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Research Article

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Efficacy of Biochar Application with Different Nutrient Sources on Okra Production in Puranchour, Kaski, Nepal

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Abstract

Agriculture plays a vital role in the economy and encounters issues such as soil degradation and climate change, making the adoption of biochar highly promising. This study aimed to investigate the impact of biochar combined with various nutrient sources on the growth and yield of okra (*Abelmoschus esculentus* L.) in Puranchour, Kaski, Nepal. A field experiment was conducted from June to September, 2024 using a randomised complete block design with five treatments replicated four times: i) Control (C); ii) Biochar @ 8 ton/ha (BC); iii) Biochar @ 8 ton/ha + Vermicompost @ 10 ton/ha (BCVC); iv) Biochar @ 8 ton/ha + Cattle Urine (1:5) (BCCU); and v) Biochar @ 8 ton/ha + Mustard Cake @ 100 kg/ha (BCMC). Results indicated that the BCVC treatment significantly enhanced plant height (28.55 cm & 128.80 cm), leaf number (12.80 & 28.30), node count (11.95 & 19.30), and stem girth (0.60 cm & 1.10 cm) at 45 and 75 days after sowing (DAS), respectively. It also promoted early germination (10.25 days), flowering (44.00 days), and fruiting (50 days) compared to other treatments, with the control showing the least favourable results. Yield parameters such as fruit length (15.55 cm), fruit girth (2.22 cm), number of fruits per plant (17.50), individual fruit weight (17.00 g), and yield (13.75 mt/ha) were highest in BCVC and lowest in the control. The findings highlight the synergistic benefits of biochar with organic amendments, suggesting its potential as a sustainable solution to improve soil fertility and crop productivity in Nepal's varied agro-climatic conditions.

Keywords: Biochar, Fertility, Nutrient, Okra, Organic

Introduction:

Biochar, a carbon-rich byproduct of pyrolysis, is defined by the International Biochar Initiative as a thermochemical conversion product containing over 10% organic carbon. Its stable carbon structure can persist for over 100 years, making it an effective tool for carbon sequestration. Biochar improves soil health by boosting water retention, minimizing nutrient loss, and enhancing the efficiency of nutrient utilization. When combined with organic matter, biochar further reduces nutrient losses, boosting crop productivity. The benefits of biochar extend beyond its ability to enhance soil fertility. Acting as a sponge, it absorbs nutrients and releases them gradually, minimizing losses through leaching and evaporation. It improves soil organic matter, structure, and overall condition. Biochar can be produced cost-effectively from organic waste, offering a sustainable solution for resource-limited farming systems.

Okra (*Abelmoschus esculentus* L.), belonging to the Malvaceae family, is an extensively cultivated summer vegetable found in tropical, subtropical, and temperate climates. It thrives in a variety of soils ranging from sandy loam to clay and temperatures between 20°C and 30°C. Okra is an exceptionally nutritious vegetable, containing sizeable quantities of essential amino acids, proteins, carbohydrates, and vitamin C, which are comparable to soybeans. In Nepal, okra is grown on 9,584 hectares, producing 112,260 metric tons annually with a productivity rate of 11.95 metric tons per hectare (MoALD, 2022). However, challenges such as poor soil fertility, inadequate fertilizer use, and ineffective crop management have led to decreased productivity (Acharya et al., 2022).

Research shows that combining organic and inorganic fertilizers can significantly improve okra yield and quality (Adekiya et al., 2020; Akhter et al., 2019). For instance, Sachan et al. (2017) reported optimal results when NPK fertilizers were used alongside farmyard manure, poultry manure, and vermicompost. Additionally, practices like mulching can reduce weeds, conserve moisture, and enhance yields (Puri et al., 2022; Shamim et al., 2018). Adding biochar to soil is another promising nutrient management strategy.

In Nepal, where agriculture is crucial to the economy and faces challenges like soil degradation and climate change, biochar adoption holds significant promise. Its use aligns with Nepal's focus on organic farming and addresses climate change impacts, such as erratic weather and soil erosion. Biochar improves water retention and soil structure, making it a critical tool for enhancing agricultural resilience in diverse agro-climatic regions. The study aims to evaluate the effect of biochar application in combination with various nutrient sources and its long-term impact on soil fertility and crop production. It will also explore the potential of charged biochar to boost crop performance and improve soil structure.

Table 1: Treatment details allocated for different plots

Treatment #	Treatments Details	Abbreviation	Remarks (Per plot Application)
T_1	Control	C	No application of Biochar
T_2	Biochar @ 8 ton/ha	BC	3.6 kg biochar per plot
T_3	Biochar @ 8 ton/ha+ Vermicompost @ 10 ton/ha	BCVC	3.6 kg biochar per plot + 4.5 kg Vermicompost per plot
T_4	Biochar @ 8 ton/ha+ Cattle Urine (1:5)	BCCU	3.6 kg biochar per plot + 6 liters of cattle urine (dilute) per plot
T_5	Biochar @ 8 ton/ha+ Mustard Cake @ 100 kg/ha	BCMC	3.6 kg biochar per plot + 45-gram mustard cake per plot

Materials and Methods:

The experiment was conducted from July to September, 2024 at College of Natural Resource Management, Puranchaur, Kaski, which lies in the mid-hill region spanning the tropical to trans Himalayan geo-ecological belt with the geographical midpoint of the country in 28° 17' 41" N latitude and 83° 56' 38" E longitude with an altitude of 1000 masl. The biochar used in the experiment was produced by the "Kon-tiki" method, a simple and effective method, especially for small farm holders (Dahal et al., 2021). The ideal temperature to produce biochar is 400-550°C (Baidoo et al., 2016; Naeem et al., 2014). The local weed found in the vicinity of the College of Natural Resource Management, Puranchaur, mostly Banmara *(Lantana camara),* was collected and sun-dried for one day for biochar preparation. The prepared biochar was ground into fine particles and used for the experiment. The experiment was conducted using a Randomized Complete Block Design (RCBD) consisting of five treatments, each replicated four times.

All the treatments were applied during field preparation before sowing. The individual plot size was 3 m * 1.5 m (4.5 m^2), accommodating 25 plants per plot. The seeds were sown with a spacing of 60 cm P-P and 30 cm R-R distance. FYM @ 10 ton/ha, and N: P: K @ 160:120:60 kg/ha was applied. Full FYM was broadcast in the soil at the time of field preparation along with the whole quantity of P and K before sowing. One third dose of N was added to the soil before seed sowing, while the remaining nitrogen was applied in between the rows of the standing crop in equal instalments about 4 weeks after sowing and at flowering and fruiting. Irrigation was applied through a hand or pipe system as per requirements. Harvesting was done manually with hands. Tender, young pods free from fibre were harvested every three days. Five plants per plot were selected for observing the growth and yield response to added biochar and nutrient sources. Observations were recorded on Growth Parameters like days for germination, plant height, number of branches, number of leaves per plant, number of nodes, stem girth, days to first flowering, and days to first picking, and Yield Parameters like number of fruits per plant, fruit length, fruit girth, fruit weight, and yield of okra. The recorded data were systemically arranged in MS Excel and statistically analysed, using R-Studio version 2024.09.0 for analysis of variances. All the values were presented as the mean, which were compared according to Critical Difference (C.D.) at P = 0.05 level. Duncan's Multiple Range Test was employed to test for significant differences between the treatments.

Results:

Growth Parameters

Efficacy of biochar application with different nutrient sources on days for germination of okra in Puranchour, Kaski, was found to be statistically significant (Table 2). The germination was earliest in BCCU (Biochar @ 8 ton/ha and Cattle urine 1:5) treatment (9.25 days) which was statistically similar with BCVC (Biochar @ 8 ton/ha and Vermi compost @ 10 ton/ha) treatment (10.25 days) and germination was found delayed in control (11.50 days) which was statistically similar with BC (Biochar @ 8 ton/ha) treatment (10.5 days), BCMC (Biochar @8ton/ha and Mustard cake @ 100 kg/ha) treatment (10.75 days). The effect of biochar application with different nutrient sources on the plant height of okra in Puranchour, Kaski, was found to be statistically significant at all stages of observation (Table 2). At 45 DAS, the maximum plant height was recorded at BCVC treatment (28.55 cm), which was statistically similar to the treatments BCCU and BCMU (27.55 cm), whereas the lowest plant height was recorded at C treatment (23.55 cm), which is statically similar to BC treatment (25.55 cm). Similarly, at 75 DAS, the maximum plant height was recorded at BCVC treatment (128.80 cm), which was statistically similar to the treatment BCCU (125.80 cm) and BCMU (123.80 cm), whereas the lowest plant height was recorded at C treatment (81.80 cm).

The number of branches of okra plants exhibited significant variation (Table 2). The highest number of branches per plant was recorded in BCVC treatment (6.20), which was statistically similar to the treatments BCCU and BCMC (5.20), whereas the minimum number of branches was observed in treatment C (3.20), which is statistically similar to BC treatment (4.20). The number of leaves of okra varied significantly at all stages of observation (Table 2). At 45 DAS, the maximum number of leaves was recorded at BCVC treatment (12.80), which was statically similar to BCCU (11.80) and BCMC treatment (10.80), and the minimum number of leaves was found in C treatment (7.50), which is statistically similar to BC treatment (9.80). Similarly, at 75 DAS, the maximum number of leaves was found at BCVC treatment (28.30), which is statically similar to BCCU treatment (27.30), whereas the lowest number of leaves was observed in treatment C (24.30), which was statistically similar to BC (25.30) and BCMC treatment (26.30).

The number of nodes of the okra plant was significantly different in different treatments at all stages of observation (Table 3). At 45 DAS, the highest number of nodes was observed in treatment BCVC (11.95), which was statistically similar to the treatment BCCU (10.45) whereas the lowest number of nodes was recorded with the treatment C (6.20), which is statistically similar to the treatments BC (7.20) and BCMC (9.70). Similarly, at 75 DAS, the highest number of nodes was observed in treatment BCVC (19.30), which was statistically similar to the treatment BCCU (16.30) and BCMC (15.30), whereas the lowest number of nodes was recorded with the treatment C (11.30), which is statistically similar to the treatments BC (12.30) and BCMC (15.30).

Similarly, stem girth varied significantly at 45 DAS and 75 DAS (Table 3). At 45 DAS, maximum stem girth was found in response to BCVC treatment (0.60 cm), which was followed by BCCU, BCMC and BC treatments (0.50 cm) which were statistically similar and the lowest values were observed in the case of treatment C (0.40 cm), followed by BC, BCCU and BCMC treatment (0.50), being at par with each BC, BCCU and BCMC. Similarly, at 75 DAS, the maximum stem girth was found at BCVC treatment (1.10), which is statically similar to BCCU treatment (1.00 cm), whereas the lowest stem

Table 2: Efficacy of Biochar Application with Different Nutrient Sources on Growth Parameters of Okra in Puranchour, Kaski, Nepal

Treatments	Days for Germination	Plant Height (cm)		Number of Branches	Number of Leaves	
		45 DAS	75 DAS		45 DAS	75 DAS
C	11.50^{a}	23.55^{c}	81.80^{c}	3.20^{c}	7.50^{c}	24.30^{d}
BC	10.50^{ab}	25.55^{bc}	101.80^{b}	4.20^{bc}	9.80^{bc}	25.30^{cd}
BCVC	10.25^{bc}	28.55^{a}	128.80^{a}	6.20^{a}	12.80^{a}	28.30^{a}
BCCU	9.25^{c}	27.55^{ab}	125.80^{a}	5.20^{ab}	11.80^{ab}	27.30^{ab}
BCMC	10.75^{ab}	27.55^{ab}	123.80^{a}	5.20^{ab}	10.80^{ab}	26.30^{cd}
Grand Mean	10.45	26.55	112.40	4.80	10.54	26.30
LSD	1.23	2.15	15.73	1.61	2.33	1.65
CV(%)	7.93	5.43	9.38	22.48	14.83	4.22

Note: *Means followed by the same letter(s) in a column are not significantly different by LSD at 5% level of significance; DAS: days after sowing; LSD: Least significant difference; CV: coefficient of variation; C: Control ; BC: Biochar @ 8 ton/ha, BCVC: Biochar @ 8 ton/ha and vermicompost @ 10 ton/ha; BCCU: Biochar @ 8 ton/ha and Cattle urine (1:5); BCMC: Biochar @ 8 ton/ha and mustard cake @ 100 kg/ha*

Table 3: Efficacy of Biochar Application with Different Nutrient Sources on Growth Parameters of Okra in Puranchour, Kaski, Nepal

Treatments	Number of Nodes		Stem Girth (cm)		Days for First Flowering	Days for First Picking
	45 DAS	75 DAS	45 DAS	75 DAS		
C	6.20[c]	11.30[c]	0.40[b]	0.80[c]	46.75[a]	52.75[a]
BC	7.20[bc]	12.30[bc]	0.50[ab]	0.90[bc]	44.75[b]	50.75[b]
BCVC	11.95[a]	19.30[a]	0.60[a]	1.10[a]	44.00[b]	50.00[b]
BCCU	10.45[a]	16.3[ab]	0.50[ab]	1.00[ab]	44.50[b]	50.50[b]
BCMC	9.70[bc]	15.30[abc]	0.50[ab]	0.90[bc]	44.50[b]	50.50[b]
Grand Mean	9.10	14.90	0.50	0.94	44.90	50.90
LSD	2.90	4.16	0.14	0.18	1.87	1.87
CV(%)	21.37	18.71	19.03	13.20	2.79	2.46

Note: *Means followed by the same letter(s) in a column are not significantly different by LSD at 5% level of significance; DAS: days after sowing; LSD: Least significant difference; CV: coefficient of variation; C: Control ; BC: Biochar @ 8 ton/ha, BCVC: Biochar @ 8 ton/ha and vermicompost @ 10 ton/ha; BCCU: Biochar @ 8 ton/ha and Cattle urine (1:5); BCMC: Biochar @ 8 ton/ha and mustard cake @ 100 kg/ha*

girth was observed in treatment C (0.80 cm), which was statically similar to BC and BCMC treatment (0.90 cm).

The lowest number of days for first flowering was observed in treatment BCVC (44.00 days), which was statistically at par with BCCU (44.50 days), BCMC (44.50 days), and BC (44.75 days), and the highest number of days taken for first flowering was recorded in treatment C (46.75). Similarly, the lowest number of days for first picking was observed in treatment BCVC (50.00 days), which was statistically at par with BC (50.75 days), BCCU (50.50 days), BCMC (50.50 days), and the highest number of days taken for first fruit picking was recorded in treatment C (52.75 days).

Yield Parameters

Application of biochar along with different sources of plant nutrients had a significant effect on the yield parameters of Okra (Table 4). The highest fruit length was observed in treatment BCVC (15.55 cm), which is statistically similar to BCCU (14.35 cm) and BCMC (14.95 cm), and the lowest fruit length was recorded in treatment C (12.35 cm), which is statistically similar to BC (13.15 cm). The maximum fruit girth was recorded in treatment BCVC (2.22 cm), which is statistically similar to BCCU and BCMC (2.12 cm), whereas the minimum fruit girth was observed in treatment C (1.95 cm), followed by treatment BC (2.03 cm).

The maximum number of fruits per plant was recorded with the treatment BCVC (17.50), which is statistically similar to the treatment BCCU (14.50) and BCMC (14.80), and the minimum number of fruits per plant was observed in the treatment C (10.50), followed by BC (11.50), which were statistically similar.

The highest average fruit weight was observed in the case of BCVC treatment (17.00 g), which was statistically similar to BCCU treatment (15.80 g), followed by BCMC (15.20 g). Conversely, the lowest fruit weight

Table 4: Efficacy of Biochar Application with Different Nutrient Sources on Yield Parameters of Okra in Puranchour, Kaski, Nepal

Treatments	Fruit Length (cm)	Fruit Girth (cm)	No. of fruits/ plant	Fruit Weight (g)	Yield (mt/ha)
C	12.35[c]	1.95[c]	10.25[c]	12.20[c]	7.75[c]
BC	13.15[bc]	2.03[bc]	11.50[bc]	13.00[bc]	9.00[bc]
BCVC	15.55[a]	2.22[a]	17.50[a]	17.00[a]	13.75[a]
BCCU	14.35[ab]	2.12[ab]	14.50[ab]	15.80[ab]	11.75[ab]
BCMC	14.95[a]	2.12[ab]	14.80[ab]	15.20[ab]	11.25[ab]
Grand Mean	14.07	2.09	13.71	14.64	10.7
LSD	1.71	0.175	3.36	2.33	2.81
CV (%)	8.18	5.599	16.45	10.67	2.10

Note: *Means followed by the same letter(s) in a column are not significantly different by LSD at 5% level of significance; DAS: days after sowing; LSD: Least significant difference; CV: coefficient of variation; C: Control; BC: Biochar @ 8 ton/ha, BCVC: Biochar @ 8 ton/ha and vermicompost @ 10 ton/ha; BCCU: Biochar @ 8 ton/ha and Cattle urine (1:5); BCMC: Biochar @ 8 ton/ha and mustard cake @ 100 kg/ha* was observed in response to the control (12.20 g), which was statistically similar to BC treatment (13.00 g). The maximum fruits yield was recorded with the treatment BCVC (13.75 mt/ha) which is statistically similar with the treatment BCCU (11.75 mt/ha) and BCMC (11.25 mt/ha) and the minimum number of fruits per plant were observed in the treatment C (7.75 mt/ha) followed by treatment BC (9.00 mt/ha), which were statistically similar.

Discussion:

Growth Parameters

This study demonstrates that applying biochar alongside various nutrient sources significantly enhances the growth parameters of okra. Among the treatments, biochar combined with vermicompost yielded the best results across most growth metrics, including germination time, plant height, leaf count, branch and node numbers, stem girth, days to first flowering, and days to first picking. This was closely followed by biochar combined with cattle urine treatment (Table 2 and Table 3). Sharma et al. (2021) observed an 18.2% increase in knol-khol plant height when biochar was used with vermicompost and a 15.8% increase when used with cattle manure (FYM), findings that align with this study's results. The increase in plant height may be attributed to biochar's capacity to improve soil pH, electrical conductivity (EC), fertility, and nutrient availability, along with its plant growth–promoting characteristics (Acharya et al., 2022). Similarly, Bhandari et al. (2019) found that a higher leaf number in okra treated with poultry manure, followed by vermicompost, which supports the current study's findings. Sarma et al. (2017) also reported increased okra leaf numbers when biochar was combined with vermicompost, consistent with the superior leaf count observed in biochar-vermicompost treatments (BCVC). Stem girth was significantly higher in BCVC treatments at both 45 and 75 DAS (Table 3), consistent with Acharya et al. (2022), who found that combining biochar, vermicompost, and cow urine enhanced stem girth. This improvement can be attributed to biochar's low bulk density, high water retention capacity, and nutrient-retaining properties, which enhance crop performance. Biochar enriched with vermicompost produced a significantly larger number of primary branches compared to other treatments. These findings are consistent with Adhikari & Piya (2020), who observed a similar effect using poultry manure. Additionally, the number of nodes per plant was notably higher in BCVC treatments at 45 and 75 DAS (Table 3). Plots treated with biochar consistently outperformed non-biochar-treated plots across various growth parameters. Ahmed et al. (2017) reported a higher branch and node count in plants treated with biochar and synthetic fertilizer compared to synthetic fertilizer alone. Likewise, Sarma et al. (2017) observed that combining biochar with vermicompost and synthetic fertilizer significantly enhanced plant height and leaf area over two consecutive years. Wu et al. (2019) reported that the application of biochar alongside potash fertilizer in cotton cultivation significantly enhanced the number of effective branches, bolls, and buds compared to the use of potash fertilizer alone. These results illustrate the potential of biochar in improving crop growth and development when used alongside fertilizers. The beneficial effects of biochar arise from its capacity to enhance the physical, chemical, and biological properties of the soil (Murtaza et al., 2021), as well as its capacity to store and gradually release essential nutrients from its porous structure, ensuring their availability to plants when needed (Dahal et al., 2021).

Yield Parameters

The findings of the study reveal that the application of organic nutrient sources along with biochar has a significant influence on the yield parameters and overall productivity of okra. Productivity was notably higher in plots where vermicompost was combined with biochar compared to the control and other treatments (Table 4). This superior performance in growth parameters directly contributed to a higher yield. Yield-related attributes such as fruit length, fruit girth, fruit weight, and the number of fruits per plant were significantly higher under biochar-vermicompost (BCVC) treatments. These results confirm that plants amended with biochar have higher yields as compared to those without biochar. Supporting this, Remigius et al. (2022) found that biochar, when applied with either organic or synthetic fertilizer, resulted in better morphological traits and yield in rice under drip irrigation for two consecutive years. Similarly, Timilsina et al. (2021) observed that combining biochar at 2 mt/ha with mineral fertilizer enhanced cauliflower curd yield compared to using mineral fertilizer alone. The yield enhancement observed with biochar application can be attributed to its capacity to promote nutrient cycling, stabilize soil pH through its liming effect, increase cation exchange capacity (CEC), and improve nutrient and water retention, nutrient use efficiency, and microbial activity (El-Naggar et al., 2019). Acharya et al. (2022), Dahal et al. (2021), and Frimpong et al. (2021) also reported increases in soil pH, nitrogen (N), phosphorus (P), potassium (K), and organic matter (OM) in biochar-amended plots, along with positive correlations between enhanced soil properties and higher crop yields. The porous structure of biochar plays a crucial role in storing and gradually releasing nutrients, thereby reducing nutrient leaching losses (Dahal et al., 2021; El-Naggar et al., 2019). This leads to increased soil fertility and improved crop productivity. Overall, the findings highlight the synergistic advantages of integrating biochar with organic or inorganic fertilizers to achieve better agricultural performance.

Conclusion:

The application of biochar in combination with organic nutrient sources like vermicompost, cattle urine, and mustard cake had enhanced the growth and yield parameters of okra in Puranchour, Kaski, Nepal. The application of Biochar @ 8 ton/ha combined with Vermicompost @ 10 ton/ha resulted in the superior growth parameters showing the highest plant height, number of leaves, number of nodes, and stem girth at 45 and 75 days after sowing, the highest number of branches, early flowering and early fruit picking, whereas the early germination of okra seeds was found when applied with Biochar @ 8 ton/ha along with Cattle urine (1:5). These enhancements in the growth parameters translated into higher yield parameters, including fruit length, girth, number of fruits per plant, individual fruit weight, and overall yield per hectare with the application of Biochar @ 8 ton/ha combined with Vermicompost @ 10 ton/ha. The inferior values for growth and yield parameters were found in the treatment control. The results underscore the synergistic effects of biochar with vermicompost and other organic amendments in improving soil properties, nutrient availability, and plant development. These results underscore the potential of biochar-based integrated nutrient management systems to sustainably boost crop productivity while maximizing resource efficiency. This study supports the integration of biochar with organic fertilizers as a viable strategy to achieve optimal growth and yield outcomes in agricultural systems.

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Declaration of conflict of interest and ethical approval:

The authors declare no conflicts of interest regarding the publication of the manuscript.

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