



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; SP-9(6): 124-129
Received: 26-03-2026
Accepted: 01-05-2026

Alok Kumar
Research Scholar, Department of
Soil Science and Agricultural
Chemistry, Faculty of Agriculture,
Prof. Rajendra Singh (Rajju
Bhaiya) University, Prayagraj,
Uttar Pradesh, India

Tarun Kumar
Assistant Professor, Department of
Soil Science and Agricultural
Chemistry, Faculty of Agriculture,
Prof. Rajendra Singh (Rajju
Bhaiya) University, Prayagraj,
Uttar Pradesh, India

Sona Kumari
Research Scholar, Department of
Soil Science and Agricultural
Chemistry, Faculty of Agriculture,
Prof. Rajendra Singh (Rajju
Bhaiya) University, Prayagraj,
Uttar Pradesh, India

Avaneesh Kumar Yadav
Research Scholar, Department of
Soil Science and Agricultural
Chemistry, Faculty of Agriculture,
Prof. Rajendra Singh (Rajju
Bhaiya) University, Prayagraj,
Uttar Pradesh, India

Corresponding Author:
Sona Kumari
Research Scholar, Department of
Soil Science and Agricultural
Chemistry, Faculty of Agriculture,
Prof. Rajendra Singh (Rajju
Bhaiya) University, Prayagraj,
Uttar Pradesh, India

Effect of seed treatment with biofertilizer and NPK application on soil health of chickpea (*Cicer arietinum* L.)

Alok Kumar, Tarun Kumar, Sona Kumari and Avaneesh Kumar Yadav

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i6Sb.5729>

Abstract

This field experiment was conducted during the *Rabi* season of 2025-2026 at the Research Farm of Prof. Rajendra Singh (Rajju Bhaiya) University, Prayagraj, to evaluate the effect of NPK fertilizers and biofertilizer with seed treatment (*Rhizobium* and PSB) on Chickpea variety 'PUSA-362' using a Randomized Block Design (RBD) with nine treatments. The experimental results revealed that while the variations in soil Bulk Density and Particle Density were statistically Non-Significant (NS), the integrated treatment combinations significantly enhanced other soil physical and chemical parameters. Specifically, treatment T₉ (*Rhizobium* Seed Treatment + 100% NPK) achieved the highest statistically Significant (S) improvement in total Pore Space (54.19%) and Water Holding Capacity (42.53%) in the surface soil layer (0-15 cm). Furthermore, T₉ significantly optimized the soil chemical health by minimizing the pH down to a favourable 6.29 and accumulating a superior Organic Carbon level of 0.57%. In terms of post-harvest nutrient availability, treatment T₉ recorded the maximum residual levels of Available Nitrogen (304.77 kg ha⁻¹) and Available Potassium (202.18 kg ha⁻¹), whereas treatment T₈ (PSB Seed Treatment + 100% NPK) yielded the highest value for Available Phosphorus (27.16 kg ha⁻¹). Thus, it can be concluded that the joint application of *Rhizobium* seed treatment with 100% recommended chemical NPK (T₉) serves as the most effective and reliable strategy to enhance overall soil health and macro-nutrient status for sustainable chickpea cultivation.

Keywords: Chickpea, biofertilizer, PSB, rhizobium, soil health, soil physical parameters, soil chemical parameters

Introduction

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops belonging to the family Fabaceae and is widely cultivated for its nutritional value and soil fertility improvement. It is a rich source of protein, carbohydrates, vitamins, minerals and dietary fibre making it an important component of human diet, particularly in vegetarian populations (Ali *et al.*, 2018) ^[1]. India is the largest producer and consumer of chickpea in the world, where the crop is mainly cultivated during the *rabi* season under both irrigated and rainfed conditions (FAO, 2023) ^[5]. Chickpea has the unique ability to fix atmospheric nitrogen through symbiotic association with *Rhizobium* bacteria, which improves soil fertility and reduces the requirement of chemical nitrogen fertilizers (Singh *et al.*, 2017) ^[19]. Balanced application of nitrogen, phosphorus, and potassium fertilizers significantly enhances plant growth, nodulation, flowering, and grain yield in chickpea (Sharma *et al.*, 2020) ^[13]. Studies has further revealed that integrated nutrient management involving chemical fertilizers along with biofertilizers such as *Rhizobium* and phosphate-solubilizing bacteria improves nutrient uptake, soil health, and overall productivity of chickpea (Kumar *et al.*, 2019) ^[8]. Inoculation with biofertilizers also increases biological nitrogen fixation and phosphorus availability, resulting in higher seed yield and better economic returns (Patel *et al.*, 2021) ^[11].

Materials and methods

The present study entitled "Effect of Seed Treatment with Biofertilizer and NPK application on Soil health of Chickpea (*Cicer arietinum* L.)" Variety PUSA-362 comprise of a field experiment

which was carried out at the Soil Science and Agricultural Chemistry Research Farm Prof. Rajendra Singh (Rajju Bhaiya) University Naini Prayagraj during *Rabi* season 2025-2026. The maximum temperature of the location reaches up to 46 °C-48 °C and seldom falls as 4 ^ 0C-5 ^ 0C. The relative humidity ranged between 20 to 94%. The average rainfall in this area is around 1100 mm annually. It comes under subtropical climate receiving the mean annual rainfall of about 1100 mm, major rainfall from July to end of September. However, occasional precipitation was also not uncommon during winter. The winter months were cold while summer months were very hot and dry. The minimum temperature during the crop season was to be 5.4 °C and the maximum is to be 41.2 °C. The minimum humidity was 48.2% and maximum was to be 87.6%.

Experiment was laid out in randomized block design with Different level of NPK and bio fertilizer with seed treatment. Plot size was 3x3m² for crop seed rate is 60-80 kg ha⁻¹ (*Cicer arietinum* L.) Var *PUSA-362*. Basal dose of fertilizer was applied in respective plots according to treatment allocation uniform furrows opened by about 5 cm. All the agronomic practices were carried out uniformly to raise the crop. The crop was harvested in March. Treatment combination for T₁- (Absolute control), T₂- (NPK @ 50%), T₃- (NPK @ 100%), T₄- (*Rhizobium* @ 20 g), T₅- (PSB @ 20 g), T₆- (*Rhizobium* @ 20 g + NPK @ 50%), T₇- (PSB @ 20 δg+NPK @ 50%), T₈ - (PSB @ 20 g + NPK @ 100%), T₉ - (*Rhizobium* @ 20 g + NPK @ 100%). Bulk density, Particle density, Pore space and Water holding capacity analyze Measuring cylinder method given by Muthuvel *et al.*,1992, Soil pH analyze Digital pH meter given by M. L. Jackson, 1958. Electrical conductivity analyze Digital conductivity meter given by Wilcox, 1950, Organic carbon analyze Wet oxidation method given by Walkley and Black, 1947, Available Nitrogen analyze Modified alkaline permanganate oxidation method given by Subbiah and Asija 1956, Available Phosphorus. analyze Olsen's extraction followed by Spectrophotometric method given by Olsen *et al.*, 1954, Available Potassium analyze Neutral normal ammonium acetate extraction fallowed by Flame photometric given by Toth and Prince, 1949.

Bulk density (Mg m-3)

The data presented in table and fig. 1 clearly shows the bulk density (Mgm⁻³) of soil as influenced by seed treatment with biofertilizer and NPK sources of nutrients. The maximum bulk density of soil was recorded 1.29 and 1.38 Mg m-3 at 0-15 and 15-30 cm in treatment T₁ (Absolute control) followed by 1.27 and 1.28 Mg m⁻³ at 0-15 and 15-30 cm in treatment T₂ (NPK @ 50%) and minimum bulk density of soil was recorded 1.12 and 1.21 Mgm⁻³ at 0-15 and 15-30 cm in treatment T₉ (*Rhizobium* @ 20 g Seed treatment + NPK @ 100%) respectively. However, this difference was statistically Non-Significant (NS) at both soil depths. Naturally, bulk density depends on soil texture and does not change in a single crop season. To make a big change in bulk density, we need to add large amounts of organic manure for many years. Since this was a short-term experiment, the fertilizers and biofertilizers did not change the soil weight and volume ratio significantly. Similar result has been recorded by.

Particle density (Mg m-3)

The data presented in table and fig. 1 clearly shows the particle density (Mgm⁻³) of soil as influenced by organic and inorganic source of nutrients. The maximum particle density of soil was recorded 2.53 and 2.57 Mg m⁻³ at 0-15 and 15-30 cm in treatment T₁ (Absolute control) followed by 2.50 and 2.63 Mg m-3 at 0-15 and 15-30 cm in treatment T₂ (NPK@50%) and minimum particle density of soil was recorded 2.29 and 2.34 Mg m⁻³ at 0-15 and 15-30 cm in treatment T₉ (*Rhizobium* @ 20 g Seed Treatment + NPK @ 100%) respectively. This small change was completely non-significant. Particle density only measures the weight of the solid soil particles, without counting any air or water spaces. Because the mineral composition of any field soil is fixed and permanent, adding chemical fertilizers or biofertilizer seed treatments cannot change the weight of the solid minerals, leading to a non-significant result. Similar result has been recorded by (Gulaiya *et al.*, 2023 and Patel *et al.*, 2024 and Begum *et al.*, 2022.)^[6, 10]

Pore space (%)

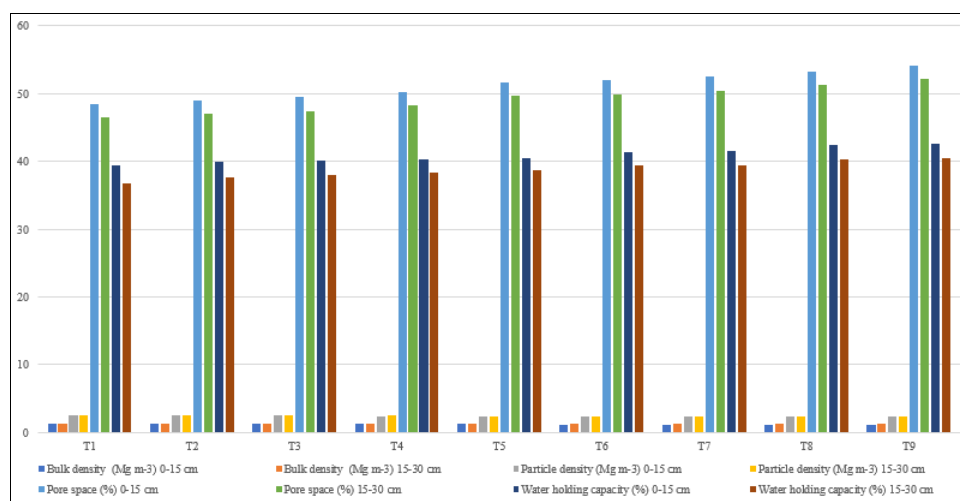
The data presented in table and fig. 1 clearly shows the pore space (%) of soil as influenced by seed treatment with biofertilizer and NPK source of nutrients. The maximum pore space of soil was recorded 54.78 and 52.15% at 0-15 and 15-30 cm in treatment T₉ (*Rhizobium* @ 20 g Seed Treatment + NPK @ 100%) followed by 53.27 and 51.20% at 0-15 and 15-30 cm in treatment T₈ (PSB @ 20 g Seed Treatment +NPK @ 100%) and minimum pore space of soil was recorded 48.50 and 46.53% at 0-15 and 15-30 cm in treatment T₁ (Absolute control) respectively. This positive change happened because 100% NPK and *Rhizobium* together helped the chickpea plant grow better roots. The growing roots pushed the soil particles and created small channels. When the roots decayed after harvest, they left behind empty spaces, which significantly increased soil porosity. Similar result has been recorded by (Gulaiya *et al.* 2023 and Patel *et al.*, 2024 and Begum *et al.*, 2022.)^[6, 10]

Water holding capacity (%)

The data presented in table and Fig. 1 clearly shows the water holding capacity (%) of soil as influenced by seed treatment with biofertilizer and NPK source of nutrients. The maximum water holding capacity of soil was recorded 42.53 and 40.51% at 0-15 and 15-30 cm in treatment T₉ (*Rhizobium* @ 20 g Seed Treatment + NPK @ 100%) followed by 42.43 and 40.25% at 0-15 and 15-30 cm in treatment T₈ (PSB @ 20 g Seed Treatment +NPK @ 100%) and minimum water holding capacity of soil was recorded 39.36 and 36.73% at 0-15 and 15-30 cm in treatment T₁ (Absolute control) respectively. This significant increase happened because better root growth and bacteria released natural sticky substances that bound soil particles together. This improved the soil structure and increased the number of small capillary pores, which are responsible for holding water against gravity. Similar result has been recorded by (Gulaiya *et al.*, 2023 and Patel *et al.*,2024 and Begum *et al.*, 2022.)^[6, 10]

Table 1: Effect of Seed Treatment with Biofertilizer and NPK application on bulk density (Mg m^{-3}), Particle density (Mg m^{-3}), Pore space (%) and Water holding capacity (%) of soil

Treatments		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	Absolute control	1.29	1.38	2.51	2.57	48.50	46.53	39.36	36.73
T ₂	NPK @ 50%	1.27	1.36	2.50	2.56	49.01	47.03	39.96	37.56
T ₃	NPK @ 100%	1.25	1.35	2.49	2.55	49.45	47.46	40.13	38.02
T ₄	Rhizobium Seed Treatment	1.24	1.34	2.44	2.52	50.28	48.27	40.33	38.36
T ₅	PSB Seed Treatment	1.23	1.33	2.43	2.46	51.69	49.65	40.53	38.61
T ₆	Rhizobium Seed Treatment + NPK @ 50%	1.20	1.32	2.36	2.45	51.94	49.90	41.36	39.40
T ₇	PSB Seed Treatment + NPK @ 50%	1.18	1.31	2.34	2.40	52.60	50.37	41.53	39.36
T ₈	PSB Seed Treatment + NPK @ 100%	1.15	1.28	2.33	2.36	53.27	51.20	42.43	40.25
T ₉	Rhizobium Seed Treatment + NPK @ 100%	1.12	1.26	2.29	2.34	54.19	52.15	42.53	40.51
F-Test		NS	NS	NS	NS	S	S	S	S
S. Ed. ($\pm$)		-	-	-	-	0.33	0.31	0.21	0.30
C.D. at 5%		-	-	-	-	0.70	0.66	0.46	0.65

**Fig 1:** Effect of Seed Treatment with Biofertilizer and NPK application bulk density (Mg m^{-3}), Particle density (Mg m^{-3}) Pore space (%) and Water holding capacity (%) of soil**Soil pH (1:2.5) w/v**

The data presented in table and fig. 2 clearly shows the pH of soil as influenced by seed treatment with biofertilizer and NPK source of nutrients. The maximum pH of soil was recorded 7.34 and 7.39 at 0-15 and 15-30 cm in treatment T₁ (Absolute control) followed 7.11 and 7.38 at 0-15 and 15-30 cm in treatment T₂ (NPK @ 50%) and minimum pH of soil was recorded 6.29 and 6.51 at 0-15 and 15-30 cm in treatment T₉ (*Rhizobium* @ 20 g Seed Treatment + NPK @ 100%) respectively. This significant reduction is caused by root and microbial activities. The *Rhizobium* bacteria in root nodules breathe actively while fixing nitrogen, releasing carbon dioxide (CO_2) gas. This gas reacts with soil moisture to form weak carbonic acid. Also, roots release hydrogen ions (H^+) during nutrient uptake, which lowers the Soil pH. Similar result has been recorded by (Datta *et al.*, 2008.)^[4]

Soil EC (dSm-1)

The data presented in table and fig. 2 clearly shows the EC of soil as influenced by seed treatment with biofertilizer and NPK source of nutrients. The maximum EC of soil was recorded 0.46 and 0.48 dSm-1 at 0-15 and 15-30 cm in treatment T₉ (*Rhizobium* @ 20 g Seed Treatment + NPK @ 100%) followed by 0.44 and 0.46 dSm-1 at 0-15 and 15-30 cm in treatment T₈ (PSB @ 20 g Seed treatment + NPK @ 100%) and minimum EC of soil was recorded 0.31 and 0.32 dSm-1 at 0-15 and 15-30 cm in treatment T₁ (Absolute control) respectively. the statistical

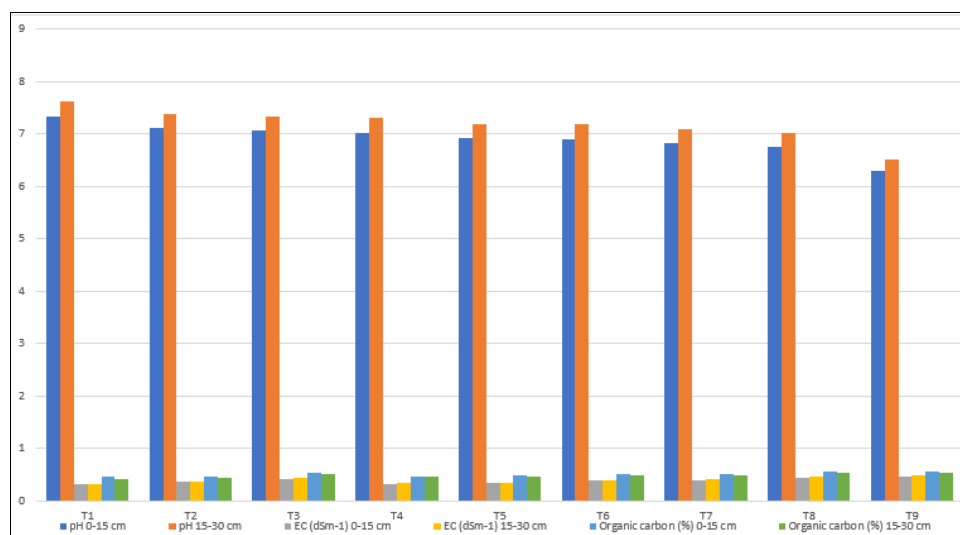
test proved this was non-Significant. Soil EC shows the amount of soluble salts in the soil water. Adding 100% chemical NPK fertilizers added some salts, which is why the numbers look higher. However, the growing chickpea plants quickly absorbed these nutrients. Also, irrigation or rain washed some salts down into deeper soil layers, preventing any significant salt accumulation in the topsoil. Similar result has been recorded by (Gulaiya *et al.*, 2023 and Patel *et al.*, 2024 and Begum *et al.*, 2022.)^[6, 10]

Organic carbon (%)

The data presented in table and fig. 2 clearly shows the organic carbon (%) of soil as influenced by seed treatment with biofertilizer and NPK source of nutrients. The maximum organic carbon of soil was recorded 0.46 and 0.48% at 0-15 and 15-30 cm in treatment T₉ (*Rhizobium* @ 20gram Seed treatment + NPK @ 100%) followed by 0.44 and 0.46% at 0-15 and 15-30 cm in treatment T₈ (PSB @ 20gram Seed Treatment + NPK @ 100%) and minimum organic carbon of soil was recorded 0.31 and 0.32% at 0-15 and 15-30 cm in treatment T₁ (Absolute control) respectively. because the top layer receives most of the organic matter, like root nodules, root exudates, and plant residues left after harvest. The lower layer (15-30 cm) has very few roots and no organic input, so the values remained non-significant. Similar result has been recorded by (Gulaiya *et al.*, 2023 and Patel *et al.*, 2024 and Begum *et al.*, 2022.)^[6, 10]

Table 2: Effect of Seed Treatment with Biofertilizer and NPK application on pH, EC (dSm⁻¹), and Organic carbon (%) of soil

Treatments		pH		EC (dSm ⁻¹)		Organic carbon (%)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T ₁	Absolute control	7.34	7.63	0.31	0.32	0.45	0.42
T ₂	NPK @ 50%	7.11	7.38	0.36	0.37	0.46	0.44
T ₃	NPK @ 100%	7.06	7.34	0.42	0.43	0.54	0.51
T ₄	Rhizobium Seed Treatment	7.02	7.30	0.32	0.34	0.47	0.45
T ₅	PSB Seed Treatment	6.91	7.18	0.34	0.35	0.49	0.46
T ₆	Rhizobium Seed Treatment + NPK @ 50%	6.90	7.18	0.38	0.39	0.51	0.48
T ₇	PSB Seed Treatment + NPK @ 50%	6.82	7.10	0.40	0.42	0.52	0.49
T ₈	PSB Seed Treatment +NPK @ 100%	6.75	7.02	0.44	0.46	0.55	0.53
T ₉	Rhizobium Seed Treatment + NPK @ 100%	6.29	6.51	0.46	0.48	0.57	0.54
	F-Test	S	S	NS	NS	S	S
	S.Ed. (±)	0.022	0.12	-	-	0.002	0.002
	C.D. at 5%	0.048	0.27	-	-	0.004	0.005

**Fig 2:** Effect of seed treatment with biofertilizer and NPK application on PH, EC (dSm⁻¹), and organic carbon (%) of soil**Available nitrogen (kg ha⁻¹)**

The data presented in table and fig. 3 clearly shows the available nitrogen (kg ha⁻¹) of soil as influenced by seed treatment with biofertilizer and NPK source of nutrients. The maximum available nitrogen of soil was recorded 304.77 and 286.39 kg ha⁻¹ at 0-15 cm and 15-30 cm in treatment T₉ (*Rhizobium* @ 20gram Seed Treatment + NPK @ 100%) followed by 287.52 and 264.52 kg ha⁻¹ at 0-15 and 15-30 cm in treatment T₈ (PSB @ 20gram Seed Treatment +NPK @ 100%) and minimum available nitrogen of soil was recorded 262.60 and 241.59 kg ha⁻¹ at 0-15 and 15-30 cm in treatment T₁ (Absolute control) respectively. This significant increase is due to the combined power of chemical and biofertilizers. 100% NPK gave a fast starter supply of nitrogen to the young plants, while *Rhizobium* seed treatment fixed atmospheric nitrogen directly into the soil through root nodules. This left a high amount of available nitrogen in the soil after harvest. Similar result has been recorded by (Gulaiya *et al.*, 2023 and Patel *et al.*, 2024 and Begum *et al.*, 2022.)^[6, 10]

Available phosphorus (kg ha⁻¹)

The data presented in table and fig. 3 clearly shows the available phosphorus (kg ha⁻¹) of soil as influenced by seed treatment with biofertilizer and NPK source of nutrients. The maximum available phosphorus of soil was recorded 27.16 and 24.37 kg ha⁻¹ at 0-15 and 15-30 cm in treatment T₈ (PSB @ 20gram Seed Treatment +NPK @ 100%) followed by 26.75 and 24.77 kg ha⁻¹ at 0-15 and 15-30 cm in treatment T₉ (*Rhizobium* @ 20gram Seed Treatment + NPK @ 100%) and minimum available phosphorus of soil was recorded 23.19 and 21.02 kg ha⁻¹ at 0-15

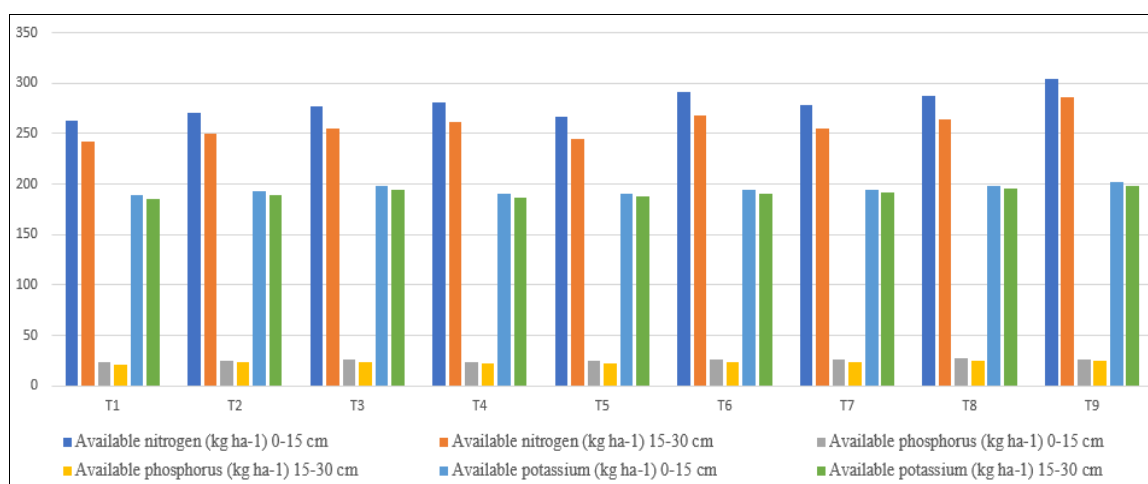
and 15-30 cm in treatment T₁ (Absolute control) respectively. when chemical phosphorus is applied, a large part gets locked up in the soil. However, in T₈, Phosphate Solubilizing Bacteria (PSB) produced organic acids that released this fixed phosphorus. In T₉, the *Rhizobium* lowered the soil pH to 6.29, which naturally made the phosphorus more soluble and available. Similar result has been recorded by (Gulaiya *et al.*, 2023 and Patel *et al.*, 2024 and Begum *et al.*, 2022.)^[6, 10]

Available potassium (kg ha⁻¹)

The data presented in table and fig. 3 clearly shows the available potassium (kg ha⁻¹) of soil as influenced by seed treatment with biofertilizer and NPK source of nutrients. The maximum available potassium of soil was recorded 202.18 kg ha⁻¹ at 0-15 cm and 197.58 kg ha⁻¹ at 15-30 cm in treatment T₉ (*Rhizobium* @ 20gram Seed Treatment + NPK @ 100%) followed by 202.18 and 197.58 kg ha⁻¹ at 0-15 and 15-30 cm in treatment T₈ (PSB @ 20gram Seed Treatment +NPK @ 100%) and minimum available potassium of soil was recorded 189.15 and 185.37 kg ha⁻¹ at 0-15 and 15-30 cm in treatment T₁ (Absolute Control) respectively. The mean value of available potassium (kg ha⁻¹) of soil was found significant. The primary reason for this significant increase is the direct addition of potassium fertilizer (MOP) under the 100% NPK treatment. Additionally, the strong root system developed by the combined treatment released organic acids into the soil. These root acids helped release the locked or non-exchangeable potassium from clay particles into an easily available form. Similar result has been recorded by (Gulaiya *et al.*, 2023 and Patel *et al.*, 2024 and Begum *et al.*, 2022.)^[6, 10]

Table 3: Effect of Seed Treatment with Biofertilizer and NPK application on Available nitrogen (kg ha⁻¹), Available phosphorus (kg ha⁻¹), and Available potassium (kg ha⁻¹) of soil

Treatments		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	Absolute control	262.61	241.59	23.19	21.02	189.15	185.37
T ₂	NPK @ 50%	271.30	249.60	25.46	23.26	193.57	189.70
T ₃	NPK @ 100%	277.18	255.51	26.29	24.09	198.45	194.48
T ₄	Rhizobium Seed Treatment	280.73	261.27	24.07	21.89	190.84	187.05
T ₅	PSB Seed Treatment	266.30	245.34	24.74	22.55	190.29	188.00
T ₆	Rhizobium Seed Treatment + NPK @ 50%	291.32	268.41	25.77	23.57	194.57	190.53
T ₇	PSB Seed Treatment + NPK @ 50%	277.78	255.56	26.35	24.15	194.24	191.65
T ₈	PSB Seed Treatment + NPK @ 100%	287.52	264.52	27.16	24.94	198.52	195.62
T ₉	Rhizobium Seed Treatment + NPK @ 100%	304.77	286.39	26.75	24.53	202.18	197.58
	F-Test	S	S	S	S	S	S
	S.Ed. (±)	1.80	1.08	0.118	0.102	0.73	1.15
	C.D. at 5%	3.59	2.31	0.25	0.217	1.57	2.46

**Fig 3:** Effect of Seed Treatment with Biofertilizer and NPK application on Available nitrogen (kg ha⁻¹), Available phosphorus (kg ha⁻¹) and Available potassium (kg ha⁻¹) of soil

Conclusion

In the present investigation, it was apparent that application of NPK and Biofertilizer with seed treatment T₉ (*Rhizobium* @ 20 gram + NPK @ 100%) was found on physical and chemical parameters of soil such as bulk density, particle density, % pore space, water holding capacity, EC, pH, organic carbon, available N, P and K than other treatment combinations. Thus, it can be concluded that different levels of NPK and Bio fertilizer improved soil available nutrient, increased soil available nitrogen, phosphorus, potassium and electrical conductivity. However, pH of soil decreases and also among the treatments T₉ recorded the best treatment which increased the availability of nutrient and influenced on physical and chemical properties of soil as well.

Acknowledgements

The authors are grateful to the Hon'ble Vice chancellor Prof. Rajendra Singh (Rajju bhaiya) University, Department of Soil Science and Agricultural Chemistry, Prayagraj for taking their keen interest and encouragement to carry out the research work.

References

1. Ali M, Kumar S. Effect of phosphorus levels on growth and yield of chickpea (*Cicer arietinum* L.). Legume Research. 2018;41(2):215-220.
2. Begum SS, Hasan A, David AA, Thomas T, Kumar T. Response of different level of organic manures and inorganic fertilizers on soil health growth and yield Attributes of Chickpea (*Cicer arietinum* L.) CV. PUSA 362 in an inceptisol of Prayagraj. Asian Jr. of Microbiol. Biotech. Env. Sc. 2022;24(3):539-543.
3. Bouyoucos GJ. The hydrometer as a new method for the mechanical analysis of soils. Soil Science. 1927;23:343-353.
4. Datta A, Sindel BM, Kristiansen P, Jessop RS, Felton WL. The effect of soil pH on chickpea (*Cicer arietinum*) genotype sensitivity to isoxaflutole. Plant and soil. 2008;303(1):49-54.
5. Food and Agriculture Organization (FAO). Global chickpea production statistics and importance. 2023.
6. Gulaiya S, Agrawal SB, Kochale P, Verma B, Patel KK. Changes in Soil behaviour under with the use of various Sources of Nutrient and Bio-fertilizer in Chickpea (*Cicer arietinum* L.). Biological Forum - An International Journal. 2023;15(8):316-319.
7. Jackson ML. The pH was determined in soil water suspensions using digital pH meter. 1958;1:2.
8. Kumar R, Singh AK, Yadav R. Integrated nutrient management in chickpea under irrigated conditions. International Journal of Chemical Studies. 2019;7(3):1450-1454.
9. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Department of Agriculture Circulars.

- 1954;939:1-9.
10. Patel MK, Yadav RS, Singh K, Sharma P, Kumar A. Physiological importance of phosphorus in plant dry matter accumulation and crop development. *Plant Growth Regulation*. 2024;102(3):301-315.
 11. Patel RK, Jha AK, Gupta S. Response of chickpea to Rhizobium and PSB inoculation under different fertility levels. *The Pharma Innovation Journal*. 2021;10(6):980-984.
 12. Patel KK, Pandey AK, Baheliya AK, Singh V, Yadav R, Pandey S, Yadav V. A comparative study of the effects of biofertilizers and chemical fertilizers on soil physical and biological properties under chickpea crop (*Cicer arietinum* L.). *International Journal of Environment and Climate Change*. 2024;14(3):72-80.
 13. Sharma P, Verma R, Patel N. Effect of NPK and biofertilizers on growth and yield of chickpea. *Journal of Pharmacognosy and Phytochemistry*. 2020;9(4):1250-1255.
 14. Subbiah BV, Asija GL. A rapid procedure for the determination of available nitrogen in soil. *Current Science*. 1956;25:259-260.
 15. Toth SJ, Prince AL. Estimation of Cation exchange capacity and exchangeable Ca, K and NA content of soil by flame photometer technique. *Soil Science*. 1949;67:439-445.
 16. Walkley A, Black IA. Critical examination of rapid method for determining organic carbon in soils, effect of variance in digestion conditions and of inorganic soil constituents. *Soil Science*. 1947;632-251.
 17. Wilcox LV. Electrical conductivity. *American water works Association Journal*. 1950;42:775-776.
 18. Muthuvel P, Udayasoorian C, Natesan R, Ramaswami PR. *Introduction to Soil Analysis*. Tamil Nadu Agricultural University, Coimbatore; 1992.
 19. Singh V, Tiwari D, Mishra P. Influence of biofertilizers on soil health and productivity of chickpea. *Indian Journal of Agricultural Research*. 2017;51(5):420-425.