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Influence of Different Levels of NPK and Biochar on Soil Properties, Growth and Yield of Black Gram (*Vigna mungo* L.) var. Shekhar-2

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Abstract
An experiment entitled *"Influence of Different Levels of NPK and Biochar on Soil Properties, Growth and Yield of Black Gram (Vigna mungo L.) var. Shekhar-2"* was carried out during the Zaid season of 2023-2024 at the Research Farm, Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, SHUATS, Prayagraj. The experiment was laid out in 3 × 3 randomized block design, consisting of three levels of NPK (0, 50 and 100% RDF) and three levels of biochar (0, 50 and 100%). Among all treatments, T_9 (100% NPK + 100% biochar) recorded the most favourable results. This treatment showed the highest improvements in bulk density, particle density, pore space, water-holding capacity, organic carbon and available nitrogen, phosphorus and potassium at both 0-15 cm and 15-30 cm soil depths. In terms of crop growth, T_9 produced the maximum plant height (41.05 cm, 49.13 cm and 60.05 cm at 30 DAS, 60 DAS and harvest, respectively), number of leaves plant^{-1} (18, 30 and 32 at 30 DAS, 60 DAS and harvest), number of pods plant^{-1} (38.72), number of seeds pod^{-1} (10.5), test weight (54.60 g per 1000 seeds) and grain yield (12.40 q ha^{-1}).Economic evaluation also indicated that T_9 was superior with a cultivation cost of ₹52,200 ha^{-1}, gross return of ₹1,20,280 ha^{-1}, net profit of ₹68,080 ha^{-1} and a benefit: cost ratio of 1:2.30. It revealed that combined application of NPK and biochar significantly improved nutrient availability and soil quality.

Keywords: Biochar, NPK, Yield, RDF, Soil Properties, Black gram

Introduction

Black gram (*Vigna mungo* (L.) Hepper; 2n = 22) is a highly nutritious grain legume crop cultivated across South and Southeast Asia (Kaewwongwal *et al.*, 2015) [13]. Black gram is commenly known as urad dal (Choudhary *et al.*, 2017) [6]. Black gram plays a vital role in South Asian vegetarian diets due to its rich nutritional composition. Its mature dry seeds contain about 24-26% protein, 60% carbohydrates, 1.3% fat and are good sources of minerals such as phosphorus (345 mg/100 g), calcium (185 mg/100 g) and iron (8.7 mg/100 g), along with essential amino acids and vitamins including niacin, thiamine, riboflavin and vitamin A (Nair *et al.*, 2024) [18]. It is commonly consumed as whole or split grains (dal) and in both fermented and unfermented flour forms (Khan *et al.*, 2021) [14]. Beyond its nutritional importance, black gram contributes to sustainable agriculture due to its ability to fix atmospheric nitrogen, thereby improving soil fertility and reducing dependence on synthetic fertilizers (Bhadu *et al.*, 2018) [3]. India is largest producer of black Gram in the world by contributing nearly 70% of the global production, followed by Myanmar and Pakistan. India produces about 2.7 million tonnes from an approximately 4.4 m ha area with an average yield of 598 kg ha^{-1} (Directorate of Economics and Statistics, 2021). However, the black gram productivity is considerably low and affected by several agronomic and environmental factors, among which soil fertility and nutrient management most critical.

Biochar has gained considerable attention as a soil amendment due to its ability to improve soil quality and enhance crop productivity. It is a carbon rich material produced from the thermal decomposition of organic biomass through pyrolysis (a process carried out under limited or no oxygen). Its high porosity, large surface area and strong nutrient and water-retention capacity make it particularly valuable for nutrient-deficient soils (Adekiya *et al.*, 2025) [1]. It also provides a favorable habitat for soil microorganisms. It contributes to long-term carbon sequestration and reduces greenhouse gas emissions.

Biochar is applied to soil at specific rates depending on soil type and crop needs, especially in soils with low organic matter (Kumar *et al.*, 2020) [20].

Nutrient balance is the key component to increase crop yields. Macronutrients, nitrogen (N), phosphorus (P) and potassium (K) are essential for the growth and development of all crops. Among them, nitrogen is often the most limiting nutrient for crop yield. In plants, most nitrogen is found in organic compounds such as nucleic acids, vitamins, hormones, membrane components, coenzymes and pigments. Phosphorus plays a critical role in energy transfer through ATP and other nucleoproteins and it is an integral part of genetic material and cell membranes. Potassium acts as an activator or cofactor for many enzymes, helps maintain osmotic balance and supports efficient water uptake (Meena *et al.*, 2023) [17]. Excess and imbalanced use of nutrients has caused nutrient mining from the soil, deteriorated crop productivity and ultimately soil health. The dose of fertilizer depends on the initial soil fertility status and moisture availability conditions. Keeping this in view an experiment was conducted during the *Zaid* season of 2023-2024 to evaluate the combined effects of NPK fertilization and biochar application on soil physico-chemical properties and crop performance.

Materials and Methods

The field experiment was conducted at the Central Research Farm, Department of Soil Science and Agricultural Chemistry, SHUATS, Prayagraj, Uttar Pradesh. The region falls under a subtropical climate with hot summers and cold winters, where temperatures range from 4-5°C in winter to 46-48°C in summer. Annual rainfall averages around 1100 mm and relative humidity varies between 20% and 94%. The experimental site is located at 25°57' N latitude and 81°59' E longitude, at an elevation of 98 m above mean sea level. The soil is classified as Inceptisol with a sandy loam texture (62.71% sand, 23.10% silt and 14.1% clay).

The experiment was laid out in a Randomized Block Design (RBD) with nine treatment combinations of three NPK levels (0, 50 and 100% RDF) and three biochar levels (0, 50 and 100%). Each treatment was replicated three times, resulting in a total of 27 plots. Black gram (*Vigna mungo* L., var. Shekhar-2) was sown during the *Zaid* season 2023-24 at a spacing of 30 × 10 cm and a seed rate of 15 kg ha^{-1} were used. Fertilizers were applied in the plots as per the treatments (Table 1)

Shekhar-2 (KU-300) is a high-yielding cultivar of black gram (*Vigna mungo* L.). It was developed and released by the Agricultural Research Station, CSAUAT, Kanpur, for cultivation under rainfed conditions and was officially notified in 2001. This variety typically yields around 11-12 q ha^{-1} under recommended management practices. Shekhar-2 exhibits notable tolerance to moisture stress and shows moderate resistance to major diseases such as yellow mosaic virus (YMV), leaf crinkle, anthracnose and bacterial leaf blight, making it suitable for diverse agro-ecological zones.

Plant height was recorded at 30, 60 DAS and at harvest by selecting and tagging five plants plot^{-1} measuring from the ground level to the base of the last fully opened leaf on the main shoot. The number of branches plant^{-1} and pods plant^{-1} was also recorded from the same tagged plants. Similarly, ten pods were randomly collected from the tagged plants to determine the number of seeds pod^{-1} by counting and averaging the total seeds. Test weight was determined by weighing 1000 randomly selected healthy seeds from each plot. Seed yield was recorded from threshed produce obtained from each net plot and expressed in kg ha^{-1}. Yield data were converted using the formula: Seed yield (kg ha^{-1}) = [Yield from net plot (kg) / Area of net plot (m²)] × 10,000.

Table 1: Detail of Treatments

S. No.	Symbol	Description
1.	T_1-L_0B_0	[@ 0 %NPK + @ 0 %Biochar]
2.	T_2-L_0B_1	[@ 0 % NPK + @ 50 % Biochar]
3.	T_3-L_0B_2	[@0 %NPK + @100 % Biochar]
4.	T_4-L_1B_0	[@50 % NPK + @ 0 % Biochar]
5.	T_5-L_1B_1	[@ 50 % NPK+ @ 50 % Biochar]
6.	T_6-L_1B_2	[@ 50 % NPK + @ 100 % Biochar]
7.	T_7-L_2B_0	[@ 100 % NPK + @ 0 % Biochar]
8.	T_8-L_2B_1	[@100 % NPK + @ 50 % Biochar]
9.	T_9-L_2B_2	[@ 100 % NPK+ @ 100 % Biochar]

Recommended dose of fertilizer@20:40:20 kg ha^{-1}and Biochar@10 ton ha^{-1}

Results and Discussion

Effect of different levels of NPK and biochar on soil properties

The application of higher NPK and biochar levels improved the physical and chemical properties of the soil. Maximum bulk density, particle density, pore space, water-holding capacity, organic carbon and available nitrogen, phosphorus and potassium at both 0-15 cm and 15-30 cm soil depths were observed in T_9 (100% NPK + 100% biochar). Similar result has been recorded by Javeed *et al.* (2017), Amurta *et al.* (2017), Chandrakar (2018), Dangi *et al.* (2020), Chintha *et al.* (2021), Hussain *et al.* (2022) and Pachar *et al.* (2025) [11, 4, 7, 5, 9, 19]. This improvement occurs because biochar has porous structure and high surface area that enhance soil aggregation, porosity, moisture retention and provides surfaces for nutrient adsorption and slow release. In addition, a balanced supply of NPK fertilizers encourages microbial activity, root proliferation and organic matter accumulation that further enrich soil structure and nutrient availability. Combination of both contributes better aeration, increase cation exchange capacity and higher nutrient mobilization in soil profile.

Table 2: Effect of NPK and Biochar on growth, yield attiributes and yield of biochar

Treatment	Plant Height (cm)			Number of Leaves Plant^{-1}			Number of pods plant^{-1}	Number of seeds pod^{-1}	Test weight (g)	Seed yield (q ha^{-1})	B: C ratio
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest					
T_1	35.40	42.59	51.30	11	24	26	12.25	7.51	51.3	7.9	1: 1.81
T_2	35.55	43.05	53.06	12	25	27	13.05	7.75	51.7	9.1	1: 1.97
T_3	36.01	43.08	54.05	13	25	27	16.6	7.97	52.0	9.63	1: 1.97
T_4	36.12	44.35	56.05	13	25	28	19.1	8.4	52.4	9.78	1: 2.11
T_5	37.21	45.01	56.12	14	26	28	24	8.78	52.7	10.4	1: 2.13
T_6	37.55	45.59	57.31	14	26	29	24.8	9.1	53.2	10.9	1: 2.12

T_7	38.81	46.01	57.09	15	27	30	28.9	9.55	53.6	11.0	1: 2.25
T_8	39.40	47.07	58.02	16	28	31	33.1	10	54.0	11.6	1: 2.26
T_9	41.05	41.05	60.05	18	30	32	38.72	10.5	54.6	12.4	1: 2.30
F-Test	S	S	S	S	S	S	S	S	NS	S	-
S.Ed. (±)	0.5	0.5	1.15	0.22	0.52	0.37	0.27	0.13	0.76	0.16	-
C.D. at 0.5 %	1.50	1.50	3.47	0.66	1.57	1.13	0.84	0.40	2.29	0.49	-

Effect of different levels of NPK and biochar on growth and yield of black gram

A critical examination of the data (tables 2) revealed that the application of NPK and biochar significantly influenced the growth and yield performance of black gram. Plant height measured at 30 DAS, 60 DAS and at harvest showed a clear increasing trend with higher nutrient inputs. The maximum height (41.05 cm, 49.13 cm and 60.05 cm) was recorded under T_9 (100% NPK + 100% biochar), followed closely by T_8, while the minimum was obtained in the untreated control (T_1). The superior plant growth under T_9 may be attributed to an improved and balanced nutrient supply that supports vigorous vegetative growth through enhanced cell division, elongation and photosynthetic activity. Similar observations have been reported by Koushal and Singh (2011) and Jat *et al.* (2012) [15, 10]. The number of leaves plant^{-1} also exhibited significant variation across the treatments at all growth stages. T_9 produced the highest number of leaves 18, 30 and 32 at 30 DAS, 60 DAS and harvest, respectively, followed by T_8 whereas the lowest leaf count was recorded in T_1. The increase in leaf number under higher nutrient levels may be due to improved nutrient uptake and chlorophyll formation, which enhance the interception of photosynthetically active radiation (PAR) and promote canopy development. These findings are similar with research of Koushal and Singh (2011) [15]. The number of pods plant^{-1} was significantly influenced highest value (38.72) recorded under T_9 followed by T_8 (33.10) while the minimum was observed in T_1 (12.25). This marked improvement in pod formation under higher nutrient regimes may be attributed to better flower initiation, reduced flower drop and enhanced nutrient translocation to reproductive organs. Similar results were documented by Sivakumar *et al.* (2013) and Deshmukh *et al.* (2014) [20, 8]. The number of seeds pod^{-1} significantly highest under T_9 (10.50) followed by T_8 (10.00) while the lowest was noted in T_1 (7.51). The improvement in seed formation may be linked to efficient nutrient mobilization and improved physiological processes during reproductive development. These observations are consistent with the findings of Usman *et al.* (2014), Jha *et al.* (2015) and Todawat *et al.* (2017) [22, 12, 21]. Although the test weight of 1000 seeds was statistically non-significant amog all treatment. Seed yield was significantly influenced by the application of NPK and biochar. The highest yield (12.4 q ha^{-1}) was obtained in T_9 followed by T_8 (11.6 q ha^{-1}) while the lowest yield was recorded in the control (7.90 q ha^{-1}). The substantial increase in yield under T_9 can be attributed to improved vegetative growth, increased pod formation, higher seed count pod^{-1} and better nutrient-use efficiency. The synergistic effect of biochar which enhances soil structure, moisture retention and nutrient-holding capacity along with balanced NPK nutrition, provided a favorable environment for the overall growth and productivity of black gram. These findings corroborate the results of Koushal and Singh (2011) and Sivakumar *et al.* (2013) [15, 20]. The economic viability of various treatments reveals that treatment T_9 recorded the highest net profit and B: C ratio of 1:2.30. In contrast, the lowest net profit and B: C ratio was observed in the T_1 treatment. This result clearly shows that the integrated application of recommended NPK along with biochar significantly enhances economic returns.

Conclusion

The study concluded that the various level of NPK and Biochar used from different sources fertilizers *i.e.* Urea (46 % N), SSP (16 % P_2O_5), MOP (60 % K_2O) and Biochar in the experiment gave the best result in the treatment T_9 (NPK @ 100 % + Biochar @ 100 %) followed by T_8 treatment. The soil properties, yield attributes and yield of black gram, highest net profit and cost benefit ratio is 1:2.30 were obtained under T_9 (NPK @ 100 % + Biochar @ 100 %). Therefore, it can be recommended for farmers to ensure higher farm income and sustainable agriculture.

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Author Contribution

The first author, Krishna Kumar Meena was responsible for conducting the field experiment, data collection and drafting the manuscript. The co-author, Pooja Kumari Meena assisted in data interpretation, literature review and revision of the manuscript. All authors read and approved the final version of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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