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Impact of NPK and Vermicompost on Physico-chemical Properties of Soil of Cluster Bean (*Cyamopsis tetragonoloba* L.) Cv. Pusa Navbahar

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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

A field experiment was conducted at the Soil Science and Agricultural Chemistry department's central research farm during the *Kharif* season, 2022-24. The plots were laid out in randomized block design (RBD) with nine treatment combinations that were replicated three times and randomly

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allocated. A variety of cluster bean, Pusa Navbahar was taken for the study trial. Recommended doses of fertilizers (NPK @ 0, 50, and 100%) was applied along with Vermicompost (Vermicompost @ 0.0, 2 and 4 t ha^{-1}). The results obtained showed that T_1 (Absolute Control) recorded maximum particle density (2.55 Mg m^{-3} and 2.55 Mg m^{-3}) and bulk density (1.35 Mg m^{-3} and 1.36 Mg m^{-3}) at 0-15 cm and 15-30 cm depth, respectively. The results showed slight change in soil pH *i.e.*, pH was recorded maximum (6.88 and 6.89) at 0-15 cm and 15-30 cm depth, respectively in T_1 (Absolute Control). EC (0.46 dS m^{-1} and 0.47 dS m^{-1}), Organic carbon (0.39% and 0.38%), Pore space (49.60% and 48.81%), Water holding capacity (46.48% and 46.89%), Available Nitrogen (288.05 kg ha^{-1} and 285.22 kg ha^{-1}), Available Phosphorus (25.28 kg ha^{-1} and 24.28 kg ha^{-1}) and Available Potassium (201.36 kg ha^{-1} and 193.73 kg ha^{-1}) was measured maximum in T_9 (NPK @ 100% + Vermicompost @ 100%) at 0-15 cm and 15-30 cm depth, respectively. Among all the treatment combinations, the increase in NPK (kg ha^{-1}) was found to be significant in cluster bean. Additionally, the research showed that using vermicompost along with NPK was a superior method of fertilization than using these components alone.

Keywords: Cluster bean; nitrogen; phosphorus; potassium; vermicompost.

1. INTRODUTION

Soil is the unconsolidated upper part of the crust of the earth that provides a natural medium for the growth and development of higher plants [1]. "The characteristics of the soil are categorized into three categories: physical, chemical, and biological, which interact to sustain the growth and development of plants. When the soil is managed properly, the productivity of the crop is sustained. The physical and chemical properties of the soil play a crucial role in vegetative and reproductive growth, along with increasing crop yield by influencing the abiotic components of the crops" [2]. "Cluster bean (*Cyamopsis tetragonoloba* L.), commonly known as guar or gawar, belongs to the subfamily Faboideae under the Leguminosae family. It is an annual legume crop widely grown for its guar gum, which contains an ample amount of soluble dietary fibers. Cluster bean is a cash crop due to its applications in agriculture, paper, juice, textiles, the purification of waste water, mining, petroleum, explosives, pharmaceuticals, and the food industry. India ranks first and produces about 80% of the world's cluster beans. The major states producing cluster beans in India are Rajasthan, Gujarat, Haryana, Punjab, Madhya Pradesh, and Uttar Pradesh. This legume is a valuable plant in a crop rotation cycle, as it reduces weeds and enhances the soil with the help of nitrogen-fixing bacteria present in the soil. Guar is an excellent soil-building crop that can increase the yield of succeeding crops" [3,4,5,6,7]. Cluster beans, among leguminous crops, are a comparatively more drought-tolerant hardy crop, grown in arid and semi-arid regions of India under rainfed conditions. The crop can tolerate moderate salinity and alkalinity conditions. The crop has deep penetrating roots to utilize available moisture more efficiently, and hence it's useful for rainfed cropping. Due to its high degree of salinity and drought tolerance, guar could be a better alternative crop for the exploitation of the semi-arid condition, where poor irregular rainfall, high temperature, and increased salt content in the soil limit the cultivation of other crops [8]. Nitrogen is an important macronutrient for all living tissues of the plant, which take part in everything from metabolism to resource allocation, growth, and development. It increases the protein content of grains, fruits, and seeds in plants. Deficient plants may have stunted growth due to decreased photosynthesis, leaf area, and longevity of green leaves. Phosphorus plays a key role in respiration, photosynthesis, cell elongation, energy storage, seed formation, and enhancing the quality of crops. Potassium plays a vital role in plant cell sap, photosynthetic activities, supporting enzymatic activities, and the transportation of sugar, protein synthesis, and starch synthesis, but it isn't bound to oxygen or carbon. Potassium also develops tolerance to drought conditions and improves plants' ability to resist pest and disease infestations. Vermicompost is an organic fertilizer that contains high nutritional contents, porosity, aeration, and water-holding capacity. It is formed by the joint action of microbes and earthworms. Besides organic waste management, vermicompost is considered an effective plant growth promoter [9].

1.1 Objectives

The experiment was conducted to study the effect of N, P, K and vermicompost on physico-chemical properties of soil of cluster bean.

Table 1. Treatment combinations of cluster bean

Treatment	Treatment Combination	Symbol
T1	Control	L_0V_0
T2	NPK @0% + Vermicompost @2 t ha^{-1}	L_0V_1
T3	NPK @0% + Vermicompost @4 t ha^{-1}	L_0V_2
T4	NPK @50% + Vermicompost @0 t ha^{-1}	L_1V_0
T5	NPK @50% + Vermicompost @2 t ha^{-1}	L_1V_1
T6	NPK @50%+ Vermicompost @4 t ha^{-1}	L_1V_2
T7	NPK @100% + Vermicompost @0 t ha^{-1}	L_2V_0
T8	NPK @100% + Vermicompost @2 t ha^{-1}	L_2V_1
T9	NPK @100% + Vermicompost @4 t ha^{-1}	L_2V_2

Note: RDF: - 20:40:40 NPK, Vermicompost 4 t ha^{-1}

2. MATERIALS AND METHODS

The field experiment was executed during the *kharif* season in 2023 at the Soil Science and Agricultural Chemistry department's central research farm, Naini Agricultural Institute (NAI), Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, U.P. It is located at 25^{0}57'69''N latitude and 81^{0}59'74''E longitude, at an altitude of 98 m above sea level. The experimental site comes under the subtropical belt, which experiences fairly cold winters and extremely hot summers. This location receives about 1100 mm of rainfall on average each year, with the majority of rain falling between July and September, and the relative humidity varies from 20 to 94%. The experiment was conducted in a randomized block design with nine treatments replicated three times using the variety Pusa Navbahar in each plot size of 2 m x 2 m and a total gross area of 196.24 m^2. The treatment combinations used in the experiment are listed in Table 1. The soil samples were randomly collected from three different sites in the experiment plot prior to tillage operation at a depth of 0–15 cm. The soil samples were also collected after crop harvest from soil depths of 0–15 cm and 15–30 cm. The soil sample was reduced in size by conning and quartering the composite soil sample. It was then air dried and put through a 2 mm sieve to prepare it for physical and chemical analysis [10] bulk density, particle density, pore space and water holding capacity: Muthuvel et al. [11]; pH: Jackson [12]; EC: Wilcox [13]; organic carbon: Walkley and Black [14]; available nitrogen: Subbaih and Asija [15], available phosphorus: Olsen et al. [16]; available potassium: Toth and Prince, [17].

2.1 Statistical Analysis

For testing the hypothesis of the data collected during the time of investigation, the ANOVA table was used. "The significant and non-significant of treatment effect was judged with the help of 'F' (variance ratio) table" [18]. The significant difference between the means was tested against the critical difference of 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Impact of NPK and Vermicompost on Soil Physical Properties

Table 2. shows that the application of different amounts of NPK and vermicompost has the following impact on soil: it decreases bulk density and particle density and increases pore space and water holding capacity of the soil. The data of the soil samples showed maximum bulk density of 1.35 Mg m^{-3} at 0-15 cm depth and 1.36 Mg m^{-3} 15-30 cm depth and particle density of 2.55 Mg m^{-3} at 0-15 cm depth and 2.55 Mg m^{-3} at 15-30 cm depth that were recorded in the treatment T_1 (Absolute control), and minimum bulk density of 1.27 Mg m^{-3} at 0-15 cm depth and 1.29 Mg m^{-3} at 15-30 cm depth and particle density of 2.51 Mg m^{-3} at 0-15 cm depth and 2.52 Mg m^{-3} at 15-30 cm depth that were recorded in the treatment T_9 (NPK @ 100% + Vermicompost @ 100%). The data of the soil samples also showed maximum percentage pore space of 49.60% at 0-15 cm depth and 48.81% at 15-30 cm depth and water holding capacity of 46.48% at 0-15 cm depth and 48.89% at 15-30 cm depth that were measured in the treatment T_9 (NPK @ 100% + Vermicompost @ 100%) and minimum percentage pore space 47.06% at 0-15 cm depth and 46.67% at 15-30 cm depth and water holding capacity 42.15% at 0-15 cm depth and 42.96% at 15-30 cm depth were recorded in treatment T_1 (Absolute control) shown in Table 2. Pore space and water holding capacity of the post-harvest soil were found to be significant. Similar findings were also observed [19,20], and [21].

Table 2. Impact of different levels of NPK and Vermicompost on physical properties of post-harvest soil

Treatment	Bulk Density ($Mg\ m^{-3}$)		Particle Density ($Mg\ m^{-3}$)		Pore space (%)		Water holding capacity (%)	
	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	1.35	1.36	2.55	2.55	47.06	46.67	42.15	42.96
T2	1.32	1.34	2.54	2.54	48.03	47.24	43.06	44.17
T3	1.29	1.31	2.53	2.54	49.01	48.42	45.26	45.70
T4	1.34	1.35	2.54	2.55	47.24	46.85	42.79	43.05
T5	1.31	1.33	2.53	2.53	48.22	47.43	43.96	44.75
T6	1.28	1.30	2.52	2.53	49.21	48.62	45.68	46.07
T7	1.33	1.34	2.53	2.53	47.43	47.04	43.00	43.75
T8	1.30	1.32	2.52	2.52	48.41	47.62	44.14	44.95
T9	1.27	1.29	2.51	2.52	49.60	48.81	46.48	48.89
F-test	**NS**	**NS**	**NS**	**NS**	**S**	**S**	**S**	**S**
S. Em. (±)	-	-	-	-	0.46	0.45	0.60	0.77
C. D. (P=0.05)	-	-	-	-	1.41	1.38	1.80	2.33

Table 3. Impact of different levels of NPK and Vermicompost on pH, EC and organic carbon of post-harvest soil

Treatment	p	H	Electrical conductivity ($dS\ m^{-3}$)		Organic carbon (%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T1	6.88	6.89	0.43	0.44	0.35	0.34
T2	6.86	6.87	0.44	0.45	0.36	0.35
T3	6.82	6.84	0.45	0.46	0.37	0.36
T4	6.87	6.88	0.43	0.44	0.36	0.35
T5	6.85	6.86	0.44	0.45	0.37	0.36
T6	6.81	6.83	0.45	0.46	0.38	0.37
T7	6.86	6.87	0.44	0.45	0.37	0.36
T8	6.84	6.85	0.45	0.46	0.38	0.37
T9	6.80	6.82	0.46	0.47	0.39	0.38
F-test	**NS**	**NS**	**NS**	**NS**	**S**	**S**
S. Em. (±)	-	-	-	-	0.01	0.01
C. D. (P=0.05)	-	-	-	-	0.02	0.02

Table 4. Impact of Different Levels of NPK and Vermicompost on Available Nitrogen, Available Phosphorus and Available Potassium of post-harvest soil

Treatment	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
T1	265.51	263.29	14.87	14.27	178.36	172.66
T2	268.14	266.02	15.36	15.26	180.46	173.58
T3	271.09	268.06	16.89	16.38	184.68	174.90
T4	274.37	271.54	15.27	15.02	186.79	179.56
T5	276.49	274.47	18.29	17.01	187.46	181.67
T6	279.25	276.41	23.27	22.45	189.89	183.59
T7	282.49	280.24	17.28	16.25	196.97	185.23
T8	285.34	283.32	20.49	19.26	198.98	192.43
T9	288.05	285.22	25.28	24.28	201.36	193.73
F-test	**S**	**S**	**S**	**S**	**S**	**S**
S. Em. (±)	3.37	4.03	0.26	0.28	2.98	2.62
C. D. (P=0.05)	10.20	12.10	0.79	0.84	8.96	7.90

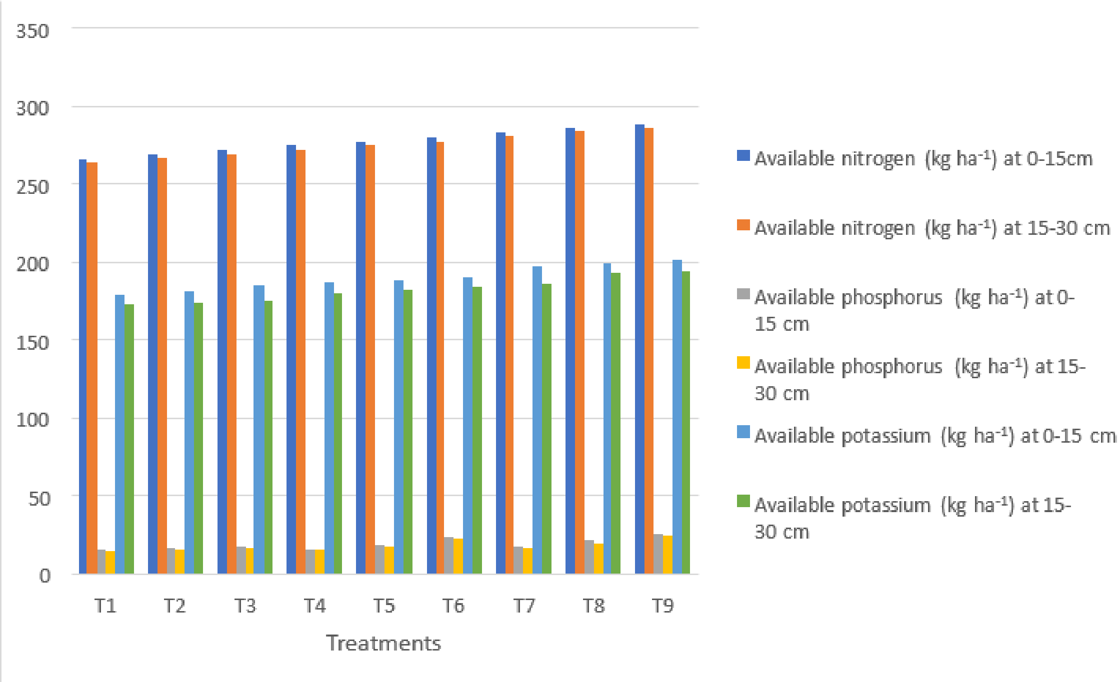

Fig. 1. Impact of different levels of NPK and Vermicompost on available nitrogen, available phosphorus and available potassium of post-harvest soil

3.2 Impact of NPK and Vermicompost on Soil Chemical Properties

Table 3. showed a slight change in pH and a negligible change in EC. The highest pH 6.88 and 6.89 but lowest EC 0.43 dS m^{-1} and 0.44 dS m^{-1} and organic carbon 0.35% and 0.34% were recorded in treatment T_1 (Absolute control) at 0-15 cm depth and 15-30 cm depth, respectively, and T_9 (NPK @ 100% + Vermicompost @ 100%) resulted in the lowest pH 6.80 and 6.82 but highest EC 0.46 dS m^{-1} and 0.47 dS m^{-1}, organic carbon 0.39% and 0.38% at 0-15 cm depth and at 15-30 cm depth, respectively. Table 4. shows the increase in available nitrogen, available phosphorus, and available potassium of the soil due to the application of varying amounts of treatment combinations of NPK and vermicompost, which were found to be significant. The data in the table stated that the lowest available nitrogen (265.51 kg ha^{-1} and 263.29 kg ha^{-1}), available phosphorus (14.87 kg ha^{-1} and 14.27 kg ha^{-1}), and available potassium (178.36 kg ha^{-1} and 172.66 kg ha^{-1}) was measured in treatment T_1 (Absolute control) at 0-15 cm depth and at 15-30 cm depth, respectively, and T_9 (NPK @ 100% + Vermicompost @ 100%) recorded the highest available nitrogen (288.05 kg ha^{-1} and 285.22 kg ha^{-1}), available phosphorus (25.28 kg ha^{-1} and 24.28 kg ha^{-1}) and available potassium (201.36 kg ha^{-1} and 193.73 kg ha^{-1}) at 0-15 cm depth and at 15-30 cm depth, respectively. Similar findings were also observed [19,20], and [21]. With the help of these physico-chemical properties of the soil, it can be determined that treatment T_9 is better followed by treatment T_8. Eventually, it becomes clear that the soil benefits from the application of vermicompost with recommended dose of fertilizers (NPK).

4. CONCLUSION

Based on the results, it can be concluded that the application of NPK and vermicompost was found to improve the soil's health in reference to the cluster bean crop. Application of T_9 (@ 100% NPK + @ 100% Vermicompost) was found to be most effective in improving the soil physico-chemical properties, as the results showed a decrease in bulk density, particle density, and pH and an increase in pore space, water holding capacity, EC, OC, available nitrogen, available phosphorus, and available potassium. The data also observed that the soil's bulk density, particle density, pH, and electrical conductivity were found to be non-significant after the crop was harvested, while the soil's organic carbon, nitrogen, phosphorus, nitrogen, porosity, and water holding capacity were found to be significant after the crop was harvested with the use of different treatment combinations of NPK and vermicompost.

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.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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