DOI : 10.58993/ijh/2024.81.3.14

Indian J. Hortic. 81(3), September 2024: 307-312

Effect of biochar on soil physical properties and growth parameters of ginger cv. Karthika

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ABSTRACT

A field study was undertaken to compare the effectiveness of paddy husk biochar (PHB) and coconut frond biochar (CFB) on soil physical properties and growth and productivity of the dual-purpose ginger variety Karthika. Three different rates of PHB and CFB at 10, 20 and 30 t ha^{-1} along with NPK as per KAU package of practices (POP) recommendation (KAU, 2016) (30 t FYM + 75: 50: 50 kg NPK ha^{-1}), KAU POP alone and absolute control were applied to a sandy soil. Characterization of biochar revealed that specific surface area (68.74 and 2.56 m^2 g^{-1}, respectively) and water holding capacity (276.33 and 256.51%, respectively) were higher for PHB compared to CFB, whereas bulk density was lower for PHB (0.27 mg m^{-3}) compared to CFB (0.35 mg m^{-3}). The physical properties of the soil were significantly improved by the application of the biochars compared to FYM as per KAU POP. The highest ginger yield was obtained for PHB @ 30 t ha^{-1} (12,858.3 kg ha^{-1}), which was at par with CFB @ 30 t ha^{-1} (12,675.0 kg ha^{-1}). From the investigations, it can be concluded that applying PHB or CFB @ 30 or 20 t ha^{-1} along with NPK as per KAU POP produces a significantly higher yield than the recommended dose of FYM as per KAU POP, hence can be regarded as an economically feasible option for sandy soil.

Key words: Scanning electron microscopy, water holding capacity, bulk density, water stable aggregates, yield.

INTRODUCTION

Ginger is one of the most widely used spices and healing agents in the world and is traded internationally as an export and import product. The productivity improvement of ginger can be achieved by suitable soil fertilisation, as demonstrated by the positive impact on the growth and quality parameters of ginger (Seyie *et al.* 16).

Soil nutrient deficit due to runoff and drainage is a key factor for a drop in soil fertility. Use of inorganic fertilisers alone necessitates their frequent addition due to low use efficiency. Biochar is a compound of stable carbon produced by the thermal decomposition of feedstock under little or no oxygen by pyrolysis reaction and has the potential to improve conventional agricultural productivity (Lehmann, 8). There are a number of reports about the nutrient retention capacity of biochar, which might be due to its porous structure, variable charge and high surface area (Liang *et al.*, 9), which facilitates greater microbial colonisation and adsorption reactions (Wyn *et al.*, 17). By generating channels and spaces in the soil for water and air, biochar has been shown to increase soil porosity, which in turn promotes plant nutrient uptake and overall crop yield (Lu *et al.*, 10). According to Rubin *et al.* (15) the high cation exchange capacity of biochar enables it to bind to nutrients and stop leaching loss of nutrients. Several studies on the general benefits of biochar and integrated nutrient management are available; however, there needs to be more comprehensive studies focusing on its crop-specific responses, especially in the context of ginger cultivation in Entisols. Accounting for all the benefits of farm yard manure (FYM) and biochar, the current research was planned to compare the effects of biochar produced from paddy husk and coconut frond at different rates along with N, P and K and Kerala Agricultural University Package of Practices (KAU POP) treatment on the crop growth of ginger in an Entisol.

MATERIALS AND METHODS

A field experiment was conducted to compare the effect of biochar and FYM application using ginger as the test crop in a sandy soil at Thiruvananthapuram, Kerala. The experimental site was situated at 8°28′48″ North latitude and 76°55′12″ East longitude at an altitude of 4 m above MSL. For this study, biochars produced by the method of slow pyrolysis from paddy husk and coconut frond using a double barrel micro biochar kiln were used. The microbiochar kiln designed at the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani (Nagula, 11) for the production of tender coconut husk biochar was adopted with necessary modifications, for the conversion of rice husk and

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coconut frond to biochar. Composite sample each from paddy husk and coconut frond biochars were collected for determining the specific surface area using the N2-BET method (Micrometrics, Tristar 3020) and surface morphology using scanning electron microscopy (SEM, JEOL JSM-7600F).

Field experiment using ginger was conducted in sandy soil in raised beds of height 25 cm and 3m × 1m size. Three blocks with eight plots each were laid out in randomized block design. The treatments included KAU POP alone (30 t FYM + 75: 50: 50 kg NPK ha^{-1} (KAU POP, 7), paddy husk biochar (PHB) and coconut frond biochar (CFB) each @ 10, 20 and 30 t ha^{-1} + NPK as per KAU POP and absolute control. Single bud sprout transplanting technique was practiced for planting and the cultivar used was the dual-purpose variety Karthika. Mulching of beds was done with coconut leaves immediately after transplanting. Harvesting was done at eight months after transplanting when the leaves started to show partial yellowing.

Observations on plant height, were recorded at 60 and 120 days of crop and also at harvest. Rhizome spread, and ginger yield were recorded at harvesting stage. Soil samples were collected from all the treatment plots before planting, 60 and 120 days of crop and also at harvest. BD of biochar and soil was determined using the method of Piper (12). Keen–Raczkowski Box method was used for determination of water holding capacity. Based on the procedure explained by Cochran and Cox (5) the data obtained from different observations were subjected to statistical analyses. Treatment significance was tested using F-test in ANOVA and CD values were calculated for the treatments which were found significant.

RESULTS AND DISCUSSION

Fig. 1 depicts scanning electron microscopy (SEM) images of paddy husk and coconut frond biochars produced at various spatial resolutions and magnifications to study the surface morphology. The SEM micrographs displayed a highly disordered and complex morphology with longitudinal channels and pores in both PHB and CFB. The high content of volatile matter in feedstock leads to the formation of pores in biochar (Elangovan, 6).

Bulk density (BD) of biochar (Table 1) varied with the feedstock used; lower BD was recorded for PHB (0.27 mg m^{-3}) compared to coconut frond biochar CFB (0.35 mg m^{-3}). The lower values of BD of biochar compared to the BD of soil (1.57 mg m^{-3}) (Table 2) explain its capability to decrease the soil bulk density and improve the soil porosity, thus having the potential to hold more water when applied to soils

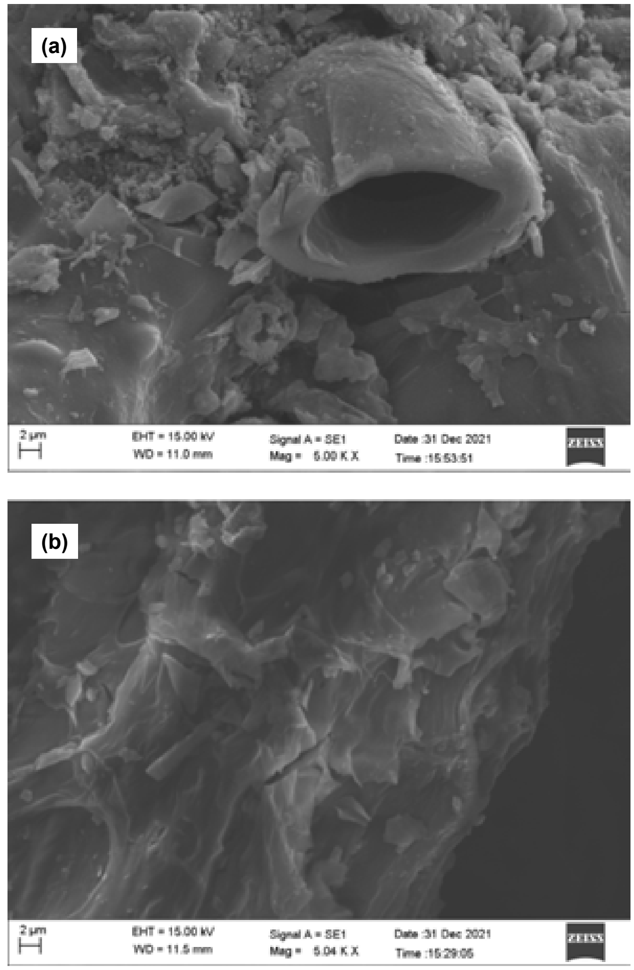

Fig. 1. SEM micrographs of biochar (a) PHB, (b) CFB.

Table 1. Physical properties of paddy husk biochar (PHB) and coconut frond biochar (CFB).

Property	PHB	CFB
Bulk density (mg m^{-3})	0.27	0.35
Specific surface area (m^2 g^{-1})	68.74	2.56
Water holding capacity (%)	276.33	256.51

Table 2. Initial physical parameters of soils of the experimental site.

Physical property	Value
Bulk density (mg m^{-3})	1.57
WHC (%)	18.21
WSA (%)	27.56

WHC = Water holding capacity; WSA = Water stable aggregates.

(Rajkumar, 14). The specific surface area of biochar produced from paddy husk was higher (68.74 $m^2 g^{-1}$) than that from coconut frond (2.56 $m^2 g^{-1}$). Residual biochar retains some pores present in the biological tissue. Furthermore, the dehydration of tissues and the release of structural H_2O, CO, CO_2 and H_2 from the biological tissue during pyrolysis generate additional internal porosity in biochar particles that improve the surface area of biochar (Elangovan, 6). The volume and distribution of pore size of biochar is positively related to surface area. The lower surface area of CFB compared to PHB can be due to the blocking of the residual pores by inorganic materials in CFB (Batista *et al.*, 1).

It was noticed that the feed stock used for biochar production had significant effects on water holding capacity (WHC). Among the feedstock used, PHB had higher WHC (276.33%) compared to CFB (256.51%). This might be due to the lower bulk density and higher surface area observed for PHB. This is in conformity with the results obtained by Purakayastha *et al.* (13), who reported that rice straw biochar had higher WHC and lower BD compared to maize straw biochar.

In the current study, the essential physical properties like BD, WHC and water stable aggregates (WSA) of the soil of the experimental site were estimated before starting the experiment (Table 2), at 60 and 120 days of crop and also at harvest. BD was found to be significantly influenced by the treatments in sandy soil at 60 DAP (days after planting), 120 DAP and at harvest (Table 3). An increasing trend was seen in BD from 60 DAP to the final harvest stage for all the treatments. Application of biochar at different rates decreased the BD, and at 60 DAP, 120 DAP and at harvest stage the lowest mean value was seen for PHB @ 30 t ha^{-1} (1.21, 1.23 and 1.25 mg m^{-3}, respectively), which was on par with all the other biochar treatments except with CFB @ 10 t ha^{-1} at 60 and 120 DAP and with CFB @ 10 and 20 t ha^{-1} at harvest. The highest BD was shown by the absolute control treatment, which was on par with KAU POP and CFB @ 10 t ha^{-1} at all stages of crop growth. At the final harvest stage treatments receiving KAU POP showed 15.54% higher BD than the treatments receiving PHB @ 30 t ha^{-1}. The density of PHB and CFB was much less than the sandy soil used for the present study, the incorporation of which decreased the BD of the soil. The significant reduction in BD of biochar-incorporated soil in the study agrees with the findings of Busscher *et al*. (3), who stated that soil incorporation of biochar reduced the bulk density by enhancing organic carbon content, which favourably influences the aggregation of soil particles and finally increases the soil volume.

The application of biochar increased the WHC (Table 4) of the soil significantly compared to the control. This could be due to the abundant micropores in the biochar-applied soil that helped to physically retain water or improve aggregation, which resulted in creating more pore spaces. Another reason for the differences in water content between biochar-treated plots and the control could be due to the differences in BD among the treatments. Throughout the crop growth period, the highest WHC was observed in the treatment receiving PHB @ 30 t ha^{-1} (41.61, 39.72 and 36.93%, respectively at 60 and 120 DAP and at harvest), which was on par with PHB @ 20 t ha^{-1}. PHB treatments recorded higher WHC than CFB treatments applied at the same rate. The lowest mean value for WHC was in control, which was on par with KAU POP. During harvesting, the KAU POP treatment showed 54.68% less WHC than the treatment receiving PHB @ 30 t ha^{-1}. The BD of the

Table 3. Bulk density (mg m^{-3}) of sandy soil as influenced by treatments at different periods of field study.

Treatment	60 DAP	120 DAP	At harvest
T_1-Absolute control	1.43	1.48	1.52
T_2-PHB @ 10 t ha^{-1} + NPK as per POP	1.27	1.29	1.32
T_3-PHB @ 20 t ha^{-1} + NPK as per POP	1.25	1.26	1.30
T_4-PHB @ 30 t ha^{-1} + NPK as per POP	1.21	1.23	1.25
T_5-CFB @ 10 t ha^{-1} + NPK as per POP	1.35	1.37	1.40
T_6-CFB @ 20 t ha^{-1} + NPK as per POP	1.31	1.35	1.39
T_7-CFB @ 30 t ha^{-1} + NPK as per POP	1.27	1.28	1.34
T_8-KAU POP (30 t FYM + 75: 50: 50 kg NPK ha^{-1})	1.37	1.42	1.48
SEm (±)	0.373	0.041	0.042
$CD_{(0.05)}$	0.112	0.124	0.127

PHB: Paddy husk biochar; CFB: Coconut frond biochar; DAP: Days after planting; POP: Package of practices; FYM: Farm yard manure.

Table 4. Water holding capacity of sandy soil as influenced by treatments at different periods of field study.

Treatment	60 DAP	120 DAP	At harvest
T_1-Absolute control	20.17	17.79	14.75
T_2-PHB @ 10 t ha^{-1} + NPK as per POP	33.79	31.73	29.01
T_3-PHB @ 20 t ha^{-1} + NPK as per POP	38.17	36.75	33.68
T_4-PHB @ 30 t ha^{-1} + NPK as per POP	41.61	39.72	36.93
T_5-CFB @ 10 t ha^{-1} + NPK as per POP	29.57	26.26	24.80
T_6-CFB @ 20 t ha^{-1} + NPK as per POP	31.86	28.63	25.21
T_7-CFB @ 30 t ha^{-1} + NPK as per POP	35.34	33.32	30.51
T_8-KAU POP (30 t FYM + 75: 50: 50 kg NPK ha^{-1})	25.02	20.42	16.73
SEm (±)	1.967	2.061	5.653
CD (0.05)	5.900	6.183	5.653

PHB: Paddy husk biochar; CFB: Coconut frond biochar; DAP: Days after planting; POP: Package of practices; FYM: Farm yard manure.

control and KAU POP-treated plots were higher, reducing the spaces where water could be retained compared to the biochar-treated plots.

The improved soil physical properties for the biochar applied treatments led to the reduced BD and increased porosity than FYM treatment, which might have enhanced root penetration, leading to improved nutrient absorption and also better plant and rhizome growth than control. Plant height, rhizome spread and ginger yield were calculated to interpret the direct influence of biochar on ginger. All these parameters were positively influenced by the incorporation of the biochars at different rates. The better performance of PHB treatments in the present study might be due to the better characteristics of PHB, like low bulk density, high surface area and water holding capacity, compared to CFB and FYM. Plant height increased with an increase in the rate of biochar application and compared to CFB, PHB had higher values for plant height (Fig. 2). The highest mean value for plant height was for PHB @ 30 t ha^{-1} throughout the crop growth period. At 60 DAP, plant height for PHB @ 30 t ha^{-1} (35.13 cm) was on par with CFB @ 30 t ha^{-1} (32.47 cm) and was followed by PHB @ 20 t ha^{-1} (29.57 cm) and CFB @ 20 t ha^{-1} (29.50 cm), which were on par and significantly lower than PHB @ 30 t ha^{-1}. At 120 DAP and at harvest, PHB @ 30 t ha^{-1} (44.50 and 45.33 cm, respectively) recorded significantly higher plant height than all other treatments. From 120 DAP to harvest, all the biochar treatments were higher than KAU POP (FYM application) except PHB @ 10 t ha^{-1} at 60 DAP and at the harvest stage and CFB @ 10 t ha^{-1} from 60 DAP to harvest stage, where the plant height was on par with KAU POP. The treatment receiving PHB @ 30 t ha^{-1} recorded 34.52, 34.69, and 33.53% increase in plant height over the treatment receiving KAU POP at 60 DAP, 120 DAP, and at the harvest stage, respectively. The increased height of plants receiving biochar might be due to the enhanced availability and uptake of essential nutrients by ginger crop due to the application of biochar, leading to improved plant growth. Increased uptake of N, P and K improved cell division and cell enlargement, which finally improved the vegetative growth, especially plant height (Bhattarai *et al.*, 2).

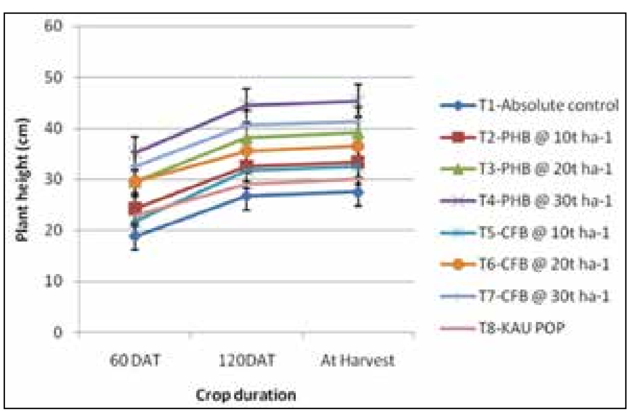

Fig. 2. Effect of treatments on plant height of ginger.

Yield attributes like rhizome spread and weight of ginger in the present study show that the treatments significantly influenced these parameters. With the increasing rate of applied biochar, rhizome spread also increased (Fig. 3) in the sandy soil. The highest rhizome spread was observed for PHB @ 30 t ha^{-1} (24.8 cm), which was on par with CFB @ 30 t ha^{-1} (23.6 cm). There was a 34.55% increase in rhizome spread in the soil treated with PHB @ 30 t ha^{-1} than KAU POP treatment. Rhizome spread for the treatment receiving KAU POP was on par with the treatment receiving CFB @ 10 t ha^{-1} and the control treatment in sandy soil. Rhizome spread was significantly lowest in the control plot.

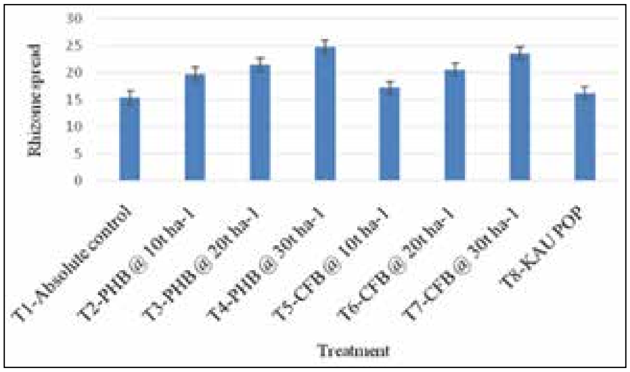

Fig. 3. Effect of different treatments on rhizome spread of ginger.

The highest dry ginger yield was obtained for PHB @ 30 t ha^{-1} (12858.3 kg ha^{-1}), which was on par with CFB @ 30 t ha^{-1} (12675.0 kg ha^{-1}) (Table 5). Dry ginger yield in all the PHB treatments were on par with CFB treatments applied at the same rate. The treatment receiving PHB @ 30 t ha^{-1} showed 81.33% more dry ginger yield compared to KAU POP receiving FYM. The lowest yield was recorded for the control plot in both the soils compared to all other treatments. The noticeable impact of biochar on yield increase of the crop is the result of improvement of soil fertility, including soil physical properties (Chan *et al.*, 4). The porous nature of biochar imparts a high surface area and; hence. can improve WHC and nutrient dynamics in soil, which further influence the soil microbial activity, which might be the reason for improvement in crop yield as reported by Liang *et al.* (9).

Field experimental results showed that biochar produced from paddy husk and coconut frond can be used to improve the yield of ginger and soil physical properties like bulk density, water holding capacity and water-stable aggregates in the sandy soil. From the investigations, it could be concluded that application of PHB or CFB @ 30 t ha^{-1} along with NPK as per POP can be considered as the economically viable and the best treatment. Therefore, biochar could be used as an organic amendment in sandy soils for sustainable agriculture.

Table 5. Effect of treatments on ginger yield in sandy soil.

Treatment	Dry ginger yield (kg ha^{-1})
T_1-Absolute control	5675.0
T_2-PHB @ 10 t ha^{-1} + NPK as per POP	9591.7
T_3-PHB @ 20 t ha^{-1} + NPK as per POP	10900.0
T_4-PHB @ 30 t ha^{-1} + NPK as per POP	12858.3
T_5-CFB @ 10 t ha^{-1} + NPK as per POP	8958.3
T_6-CFB @ 20 t ha^{-1} + NPK as per POP	10800.0
T_7-CFB @ 30 t ha^{-1} + NPK as per POP	12675.0
T_8-KAU POP (30 t FYM + 75: 50: 50 kg NPK ha^{-1})	7091.7
$SEm_{(\pm)}$	638.09
CD (0.05)	1914.7

PHB: Paddy husk biochar; CFB: Coconut frond biochar; POP: Package of practices; FYM: Farm yard manure.

ACKNOWLEDGEMENTS

The authors express sincere thanks to Kerala Agricultural University, Kerala and Ministry of Science and Technology, GoI for granting the fellowships and other facilities to conduct the research work.

AUTHORS' CONTRIBUTION

Field experiment, data collection, writing (NJP); Data analysis and manuscript editing (RB).

DECLARATION

Authors declare that no conflict of interest exist.

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Received : November, 2023; Revised : May, 2024; Accepted : May, 2024