Plant Archives Vol. 25, No. 2, 2025 pp. 2816-2820 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.2.405

EFFECT OF ENRICHED BIOCHAR WITH BIOFERTILIZERS ON GROWTH AND YIELD OF TURMERIC (*CURCUMA LONGA* L.)

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(Date of Receiving-27-07-2025; Date of Acceptance-30-09-2025)

ABSTRACT

A field experiment entitled "Studies on effect of enriched biochar with biofertilizers on growth and yield of turmeric (*Curcuma longa* L.)" was conducted during the *kharif* season of 2024–2025 at the Post Graduate Institute for Horticultural Sciences, Mulugu, Siddipet district, Telangana. The study was laid out in a Randomized Block Design with twelve treatments replicated thrice. Among the treatments, T_6 [Enriched Biochar (3 t ha^{-1}) + 100% RDF + FYM (6 t ha^{-1})] proved significantly superior by recording the highest plant height (101.35 cm), maximum number of tillers per plant (1.53) and maximum fresh yield per hectare (24.42 t ha^{-1}). The treatment T_{10} [EB (3 t ha^{-1}) + VAM (10 kg ha^{-1}) + 100% RDF + FYM (6 t ha^{-1})] recorded the highest number of leaves (19.33) at 150 days after transplanting. The results indicate that enriched biochar in combination with recommended fertilizer dose and FYM significantly enhances growth and productivity of turmeric. Hence, T_6 emerged as the most promising treatment for improving yield potential in turmeric under field conditions.

***Key words*:** Turmeric, Enriched biochar, Biofertilizers, *Duggirala red* variety, RDF

Introduction

Turmeric (*Curcuma longa* L.), known as the "golden spice," is a perennial herb of the family Zingiberaceae, originating from tropical South-East Asia. It is a triploid species (2n=3x=63) cultivated mainly for its rhizomes, which are valued for their colour, flavour, curcumin content, and diverse applications in food, dye, cosmetics, and pharmaceuticals (Rathaur *et al*., 2012; Angles *et al*., 2011; Sahu and Sushila, 2021). Curcumin, the principal bioactive compound, is renowned for antioxidant, anti-inflammatory, antimicrobial, and anti-carcinogenic properties, with therapeutic potential against chronic diseases including cancer, Alzheimer's and diabetes (Negi *et al*., 2018). India, producing nearly 80% of the world's turmeric, is the leading producer, consumer, and exporter, with Telangana as the top-producing state (Priyanka *et al*., 2025). The superior quality of Indian turmeric and increased global demand, especially post COVID-19, have further boosted its significance in international markets (Krishnan and Thirumathi, 2024). Turmeric yield and curcumin content are governed by genetics, environment, soil health and nutrient availability. However, excessive use of synthetic inputs reduces quality, prompting interest in eco-friendly practices.

Biofertilizers such as VAM, phosphorus-solubilizing microorganisms improve nutrient uptake in deficient soils (Mazid and Khan, 2014; Avitoli *et al*., 2012). Likewise, biochar, a carbon-rich, porous material, enhances soil fertility by improving porosity, water-holding capacity, CEC and microbial activity (Sohi *et al*., 2009; Lu *et al*., 2022). It promotes root growth, higher nutrient assimilation and stress tolerance, leading to improved yields (Chen *et al*., 2008; Xiang *et al*., 2017). Integrating enriched biochar with biofertilizers has shown promise in boosting rhizome yield and curcumin quality in turmeric (Sadanandam and Hamza, 1998; Rathinapriya *et al*., 2025). This study was conducted to evaluate the effect of enriched biochar with biofertilizers on growth and yield parameters of turmeric.

Material and Methods

A present investigation was conducted at the Post Graduate Institute for Horticultural Sciences, SKLTGHU, Mulugu, Siddipet District, Telangana during *Kharif* 2024-2025. The experiment was laid out in a complete RBD with 12 treatments and 3 replications. The site is situated at 17°7212 N latitude, 78°6252 E longitude, at 526 m MSL, with subtropical climate and average annual rainfall of 615.6 mm. The treatments used in this experiment are as follows T_1-Vermicompost (5t ha^{-1}) + FYM (6t ha^{-1}); T_2- EB (3t ha^{-1}) + FYM (6t ha^{-1}) ;T_3- VAM (10kg ha^{-1}) + FYM (6t ha^{-1}); T_4-EB (3t ha^{-1}) + Azotobacter (10kg ha^{-1}) + PSB (10kg ha^{-1}) + FYM (6t ha^{-1});T_5-EB (3t ha^{-1}) +50 % RDF+ FYM (6t ha^{-1});T_6- EB (3t ha^{-1}) +100 % RDF+ FYM (6t ha-1);T_7-EB (3t ha^{-1}) + Vermicompost (5t ha^{-1}) +50 % RDF+ FYM (6t ha^{-1});T_8-EB (3t ha^{-1}) + Vermicompost (5t ha^{-1}) +100 % RDF+ FYM (6t ha^{-1});T_9-EB (3t ha^{-1}) + VAM (10kg ha^{-1}) +50 % RDF+FYM (6t ha^{-1});T_{10}- EB (3t ha^{-1}) + VAM (10kg ha^{-1}) +100 % RDF+FYM (6t ha^{-1}); T_{11}-EB (3t ha^{-1}) + Azotobacter (10kg ha^{-1}) + PSB (10kg ha^{-1}) + 50% RDF + FYM (6t ha^{-1});T_{12}- 100 % RDF + FYM (25t ha^{-1}) where EB stands for Jeevamrutham enriched biochar.

The soil was sandy loam, slightly acidic (pH 6.92), EC 0.16 dS m^{-1}, available N 245 kg ha^{-1}, P 47.5 kg ha^{-1}, K 450 kg ha^{-1} and SOC 0.7%. Jeevamrutham-enriched biochar contained 78.1% C, 0.92% N, 0.26% S, 12.1% ash, pH 10.04, bulk density 228.85 kg m^{-3} and water-holding capacity 413.4%.Planting material was sourced from Turmeric Research Station, Kammarapally and biochar from Kanha Shanti Vanam, Hyderabad.

Plant height (cm)

Plant height was measured from the ground level to the tip of the petiole of the uppermost (youngest) leaf. Measurements were taken from five randomly tagged plants plot^{-1} and the mean values were calculated and statistically analyzed at all growth stages. Plant height was expressed in centimetres.

Number of tillers per plant

The total number of tillers produced by each of the five randomly tagged plants was counted at 150 DAT. The average number of tillers plant^{-1} was then calculated and expressed accordingly.

Number of leaves per plant

Fully opened leaves on each of the five randomly selected plants were counted and the mean value of five plants were calculated and expressed in number.

Table 1: Effect of enriched biochar with biofertilizers on plant height (cm), number of tillers per plant and number of leaves per plant of turmeric at 150DAT.

Treatments	Plant height	No. of tillers	No. of leaves
T_1	76.343^{de}	1.21	13.07^{bcd}
T_2	88.88^{abcd}	1.13	11.87^{d}
T_3	70.51^{e}	1.07	11.4^{d}
T_4	80.87^{cde}	1.17	13^{cd}
T_5	77.78^{cde}	1.27	13.4^{bcd}
T_6	101.35^{a}	1.53	18.27^{ab}
T_7	89.5^{abcd}	1.41	15.4^{abcd}
T_8	88.03^{abcd}	1.37	17.2^{abc}
T_9	87.46^{bcd}	1.23	13.8^{bcd}
T_{10}	98.75^{ab}	1.43	19.33^{a}
T_{11}	90.84^{abc}	1.33	14.73^{abcd}
T_{12}	84.76^{cd}	1.31	15.87^{abcd}
SE m	4.10	0.16	1.56
CD at 5%	12.09	N. S	4.60
CV	8.39	21.73	18.25

Fresh rhizome yield per hectare

Fresh rhizome yields from each plot were measured in kilograms using a weighing balance. Based on the gross plot yield, the fresh yield hectare^{-1} was estimated and expressed in tonnes per hectare.

Dry recovery %

A sample of one kilogram of fresh rhizome from each replicated treatment of each plot was weighed and boiled. The boiling process was continued for about 45 to 60 minutes by the time rhizomes become soft and gave a typical odour. The dry weight was recorded after sun drying and processing percentage was worked.

$$\text{Dry recovery (\%)} = \frac{\text{Dry weight of the sample (kg)}}{\text{Fresh weight of the sample (kg)}} \times 100$$

Results and Discussion

The results of the present investigation regarding the response of combination of enriched biochar, biofertilizers,

Plate 1: Biochar.

Plate 2: Experimental plot.

Table 2: Effect of enriched biochar with biofertilizers on fresh yield per hectare and dry recovery percentage of turmeric at harvest.

Treatments	Fresh yield t ha^{-1}	Dry recovery %
T_1	14.37^{c}	22.13^{abc}
T_2	16.15^{c}	22.27^{ab}
T_3	11.03^{d}	21.99^{abc}
T_4	16.14^{c}	21.85^{bc}
T_5	15.87^{c}	22.42^{ab}
T_6	24.42^{a}	20.6^{d}
T_7	21.53^{b}	20.95^{d}
T_8	21.12^{b}	21.85^{bc}
T_9	16.02^{c}	20.9^{d}
T_{10}	22.24^{ab}	21.02^{d}
T_{11}	16.34^{c}	21.35^{cd}
T_{12}	21.01^{b}	22.75^{a}
SE m (±)	0.86	0.26
CD at 5%	2.53	0.76
CV	8.30	2.05

RDF and organic manures on growth and yield of Turmeric have been discussed and interpreted in light of previous research work. The data related to growth and yield parameters were presented in Table 1 and 2 respectively.

Growth parameters

Plant height (cm)

The results showed significant differences among treatments for plant height at 150 DAT The maximum height (101.35 cm) was recorded in T_6 [EB (3 t ha^{-1}) + 100% RDF + FYM (6 t ha^{-1})], which was on par with T_{10} (98.75 cm), T_{11} (90.84 cm), T_7 (89.50 cm), T_2 (88.88 cm), and T_8 (88.03 cm). The minimum height (70.51 cm) was observed in T_3 [VAM (10 kg ha^{-1}) + FYM (6 t ha^{-1})]. The increase in plant height under T_6 may be attributed to the synergistic effect of enriched biochar, FYM, and inorganic fertilizers, which enhance nutrient cycling, microbial activity, water retention, and soil aeration (Lehmann *et al.*, 2011; Agegnehu *et al.*, 2017). EB improves CEC and nutrient retention, while FYM and VC stimulate microbial enzymatic activity, accelerating organic matter decomposition (Kumar *et al.*, 2018). This indicates that EB in combination with VC or FYM can effectively substitute part of the RDF, supplying sufficient nutrients for robust vegetative growth. Similar findings were reported by Archibong *et al.*, (2024), Amala *et al.*, (2019), and Kumar *et al.*, (2022) in turmeric.

Number of tillers plant^{-1}

The number of tillers recorded at 150 DAT did not differ significantly among the treatments. This suggests that tillering in turmeric may be less responsive to soil amendments.

Number of leaves plant^{-1}

The number of leaves per plant at 150 DAT was significantly influenced by treatments. The maximum (19.33) was recorded in T_{10}, which was at par with T_6 (18.27), T_8 (17.20), T_{12} (15.87), T_7 (15.40), and T_{11} (14.73). The minimum (11.40) was observed in T_3. Improved leaf production under T_6 and T_{10} can be linked to increased nutrient availability during the rhizome formation phase, when photosynthetic demand is high. Adequate nitrogen supply promotes protein and chlorophyll synthesis, while EB improves microbial activity and nutrient mobilization (Bailey *et al.*, 2010; Thangarajan *et al.*, 2018). The results also showed that EB combined with VC could reduce RDF dependency up to 50%, emphasizing the role of organic manures in sustaining leaf growth. Poapst *et al.*, (1970) highlighted the hormone-like activity of VC in improving nutrient absorption and metabolism, which supports these findings. Similar results were reported in turmeric by Kumar *et al.*, (2022) and in other crops by Luyima *et al.*, (2019) and Parker *et al.*, (2020).

Yield parameters

Fresh rhizome yield (t ha^{-1})

Significant differences were observed in rhizome yield

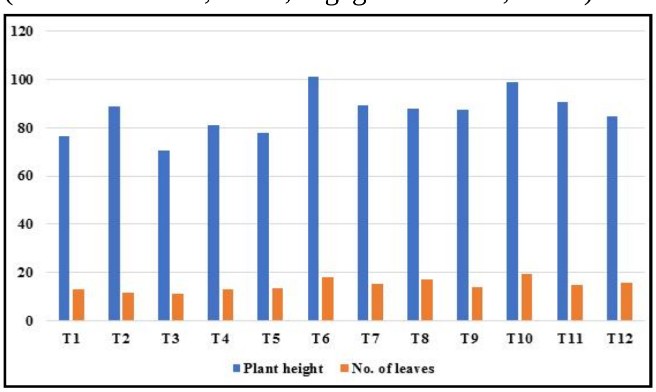

Fig. 1: Effect of enriched biochar with biofertilizers on plant height (cm) and number of leaves.

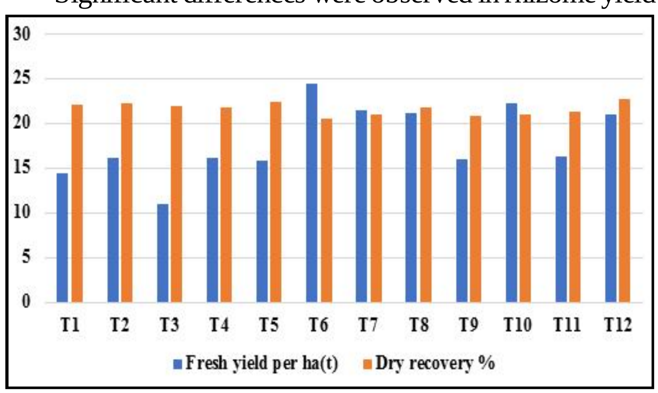

Fig. 2: Effect of enriched biochar with biofertilizers on fresh yield and dry recovery.

per hectare among the treatments. The highest yield (24.42 t ha^{-1}) was obtained in T_6, which was statistically at par with T_{10} (22.24 t ha^{-1}), while the lowest yield (11.03 t ha^{-1}) was in T_3. The superior yield in T_6 and T_{10} can be attributed to balanced nutrient supply from EB, FYM, and fertilizers, improving soil physical, chemical, and biological health. EB retains nutrients through adsorption and CEC, enhances root biomass and nutrient uptake, and regulates the release of N and P (Steiner, 2008; Xiang *et al*., 2017). FYM supplies humic acids that activate enzymes and improve nutrient mobilization (Sugito and Maftuchah, 1995; Gill *et al*., 1999). The increase in plant height, no. of leaves might also play a crucial role in increasing the rhizome yield through source- sink relationship.Similar increases in turmeric yield with integrated nutrient management were reported by Tripura *et al*., (2018), Kumar *et al*., (2022), and Archibong *et al*., (2024).

Dry recovery (%)

Dry recovery percentage differed significantly across treatments. The highest (22.75%) was obtained in T_{12} [100% RDF + FYM (25 t ha^{-1})], which was on par with T_5 (22.42%) and T2 (22.27%). The lowest (20.6%) was recorded in T6. The higher dry recovery in T_{12} may be due to consistent and sufficient nutrient supply from higher FYM and RDF, which improved carbohydrate accumulation and sink development in rhizomes. However, comparable results from T_2 and T_5 indicate that EB combined with organic manures and 50% RDF was effective in enhancing dry matter accumulation. These results emphasize the role of integrated nutrient management in balancing productivity and quality. Similar results were reported in cassava (Yuniwati*et al*., 2018), potato (Karim *et al*., 2020; Srikanth *et al*., 2024), and turmeric (Kumar *et al*., 2022).

Conclusion

The study demonstrated that enriched biochar (EB) had a positive effect on turmeric growth and yield. Treatments with EB recorded higher plant height and number of leaves, indicating better nutrient uptake and soil health. The number of tillers did not vary significantly, but EB supported optimum growth. Maximum fresh rhizome yield per hectare was observed with EB + 100% RDF + FYM, while EB with FYM or vermicompost produced yields comparable to full RDF, reducing fertilizer need by 50%. EB also maintained good dry recovery percentage, proving its role in improving yield and quality for sustainable turmeric production.

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