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Economic implications and quality assessment of biochar-enriched potting media: A case study on *Terminalia bellerica* seedlings

Pankaj Sherke, Suresh Ramanan S*, Naresh Kumar, Ashta Gupta and A. Arunachalam

ABSTRACT: *Terminalia bellerica Roxb. is a tall, deciduous, indigenous tree species widely recognized for its medicinal value and is a key ingredient in Triphala, a traditional Ayurvedic formulation that also includes Terminalia chebula and Emblica officinalis. Adapted to specific climatic conditions, it plays an important role in local economies, highlighting its ecological and economic significance in India's forest ecosystems. Among the treatments, conventional media (T1: soil + sand + FYM, 1:1:1) was compared with various biochar-based combinations, particularly T2 (soil + biochar + FYM, 1:1:1). Biochar, known for its low bulk density, porous structure, and nutrient-retention capacity, significantly reduced the filled polybag weight and enhanced water retention. Water retention analysis across all treatments demonstrated the effectiveness of biochar as a sustainable nursery media amendment. The study aimed to evaluate the effect of biochar as a substrate on the growth and development of selected tree species seedlings and to assess the influence of varying biochar proportions on seedling quality parameters.*

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1. INTRODUCTION

Biochar is a stable, carbon-rich material produced through pyrolysis of biomass at temperatures ranging between 450–600°C under limited oxygen conditions (Fascella et al., 2020). Its highly porous structure offers multiple environmental and agronomic benefits, such as enhanced carbon sequestration, mitigation of greenhouse gas emissions, and improved soil health. These improvements occur through increased soil porosity, better nutrient and water retention, elevated microbial activity, and pH regulation (Chrysargyris et al., 2020; Das et al., 2022; Khalid et al., 2020; Sharma et al., 2022; Xing et al., 2022).

Owing to these properties, biochar has gained attention as a sustainable alternative to conventional substrates like peat and vermiculite in agricultural and nursery applications (Natalli et al., 2024; Robert and Braghiroli, 2022). In forestry, it contributes to improved seedling survival, enhanced soil fertility, and wildfire risk reduction through the stabilization of woody residues (Cassel and Nielsen, 2018; Dattappa et al., 2024). Several studies have emphasized its role in soil fertility enhancement (Ayaz et al., 2021; Humnessa et al., 2023; Minhas et al., 2020).

In conventional nursery practices, the standard potting medium often consists of a 1:1:1 ratio of soil, sand, and farmyard manure (FYM). However, large-scale seedling production significantly increases the demand for river-sourced sand, which can lead to cost escalation and ecological degradation of riverine ecosystems. Therefore, there is an urgent need to explore environmentally responsible and economically viable alternatives.

This study aims to investigate the effects of substituting sand with biochar in the standard nursery potting mixture (soil:sand:FYM in 1:1:1 ratio) on the growth and development of Terminalia bellerica seedlings. Specifically, it evaluates biochar's potential to serve as a technically sound and economically beneficial alternative to river sand. The study assesses key seedling growth parameters along with cost implications, aiming to determine the feasibility of integrating biochar into nursery operations without compromising seedling quality.

2. MATERIALS AND METHODS

The study, conducted from October 2024 to May 2025 at ICAR-CAFRI, Jhansi (semi-arid, 211 msl), evaluated the impact of seven potting media on *Terminalia bellerica* seedling growth using different combinations of soil, FYM, sand, and biochar. Treatments included T1 (Soil: Sand: FYM), T2-T4 (Soil: Biochar: FYM in varying ratios), T5 (Soil: FYM), T6 (Soil only), and T7 (Biochar only), each replicated thrice with 15 seedlings. Seedlings were raised in polybags, and their dry and wet weights were recorded electronically.

Suresh Ramanan S
suresh.s@icar.org.in; sureshramanan01@gmail.com

ICAR-Central Agroforestry Research Institute, Jhansi 284003, Uttar Pradesh

3. RESULTs AND DISCUSSION

Effect of Biochar on Seedling Growth Attributes

The application of biochar-enriched potting media (T2) had a pronounced positive impact on the growth and development of Terminalia bellerica seedlings. Among the seven treatments tested (T1–T7), T2 demonstrated superior performance across several key morphological and physiological parameters.

T2 produced the highest root length (132.5 cm), fresh root weight (1.31 g), and dry root weight (0.52 g), suggesting robust belowground development. The root-to-shoot (R:S) ratio in T4 was 0.60, indicating a balanced and stress-resilient seedling architecture. While collar diameter remained statistically similar across treatments, shoot traits such as shoot length (13.3 cm) and number of leaves (10.2) were also notably improved in T2, second only to T6 (16.4 cm and 11.0 leaves, respectively).

Biomass analysis reinforced the effectiveness of T2, which recorded the highest seedling quality (SQ = 45.02), although its seedling quality index (SQI = 0.02) was lower compared to T4 (0.12) and T6 (0.10), which showed better biomass balance. T3, while exhibiting lower shoot traits and water retention, had lower root development and a lower R:S ratio (0.31), indicating potential limitations under stress conditions. Treatments T1, T6, and T7 were intermediate in performance, whereas T5 consistently exhibited poor shoot and root attributes.

These results confirm that substituting river sand with biochar in the conventional soil:sand:FYM (1:1:1) mix significantly improves seedling vigor, particularly by enhancing root architecture, biomass accumulation, and potentially field establishment capacity.

Water Holding Capacity

Water holding capacity, an important determinant of media efficiency, varied significantly across treatments. T6 showed the highest retention (92.77%), which can be attributed to favorable structural properties, likely from a high organic component or soil composition. T2 exhibited moderate water retention (59.09%), which was substantially higher than the conventional mix T1 (21.6%). This suggests that biochar enhances moisture availability, reducing irrigation frequency and potentially improving survival under field stress. The 71.17% difference between T6 and T4 emphasizes the critical role of media composition in influencing substrate water dynamics.

Economic Implication of Biochar Substitution

In addition to technical advantages, T2 also delivered significant economic benefits, particularly in transportation logistics. A cost comparison was conducted for raising 1 lakh seedlings and transporting them to a plantation site located 50 km from the nursery. T1 (conventional mix: soil:sand:FYM) was used as the baseline.

Due to biochar's lower bulk density, the total weight of polybags in T2 was reduced to 59 tons, compared to 79 tons in T1. This reduction translated to substantial savings across multiple cost components:

Table 1. Growth attributes of *Terminalia bellerica* Roxb. seedling in 45 days after transplanting

Treatment	CD	No. of	SL	RL	Shoot and root biomass				R:S	SQ	SQI
	(mm)	leaves	(cm)	(cm)	SFW	RFW	SDW	RDW	ratio		
T1	3.30±	7.8±	12.72±	99.5±	3.13±	0.84±	0.86±	0.30±	0.35±	35.78±	0.03±
	0.36^{a}	1.92^{cd}	2.55^{bc}	27.4^{ab}	0.60^{ab}	0.38^{a}	0.20^{abc}	0.15^{ab}	0.40	10.6^{ab}	0.01^{b}
T2	3.41±	10.2±	13.30±	132.5±	3.73±	1.31±	1.18±	0.52±	0.44±	45.02±	0.02±
	0.46^{a}	0.84^{ab}	1.08^{ab}	4.1^{a}	0.15^{a}	0.43^{b}	0.07^{ab}	0.14^{a}	0.46	10.5^{a}	0.01^{b}
T3	2.86±	8.0±	9.64±	88.3±	2.84±	0.69±	0.76±	0.24±	0.31±	31.48±	0.02±
	0.59^{a}	3.00^{bcd}	2.88^{c}	34.9^{ab}	1.13^{ab}	0.40^{b}	0.34^{bc}	0.14^{b}	0.37	9.0^{ab}	0.01^{b}
T4	1.98±	9.7±	13.03±	80.4±	3.08±	0.85±	0.66±	0.40±	0.60±	22.55±	0.12±
	1.82^{a}	2.31^{abc}	2.11^{abc}	59.6^{a}	0.36^{ab}	0.28^{b}	0.49^{abc}	0.10^{ab}	0.19	26.1^{ab}	0.08^{a}
T5	3.37±	6.6±	11.66±	52.3±	2.32±	0.82±	0.64±	0.25±	0.39±	20.17±	0.04±
	0.60^{a}	0.55^{d}	1.68^{bc}	11.4^{b}	0.35^{b}	0.04^{ab}	0.14^{c}	0.04^{b}	0.27	4.3^{b}	0.00^{ab}
T6	2.08±	11.0±	16.40±	66.7±	4.07±	0.78±	0.88±	0.37±	0.42±	19.93±	0.10±
	1.90^{a}	1.00^{a}	0.50^{a}	48.8^{ab}	0.39^{a}	0.34^{ab}	0.64^{a}	0.14^{ab}	0.36	22.8^{b}	0.10^{ab}
T7	2.35±	8.0±	10.79±	110.7±	2.39±	0.88±	0.64±	0.34±	0.53±	36.52±	0.02±
	1.35^{a}	0.00^{bcd}	1.45^{bc}	31.2^{a}	0.33^{b}	0.13^{c}	0.09^{c}	0.04^{ab}	0.21	7.8ab	0.03b

Note: Treatment with the same letters is not significantly different according to the LSD test;

± indicates the standard error of the mean

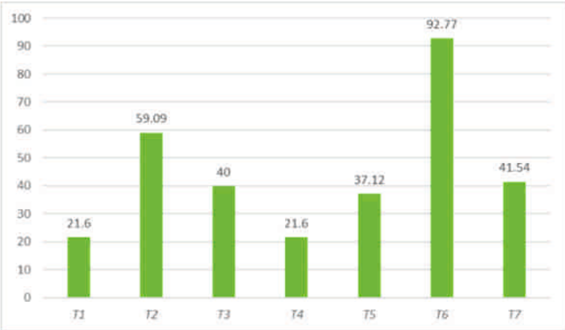

Fig 1. Water holding capacity in treatment (T_1 to T_7)

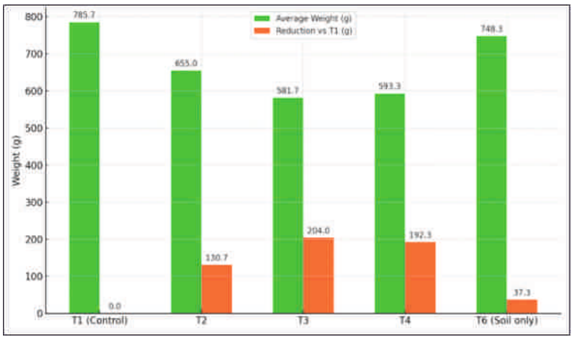

Fig 2. Comparison of effect of biochar on polybag weight

Table 2. Economic analysis of transportation cost in T1 and T2

Category	T1 (Soil+ sand+ FYM) (1:1:1)	T2 (Soil+ biochar+ FYM) (1:1:1)
Total weight (in tons)	79	59
Distance (km)	50	50
Rate (per tons)	₹1250	₹1250
Freight cost	₹98750	₹73750
Loading cost	₹7900	₹5900
Fuel charge (liter)	(112) ₹9832	(81) ₹7213
Total cost	₹124482	₹94863

Thus, T2 reduced the total transportation cost by ₹29,619, representing a 23.8% cost reduction. These savings primarily resulted from the lighter load, which lowered freight, fuel consumption, and loading effort.

Synthesis and Implications

Integrating biochar as a partial substitute for river sand in potting media not only improves seedling physiological performance but also yields measurable economic benefits in large-scale nursery operations. Beyond immediate cost savings, reducing reliance on river sand has significant ecological advantages, helping to mitigate riverbed degradation and pressure from sand mining.

These findings underscore biochar's potential as a technically sound, cost-effective component in sustainable forestry practices. Future research should examine the long-term field performance of seedlings raised in biochar-enriched media, optimize application rates, and explore synergies with other organic amendments across varied agro-climatic zones.

4. CONCLUSION

This study, conducted at ICAR-CAFRI, Jhansi, under semi-arid conditions, assessed the impact of different potting media on *Terminalia bellerica* Roxb. seedlings. The biochar-enriched treatment T2 (Soil: Biochar: FYM at 1:1:1) emerged as the most effective, offering superior root development, balanced growth, and the highest root-to-shoot ratio—critical for field survival. While T6 showed maximum shoot growth and water retention, its limited root development made it less balanced, whereas T4 recorded the highest seedling quality index (SQI), indicating efficient biomass distribution. Economically, biochar's low bulk density reduced media weight by 25.32%, resulting in transport cost savings of ₹29,619 and lowering fuel and labor requirements. Water holding capacity varied across treatments, with T6 achieving the highest retention at 92.77%, while T2 (59.09%) maintained sufficient levels to support healthy growth; in contrast, conventional treatments like T1 and T4 showed poor moisture retention. Overall, incorporating 20-25% biochar proved optimal for enhancing growth, resource efficiency, and cost savings, establishing its value as a sustainable, lightweight, and climate-resilient potting medium for large-scale nursery use

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REFERENCES

Ayaz, M., Feizienė, D., Tilvikienė, V., Akhtar, K., Stulpinaitė, U., & Iqbal, R. (2021). Biochar Role in the Sustainability of Agriculture and Environment. Sustainability, 13(3), 1330. https://doi.org/10.3390/su13031330.

Cassel, D. K., & Nielsen, D. R. (2018). Field Capacity and Available Water Capacity. In A. Klute (Ed.), SSSA Book Series (pp. 901–926). Soil Science Society of America, American Society of Agronomy. https://doi.org/10.2136/sssabookser 5.1.2ed.c36.

Chrysargyris, A., Xylia, P., Akinci, G., Moustakas, K., & Tzortzakis, N. (2020). Printed Paper Waste as an Alternative Growing Medium Component to Produce Brassica Seedlings under Nursery Conditions. Sustainability, 12(15), 5992. https://doi.org/10.3390/su12155992.

Das, S. K., Ghosh, G. K., & Avasthe, R. (2022). Biochar and organic manures on produce quality, energy budgeting, and soil health in maize-black gram system. Arabian Journal of Geosciences, 15(18), 1527. https://doi.org/10.1007/s12517-022-10790-3.

Dattappa, Rachana, B L, C., P L, R., Ali, S., & C M, A. (2024). Biochar: A Green Revolution in Forestry. Vigyan Varta an International E-Magazine for Science Enthusiasts, Vol. 5, (Issue 11).

Fascella, G., Mammano, M. M., D'Angiolillo, F., Pannico, A., & Rouphael, Y. (2020). Coniferous wood biochar as substrate component of two containerized Lavender species: Effects on morpho-physiological traits and nutrients partitioning. Scientia Horticulturae, 267, 109356. https://doi.org/10.1016/j.scienta.2020.109356.

Humnessa, T., Zebena, A., & Derero, A. (2023). Effect of Poultry Manure and its Biochar on Seedling Vigor of Selected Multipurpose Tree Species. Journal of Forest Research, 12(335).

Khalid, S., Shahid, M., Murtaza, B., Bibi, I., Natasha, Asif Naeem, M., & Niazi, N. K. (2020). A critical review of different factors governing the fate of pesticides in soil under biochar application. Science of The Total Environment, 711, 134645. https://doi.org/10.1016/j.scitotenv.2019.134645.

Minhas, W. A., Hussain, M., Mehboob, N., Nawaz, A., UL-Allah, S., Rizwan, M. S., & Hassan, Z. (2020). Synergetic use of biochar and synthetic nitrogen and phosphorus fertilizers to improves maize productivity and nutrient retention in loamy soil. Journal of Plant Nutrition, 43(9), 1356–1368. https://doi.org/10.1080/01904167.2020.1729804.

Natalli, L. H., Hillig, E., Lombardi, K. C., Godinho, M., & Nuñez, R. P. (2024). Use of biochar as a component of substrates in horticulture and forestry: A review. Revista Brasileira de Ciência Do Solo, 48, e0240027. https://doi.org/10.36783/18069657rbcs20240027.

Robert, É., & Braghiroli, F. L. (2022). Development of a Biochar-Based Substrate Added with Nitrogen from a Mining Effluent for the Production of Picea mariana Seedlings. Clean Technologies, 4(3), 770–784. https://doi.org/10.3390/cleantechnol4030047.

Sharma, S., Rana, V. S., Rana, N., Prasad, H., Sharma, U., & Patiyal, V. (2022). Biochar from fruit crops waste and its potential impact on fruit crops. Scientia Horticulturae, 299, 111052. https://doi.org/10.1016/j.scienta.2022.111052.

Xing, Y., Tan, S., Liu, S., Xu, S., Wan, W., Huang, Q., & Chen, W. (2022). Effective immobilization of heavy metals via reactive barrier by rhizosphere bacteria and their biofilms. Environmental Research, 207, 112080. https://doi.org/10.1016/j.envres.2021.112080.