	6.633	8.22	18.53	24.91	75.80	45.23
T9	26.43	69.09	79.71	6.733	8.31	18.6	25.11	77.20	48.22
C.D. at 5%	0.15	0.269	0.279	0.054	S	S	S	0.58	1.395
S.Em. (±)	0.05	0.089	0.091	0.018	**0.13**	0.24	0.41	0.193	0.461
F-Test	S	S	S	S	**0.39**	0.72	1.22	S	S

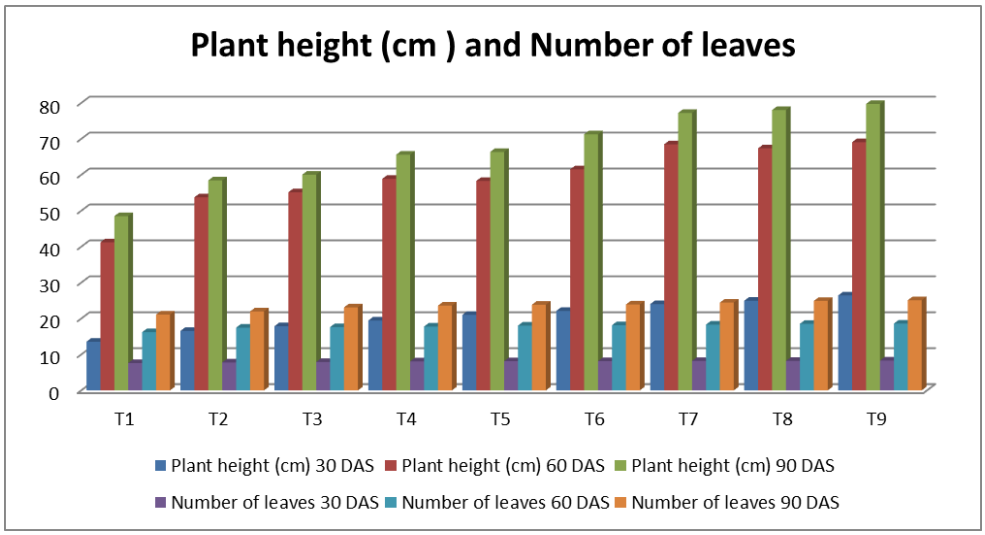

Fig. 5. Effect of NPK, and Neem cake on plant growth parameter of cluster bean

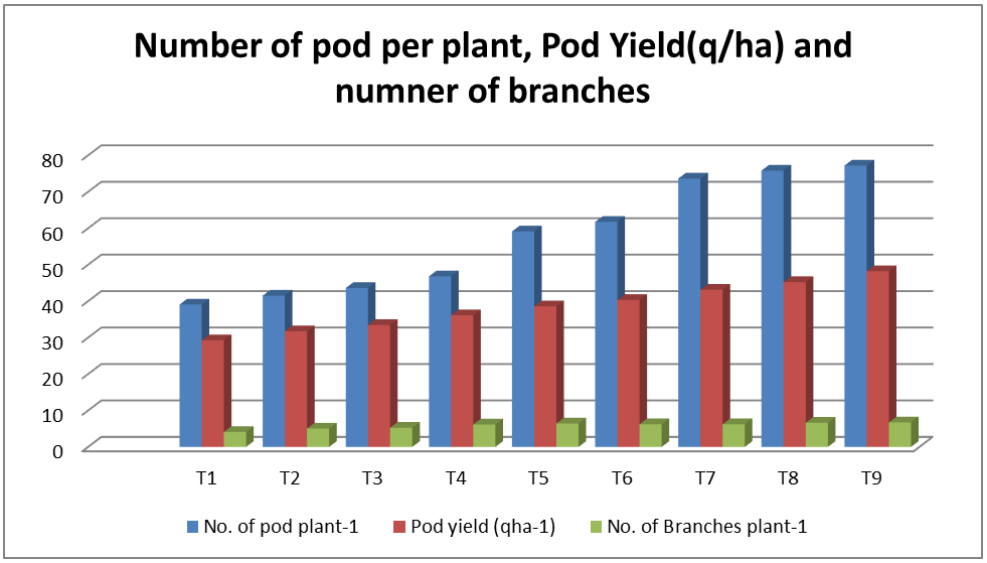

Fig. 6. Effect of NPK, and Neem cake on yield parameter of cluster bean

Table 5. Economics of different treatment combination of Cluster bean

Treatment	Pod yield (qha-1)	Selling price (Rs/q)	Cost of Cultivation (Rs/ha)	Gross return (Rs)	Net return (Rs.)	C:B Ratio
T1	29.25	3000	53850	87750	33900	1.62
T2	31.74	3000	55850	95220	39370	1.7
T3	33.44	3000	57850	100320	42470	1.73
T4	36.12	3000	55400	108360	52960	1.95
T5	38.58	3000	57400	115740	58340	2.01
T6	40.33	3000	59400	120990	61590	2.03
T7	43.11	3000	56950	129330	72380	2.27
T8	45.23	3000	58950	135690	76659	2.3
T9	48.22	3000	60950	144660	83710	2.37

3.4 Economics of Cluster Bean

Among the various treatments, treatment T9 provided the highest net return of Rs. 83710 ha^{-1} that excelled rest of the treatments [14-17]. Treatment T8 was observed as the next superiorand best treatment by fetching the net returns of Rs. 33900 ha^{-1}. However, the control plot treatment showed lowest net returns of Rs.18350 ha^{-1}. The highest mean B: C ratio of 2.37 was recorded with the application of over other treatments for cluster bean cultivation [18-21].

4. CONCLUSION

The current study's findings indicate that treatment T9 [N20P40K40+Neem Cake@ 5 q ha-1]—performed best across the board in terms of all soil health metrics. Additionally, T9 has the maximum vegetative growth, yield qualities, and beneficial effects on net return up to ₹83710 ha-1 with a cluster bean B: C ratio of 1:2.37. Since the trial was conducted over a single season, the data can be verified before recommendations are made. As a result, it is recommended that T9 be chosen as the most appropriate for sustainable soil health metrics, cluster beans to increase output, and farmers' economics.

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 manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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