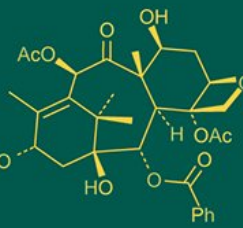
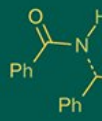


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Effect of biochar application on growth and yield of brinjal (*Solanum melongena* L.) under Bundalkhand Region

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Abstract

Brinjal, (*Solanum melongena* L.) is important vegetable belonging to the Solanaceae family and is one of the key vegetable crops grown extensively in tropical and subtropical regions worldwide. The experiment was carried out during *kharif* season, 2025-26 at Organic Research Farm, Karguanji, Department of Soil Science & Agricultural Chemistry, Institute of Agricultural Sciences, Bundelkhand University, Jhansi, U.P., situated at Jhansi district of Uttar Pradesh (India). The experiment was carried to find out the effect and best treatment among zeolite and SBB application on soil quality and nutrient of brinjal. Different growth, yield and plant branch parameters were recorded during the experiment. The results were found to be significant for all the parameters studied. The growth parameters at 30, 60, 90 DAT were found to be maximum under T₃ 200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB + 15 T/ha Zeolite i.e., plant height, number of branch per plant at 30, 60, 90 DAT, number of leaves per plant at 30, 60, 90 DAT and the grain yield of brinjal. The yield parameters and yield were found to be highest in T₃.

Keywords: Biochar, zeolite, brinjal, *Solanum melongena* L., soil quality, nutrient management, growth parameters, yield, Bundelkhand region, sustainable agriculture

Introduction

Brinjal, scientifically known as "*Solanum melongena*" L., is an important vegetable belonging to the Solanaceae family and is one of the key vegetable crops grown extensively in tropical and subtropical regions worldwide. It is primarily cultivated for its unripe fruits, which are utilized in various culinary dishes, pickling, and the dehydrated food industry. Additionally, brinjals are recognized for their medicinal properties and are particularly rich in vitamin A, making them beneficial for diabetic patients. Although brinjals are technically perennial plants, they are commonly grown as annual crops (Joshi, 2003). The yield of brinjals in Asia averages 34.15 tons per hectare, covering an area of 1,718,049 hectares (FAO, 2022). In Nepal, brinjal cultivation spans 11,292 hectares, with a total production of 149,075 tons and a productivity rate of 13.20 tons per hectare. In the Kaski district of Nepal, brinjals are grown on 125 hectares, yielding 2,136 tons with a productivity of 17.08 tons per hectare (MoALD, 2023). The low productivity of brinjals in Nepal can be attributed to various biotic and abiotic factors, as well as the lack of suitable cultivars. Significant insect pests, such as aphids, brinjal fruit borers, and shoot borers, pose risks to the crop (Gallo *et al.* 1988) [9]. Additionally, environmental stressors like high temperatures, excessive soil humidity, salinity, water stress, and competition from weeds can lead to substantial yield reductions. Borers are known to adversely affect crop yields (Gallo *et al.* 1988). Additionally, factors such as high temperatures, excessive soil humidity, salinity, water stress, and weed competition can lead to significant reductions in yield (Attna *et al.* 2023). The high Si and Al contents in sugarcane bagasse fly ash can be used to synthesize zeolite-type adsorbents for removing heavy metals from wastewater. Especially, zeolite type A gives high heavy metal removals because of its higher surface area with small pore size and high adsorption capacity than other types, so it promotes good adsorption of heavy metals.

(Jangkorn *et al.* 2022) ^[12]. In previous studies, the synthesized zeolite P from bagasse fly ash is used for eliminating lead and cadmium in an aqueous solution (Shah *et al.* 2013) ^[21], and the removal of copper is reported by the study of Oliveira *et al.* by the synthesized zeolite Na-A from sugarcane bagasse fly ash (Oliveria *et al.* 2019). In addition, the synthesized zeolite A from bagasse fly ash and sugarcane waste ash have been used for removing lead and cadmium in wastewater (Jangkorn *et al.* 2022; Fungaro *et al.* 2021) ^[8]. Although zeolites can adsorb with various toxic metals, improving zeolites to increase adsorption capacity with specific target contaminates is continuously interested. The natural zeolite modified with amine is used for remediation hexavalent chromium (Cr (VI)) in an aqueous media, and MEL-type zeolite nanosheet has been applied as a porous material for water purification from landfill leachate comprising PbCl ^[2] and CuCl ^[2] (Nasrollahzadeh *et al.* 2020; Mousavi Khadem *et al.* 2022) ^[15].

Materials and Methods

The pot experiment was conducted at the Organic Research Farm in Kargua ji, within the Department of Soil Science at the Institute of Agricultural Sciences, Bundelkhand University, Jhansi, Uttar Pradesh. The farm is located in the Jhansi district, at a latitude of 25° 31' 07.1" N and a longitude of 78° 33' 47.4"E, with an elevation of 284 meters above mean sea level (MSL). The area features a slope that ranges from gentle to steep (0.5 to 10%) and has low to medium organic carbon content, as well as varying water holding capacities from very low to high. Farming conditions and cropping patterns differ based on soil type, water availability, vegetation, and livestock.

The experiment, which involved six treatment combinations, was designed as a completely randomized design with four replications. The layout included the following treatments: T₀ (Control), T₁ (100 Kg/ha N: 40 Kg/ha P: 40 Kg/ha K + 15 T/ha SBB+15 T/ha Zeolite), T₂ (150 Kg/ha N: 50 Kg/ha P:

50 Kg/ha K + 10 T/ha SBB + 15 T/ha Zeolite), T₃ (200 Kg/ha N: 75 Kg/ha P: 75 Kg/ha K + 5 T/ha SBB + 15 T/ha Zeolite), T₄ (100 Kg/ha N: 50 Kg/ha P: 50 Kg/ha K + 10 T/ha SBB + 15 T/ha Zeolite), and T₅ (150 Kg/ha N: 75 Kg/ha P: 75 Kg/ha K + 15 T/ha SBB + 15 T/ha Zeolite). Various growth and yield parameters were recorded throughout the experimental treatments.

Results and Discussion

The data related to plant height and the number of branches per plant at different growth stages is presented in Tables 1 and 2. The findings indicate a significant impact of N: P: K application alone and in combination with various levels of zeolite and SBB on plant height and the number of branches. At all growth stages—30, 60, 90 days, and at harvest- brinjal plants exhibited the highest plant height and number of branches with the application of T₃ 200 Kg/ha N: 75 Kg/ P: 75 Kg/ K+5T / ha SBB + 15 T/ha Zeolite. This treatment was comparable to T₅ - 150 Kg/ha N: 75 Kg/ P: 75 Kg / K+15T / ha SBB+15 T/ha Zeolite (28.62 cm) but was significantly superior to the other treatments at all stages of growth. In contrast, the control plot showed the lowest plant height and number of branches per plant.

The reason for the increase in vegetative growth may be due to the availability of the necessary nutrients in the chemical fertilizer N, P and K added to the soil close to the root zone, its transfer to the vegetative system and its exploitation in the biological and physiological processes inside the plant such as carbon assimilation, respiration and the processes involved in the synthesis of nuclear acids necessary in the division of cells and new tissues that help the growth of different parts of the plant (Patil *et al.*, 2008 in tomato crop and Alias *et al.*, 2021 in Brinjal crop) ^[2, 20]. Similar finding was observed by Neumann and Laing (2006) ^[17], Shanmugaiah *et al.* (2009) ^[22] in cotton, and Akladios and Abbas (2014) in maize and Doni *et al.* (2014) ^[7] in rice.

Table 1: Effect of Biochar amended Soil application on Plant height (cm) at 30, 60, 90 DAT.

Symbol	Treatment	Plant height (cm)		
30 DAT	60 DAT	90 DAT		
T ₀	Control	25.44	49.16	62.6
T ₁	100 Kg/ha N: 40 Kg/ P: 40 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite	25.56	50.61	64.39
T ₂	150 Kg/ha N: 50 Kg/ P: 50 Kg/ K + 10 T/ ha SBB+ 15 T/ha Zeolite	28.31	56.57	68.9
T ₃	200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB+ 15 T/ha Zeolite	29.19	60.07	74.29
T ₄	100 Kg/ha N: 50 Kg/ P: 50 Kg/ K + 10 T/ ha SBB+ 15 T/ha Zeolite	27.21	56.36	66.75
T ₅	150 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB+ 15 T/ha Zeolite	28.62	58.02	70.67
	S.Em ±	0.129	1.289	1.327
	CD at 5%	0.386	3.859	3.973

In the first observation at 30 DAT the maximum number of branches (6.51 cm) was obtained in the treatment T₃ 200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB+15 T/ha Zeolite, and the treatment T₅ - 150 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite, (5.92 cm) The minimum number of branches was recorded in the treatment T₀ i.e. absolute control (3.88 cm). Similarly at 60 DAT the maximum number of branches (10.24 cm) was obtained in the treatment T₃ i.e. 200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB + 15 T/ha Zeolite which was at par with the

treatment T₅-150Kg / ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite. The minimum number of branches was recorded in the treatment T₀ i.e. absolute control (7.09 cm). At 90 DAT the maximum number of branches (14.75 cm) was obtained in the treatment T₃ i.e. 200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB+15 T/ha Zeolite which was at par with the treatment T₅ - 150 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite. The minimum number of branches was recorded in the treatment absolute control i.e. T₀.

Table 2: Effect of Biochar amended Soil application on Number of branches per plant at 30, 60, 90 DAT

	Treatment	Number of branches per plant		
30 DAT	60 DAT	90 DAT		
T ₀	Control	3.88	7.03	11.56
T ₁	100 Kg/ha N: 40 Kg/ P: 40 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite	4.28	8.12	12.34
T ₂	150 Kg/ha N: 50 Kg/ P: 50 Kg/ K + 10 T/ ha SBB + 15 T/ha Zeolite	5.67	9.16	12.64
T ₃	200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB + 15 T/ha Zeolite	6.51	10.24	14.75
T ₄	100 Kg/ha N: 50 Kg/ P: 50 Kg/ K + 10 T/ ha SBB + 15 T/ha Zeolite	5.28	9.025	12.6125
T ₅	150 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite	5.92	9.31	13.53
	S.Em ±	0.026	0.129	1.144
	CD at 5%	0.077	0.386	0.432

The number of days taken to first flowering after transplanting (DAT) has been presented in Table-3. The data revealed that minimum number of days to first flowering 40.66 days was noted in the T₃ i.e. 200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB + 15 T/ha Zeolite, which was non-significant to rest of the treatments whereas maximum number of days taken first flowering (48.15 days) was recorded in the treatment control. i.e. T₀

This might be due to presence of nitrogen and other inputs like biofertilizers which encouraged earlier flowering. In control, as no fertilizer was applied there the nutrient stress resulted in late flowering. The added nutrient would have improved the physical, chemical and biological properties of

soil which helps in better nutrient absorption and utilization by plant resulting better plant growth and flowering. This might be attributed to certain growth promoting substances secreted by the biofertilizers which in turn might have led to better root development, better transportation of water, uptake and deposition of nutrients. These results are in conformity with the findings of Hangarge *et al.* (2001) ^[10] in chilli, Anburani and Manivannan (2002) ^[3] in brinjal, Chumyani *et al.* (2012) ^[6] in tomato, Vimera *et al.* (2012) ^[24] in king chilli and Chumei *et al.* (2013) ^[5] in brinjal, Jaishwal *et al.* (2019) ^[11] in brinjal, who found improved flowering characters with treatment biochar and zeolite amended soil.

Table 3: Effect of Biochar amended Soil application on Days to 1st flowering.

Symbol	Treatment	Days to 1st flowering
T ₀	Control	48.15
T ₁	100 Kg/ha N: 40 Kg/ P: 40 Kg/ K + 15 T/ ha SBB +15 T/ha Zeolite	44.52
T ₂	150 Kg/ha N: 50 Kg/ P: 50 Kg/ K + 10 T/ ha SBB +15 T/ha Zeolite	42.61
T ₃	200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB +15 T/ha Zeolite	40.66
T ₄	100 Kg/ha N: 50 Kg/ P: 50 Kg/ K + 10 T/ ha SBB +15 T/ha Zeolite	43.68
T ₅	150 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB +15 T/ha Zeolite	41.08
	S.Em ±	1.788
	CD at 5%	5.245

Fruits radical length (cm)

In the first observation at first harvesting the maximum fruit radical length (5.48 cm) was obtained in the treatment T₃ 200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB + 15 T/ha Zeolite, which was at par with the treatment T₅-150 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB+15 T/ha Zeolite. The minimum stem diameter was recorded in the treatment T₀ i.e. absolute control (4.95 cm). In the observation at second harvesting the maximum fruit radical length was obtained in the treatment T₃ 200 Kg/ha N: 75 Kg/ P: 75 Kg / K+5T / ha SBB + 15 T/ha Zeolite, which was at par with the treatment T₅-150 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite and the treatment T₂ i.e. 150 Kg/ha N: 50 Kg/ P: 50 Kg/ K+10T / ha SBB+15 T/ha Zeolite. The

minimum number of fruit radical length was recorded in the treatment T₀ i.e. absolute control.

Higher vegetative growth might have helped in synthesis of greater amount of food material which were later translocated into developing fruits resulting in increased fruit girth (Chumyani *et al.* (2012) ^[6] in tomato and Vimera *et al.* (2012) ^[24]. The increase in plant growth might be associated with secretion of auxin, gibberellins and cytokinin's. The increase in biomatter production may be due to the production of plant growth promoters or through indirect stimulation of nutrient uptake and by producing siderophore or antibiotics to protect plants from deleterious rhizosphere organism (Sundramoorthy and Balabaskar, 2013).

Table 4: Effect of Biochar amended Soil application on Fruits radical length (cm) at 1st Harvesting and 2nd Harvesting.

Symbol	Treatment	Fruits radical length (cm)	
At 1st Harvesting	At 2nd Harvesting		
T ₀	Control	4.63	4.50
T ₁	100 Kg/ha N: 40 Kg/ P: 40 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite	4.83	4.60
T ₂	150 Kg/ha N: 50 Kg/ P: 50 Kg/ K + 10 T/ ha SBB + 15 T/ha Zeolite	5.01	4.70
T ₃	200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB + 15 T/ha Zeolite	5.48	5.40
T ₄	100 Kg/ha N: 50 Kg/ P: 50 Kg/ K + 10 T/ ha SBB + 15 T/ha Zeolite	4.95	4.63
T ₅	150 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite	5.13	5.08
	S.Em ±	0.654	0.726
	CD at 5%	1.054	1.361

Fruits diameter (cm)

The observation on fruits diameter were taken at in at first and second harvesting. The fruit production attained at different stages have been presented in Table-9 the first observation at first harvesting the maximum fruits diameter (4.40 cm) was obtained in the treatment T₃ 200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB + 15 T/ha Zeolite, which was at par with the treatment T₅-150 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite. The minimum fruits

diameter was recorded in the treatment T₀ i.e. control (3.78 cm). In the observation at second harvesting the maximum fruits diameter was obtained in the treatment T₃ 200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB + 15 T/ha Zeolite which was at par with the treatment T₅-150 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite and the treatment T₂ i.e. 150 Kg/ha N: 50 Kg/ P: 50 Kg/ K + 10 T/ ha SBB + 15 T/ha Zeolite. The minimum number of fruits diameter was recorded in the treatment T₀ i.e. control.

Table 5: Effect of Biochar amended Soil application on Fruits diameter (cm) at 1st Harvesting and 2nd Harvesting.

Symbol	Treatment	Fruits diameter (cm)	
At 1st Harvesting	At 2nd Harvesting		
T ₀	Control	3.78	3.57
T ₁	100 Kg/ha N: 40 Kg/ P: 40 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite	3.98	4.15
T ₂	150 Kg/ha N: 50 Kg/ P: 50 Kg/ K + 10 T/ ha SBB + 15 T/ha Zeolite	4.15	4.55
T ₃	200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB + 15 T/ha Zeolite	4.40	4.93
T ₄	100 Kg/ha N: 50 Kg/ P: 50 Kg/ K + 10 T/ ha SBB + 15 T/ha Zeolite	4.13	4.25
T ₅	150 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite S.E.m ±	4.280.235	4.800.254
	CD at 5%	0.852	0.823

Fruit production (gm)

The observation on fruit production were taken at in at first and second harvesting. The fruit production attained at different stages have been presented in Table-8 In the first observation at first harvesting the maximum fruit production (117.65 gm) was obtained in the treatment T₃ 200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB+15 T/ha Zeolite, which was at par with the treatment T₅-150 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite. The minimum fruit production was recorded in the treatment T₀ i.e. control (53.65 gm). In the observation at second harvesting the maximum fruit production was obtained in the treatment T₃ 200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB + 15 T/ha Zeolite which was at par with the treatment T₅-150 Kg/ha N: 75 Kg/ P: 75 Kg/ K+15T / ha SBB + 15 T/ha Zeolite and the treatment T₂ i.e. 150 Kg/ha N: 50 Kg/ P: 50 Kg / K+10T / ha SBB + 15 T/ha Zeolite. The minimum number of fruit

production was recorded in the treatment T₀ i.e. control.

The probable reason for enhanced fruit yield may be due to cumulative effects of nutrients on vegetative growth which ultimately led to more photosynthetic activities while, application of zeolite and nutrient enhanced carbohydrate and nitrogen metabolism of pectic substances, as well as improved the water metabolism and water relation in the plants. Biofertilizer enriched compost in combination with RDF could be a supplementary strategy for increasing yield and for reducing the fertilizer pollution. *Trichoderma* brings multiple benefits which are altogether positively contributes towards soil fertility improvement and ultimately promotes productivity followed by (Singh *et al.*, 2013). These findings are in agreement with the findings of Kashyap *et al.* (2014) ^[13], Umalaxmi *et al.* (2015) ^[23] and Patidar and Bajpai (2018) ^[19] in brinjal crop

Table 6: Effect of Biochar amended Soil application on Fruit production (gm) at 1st Harvesting and 2nd Harvesting.

Symbol	Treatment	Fruit production (gm)	
At 1st Harvesting	At 2nd Harvesting		
T ₀	Control	53.75	108.38
T ₁	100 Kg/ha N: 40 Kg/ P: 40 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite	70.39	118.75
T ₂	150 Kg/ha N: 50 Kg/ P: 50 Kg/ K + 10 T/ ha SBB + 15 T/ha Zeolite	77.50	133.75
T ₃	200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB + 15 T/ha Zeolite	117.65	151.25
T ₄	100 Kg/ha N: 50 Kg/ P: 50 Kg/ K + 10 T/ ha SBB + 15 T/ha Zeolite	72.50	125.23
T ₅	150 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 15 T/ ha SBB + 15 T/ha Zeolite	83.92	136.25
	S.E.m ±	1.665	2.612
	CD at 5%	3.451	4.525

Conclusion

The present investigation was aimed at identifying the best combination of beneficial biochar and zeolite for getting good growth, yield of brinjal crop. This will be helpful in maintaining good soil health for longer time and enhances nutrient availability in soil and ultimately helps in getting better crop yield and physical properties. This is ecofriendly and helps to maintain harmony with nature. Based on the results of the experiment, it can be concluded that: In pot-culture experiment, the treatment combination of T₃ 200 Kg/ha N: 75 Kg/ P: 75 Kg/ K + 5 T/ ha SBB + 15 T/ha Zeolite showed better performance for most of the traits considered followed by T₅ (100 Kg/ha N: 50 Kg/ P: 50

Kg/ K + 10 T/ ha SBB + 15 T/ha Zeolite) and comparatively poor performance was noticed in T₀ (Control).

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