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Effect of various crop residue biochar on soil carbon pools and yield of watermelon in Alfisols of Konkan

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Abstract

The study on “Effect of various crop residue biochar on soil carbon pools and yield of watermelon in Alfisols of Konkan” conducted at the College of Horticulture, Dapoli, during the Rabi season 2022 focused on the impact of three biochars rice husk biochar (RHB), coconut husk biochar (CHB), and areca nut husk biochar (AHB) on soil carbon pools under watermelon crop in Alfisols of Konkan. Fourteen treatments combining two biochar levels (2, 4 ton ha^{-1}) and two levels of recommended dose of fertilizer (100% and 75%) were examined using a randomized block design with three replications. The experimental soil was sandy loam, moderately acidic with high organic carbon, medium nitrogen availability, low phosphorus availability, and elevated potassium content. Application of biochar, recognized for its recalcitrant nature, resulted in carbon sequestration in soil. Biochar enhanced soil carbon pools, including organic carbon, water-soluble carbon, labile carbon, microbial biomass carbon, inorganic carbon, and total carbon, at different watermelon growth stages and yield of watermelon.

Keywords: Biochar, carbon pools, watermelon, soil, Konkan etc.

Introduction

Crop residue management is a pressing issue in agriculture, with woody plant debris posing composting challenges. Instead, farmers often resort to burning, releasing greenhouse gases and losing valuable biomass. In India, converting millions of tons of unused crop leftovers into biochar could address this issue, providing a sustainable soil amendment to enhance carbon content and fertility. Modern agriculture's reliance on inorganic fertilizers has negatively impacted soil fertility and carbon pools. The integration of organic sources, especially biochar, is recognized as a key strategy for maintaining soil quality and fertility. Biochar, with its large surface area and microspores, aids nutrient retention, serves as a habitat for beneficial microbes, and promotes organic carbon storage in soil, contributing to improved soil health and carbon sequestration. Biochar, a solid carbon-rich material derived from biomass through pyrolysis in oxygen-limited conditions, holds promise as a solution to agricultural challenges. The controlled pyrolysis process converts organic waste from forestry and agriculture into biochar, resembling charcoal and offering an alternative to crop burning in India. The production of biochar is influenced by factors such as processing temperature, heating rate, reactor pressure, and biomass composition. The potential of biochar extends beyond soil enhancement, as it is studied for its role in combating climate change, promoting water conservation, enabling renewable energy production, and serving as a component for sustainable agriculture. With its multifaceted benefits, biochar emerges as a valuable asset in addressing agricultural and environmental challenges.

Watermelon, a key cucurbit crop prevalent in India and tropical and subtropical regions, originated in Africa. Requiring temperatures above 25 °C to thrive, its fruit, known as a pepo, is highly nutritious. Lycopene, a major carotenoid, reduces the risk of cardiovascular diseases. Phytochemicals present in watermelon contribute to its health benefits, showcasing anti-cancer and antioxidant characteristics.

Materials and Methods

A field trial was undertaken at the College of Horticulture, Dapoli, during *Rabi* season 2022 and analytical work was done at the PG laboratory of Department of Soil Science and Agricultural Chemistry and instant facilities were available from Central Instrumentation Centre (CIC), Department of Soil Science and Agricultural Chemistry.

During the investigation, three various biochars such as rice husk biochar (RHB), coconut husk biochar (CHB) and areca nut husk biochar (AHB) were prepared. In experiment 14 treatments in which a combination of two different levels of these biochars (2 and 4 t ha^{-1}) and two levels of RDF (100% and 75%) laid in RBD design with three replications were studied. The treatment details were T_1- RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1}, T_2 -100% RDF + CHB (2 ton ha^{-1}), T_3 -75% RDF + CHB (2 ton ha^{-1}), T_4 -100% RDF + CHB (4 ton ha^{-1}), T_5 -75% RDF + CHB (4 ton ha^{-1}), T_6 - 100% RDF + RHB (2 ton ha^{-1}), T_7 -75% RDF + RHB (2 ton ha^{-1}), T_8 - 100% RDF + RHB (4 ton ha^{-1}), T_9 -75% RDF + RHB (4 ton ha^{-1}), T_{10} -100% RDF + AHB (2 ton ha^{-1}), T_{11} -75% RDF + AHB (2 ton ha^{-1}), T_{12} -100% RDF + AHB (4 ton ha^{-1}), T_{13} - 75% RDF + AHB (4 ton ha^{-1}), T_{14} -Absolute control (RHB- Rice husk biochar, CHB- Coconut husk biochar, AHB- Areca nut husk biochar) and FYM @ 15 ton ha^{-1} applied to all treatments. Weight of each fruit was taken and fruit yield per kg was calculated during harvesting.

Characterization of biochars was done which recorded the alkaline pH of biochars RHB (9.34), CHB (9.05) and AHB (9.38) and electrical conductivity about 0.321 dSm^{-1} in RHB, 0.143 dSm^{-1} in CHB and 0.289 dSm^{-1} in AHB. The total carbon content found in biochars was 83.54% (RHB), 74.50% (CHB) and 80.20% (AHB). Similarly, nitrogen, phosphorus and potassium percentages found in biochars were RHB (0.182%, 0.153%, 0.15%), CHB (0.156%, 0.077%, 0.13%) and AHB (0.166%, 0.103%, 0.14%) respectively. The experimental soil was sandy loam in texture, moderately acidic in nature, very high level of organic carbon, medium in nitrogen availability, low in phosphorus availability and high content of potassium in soil making ideal for watermelon cultivation. Ayesha variety of watermelon was used for investigation. Methodology used for analysis of soil carbon pools are as given in Table 1.

Table 1: Methodology used for soil carbon pools

Sr. No.	Soil Carbon Pools	Method	Reference
1.	Soil organic carbon	Walkley and Black's Wet oxidation method	Jackson (1973) [2]
2.	Water Soluble Carbon (WSC)	0.1 N $K_2Cr_2O_7$ and H_2SO_4 method	Chio *et al.* (1986) [1]
3.	Soil Inorganic Carbon (SIC)	Dry combustion method	Tiessen and Moir, (1993) [3]
4.	Labile Carbon (LC)	H_2SO_4 Method	Chan *et al.* (2001) [4]
5.	Soil Total Carbon (TC)	Dry combustion method	Tiessen and Moir, (1993) [3]
6.	Microbial biomass carbon	Chloroform fumigation method	Vance *et al.* (1987) [5].

Results and Discussion

The results of the effect of various crop residue biochar on soil carbon pools i.e., soil organic carbon (OC), water soluble carbon (WSC), labile carbon (LC), microbial biomass carbon (MBC), inorganic carbon (IC) and total carbon (TC) at harvest under watermelon crop presented in Table No. 2 and 3.

The changes in soil organic carbon of soil were due to the influence of different levels of recommended dose of fertilizers with various crop residue biochar. The results revealed that an increasing rate of biochar application influenced soil organic carbon considerably. Soil organic carbon ranged from 14.11 to 17.16 g kg^{-1} at harvest. During the harvest stage, the maximum organic carbon value was 17.16 g kg^{-1} in treatment T_8, which comprised 100% RDF with 4 t ha^{-1} of RHB. This value was on par with treatments T_4 containing 100% RDF + 4 t ha^{-1} of CHB) at 16.80 g kg^{-1}, T_5 containing 75% RDF + 4 t ha^{-1} of CHB at 15.93 g kg^{-1}, T_9 consisting 75% RDF + 4 t ha^{-1} of (RHB) at 16.49 g kg^{-1}, T_{12} containing 100% RDF + 4 t ha^{-1} of AHB at 16.97 g kg^{-1}, and T_{13} consisting 75% RDF with 4 t ha^{-1} of areca nut husk biochar (AHB) at 16.34 g kg^{-1}. The lowest organic carbon value at harvest was 14.11 g kg^{-1}, found in treatment T_{14}, which served as the absolute control.

Application of biochar and FYM along with inorganic fertilizers significantly improved soil organic carbon content. After the addition of biochar, organic carbon fractions within the soil also increased significantly. The increase in carbon fractions might be due to the application of biochar, RDF along with FYM and native soil organic matter status of soil (Shilpa, 2019) [8]. Increase in soil organic carbon was observed might be due to the placement of biochar directly with the raised beds where the root rhizosphere ecology was influenced.

Water soluble carbon affected positively by application of biochar, RDF and FYM. Application of 100% RDF along with 4 t ha^{-1} of rice husk biochar (T_8) resulted in a higher water-soluble carbon (WSC) content and it was at par with treatments T_4 (100% RDF + 4 t ha^{-1} of coconut husk biochar) at 81.82 mg kg^{-1}, T_5 receiving 75% RDF + 4 t ha^{-1} of coconut husk biochar (CHB) at 80.62 mg kg^{-1}, T_9 consisting 75% RDF + 4 t ha^{-1} of rice husk biochar (RHB) at 81.58 mg kg^{-1}, T_{12} containing 100% RDF + 4 t ha^{-1} of areca nut husk biochar (AHB) at 81.96 mg kg^{-1}, and T_{13} receiving 75% RDF + 4 t ha^{-1} of areca nut husk biochar AHB at 80.63 mg kg^{-1}.WSC ranged from 54.85 mg kg^{-1} to 80.85 mg kg^{-1} at harvest and lowest WSC at 53.76 mg kg^{-1} found in absolute control. WSC is considered as the most sensitive indicator of labile organic matter and carbon within the soil. As the organic carbon improved it led to an increase in water soluble carbon which might be due to more carbon added into the soil and there was a conversion of organic carbon from one form to another form by the processes of decomposition, microbial transformation as well as enzymatic transformation. Sandhu *et al.*, (2017) [7] recorded application of corn stover biochar @ 10 mg ha^{-1} increased WSC.

Labile carbon pool significantly affected by application of biochar. The highest labile carbon (351.98 mg kg^{-1}) was found in treatment T_8 receiving 100% RDF along with 4 t ha^{-1} RHB at harvest stage. But statistically treatment T_8 receiving 100% RDF along with 4 t ha^{-1} RHB was found at par with T_4 (348.75 mg kg^{-1}) and T_{12} (353.05 mg kg^{-1}) treatments in which 4 ton of CHB and RHB with 100 percent RDF was applied respectively. Labile carbon was also a sensitive indicator of soil quality. Labile carbon has a rapid turnover rate and it is sensitive to microbial attack, easily oxidisable and sensitive to changes occurring in soil organic carbon. Application of biochar, FYM and inorganic fertilizers showed significantly higher labile carbon than control. This might be due to higher labile compounds being added by biochar rates into the soil

(Tirol *et al.* 2004) [10]. Arun Kumar *et al.*, (2019) [9] found labile carbon was positively affected by the application of biochar.

Biochar application improved microbial population which leads to improvement in MBC. Application of Treatment T_8, which received 100% recommended dose of fertilizer (RDF) along with 4 t ha^{-1} of rice husk biochar (RHB), exhibited higher microbial biomass carbon (279.88 mg kg^{-1}) and was at par to treatments T_4, which consisted of 100% RDF with coconut husk biochar (CHB) at 4 t ha^{-1} (268 mg kg^{-1}), T_9 containing 75% RDF with RHB at 4 t ha^{-1} (266.92 mg kg^{-1}), and T_{12} receiving 100% RDF with areca nut husk biochar (AHB) at 4 t ha^{-1} (274.18 mg kg^{-1}). The absolute control, represented by treatment T_{14}, showed the lowest value of microbial biomass carbon (200.55 mg kg^{-1}) at the harvest stage. Microbial biomass carbon (MBC) measures biological activity and carbon contained in living components of soil organic matter within the soil. In the present investigation, it was found that due to a considerable increase in microbial population after addition of biochar in soil as it improves chemical and physical properties within soil such as pH, CEC, porosity, water holding capacity, and surface area which led to increased MBC. Hale *et al.*, (2015) [11] concluded that microbial biomass carbon in soil increases after the application of biochar which might be due to properties of biochar such as large surface area and high porosity which provide the best habitat for microbes by maintaining water and air. Biochar itself acts as a good carbon source for the growth of microbes (Fowles 2007) [6].

Soil inorganic carbon at harvest did not differ significantly. The highest value of soil inorganic carbon was recorded about 1.56 g kg^{-1} at harvest of watermelon. The lowest value of soil inorganic carbon was recorded in treatment (T_{14}) which was absolute control and found to be 1.22 g kg^{-1}.

At the harvest of watermelon, the highest total carbon of soil was recorded (18.72 g kg^{-1}) in treatment T_8, which consisted of 100% recommended dose of fertilizer (RDF) along with 4 t ha^{-1} of rice husk biochar (RHB). It was at par with treatments T_4 with 100% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) (18.30 g kg^{-1}), T5 with 75% RDF and 4 t ha^{-1} of coconut husk biochar (CHB) (17.39 g kg^{-1}), T9 with 75% RDF and 4 t ha^{-1} of rice husk biochar (RHB) (17.97 g kg^{-1}), T_{12} with 100% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) (18.50 g kg^{-1}), and T_{13} with 75% RDF and 4 t ha^{-1} of areca nut husk biochar (AHB) (17.81 g kg^{-1}). The absolute control showed the lowest total carbon (15.33 g kg^{-1}) at harvest. Total carbon content in soil was significantly increased after the application of biochar and RDF along with FYM. There was a significant improvement in soil organic carbon which led to an increase in TC. This might be due to the increased level of biochar and RDF along with FYM which increased the carbon status in the soil which was due to the high carbon content present in biochar. The functional groups present in biochar such as phenolic and carbonyl carbon helped to adsorb organic compounds.

Table 2: Effect of biochars on soil carbon pools under watermelon crop at harvest stage

Tr. No.	Treatment details	Soil Organic carbon (g kg^{-1})	Water Soluble Carbon (WSC) (mg kg^{-1})	Labile Carbon (LC) (mg kg^{-1})
T_1	RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1})	14.16	60.23	279.33
T_2	100% RDF + CHB (2 t ha^{-1})	15.54	70.51	326.54
T_3	75% RDF + CHB (2t ha^{-1})	14.75	69.75	316.44
T_4	100% RDF + CHB (4t ha^{-1})	16.80	81.82	348.75
T_5	75% RDF + CHB (4 t ha^{-1})	15.93	80.62	338.47
T_6	100% RDF + RHB (2 t ha^{-1})	15.73	72.73	334.15
T_7	75% RDF + RHB (2 t ha^{-1})	15.23	70.59	323.33
T_8	100% RDF + RHB (4 t ha^{-1})	17.16	82.24	358.22
T_9	75% RDF + RHB (4 t ha^{-1})	16.49	81.58	346.00
T_{10}	100% RDF + AHB (2 t ha^{-1})	15.64	71.55	331.33
T_{11}	75% RDF + AHB (2 t ha^{-1})	15.03	69.67	321.00
T_{12}	100% RDF + AHB (4 t ha^{-1})	16.97	81.96	353.05
T_{13}	75% RDF + AHB (4 t ha^{-1})	16.34	80.63	342.00
T_{14}	Absolute control	14.11	53.76	268.81
	S.E. (±)	0.43	3.26	4.15
	CD (P=0.05)	1.25	9.46	12.05
Initial Values		14.00	52.11	270.01

Table 3: Effect of various biochars on soil carbon pools under watermelon crop at harvest stage

Tr. no.	Treatment details	Microbial biomass carbon (MBC) (mg kg^{-1})	Soil inorganic carbon (IC) (g kg^{-1})	Total Carbon (TC) (g kg^{-1})
T_1	RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1})	208.75	1.25	15.41
T_2	100% RDF + CHB (2 t ha^{-1})	245.84	1.41	16.75
T_3	75% RDF + CHB (2t ha^{-1})	223.05	1.35	16.10
T_4	100% RDF + CHB (4t ha^{-1})	268.00	1.50	18.30
T_5	75% RDF + CHB (4 t ha^{-1})	257.73	1.46	17.39
T_6	100% RDF + RHB (2 t ha^{-1})	253.42	1.44	17.17
T_7	75% RDF + RHB (2 t ha^{-1})	231.96	1.40	16.63
T_8	100% RDF + RHB (4 t ha^{-1})	279.88	1.56	18.72
T_9	75% RDF + RHB (4 t ha^{-1})	266.92	1.48	17.97
T_{10}	100% RDF + AHB (2 t ha^{-1})	250.29	1.42	17.06
T_{11}	75% RDF + AHB (2 t ha^{-1})	229.53	1.39	16.42

T_{12}	100% RDF + AHB (4 t ha^{-1})	274.18	1.53	18.50
T_{13}	75% RDF + AHB (4 t ha^{-1})	261.32	1.47	17.81
T_{14}	Absolute control	200.55	1.22	15.33
	S.E. (±)	4.47	0.08	0.46
	CD (P=0.05)	13.00	NS	1.34
Initial Values		184.12	1.15	15.15

Yield of watermelon

The result revealed that treatment T_8 containing 100% RDF + RHB 4 t ha^{-1} recorded the highest fruit yield (48.85 t ha^{-1}) This value was statistically at par to treatments T_{12} receiving 100% RDF with AHB 4 t ha^{-1} (48.58 t ha^{-1}), T_4 containing 100% RDF with CHB 4 t ha^{-1} (48.58 t ha^{-1}). T_5 containing 75% RDF with 4 t ha^{-1} of coconut husk biochar (47.25 t ha^{-1}), T_9 consisting of 75% RDF with 4 t ha^{-1} of rice husk biochar (47.60 t ha^{-1}), T_{12} containing 100% RDF with 4 t ha^{-1} of areca nut husk biochar (48.58 t ha^{-1}), and T_{13} comprising of 75% RDF with 4 t ha^{-1} of areca nut husk biochar (47.35 t ha^{-1}), while significantly exceeding remaining treatments. The lowest fruit yield was observed in treatment (T_{14}) absolute control was (19.01 t ha^{-1}). The yield of crops depends on the production and mobilization of carbohydrates, intake of water and nutrients from the soil. It is also affected by the environment during growth. The application of biochar showed an increase in fruit yield of watermelon as compared to control. It may be due to intake of nutrients through a combination of biochar, FYM and inorganic fertilizers (Shilpa, 2019) [8].

Table 4: Effect of various crop residue biochar on yield of watermelon

Tr. No.	Treatment details	Fruit yield (t ha^{-1})
T_1	RDF (150:50:50) N: P_2O_5: K_2O kg ha^{-1}	29.00
T_2	100% RDF + CHB (2 t ha^{-1})	37.32
T_3	75% RDF + CHB (2 t ha^{-1})	35.36
T_4	100% RDF + CHB (4 t ha^{-1})	48.48
T_5	75% RDF + CHB (4 t ha^{-1})	47.25
T_6	100% RDF + RHB (2 t ha^{-1})	39.50
T_7	75% RDF + RHB (2 t ha^{-1})	37.24
T_8	100% RDF + RHB (4 t ha^{-1})	48.85
T_9	75% RDF + RHB (4 t ha^{-1})	47.60
T_{10}	100% RDF + AHB (2 t ha^{-1})	38.30
T_{11}	75% RDF + AHB (2 t ha^{-1})	36.48
T_{12}	100% RDF + AHB (4 t ha^{-1})	48.58
T_{13}	75% RDF + AHB (4 t ha^{-1})	47.35
T_{14}	Absolute control	19.01
	S.E. (±)	0.68
	CD (P=0.05)	2.04

Conclusion

The application of various rates of biochar along with inorganic fertilizers recorded enhanced soil carbon pools as well as yield of watermelon crop in Alfisols of Konkan. It was concluded that application of 100% RDF along with RHB (4t ha^{-1}) significantly improved soil carbon pools such as soil organic carbon, soil total carbon, water soluble carbon, labile carbon and microbial biomass carbon. Yield of watermelon crop also positively affected by biochar application. Overall results concluded that application inorganic fertilizers should be combined with biochar which help to achieve multiple benefits of carbon sequestration, environment protection.

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