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Evaluation of cotton stalk-derived biochar as a potential carrier for microbial inoculants

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ABSTRACT

The study was conducted to explore the feasibility of utilizing biochar produced from cotton stalks as a carrier medium in preparing biofertilizer formulations, focusing primarily on studying its physicochemical attributes suitable as carrier material. The biochar was synthesized through pyrolysis in heap method and evaluated for characteristics vital to supporting microbial life and suitability for agricultural use. Analytical results of cotton stalk biochar revealed an alkaline pH of 8.8 and electrical conductivity (EC) of 2.9 dSm^{-1}. Nutrient profiling indicated a substantial presence of essential elements, notably nitrogen, phosphorus, potassium and carbon. The biochar also exhibited notably high water holding capacity (129.96%), suggesting that it can effectively support microbial viability. These results indicate the potentiality of this biochar in enhancing biofertilizer efficacy and contributing to environmentally sustainable agriculture.

Keywords: *Biochar, Carrier Material, Microbial Inoculants and Sustainable Agriculture*

The product obtained from the pyrolysis of biomass is known as biochar which is rich source of carbon (Dang *et al*., 2023). Its highly porous structure, enriched nutrient content and strong water and nutrient retention capabilities make it conducive for microbial habitation and proliferation. The adsorptive and porous properties of biochar enhance the immobilization and protection of plant growth-promoting rhizobacteria (PGPR), ultimately improving plant vigor and productivity (Ajeng *et al*., 2020).

Biochar has unique properties, such as enriched organic carbon content and high porosity, make it as an effective carrier for microbial inoculants, enhancing microbial survival and plant growth. Its application has been shown to improve microbial colonization, viability, and persistence in both soil and rhizosphere environments (Bolan *et al*., 2023). Combining cotton stalk biochar (CSB) with *Bacillus* based biofertilizer enhances root growth and antioxidant enzyme activity in cotton under cadmium induced stress (Zhu *et al*., 2022). Among the commonly used carrier materials, peat was recognized for its favorable attributes; however, its limited availability restricts its widespread application.

This study addresses this limitation by evaluating cotton stalk derived biochar as carrier material against peat as cotton stalk is available in plenty and it is getting wasted by the farmers by burning it in the field itself. This investigation aims to determine its key physicochemical characteristics and assess its compatibility with microbial inoculants. Insights from this work could address the development of improved biofertilizer formulations with extended shelf life and better field performance, supporting sustainable agricultural practices.

MATERIAL AND METHODS

This study was executed at Agricultural Research Station, Amaravathi and Department of Soil Science, RARS, Lam, Guntur, Acharya N.G. Ranga Agricultural University. Biochar was produced through pyrolysis using heap method under slow pyrolytic conditions at temperatures ranging from 350°C to 400°C. The cotton stalks were tightly packed into a heap and plastered with cow dung and clay leaving a small vent to introduce a burning log into the heap. Once sealed with mud to create an anaerobic environment, combustion was initiated through putting a burning wood into the heap through vent and completely made air proof. The cotton stalks were pyrolyzed into biochar (International Biochar Initiative, 2015). The resultant biochar was collected, powdered, sieved (2 mm) and characterized for different properties. pH and EC were measured using standard protocols involving a 1:20 (w/v) biochar-water suspension (http://www.biochar-international.org/characterizationstandard) and appropriate instrumentation (Jackson, 1973), while bulk density and Water holding capacity were determined through Keen's cup method (Keen and Raczkowski, 1921) and nutrient analysis was carried for total nitrogen which was estimated by Kjeldahl method (Chopra and Kanwar, 1976). Phosphorus (P) was determined in the diacid digest by vanadomolybdo-phosphoric yellow color method (Piper, 1966). Potassium (K) was quantified through flame photometry post-digestion (Piper, 1966). Total carbon (C) was measured using dry combustion at 950°C (Nelson and Sommers, 1982) and calcium and magnesium were determined by EDTA titration method (Derderian, 1961).

RESULTS AND DISCUSSION

Cotton derived biochar was characterized for physical, physicochemical and chemical properties and the data is presented in Table1**.**

Physical Properties of Biochar

Low bulk density of biochar (0.53 gcm^{-3}) obtained during the study indicates its lightweight, ease of handling, transportation and uniform mixing with inoculant formulations. A high water holding capacity of 129.96% indicates that it can maintain adequate moisture levels to support microbial life during storage (Gul *et al*., 2015). These attributes make cotton stalk biochar a promising carrier for the development of microbial products for agriculture.

Physico-chemical Properties of Biochar

The biochar exhibited an alkaline pH of 8.8, attributed to the deprotonation of functional groups such as carboxylates and hydroxyls present on its surface, leading to the generation of conjugate bases that raise pH levels (Tag *et al*., 2016). The EC of biochar was 2.9 dSm^{-1} and it is likely due to the accumulation of soluble cations including Kz , Mg^{2}z and Ca^{2}z , which supports its suitability for microbial applications without posing salinity stress (Dias *et al*., 2010). Total carbon content of cotton stalk derived biochar was 75.67%.

Chemical Properties of Biochar

The cotton stalk biochar analyzed in this study contained 3.6% nitrogen, 2.1 g kg^{-1} of phosphorus and 14.3 g kg^{-1} of potassium (Table 1). The nutrient-rich characteristics make it a favorable substrate for microbial inoculant formulations.

The relatively high nutrient levels are likely due to thermal degradation and the concentration of mineral elements during the slow pyrolysis process. Similar findings were reported by earlier studies where biochar retained and concentrated essential nutrients,

Table 1. Physical, physicochemical and chemical properties of CSB

S.No	Characters	CSB values
1	pH	8.8
2	EC (dS m^{-1})	2.9
3	Nitrogen (%)	3.6
4	Phosphorous (g kg^{-1})	2.1
5	Potassium (g kg^{-1})	14.3
6	Calcium (g kg^{-1})	4.4
7	Magnesium (g kg^{-1})	0.61
8	Total carbon (%)	75.67
9	C:N	64.13
10	Bulk density (mg m^{-3})	0.53
11	Water holding capacity (%)	129.96
12	Moisture content (%)	7.46

enhancing its value for agricultural applications (Bera *et al*., 2018).

The use of biochar as a carrier of microbial inoculant has been shown to enhance the persistence, survival and colonization of inoculated microbes in soil and plant roots, which play a crucial role in soil biochemical processes, nutrient and carbon cycling (Bolan *et al*., 2023). The characters of biochar that favour microbial habitation include vast amounts of organic carbon, nutrients including N, P, K, increased porosity and high water-holding capacity (Wu *et al*., 2021). Microorganisms in formulations with biochar increased the survival and thus, improve microbial integration and proliferation in the soil and rhizosphere (Azeem *et al*., 2021).

CONCLUSION

This study reveals that cotton stalk derived biochar possesses desirable characteristics such as, high carbon content, alkaline pH and superior moisture retention, making it a promising carrier material for microbial inoculants. Its lightweight and nutrient profile provides a supportive matrix for the survival and functionality of beneficial microbes in biofertilizer applications. These qualities suggest that cotton stalk biochar can be a cost effective and sustainable alternative to conventional carriers like peat, especially in regions where peat is scarce. Adoption of such carrier materials could pay a way for the development of efficient, shelf-stable biofertilizers that align with the goals of sustainable and environmentally conscious agriculture.

LITERATURE CITED

Ajeng A A, Abdullah R, Ling T C, Ismail S, Lau B F, Ong H C, Chew K W, Show P L and Chang J S 2020. Bioformulation of biochar as a potential inoculant carrier for sustainable agriculture. *Environmental Technology and Innovation*. 20: 101168.

Azeem M, Hassan T U, Tahir M I, Ali A, Jeyasundar P G S A, Hussain Q, Bashir S, Mehmood S and Zhang Z 2021. Tea leaves biochar as a carrier of *Bacillus cereus* improves the soil function and crop productivity. *Applied Soil Ecology*. 157: 103732.

Bera T, Purakayastha T J, Patra A K and Datta S C 2018. Comparative analysis of physicochemical, nutrient and spectral properties of agricultural residue biochars as influenced by pyrolysis temperatures. *Journal of Material Cycles and Waste Management*. 20(3): 1115-1127.

Bolan S, Hou D, Wang L, Hale L, Egamberdieva, D, Tammeorg P, Li R, Wang B, Xu J, Wang T and Sun H 2023. The potential of biochar as a microbial carrier for agricultural and environmental applications. *Science of the Total Environment*. 886: 163968.

Chopra S L and Kanwar J S 1976. Analytical agricultural chemistry. Kalyani Publishers, New Delhi. *Journal of Tropical Forest Science*. 6(4): 408-42.

Dang Y, Wang H, Li X, Zhang J and Liu Y 2023. Comprehensive review on recent production trends and applications of biochar for greener environment. *Science of the Total Environment*. 876: 162594.

Derderian M D 1961. Determination of calcium and magnesium in plant material with EDTA. *Analytical Chemistry*. 33(12): 1796-1798

Dias B O, Silva C A, Higashikawa F S, Roig A and Sanchez-Monedero M A 2010. Use of biochar as bulking agent for the composting of poultry manure: effect on organic matter degradation and nitrogen conservation. *Bioresource Technology*. 101(4): 1239-1246.

Gul S and Whalen J K 2015. Physico-chemical properties and microbial responses in biochar-amended soils: mechanisms and future directions. *Agriculture, Ecosystems and Environment*. 206: 46-59.

International Biochar Initiative 2015. *Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil*. Version 2.1. International Biochar Initiative. 11.

Jackson M L 1973. *Soil chemical analysis.* Oxford Indian book house publishing house, Bombay. 38.

Keen B A and Raczkowski H 1921. The relation between the clay content and certain physical properties of a soil. *The Journal of Agricultural Science*. 11(4): 441-449.

Nelson D W and Sommers L E 1982. Total carbon, organic carbon and organic matter. Methods of soil analysis: Part 2 *Chemical and microbiological properties*. 9: 539-579.

Piper C S 1966. *Soil and plant analysis*. Hans Publishers, Bombay. 137-153.

Tag A, Wang H, Zhang X and Zhang S 2016. Physico-chemical properties and microbial responses in biochar-amended soils: mechanisms and future directions. *Agriculture, Ecosystems and Environment*. 206: 46-59.

Wu W, Zhang X, Zhang H, Wang X and Zhang S 2021. Association of biochar properties with changes in soil bacterial, fungal and fauna communities and nutrient cycling processes. *Biochar*. 3(2): 239-254.

Zhu Y, Lv X, Li T, Zhong M, Song J, Wang H and Cui J 2022. Cotton straw biochar and compound *Bacillus* biofertilizer reduce Cadmium stress on cotton root growth by regulating root exudates and antioxidant enzymes system. *Frontiers in Plant Science*. 13: 1051935.

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