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Effect of Different Levels of NPK, Biochar and *Azotobacter* on Physico-chemical Properties of Soil on Cowpea (*Vigna unguiculata*)

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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

In light of this, the following goals are present in the experiment "Effect of Different Levels of NPK and Biochar, Azotobacter on Physico-chemical Properties of Soil and Yield Attributes of Cowpea to calculate the impact of various NPK, Biochar, and Azotobacter dosages on the physical-chemical characteristics of soil. An excavated soil sample from the experimental site revealed that the land topography ranged from nearly level to sloped by 1% to 6%, with soil area falling into the Inceptisol

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order. The soil texture was sandy loam, with sand percentages of 62.65%, silt percentages of 21.09, and clay percentages of 16.26. The pH of soil was 6.89, and its electrical conductivity (EC) was non-saline (0.42 ds m-1). Organic carbon content was low to medium, available nitrogen was low to medium (280.78 kg ha-1), available phosphorus was 17.34 kg ha-1, and available potassium was 168.16 kg ha-1. Two factors with three levels of @NPK 0, 50, and 100% ha-1, three levels of @Biochar 0, 50, and 100% ha-1, and a randomized block design were used in the statistical analysis. During field testing, nine different treatments were used; the best outcomes were significant. The results indicate that the physical and chemical parameters of the soil, including the cumulative mean values for bulk density (1.39 and 1.41 mg m-3), particle density (2.46 and 2.47 mg m-3), and soil pH (6.89 and 6.91), attained their maximum in T1 (Absolute control) at depths of 0-15 cm and 15-30 cm, respectively. Additionally, the percentage pore space was found to be 48.22% and 47.39%, and the water holding capacity was found to be 44.14% and 45.34%), electrical conductivity (EC) was measured at 0.49 ds m-1 and 0.52 ds m-1, the percentage of organic carbon was determined to be 0.40%), and the available nitrogen was found to be (299.78 kg ha-1 and 295.76 kg ha-1, available phosphorus was (23.78 kg ha-1 and 21.98 kg ha-1), and the available potassium was (179.25 kg ha-1 and 176.56 kg ha-1).

Keywords: Biochar; Azotobacter; cowpea; NPK.

1. INTRODUCTION

“Soil is one of the most crucial natural resources for sustaining life on Earth, serving as a complex, dynamic, and living system that supports various ecological functions” [1]. “Composed of minerals, organic matter, water, and air, soil forms over millennia through rock weathering and organic matter decomposition. It acts as a medium for plant growth, where soil quality significantly influences crop productivity. Key soil attributes such as texture, aggregate size, porosity, aeration, water-holding capacity, pH, bulk density, and particle density play vital roles in plant development. The rate of water infiltration into soil is affected by soil texture, physical condition, and vegetation cover” [1].

Prasad and Kumar [2] explored “the quality and yield of cowpea under varying levels of NPK fertilization. Their research indicated that while increased nitrogen application led to higher yields, a threshold was observed beyond which additional nitrogen did not result in further yield improvement. This finding underscores the need for optimal nutrient management to maximize crop yields while preventing resource waste and environmental harm. It suggests that farmers should tailor their fertilizer application based on crop needs, soil nutrient status, and environmental conditions to promote sustainable agriculture. Moreover, the study highlights the importance of research and educational efforts to inform farmers about effective nutrient management practices”.

Asai et al. [3] describe “biochar as a form of biomass-derived charcoal produced through pyrolysis, a process involving heating biomass in low or no oxygen conditions. Biochar has potential benefits including improving soil fertility and enhancing carbon sequestration”. The conversion of organic waste into biochar through pyrolysis is a viable method to increase carbon sequestration rates, reduce farm waste, and enhance soil quality.

“Azotobacter species are non-symbiotic heterotrophic bacteria that can fix approximately 20 kg of nitrogen per hectare annually, offering promising potential for agriculture” [4]. These bacteria convert atmospheric nitrogen into forms usable by plants and are recognized as rhizobacteria that promote plant growth by enhancing nitrogen fixation and phosphate solubilization.

Cowpea (*Vigna unguiculata*) is a significant leguminous vegetable cultivated in India, known for its adaptability to the humid tropics and subtropical regions [5]. Commonly referred to as black-eyed pea, southern pea, or crowder pea, cowpea is grown for its long, green pods, seeds, and foliage used as fodder. The seeds are nutritionally rich, containing 54.5% carbohydrates, 24.1% protein, and 0.1% fat. Aramendiz-Tatis et al. [6] highlight that cowpea seeds possess a high protein content ranging from 21.2% to 27.9%, along with 52 g of carbohydrates and 68 mg of iron per 100 g, making them valuable for fodder, vegetable, and green manuring purposes.

2. MATERIALS AND METHODS

2.1 Experimental Site and Soil Location

The investigation site of the crop research farm is situated 5 kilometers distant on the right bank of the Yamuna River and is located at 250 58' N latitude and 810 52' E longitude. It has an elevation of 98 meters above mean sea level. Representative of the Agro-Climatic Zone (Upper Gangetic Plain Region) and the Agro-Ecological Sub-region (North Alluvial Plain Zone, 0–1% slope).

2.2 Climatic Condition

The area of Prayagraj district comes under sub-tropical belt in the Southeast of Uttar Pradesh, which experiences extremely hot summers and fairly cold winters. The maximum temperature of the location reaches up to 45^0C – 48^0C and seldom falls as low as 3^0C – 5^0C. The relative humidity ranged between 25 to 95 percent. The average rainfall in this area is around 1000-1200 mm annually.

2.3 Treatment Combination

Table 1. Treatment combination

Treatment	Treatment Combination	Symbol
T1	[Absolute Control]	R0B0A0
T2	@N10P30K20 kg ha^{-1}+@BC0 t ha^{-1}+@AZ 1.25 kg ha^{-1}	R1B0A1
T3	@N20P60K40 kg ha^{-1}+@BC0 t ha^{-1}+@AZ 2.5 kg ha^{-1}	R2B0A2
T4	@N0P0K0 kg ha^{-1}+@BC2.5 t ha^{-1}+@AZ0 kg ha^{-1}	R0B1A0
T5	@N10P30K20 kg ha^{-1}+@BC2.5 t ha^{-1}+@AZ 1.25 kg ha^{-1}	R1B1A1
T6	@N20P60K40 kg ha^{-1}+@BC2.5 t ha^{-1}+@AZ 2.5 kg ha^{-1}	R2B1A2
T7	@N0P0K0 kg ha^{-1}+@BC5 t ha^{-1}+@AZ 0 kg ha^{-1}	R0B2A0
T8	@N10P30K20 kg ha^{-1}+@BC5 t ha^{-1}+@AZ 1.25 kg ha^{-1}	R1B2A1
T9	@N20P60K40 kg ha^{-1}+@BC5 t ha^{-1}+@AZ 2.5 kg ha^{-1}	R2B2A2

NOTE: Recommended Dose of Fertilizers (RDF) [NPK]: -20:60:40, Biochar: -5 t $ha^{-1,}$ Azotobacter: - 2.5 kg ha^{-1}

2.4 Experimental Details

A randomized block design (RBD), comprising nine treatment combinations reproduced three times with distinct treatment allocations in each replication, was used to set up the current investigation. At the research site, this results in twenty-seven plots. In this study, three different doses of biochar and an azotobacter seed treatment were applied in addition to inorganic fertilizers such as potassium, phosphorus, and nitrogen as RDF. As suitable, the cowpea crop was manually seeded on August 1st, 2023. The seed variety Maruti-52 was planted at a rate of 25 kg per hectare, with a row-to-row spacing of 45 cm and a plant-to-plant spacing of 15 cm.

2.5 Fertilizer Application

The recommended doses of NPK 20:60:40 (100%) were applied to the crop: N (44 kg ha^{-1}), P2O5 (375 kg ha^{-1}), and K2O (66.67 kg ha^{-1}). The 100% application of N, P, and K was used as the basal dose at the time of sowing. In addition to these applications Biochar 5 t ha-1 and seed treatment with Azotobacter 2.5 kg ha^{-1}. The sources of NPK fertilizers were nitrogen through urea (N2O 46%). Phosphorus through single superphosphate (P2O5 16%) and potassium through muriate of potassium (K2O 60%) were applied earlier to sowing in regards to treatments just before the seed sowing. Nitrogen and urea (N 46%) were applied in two different doses [7].

2.6 Statistical Analysis

The statistical analysis of the data was carried out using STATISTICA software [8].

3. RESULTS AND DISCUSSION

3.1 Effect of Different Levels of NPK Biochar and Azotobacter Physical Properties of Soil (Post Harvest) on Cowpea

The data showed that the treatment T1 (Absolute control) non-significantly influenced the Bulk density of soil (1.39 Mg m-3 and 1.41 Mg m-3)[9], Particle density of soil (2.46 Mg m-3and 2.47 Mg m- 3) at 0-15 cm and 15-30 cm depth and significantly influenced Percentage pore space(48.22% and 47.39%), Water holding capacity (44.14% and 45.34%) of soil were found maximum in treatment T9 (@ N20P60K40 kg ha^{-1} + @BC5 t ha^{-1} + @ AZ2.5 Kg ha^{-1}) over T1 (Absolute control) treatment at 0-15 cm and 15-30 cm depth, respectively.

3.2 Effect of Different Levels of NPK Biochar and Azotobacter on Chemical Properties of Soil (post-harvest) on Cowpea

The data showed that the treatment T1 (Absolute control) non-significantly influenced the soil pH is maximum (6.89 and 6.91) at 0-15 cm and 15- 30 cm depth [10], respectively and Electrical Conductivity (0.42 and 0.44 dS m^{-1})[11], There was significantly influenced maximum build-up of Percentage Organic Carbon (0.41% and 0.40%) [12]. Available Nitrogen (299.48 kg ha^{-1} and 295.76 kg ha^{-1}) [13], Available Phosphorus (23.78 kg ha^{-1} and 21.98 kg ha^{-1}) [14] and Available Potassium (179.25 kg ha^{-1} and 176.56 kg ha^{-1}) [15] were observed under the treatment T9 (@N20P60K40 kg ha^{-1}+@BC5 t ha^{-1}+@AZ 2.5 kg ha^{-1}) content in soil, however minimum values were detected in the treatments T1 (Absolute control) at 0-15 cm depth and at 15- 30 cm depth, respectively .

Table 2. Effect of different levels of NPK biochar and azotobacter on physical properties of soil (post-harvest) on cowpea

Treatments		Bulk Density (Mgm-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	[Absolute Control]	1.39	1.41	2.46	2.47	42.55	42.29	39.26	40.12
T2	@N10P30K20 kg ha^{-1}+@BC0 t ha^{-1}+@AZ 1.25 kg ha^{-1}	1.37	1.39	2.45	2.45	44.44	43.30	40.11	40.78
T3	@N20P60K40 kg ha^{-1}+@BC0 t ha^{-1}+@AZ 2.5 kg ha^{-1}	1.38	1.40	2.45	2.46	43.36	42.75	39.80	40.57
T4	@N0P0K0 kg ha^{-1}+@BC2.5 t ha^{-1}+@AZ0 kg ha^{-1}	1.34	1.36	2.43	2.44	45.85	45.53	41.67	41.83
T5	@N10P30K20 kg ha^{-1}+@BC2.5 t ha^{-1}+@AZ 1.25 kg ha^{-1}	1.35	1.37	2.43	2.44	45.73	44.98	41.13	42.32
T6	@N20P60K40 kg ha^{-1}+@BC2.5 t ha^{-1}+@AZ 2.5 kg ha^{-1}	1.36	1.38	2.44	2.45	45.67	44.85	41.33	42.91
T7	@N0P0K0 kg ha^{-1}+@BC5 t ha^{-1}+@AZ 0 kg ha^{-1}	1.33	1.35	2.42	2.43	46.85	45.83	42.56	43.47
T8	@N10P30K20 kg ha^{-1}+@BC5 t ha^{-1}+@AZ 1.25 kg ha^{-1}	1.32	1.34	2.41	2.42	47.01	46.21	43.33	43.87
T9	@N20P60K40 kg ha^{-1}+@BC5 t ha^{-1}+@AZ 2.5 kg ha^{-1}	1.31	1.33	2.40	2.41	48.22	47.39	44.14	45.34
F- test		**NS**	**NS**	**NS**	**NS**	**S**	**S**	**S**	**S**
S.Em. (±)		-	-	-	-	0.768	0.760	0.683	0.546
C.D (P=0.05)		-	-	-	-	2.30	2.27	2.048	1.638

Table 3. Effect of different levels of NPK biochar and azotobacter on chemical properties (pH, EC, Organic carbon) of soil (post-harvest) on cowpea

Treatments		**pH**		**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**
T1	[Absolute Control]	6.89	6.91	0.42	0.44	0.34	0.33
T2	@N10P30K20 kg ha^{-1}+@BC0 t ha^{-1}+@AZ 1.25 kg ha^{-1}	6.87	6.89	0.44	0.46	0.35	0.34
T3	@N20P60K40 kg ha^{-1}+@BC0 t ha^{-1}+@AZ 2.5 kg ha^{-1}	6.88	6.90	0.43	0.45	0.35	0.34
T4	@N0P0K0 kg ha^{-1}+@BC2.5 t ha^{-1}+@AZ0 kg ha^{-1}	6.84	6.86	0.47	0.49	0.36	0.35
T5	@N10P30K20 kg ha^{-1}+@BC2.5 t ha^{-1}+@AZ 1.25 kg ha^{-1}	6.85	6.87	0.46	0.48	0.37	0.35
T6	@N20P60K40 kg ha^{-1}+@BC2.5 t ha^{-1}+@AZ 2.5 kg ha^{-1}	6.86	6.88	0.45	0.47	0.38	0.36
T7	@N0P0K0 kg ha^{-1}+@BC5 t ha^{-1}+@AZ 0 kg ha^{-1}	6.83	6.84	0.47	0.50	0.39	0.37
T8	@N10P30K20 kg ha^{-1}+@BC5 t ha^{-1}+@AZ 1.25 kg ha^{-1}	6.82	6.83	0.48	0.51	0.40	0.38
T9	@N20P60K40 kg ha^{-1}+@BC5 t ha^{-1}+@AZ 2.5 kg ha^{-1}	6.81	6.82	0.49	0.52	0.41	0.40
F- test		**NS**	**NS**	**NS**	**NS**	**S**	**S**
S.Em. (±)		-	-	-	-	0.0046	0.0043
C.D (P=0.05)		-	-	-	-	0.0140	0.0131

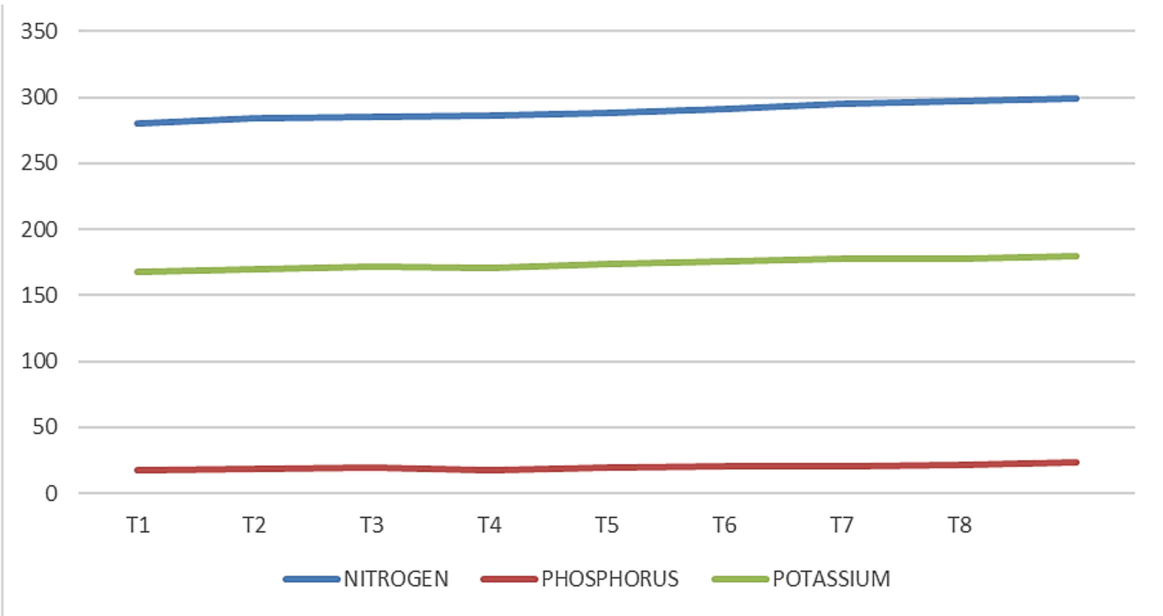

Fig. 1. Graphical representation of Av. Nitrogen, phosphorus and potassium at soil depth 0-15 cm

Table 4. Effect of different levels of NPK biochar and azotobacter chemical properties (Available Nitrogen, Available Phosphorus, Available Potassium) of soil (post-Harvest) on cowpea

Treatments		Available Nitrogen (kg ha^{-1})		Available Phospho rus (kg ha^{-1})		Available Potassiu m (kg ha^{-1})	
		0-15 cm	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**
T1	[Absolute Control]	280.04	273.04	17.34	15.56	168.16	165.23
T2	@N10P30K20 kg ha-1+@BC0 t ha-1+@AZ 1.25 kg ha-1	283.87	275.17	18.69	16.77	169.78	166.76
T3	@N20P60K40 kg ha-1+@BC0 t ha-1+@AZ 2.5 kg ha-1	285.28	276.28	19.19	17.24	171.26	168.65
T4	@N0P0K0 kg ha-1+@BC2.5 t ha-1+@AZ0 kg ha-1	286.48	287.98	17.68	15.17	170.76	169.34
T5	@N10P30K20 kg ha-1+@BC2.5 t ha-1+@AZ 1.25 kg ha-1	288.14	288.64	19.49	17.19	173.24	171.67
T6	@N20P60K40 kg ha-1+@BC2.5 t ha-1+@AZ 2.5 kg ha-1	290.87	290.87	20.18	18.98	175.65	172.59
T7	@N0P0K0 kg ha-1+@BC5 t ha-1+@AZ 0 kg ha-1	294.56	292.16	20.48	17.45	177.85	174.67
T8	@N10P30K20 kg ha-1+@BC5 t ha-1+@AZ 1.25 kg ha-1	296.76	290.76	21.42	19.65	178.12	175.15
T9	@N20P60K40 kg ha-1+@BC5 t ha-1+@AZ 2.5 kg ha-1	299.43	293.36	23.78	21.98	179.25	176.56
F- test		**S**	**S**	**S**	**S**	**S**	**S**
S.Em. (±)		3.835	3.336	0.326	0.213	2.687	2.006
C.D (P=0.05)		11.498	10.001	0.977	0.639	8.075	6.015

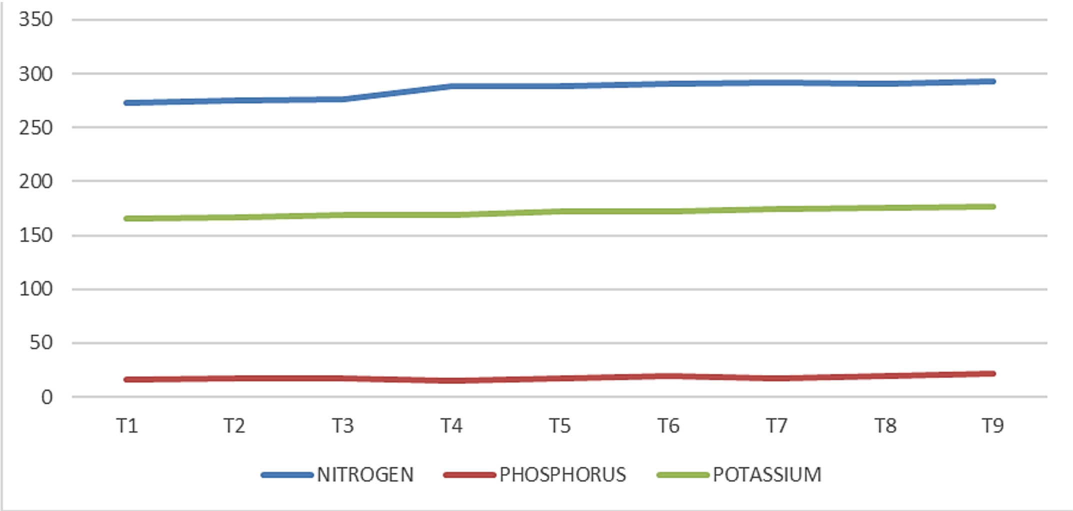

Fig. 2. Graphical representation of Av. Nitrogen, phosphorus and potassium at soil depth 15-30 cm

4. CONCLUSION

Based on the findings, the combined application of organic manure and inorganic fertilizer significantly enhanced soil health in relation to cowpea cultivation. Specifically, the application of T9 (comprising 100% NPK, 100% Biochar, and 100% Azotobacter) emerged as the most effective treatment for improving key soil properties. These enhancements included increased pore space, enhanced water holding capacity, elevated levels of organic carbon, and greater availability of nitrogen, phosphorus, and potassium. This integrated approach not only optimized soil conditions but also potentially enhanced crop productivity and sustainability in cowpea farming systems.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Auther(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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