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Impact of NPK, Rhizobium and FYM on Physico-Chemical Properties of Soil for Cluster Bean (*Cyamopsis tetragonoloba* L.) Cv. Radha SPL

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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

An experiment was conducted to study the impact of NPK, Rhizobium and FYM on Soil properties, and Yield of Cluster Bean (*Cyamopsis tetragonoloba* L.) Cv. Radha SPL at Research farm of Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, during *kharif*

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season of 2023-24. The experiment with 18 treatments, was laid out in randomized block design with three replications. The pre and post-harvest soil samples taken for analysis revealed sandy loam in texture. and treatment T_{18} - [$N_{20}P_{40}K_{40}$+ FYM@ 5 t ha^{-1}+Rhizobium@ 600 g ha^{-1}] showed a slight decrease in soil pH (7.18), D_b (1.21 Mg.m^{-1}) and D_p (2.20 Mg.m^{-1}) along with increase in EC, pore space, water holding capacity and organic carbon *i.e.,*0.29 dSm^{-1}, 46.88%, 44.90%, 0.55% respectively. The maximum available nitrogen 292 kg ha^{-1}, phosphorus 31.18kg ha^{-1} and potassium 264 kg ha^{-1} were recorded in T_{18}. made it best treatment among soil health parameters.

Keywords: Cluster bean; soil health; nitrogen; phosphorus; potassium; FYM; rhizobium.

1. INTRODUCTION

Soil fertility/status determines the foundation or strength of the soil in providing support for plants, environment and future stability of ecosystems [1]. Its physico-chemical properties include pH, nutrient availability, organic matter, microbial activity and the state of life in the options of fauna [2]. Some of the management practices concerning soil are water holding capacity, water drainage, aeration, and prevention of soil erosion. The conservation practices include organic amendments, cover crops, reduced tillage, crop rotation and top soil health [3].

Cluster bean, also known as guar (*Cyamopsis tetragonoloba*), is a leguminous crop that can improve soil health by fixing atmospheric nitrogen through its symbiotic relationship with Rhizobium bacteria in its root nodules. This nitrogen fixation enriches the soil, reducing the need for synthetic fertilizers and enhancing fertility. Cluster bean's presence in crop rotation systems improves soil structure and organic matter content, forming soil aggregates for better aeration and water infiltration [4]. The plant's biomass, when left as crop residue, adds organic matter to the soil, boosting nutrient content and supporting beneficial microbial activity. Cluster bean also helps control soil erosion due to its ground cover, reducing water runoff and wind impact [5]. Cluster beans improve soil structure and fertility by adding organic matter and enhancing microbial activity. FYM enriches soil with essential nutrients, improving water-holding capacity, especially in arid regions. Rhizobium inoculation enhances nitrogen fixation, promotes root growth, and yields. Integrating these practices can lead to better crop performance, reduced dependency on chemical fertilizers, and environmentally friendly farming methods [6].

Rhizobium is a genus of Gram-negative soil bacteria that fix nitrogen. Rhizobium species from an endosymbiotic nitrogen-fixing association with roots of legumes and other flowering plants. The bacteria colonize plant cells within root nodules, where they convert atmospheric nitrogen into ammonia using the enzyme nitrogenase and then provide organic nitrogenous compound such as glutamine or ureides to the plant [7].

NPK fertilizers are inorganic fertilizers used for increasing crop production and fertility of the soil; However, their consequences on soil over the years could be complicated. In addition, NPK fertilizers can disturb the nutrient balance, cause soil acidification and decrease of microbial activity [8]. Indiscriminate use of fertilizers results in the disruption of the soil structure, the reduction of organic matter and the pollution of water sources which leads to the appearance of eutrophication and problems with the aquatic habitats. They also react certain substances with organisms to change their environmental levels and particularly affecting nitrogen and phosphorus levels, with this change can lead to a decrease in beneficial microbes. In this matter, the frequent use of inorganic fertilizers leads to dependency and influences the supply of organic matter and the natural nutrient cycling. Soil conservation practices are crucial and form the basis of long run management of the soil [9].

Farmyard manure (FYM) is one kind of natural organic manure applied for enhancing the fertility of soil as well as agricultural production. This improves the physical properties of the soil by raising the organic matter content & slow-release mechanism hence improves aeration, water intake, and root penetration [10]. The chemical composition of FYM is N (0.5%), P (0.2%) and K (0.5%). It enhances water uptake because the water dries up in dry periods and the frequency of watering is decreased. FYM enhances the microbial population in the soil helping in checking soil erosion and equally improves the pH of the soil [11].

2. MATERIALS AND METHODS

2.1 Location of Experimental Site

The experiment was conducted at research farm of Soil Science, Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute (NAI), Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj. The area is situated on the south of Prayagraj, on the right side of the river Yamuna on the south of Rewa road at a distance of about 6 km from Prayagraj city. It is situated at $25^0$57'69" N latitude, $81^0$59'74" E longitude and at the altitude of 98 meter above the sea level. The experiment containing 18 treatments, was laid out in randomized block design with three replications during *kharif,* 2023-2024 for Three factors being inorganic NPK (0%, 50% and 100%), FYM (0%, 50% and 100%) and Rhizobium (0% and 100%). The soil samples were randomly collected from one site in the experiment plot prior to tillage operation from the depth of 0-15 to 15-30 cm. The volume of the soil sample then reduced by conning and quartering the composites soil samples. Following this, they underwent air drying and were sieved through a 2 mm mesh, preparing them for both physico-chemical analysis. Soil physical analysis was conducted after post-harvest operations. After harvest, soil samples were collected from field.

3. RESULTS AND DISCUSSION

3.1 Soil Physical Properties

The maximum bulk density was recorded (1.38 Mg m^{-3}) in 0-15 cm depth and (1.46Mg m^{-3}) in 15-30 cm depth under treatment T_1 (0% NPK + 0% FYM + 0% Rhizobium). The maximum particle density was recorded (2.33 Mg m^{-3}) in 0-15 cm depth and (2.47 Mg m^{-3}) in 15-30 cm depth under treatment T_1 (0% NPK + 0% FYM + 0% Rhizobium). Data revealed that application of treatment T_{18} (100% NPK + 100% FYM + 100% Rhizobium) recorded the highest porosity (46.8%) in 0-15 cm depth among all the treatments, which was the next superior and equally effective treatment in respect to porosity in soil after crop harvesting, Application of T_{18} (100% NPK + 100% FYM + 100% Rhizobium) recorded the highest porosity (44.37 %) in 15-30 cm depth in soil, which was significantly superior to other treatments. Increased organic matter can improve soil structure and increase soil pore space the retention of dissolved organic matter leading to change in physical properties of soil. The maximum water holding capacity was recorded (44.9%) in 0-15 cm depth and (43.46%) in 15-30 cm depth in treatment T_{18} (100% NPK + 100% FYM + 100% Rhizobium).

3.2 Soil Chemical Properties

The maximum EC was recorded (0.29 dS m^{-1}) in 0-15 cm and (0.26 dS m^{-1}) in 15-30 cm depth in treatment of T_{18} (100% NPK + 100% FYM + 100% Rhizobium). That the application of T_{18} (100% NPK + 100% FYM + 100% Rhizobium) recorded the highest organic carbon is (0.55 %) in 0-15 cm soil and (0.53%) in 15-30 cm soil, which was significantly superior to other treatments. The maximum nitrogen was recorded (292 kg ha^{-1}) in 0-15 cm depth and (277 kg ha^{-1}) in 15-30cm depth under treatment T_{18} (100% NPK + 100% FYM + 100% Rhizobium) Significant buildup of the soil available N could be attributed to increased activity of nitrogen fixing rhizobia thereby resulting in higher accumulation of N in the soil leading to better nodulation and mineralization of organic N with phosphorus application**.**

Table 1. Methodology employed for analysis

Particulars	Method employed
Bulk density (Mg m^{-3})	Graduated Measuring Cylinder (Muthuaval *et al.,* 1992) [12]
Partical density (Mg m^{-3})	Graduated Measuring Cylinder (Muthuaval *et al.,* 1992) [12]
Pore space (%)	Graduated Measuring Cylinder (Muthuaval *et al.,* 1992) [12]
Soil pH (1:2)	pH meter (Glass electrode) (Jackson, 1958) [13]
Soil EC (dS m^{-1})	EC meter (Conductivity Bridge) (Wilcox, 1950) [14]
Organic carbon (%)	Wet Oxidation Method (Walkley and Black, 1947) [15]
Available nitrogen (kg ha^{-1})	Kjeldhal Method (Subbiah and Asija, 1956) [16]
Available phosphorus (kg ha^{-1})	Colorimetric method (Olsen *et al.,* 1954) [17]
Available potassium (kg ha^{-1})	Flame photometric method (Toth and Prince, 1949) [18]

Table 2. Effect of NPK, Rhizobium and FYM on Physico-Chemical Properties of Soil for Cluster Bean (*Cyamopsis tetragonoloba* L.) Cv. Radha SPL on bulk density, particle density, pore space and water holding capacity of soil after crop harvest

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
T_1	1.38	1.46	2.33	2.47	42.51	41.72	42.52	40.08
T_2	1.29	1.39	2.29	2.39	42.92	41.95	42.87	41.70
T_3	1.27	1.37	2.25	2.33	43.88	42.11	43.14	42.17
T_4	1.25	1.36	2.26	2.36	44.82	42.62	43.69	42.41
T_5	1.24	1.35	2.24	2.30	45.27	43.03	44.19	42.82
T_6	1.23	1.30	2.23	2.28	45.86	43.56	44.58	42.90
T_7	1.29	1.40	2.32	2.38	42.71	41.08	42.72	41.06
T_8	1.28	1.37	2.30	2.39	42.87	41.36	42.89	41.35
T_9	1.25	1.36	2.28	2.35	44.51	42.77	43.80	42.62
T_{10}	1.24	1.32	2.27	2.34	44.93	42.92	43.95	42.78
T_{11}	1.23	1.31	2.24	2.31	45.05	43.95	44.27	43.19
T_{12}	1.22	1.32	2.22	2.27	45.62	44.92	44.64	43.37
T_{13}	1.32	1.38	2.31	2.41	43.10	42.11	42.97	41.43
T_{14}	1.30	1.36	2.29	2.37	43.23	42.63	43.09	41.62
T_{15}	1.26	1.32	2.28	2.35	45.08	43.08	43.48	42.25
T_{16}	1.25	1.30	2.25	2.33	45.87	43.36	43.76	42.66
T_{17}	1.23	1.31	2.23	2.30	46.17	44.06	44.36	43.32
T_{18}	1.21	1.29	2.20	2.27	46.88	44.37	44.90	43.46
F-Test	NS	NS	NS	NS	S	S	S	S
S. Em. (±)	-	-	-	-	1.17	1.95	0.49	0.38
C.D. at 5%	-	-	-	-	0.40	0.65	1.73	1.10

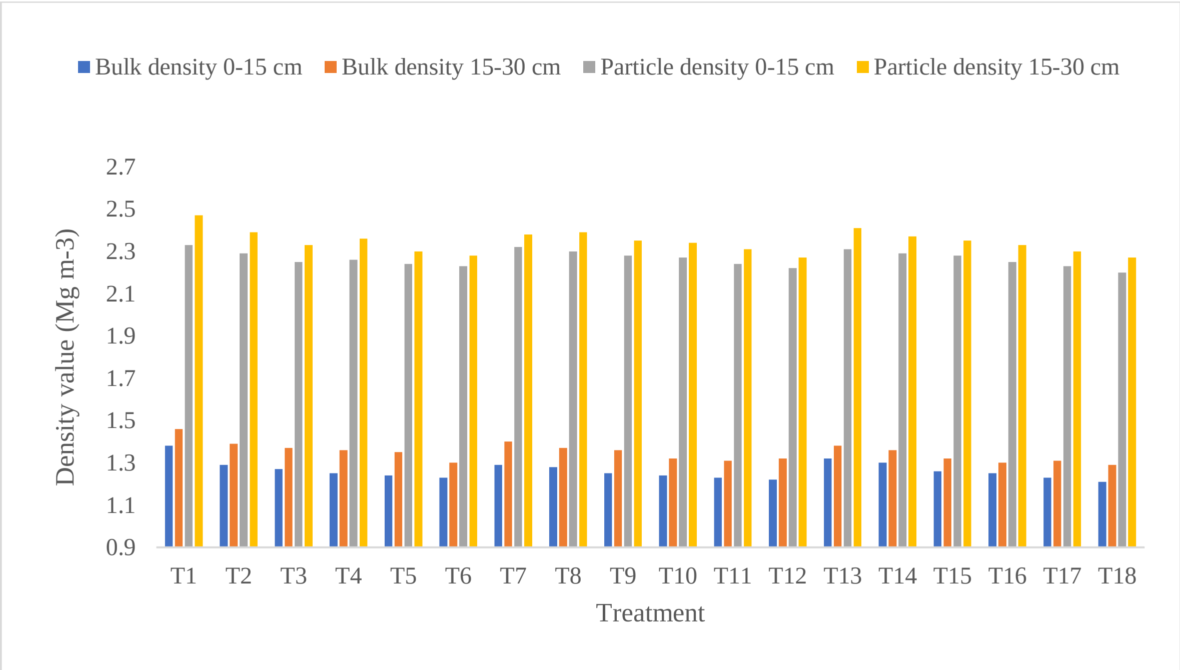

Fig. 1. Effect of NPK, Rhizobium and FYM on Physico-Chemical Properties of Soil for Cluster Bean (*Cyamopsis tetragonoloba* L.) Cv. Radha SPL on bulk density, particle density of soil after crop harvest

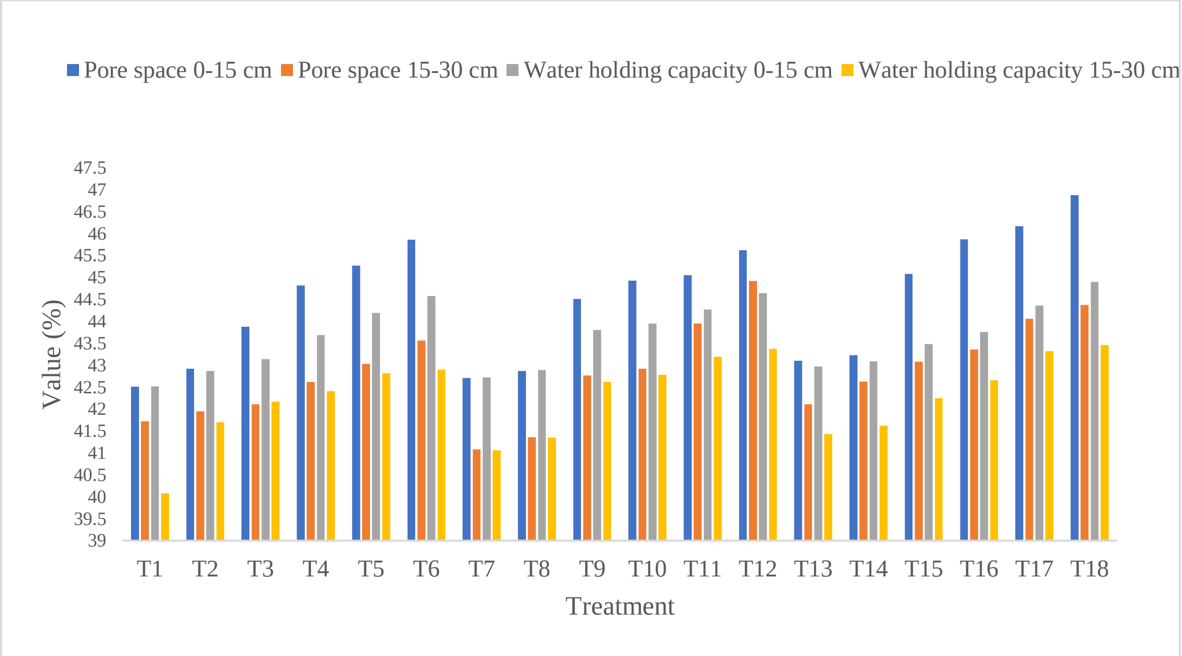

Fig. 2. Effect of NPK, Rhizobium and FYM on Physico-Chemical Properties of Soil for Cluster Bean (*Cyamopsis tetragonoloba* L.) Cv. Radha SPL on pore space and water holding capacity of soil after crop harvest

Table 3. Effect of NPK, Rhizobium and FYM on Physico-Chemical Properties of Soil for Cluster Bean (*Cyamopsis tetragonoloba* L.) Cv. Radha SPL on pH, electrical conductivity, organic compound of soil after crop harvest

Treatment	pH (1:2) w/v		Electrical Conductivity (dS m^{-1})		Organic Carbon (%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	7.50	7.47	0.23	0.20	0.48	0.32
T_2	7.39	7.43	0.24	0.22	0.48	0.39
T_3	7.32	7.38	0.25	0.23	0.51	0.43
T_4	7.30	7.35	0.26	0.24	0.51	0.45
T_5	7.28	7.32	0.26	0.25	0.53	0.47
T_6	7.26	7.29	0.27	0.26	0.54	0.51
T_7	7.41	7.45	0.24	0.22	0.49	0.44
T_8	7.37	7.42	0.24	0.23	0.49	0.45
T_9	7.29	7.32	0.25	0.24	0.52	0.48
T_{10}	7.27	7.30	0.25	0.23	0.52	0.49
T_{11}	7.26	7.28	0.26	0.24	0.53	0.50
T_{12}	7.24	7.26	0.27	0.25	0.54	0.52
T_{13}	7.35	7.39	0.24	0.22	0.50	0.45
T_{14}	7.33	7.36	0.24	0.23	0.50	0.46
T_{15}	7.25	7.27	0.26	0.24	0.53	0.51
T_{16}	7.23	7.26	0.27	0.24	0.53	0.51
T_{17}	7.21	7.24	0.28	0.25	0.54	0.52
T_{18}	7.18	7.20	0.29	0.26	0.55	0.53
F-Test	NS	NS	NS	NS	S	S
S. Em. (±)	-	-	-	-	0.01	0.03
C.D.at 5%	-	-	-	-	0.02	0.07

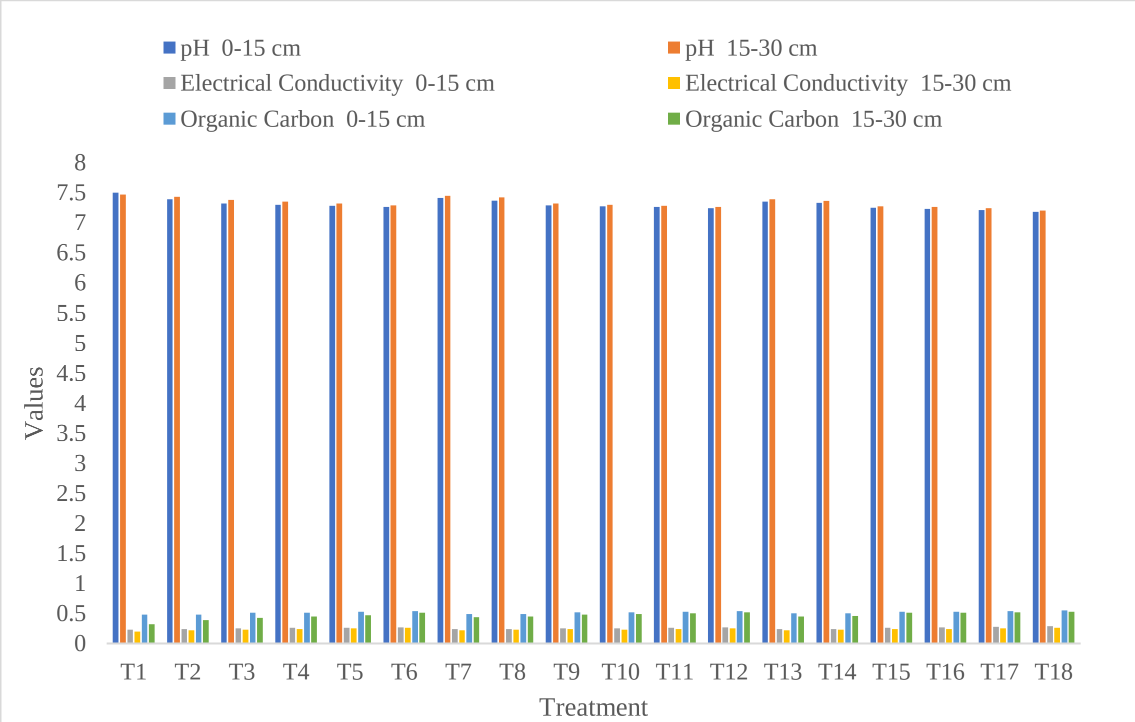

Fig. 3. Effect of NPK, Rhizobium and FYM on Physico-Chemical Properties of Soil for Cluster Bean (*Cyamopsis tetragonoloba* L.) Cv. Radha SPL on pH, electrical conductivity, organic compound of soil after crop harvest.

Table 4. Effect of NPK, Rhizobium and FYM on Physico-Chemical Properties of Soil for Cluster Bean (*Cyamopsis tetragonoloba* L.) Cv. Radha SPL on Nitrogen, Phosphorous and Potassium content of soil after crop harvest

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
T_1	179	147	18.49	15.63	206	175
T_2	191	152	19.50	16.05	208	176
T_3	192	154	20.78	17.66	210	177
T_4	195	156	21.88	18.73	213	178
T_5	220	180	22.37	19.81	216	179
T_6	241	183	22.98	20.83	219	180
T_7	245	185	24.95	21.73	226	182
T_8	247	187	25.32	22.51	228	183
T_9	250	191	25.85	22.97	230	185
T_{10}	252	193	26.22	23.53	233	186
T_{11}	255	195	26.97	24.02	236	188
T_{12}	260	210	27.12	24.32	240	189
T_{13}	266	216	28.28	24.63	246	191
T_{14}	270	227	28.83	25.61	250	192
T_{15}	275	243	29.08	25.93	253	193
T_{16}	278	248	29.66	26.23	256	194
T_{17}	286	256	30.77	26.71	259	195
T_{18}	292	277	31.18	27.74	264	196
F-Test	S	S	S	S	S	S
S. Em. (±)	5.43	5.04	0.62	0.44	4.44	2.80
C.D. at 5%	16.29	15.11	1.84	1.32	13.32	8.40

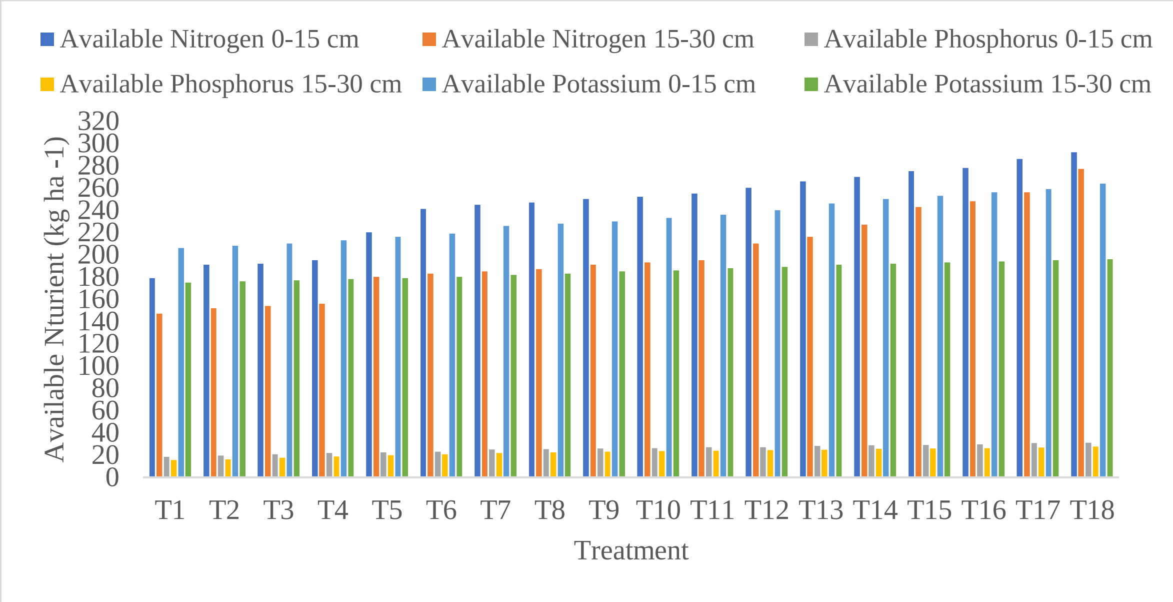

Fig. 4. Effect of NPK, Rhizobium and FYM on Physico-Chemical Properties of Soil for Cluster Bean (*Cyamopsis tetragonoloba* L.) Cv. Radha SPL on Nitrogen, Phosphorous and Potassium content of soil after crop harvest

The maximum phosphorus was recorded (31.18 kg ha^{-1}) in 0-15 cm depth and (27.74 kg ha^{-1}) in 15-30 cm depth under treatment T_{18} (100% NPK + 100% FYM + 100% Rhizobium). The increase in available P content of soil might be due to greater mobilization of native soil P by vigorous root proliferation and contribution through biomass**.**

The maximum potassium was recorded (264 kg ha^{-1}) in 0-15 cm depth and (196 kg ha^{-1}) in 15-30 cm depth under treatment T_{18} (100% NPK + 100% FYM + 100% Rhizobium).

4. CONCLUSION

The experiment concluded that the treatment combination T_{18} showed the best results on soil physico-chemical properties for cluster bean (*Cyamopsis tetragonoloba* L.) in comparison to other treatment combinations. The results showed that the treatment combination T_{18} improved the soil by decreasing bulk density and increasing water holding capacity, pore space, organic carbon, available nitrogen, phosphorus and potassium content. Therefore, it is suggested that T_{18} was most suitable to improve soil health and obtain higher yield of cluster bean.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares 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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