



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(8): 1251-1254
Received: 11-05-2026
Accepted: 15-06-2026

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Effect of cotton stalk biochar on growth and yield of finger millet (*Eleusine coracana* L.)

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i8p.6411>

Abstract

A field experiment entitled “Effect of cotton stalk biochar on growth and yield of finger millet (*Eleusine coracana* L.)” was conducted during Kharif 2025 at the Agricultural Research Station, Siruguppa, University of Agricultural Sciences, Raichur. The study comprised eleven treatments including absolute control, recommended dose of fertilizers (RDF), Farmyard manure and different levels of cotton stalk biochar with 100 and 75 per cent RDF, laid out in a randomized complete block design with three replications. The results revealed that 100 per cent RDF + 4.0 t ha⁻¹ cotton stalk biochar (T₇) recorded the highest grain yield (3743 kg ha⁻¹) and straw yield (6886 kg ha⁻¹), remaining on par with T₆ (100 per cent RDF + 3.0 t ha⁻¹ cotton stalk biochar). T₇ also recorded superior growth in terms of plant height (106.8 cm) and total dry matter production (38.53 g plant⁻¹), along with higher effective tillers (100.2 m⁻²), finger length (6.2 cm) and ear head weight (6.41 g). Total N, P and K uptake was highest in T₇, while N, P and K use efficiency recorded 69.1, 34.7 and 159.3 per cent, respectively. Post-harvest soil under T₇ recorded higher organic carbon (4.81 g kg⁻¹) and available N, P₂O₅ and K₂O (251.20, 43.44 and 361.34 kg ha⁻¹, respectively). Economically, T₇ recorded the highest gross returns (₹119,186 ha⁻¹), whereas T₆ recorded the highest net returns (₹80,275 ha⁻¹) and B: C ratio (3.19). Hence, integration of RDF with 3–4 t ha⁻¹ cotton stalk biochar improved productivity, nutrient utilization and soil fertility of finger millet.

Keywords: Biochar, finger millet, soil fertility and economics

Introduction

India has emerged as the world's most populous country, increasing pressure on land, water, and soil resources and necessitating higher agricultural productivity without compromising environmental sustainability. Prolonged and excessive use of chemical fertilizers has contributed to soil degradation, nutrient imbalance, depletion of soil organic matter and deterioration of soil quality. Hence, sustainable nutrient management practices involving suitable organic amendments are essential for maintaining soil fertility and crop productivity. India generates about 500 million tonnes of crop residues annually, of which nearly 141 million tonnes are surplus, and a considerable quantity is burned in the field, causing environmental pollution and nutrient losses. Conversion of crop residues into biochar through pyrolysis provides a sustainable alternative for residue management. Biochar is a stable, carbon-rich material that can improve soil structure, water-holding capacity, nutrient retention and microbial activity, besides contributing to carbon sequestration. However, its effectiveness depends on the feedstock, application rate, soil type and crop.

Finger millet (*Eleusine coracana* L.) is an important cereal crop and the third most important millet after sorghum and pearl millet. It is nutritionally rich, particularly in calcium (344 mg 100 g⁻¹), dietary fibre (15–20%) and phenolic compounds (0.3–3%). Globally, finger millet is cultivated over 4.0–4.5 million hectares, producing about 5.0 million tonnes with an average productivity of 1000 kg ha⁻¹. India is the leading producer, with an area of 13.49 lakh hectares, production of 20.07 lakh tonnes and productivity of 1488 kg ha⁻¹ (Anon., 2025a). Karnataka ranks first in area (9.52 lakh hectares) and production (14.39 lakh tonnes), with a productivity of 1512 kg ha⁻¹. Owing to its nutritional importance and adaptability, finger millet is an important crop for food and nutritional security.

Considering the importance of finger millet and the need for sustainable crop residue management and soil fertility improvement, the present investigation entitled “Effect of cotton stalk biochar on growth and yield of finger millet (*Eleusine coracana* L.)” is proposed with specific research objectives.

Materials and Methods

A field experiment to evaluate the effect of cotton stalk biochar on growth and yield of finger millet (*Eleusine coracana* L.) was conducted during Kharif 2025 at the Agricultural Research Station, Siruguppa, University of Agricultural Sciences, Raichur, Karnataka. The site is located in agro-climatic zone III (Northern Dry Zone) at 15°69'N, 76°89'E and 358 m altitude. The experimental soil was classified as deep black Vertisol, alkaline (pH 8.11), low in organic carbon (3.98 g kg⁻¹) and available nitrogen (232 kg ha⁻¹), with medium levels of available phosphorus (38 kg ha⁻¹) and high in available potassium (347 kg ha⁻¹).

The experiment was laid out in a randomized complete block design (RCBD) with eleven treatments and three replications. The treatments comprised T₁: absolute control; T₂: 100% RDF (100:50:50 kg N: P₂O₅: K₂O ha⁻¹); T₃: 100% RDF + FYM @ 7.5 t ha⁻¹; T₄, T₅, T₆ and T₇: 100% RDF + 1.0, 2.0, 3.0 and 4.0 t ha⁻¹ cotton stalk biochar, respectively; and T₈, T₉, T₁₀ and T₁₁: 75% RDF + 1.0, 2.0, 3.0 and 4.0 t ha⁻¹ cotton stalk biochar, respectively. Biochar and FYM were incorporated into the respective treatment plots 30 days before sowing. Finger millet variety HR -13 was sown at a spacing of 30 × 10 cm.

Standard agronomic practices including land preparation, thinning, gap filling, herbicide and fertilizer applications were followed. Growth and yield measurements were recorded at key stages. Soils and plant samples were analyzed for physico-chemical properties using standard protocols. Economic returns and benefit-cost ratio were computed. Data were subjected to ANOVA as per Panse and Sukhatme (1967) [10].

Results and Discussion

The impact of biochar on growth attributes such as Plant height and total dry matter production was recorded at 30, 60 and 90 days after sowing (DAS) and at harvest. Both parameters differed significantly among the treatments and increased progressively with advancement of crop growth. Treatment T₇ recorded the higher plant height and total dry matter production at all the crop growth stages, remaining on par with T₆, whereas the lower values were recorded in the absolute control (T₁).

The superior growth and dry matter accumulation under T₇ could be attributed to the combined effect of the recommended dose of fertilizers and cotton stalk biochar, which improved the soil environment, nutrient availability and retention, thereby promoting better root development, nutrient uptake and photosynthetic activity. In contrast, the lower growth and dry matter production in the absolute control may be due to the absence of external nutrient inputs, resulting in limited nutrient availability and restricted vegetative growth. The present findings are in agreement with Kalyani *et al.* (2016) [8] and Jyothishree (2020) [7].

Yield attributes such as number of effective tillers, number of fingers per ear head, finger length and ear head weight, grain yield and straw yield were significantly improved by biochar and RDF treatments. Grain and straw yields were significantly higher in T₇,

recording 3743 and 6886 kg ha⁻¹, respectively, which were on par with T₆ (3673 and 6806 kg ha⁻¹, respectively). The superior performance of T₇ was attributed to improved nutrient availability and retention under the combined application of RDF and cotton stalk biochar, which enhanced reproductive development and assimilate translocation. The higher yield attributes consequently resulted in greater grain and straw production. These findings were consistent with Yeboah *et al.* (2016) [11] and Badu *et al.* (2019) [5].

Biochar and RDF application significantly enhanced nitrogen, phosphorus and potassium uptake and use efficiency by finger millet. Total N, P and K uptake was significantly higher in T₇. Nutrient use efficiency was higher in T₁₁, which was followed closely by T₇. Higher nutrient uptake was attributed to greater biomass and grain and straw production, while improved nutrient use efficiency resulted from better nutrient retention and availability under biochar. These findings were in agreement with Faloye *et al.* (2019) [6] and Ahmed *et al.* (2014) [12].

Post-harvest soil properties were favourably influenced by cotton stalk biochar application. T₇ recorded the most favourable values for bulk density, water holding capacity, organic carbon, available N, P₂O₅ and K₂O, exchangeable Ca, Mg and available S, and was generally comparable with T₆. The improvement may be attributed to the carbon-rich nature of biochar, which enhanced moisture conservation and nutrient retention in soil. However, soil pH, EC and DTPA-extractable Fe, Mn, Zn and Cu did not differ significantly among treatments. Similar improvements in soil properties following biochar application were reported by Jyothishree (2020) [7] and Adekiya *et al.* (2025) [1].

Microbial population-including bacteria, fungi and actinomycetes-were significantly enhanced in biochar plus RDF treatments, with T₇ showing the higher counts. The increase in soil microbial populations indicates a more favourable soil biological environment, which can enhance nutrient mineralization and support crop growth in agreement with Lehmann *et al.* (2003) [9].

The cost of cultivation increased with higher rates of cotton stalk biochar due to the additional input cost; however, this was compensated by improved crop productivity and higher returns. T₆ recorded the highest net returns (₹80,275 ha⁻¹) and benefit-cost ratio (3.19), while T₇ recorded the highest gross returns (₹119,186 ha⁻¹), indicating that integration of RDF with cotton stalk biochar, particularly at 3.0 t ha⁻¹, was economically advantageous under finger millet cultivation.

Conclusion

Application of cotton stalk biochar along with RDF improved the growth, yield attributes, grain and straw yield, nutrient uptake, nutrient use efficiency, soil fertility and biological properties of finger millet. Among the treatments, T₇ (100% RDF + 4.0 t ha⁻¹ cotton stalk biochar) recorded superior growth, yield attributes, grain and straw yield, NPK uptake and post-harvest soil properties, while T₆ (100% RDF + 3.0 t ha⁻¹ cotton stalk biochar) remained comparable for most of the major parameters. Nutrient use efficiency was higher under T₁₁, followed by T₇, whereas T₆ recorded the higher net returns and B: C ratio. Thus, under the conditions of the present investigation, integration of 100% RDF with 3.0–4.0 t ha⁻¹ cotton stalk biochar was effective in improving finger millet productivity and soil fertility, with 3.0 t ha⁻¹ offering better economic returns.

Table 1: Effect of different treatments on yield and yield attributes of finger millet

Treatments	Finger length (cm)	Weight of ear head (g)	1000 grain weight (g)	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Harvest Index
T ₁	4.6	3.90	2.73	1457	3326	0.30
T ₂	5.0	4.40	2.87	2580	5361	0.32
T ₃	5.4	5.20	3.01	3273	6250	0.34
T ₄	5.3	4.90	2.93	2870	5639	0.34
T ₅	5.3	5.10	2.94	3117	6112	0.34
T ₆	6.1	6.12	3.17	3673	6806	0.35
T ₇	6.2	6.41	3.22	3743	6886	0.35
T ₈	5.2	4.90	2.89	2680	5392	0.33
T ₉	5.3	4.99	2.92	2740	5405	0.34
T ₁₀	5.4	5.15	2.99	3180	6209	0.34
T ₁₁	5.7	5.30	3.02	3343	6270	0.35
S.Em. ±	0.26	0.24	0.09	98	178	0.01
C.D. at 5%	0.76	0.72	NS	288	525	NS

Note:

- Calculated quantity of biochar and farmyard manure (FYM) was incorporated into the respective treatment plots 30 days before the sowing of finger millet
- RDF-Recommended dose of fertilizers (100:50:50 kg N: P₂O₅: K₂O ha⁻¹)

Table 2: Effect of different treatments on available nutrients status of soil

Treatments	Organic carbon (g kg ⁻¹)	Available nutrients (kg ha ⁻¹)		
		Nitrogen	Phosphorus	Potassium
T ₁	3.80	197.58	33.12	281.26
T ₂	3.97	212.48	35.70	309.32
T ₃	4.47	227.98	37.90	324.64
T ₄	4.10	220.72	36.80	318.09
T ₅	4.22	224.62	37.20	321.60
T ₆	4.60	247.38	42.20	356.76
T ₇	4.81	251.20	43.44	361.34
T ₈	4.10	216.95	35.90	313.59
T ₉	4.22	219.63	36.40	316.48
T ₁₀	4.21	226.02	37.80	323.17
T ₁₁	4.67	226.23	40.90	349.13
S. Em. ±	0.19	6.74	1.83	9.76
C.D. at 5%	0.56	19.89	5.40	28.79

Note:

- Calculated quantity of biochar and farmyard manure (FYM) was incorporated into the respective treatment plots 30 days before the sowing of finger millet
- RDF-Recommended dose of fertilizers (100:50:50 kg N: P₂O₅: K₂O ha⁻¹)

Table 3: Effect of different treatments on economics of finger millet

Treatments	Gross returns (₹ ha ⁻¹)	Net returns (₹ ha ⁻¹)	B: C
T ₁	47026	26571	2.30
T ₂	82761	56840	3.19
T ₃	104450	69154	2.96
T ₄	91739	62218	3.11
T ₅	99612	66491	3.01
T ₆	116996	80275	3.19
T ₇	119186	78865	2.96
T ₈	85792	57638	3.05
T ₉	87605	55851	2.76
T ₁₀	101609	66255	2.87
T ₁₁	106560	67606	2.74
S. Em. ±	3010	3010	0.09
C.D. at 5%	8880	8880	0.28

Note:

- Calculated quantity of biochar and farmyard manure (FYM) was incorporated into the respective treatment plots 30 days before the sowing of finger millet RDF-Recommended dose of fertilizers (100:50:50 kg N: P₂O₅: K₂O ha⁻¹)

Acknowledgement

This research was a part of M. Sc. thesis and the author greatly appreciate research facilities and support provided from the College of Agriculture, Raichur for conducting this research study. The author is grateful to members of the advisory committee, major advisor, Dr. Ashok kumar gaddi, Professor, Department of Soil Science, College of Agriculture, Hagari and members Dr. Veeresh H, Professor and Head (Soil Science), College of Agriculture, Raichur. Dr. Ravi S, Senior Scientist, ICAR-KVK, Hagari and Dr. Ajayakumar M.Y, Professor and Head (Agronomy), College of Agriculture, UAS Raichur. For their engrossing guidance, incessant encouragement, constructive suggestions propitious assistance, keen and sustained interest, kind and gracious patronage during the entire course of investigation and preparation of this manuscript.

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