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Effects of biochars on soil carbon pools under aerobic rice cultivation

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Abstract

A field experiment was conducted at ZAHRS, College of Agriculture, UAHS, Shivamogga, during summer 2018 to know the effect of biochars on soil carbon pools under aerobic rice cultivation. The experiment was planned with 16 treatments consisting of four levels of biochar at 2, 4, 6 and 8 t ha^{-1} and two levels of FYM at 5 and 10 t ha^{-1} which were applied alone, and in combinations. The recommended dose of fertilizer (RDF) was applied commonly to all the treatments. The treatments were imposed in RCBD design with three replications for each treatment. The aerobic rice (MAS 946-1) was taken up as a testing crop. The result revealed that application of 8 t ha^{-1} biochar, 10 t ha^{-1} FYM with RDF (100:50:50 kg ha^{-1}) to soil significantly increased the soil carbon pools *viz.* potassium dichromate oxidizable carbon (PDOC), potassium permanganate oxidizable carbon (PPOC), and soil microbial biomass carbon (SMBC) contents in soil at harvest of aerobic rice due to combined application of biochar (8 t ha^{-1}) and FYM (10 t ha^{-1}) applied with RDF compared to biochar, FYM, and RDF alone. Cold water extractable carbon (CWEC), total organic carbon (TOC), and total carbon (TC) contents in soil increased with increase in biochar rate but statistically no significant.

Keywords: Biochar, carbon pools, aerobic rice, soil *etc.*

1. Introduction

Biochar is a fine grained, highly porous charcoal substance that is distinguished from other charcoals in its intended use as a soil amendment. The particular heat treatment of organic biomass used to produce biochar contributes to its large surface area and its characteristic ability to persist in soils with very little biological decay (Lehmann *et al.* 2006) [7]. While raw organic materials supply nutrients to plants and soil microorganisms, biochar serves as a catalyst that enhances plant uptake of nutrients and water. Compared to other soil amendments, the high surface area and porosity of biochar enable it to adsorb or retain nutrients and retain water and also provide a habitat for beneficial microorganisms to flourish (Glaser *et al.*, 2002 and Warnock *et al.*, 2007) [8, 9]. Addition of biochar to soils has attracted widespread attention as a method to sequester carbon in soil. Increased soil carbon sequestration can improve soil quality because of the vital role that carbon plays in chemical, biological, and physical soil processes and many interfacial interactions. The research conducted in different parts of world suggests the beneficial effect of biochar in increasing soil carbon pools. Biochar amend into soils can potentially lock C (Zhang *et al.*, 2014) [10]. However, soil C mineralization can be altered by biochar within a short time, and the mechanism underlying this process warrants further investigation (Verheijen *et al.*, 2014) [1]. A small fraction of labile C in biochar can be mineralized within a short period (Kuzyakov *et al.*, 2009) and can stimulate soil microorganism growth (Quilliam *et al.*, 2013) [3]. Biochar can provide a substrate for soil microorganisms, thereby enhancing microorganism activity (Gomez *et al.*, 2014) [2]. This microbial growth induces soil C mineralization or degradation (Smith *et al.*, 2010; Luo *et al.*, 2011) [5]. However, effects of biochar application on soil organic carbon mineralization or its potentiality as nutrient source deserve detailed investigation. Keeping this in view, the present research was conducted with the objective of the effect of biochar application on different soil carbon pools under aerobic rice cultivation in sandy loam soil.

2. Materials and methods

A field experiment was conducted at ZAHRS, College of Agriculture, UAHS, Shivamogga, during summer 2018 to know the effect of biochar on soil carbon pools under aerobic rice cultivation. Initial characterization of soil experimental site indicated that soil had a Bulk density of 1.73 Mg cm^{-3}, maximum water holding capacity of 24.58 per cent, field capacity of

11.80 per cent and pH of 5.88, EC of 0.22 dSm^{-1} with the CEC of 14.43 cmol (p+) kg^{-1}. Further, the soil was low in available nitrogen (213.35 kg ha^{-1}), high in available phosphorus status (58.17 kg ha^{-1}) and medium in available potassium status (157.63 kg ha^{-1}). The exchangeable Ca and Mg were 2.85 and 1.74 (cmol (p^+) kg^{-1}), Available sulphur was 11.59 ppm and all the DTPA extractable micronutrients were above the critical limits (Fe- 12.18, Mn-2.58, Zn-2.18 and Cu-1.13 ppm) and initial carbon pools of experimental soil was Potassium dichromate oxidizable carbon (PDOC) or soil organic carbon (SOC) 4.68 g kg^{-1}, Potassium permanganate oxidizable carbon (PPOC) 310.25 mg kg^{-1}, Soil microbial biomass carbon (SMBC) 115.00 mg kg^{-1}, Cold water extractable carbon (CWEC) 88.16 mg kg^{-1}, Total organic carbon (TOC) 5.99 g kg^{-1}, Total inorganic carbon (TIC) 0.28 g kg^{-1} and Total carbon (TC) 6.27g kg^{-1}.The soil belongs to the taxonomic class of *Typic haplusdalf* with sandy loam texture. The experiment was planned with 16 treatments consisting of four levels of biochar at 2, 4, 6 and 8 t ha^{-1} and two levels of FYM at 5 and 10 t ha^{-1} which were applied alone, and in combinations. The recommended dose of fertilizer (RDF) was applied commonly to all the treatments. The treatments were imposed in RCBD design with three replications for each treatment. The aerobic rice (MAS 946-1) was taken up as a testing crop. Soil samples were collected from respective treatments at harvest of crop and was analyzed for different soil carbon pools by adopting standard procedures (Table 1).

3. Results and discussion

3.1 Effect of levels of biochar on soil carbon pools under aerobic rice cultivation

The data pertaining to different soil carbon pools at panicle initiation and at harvest of aerobic rice as influenced by application of CS-biochar and FYM with increasing levels of CS-biochar and combined application with FYM are presented in Tables 2 and 3.

3.1.1 Potassium dichromate oxidizable carbon (PDOC) or Soil Organic Carbon (SOC)

Influences of levels of CS-biochar and FYM on soil potassium dichromate oxidizable carbon (PDOC) or soil organic carbon (SOC) at panicle initiation and at harvest stage are presented in Table 2. At panicle initiation stage PDOC content of soil was not influenced significantly due to application of CS-biochar and FYM. However, its values in the experimental plots ranged between 4.10 to 7.62 g kg^{-1}. At harvest stage of crop, with increased levels of CS-biochar (2 to 8 t ha^{-1}) with FYM (10 t ha^{-1}) significantly increased the soil PDOC compared to the absolute control (4.10 g kg^{-1}) and RDF alone (4.15 g kg^{-1}). However, the treatment, T_{16} (CS-biochar 8 t ha^{-1} + FYM 10 t ha^{-1} + RDF) recorded significantly higher amount (9.79 g kg^{-1}) of PDOC compared to all other treatments.

Soil organic matter is the major source of CO_2 in the carbon cycle and sensitive carbon reservoir to climate change and atmospheric CO_2 concentrations. Therefore, management of soil organic matter requires a thorough understanding of the dynamics and changes in soil organic matter composition and in the structural features of humic substances induced by cropping system may serve as a guide to soil organic matter management as studied by Navarrette *et al.* (2010). This could be due to the addition of a larger amount of biochar and FYM on the surface layer of soil and low mineralization process and addition of organic manures (FYM) and fertilizers through an external source. Similar results have been reported by Yao *et al.* (2010). Thus indicating that management practices involving the addition of organic manures and fertilizers helped to maintain the higher organic carbon level. These results are in conformity with the findings of Shrestha *et al.* (2008) [13].

3.1.2 Labile soil organic carbon pools

Results given in Table 2 indicate the effect of CS- biochar an FYM with increasing levels of CS-biochar on the distribution of labile soil organic carbon pools in soil at panicle initiation and at harvest stage of aerobic rice.

It was noticed from the results given in Table 2 that the labile organic carbon pools *viz.*, potassium permanganate oxidizable carbon (PPOC) soil microbial biomass carbon (SMBC) and cold water extractable carbon (CWEC) increased over control, T_1 (absolute control) due to the addition CS-biochar and FYM particularly increased levels of CS-biochar (2 to 8 t ha^{-1}) at both panicle initiation and at harvest stage of crop. However, the increased in labile carbon pools was found to be non-significant at panicle initiation stage among the treatments which received CS-biochar and FYM. With respect to PPOC, SMBC and CWEC pools in soil varied from 431.86 mg kg^{-1} to 773.43 mg kg^{-1}, 269.50 to 512.61 mg kg^{-1} and 164.34 to 403.71 mg kg^{-1}, respectively at panicle initiation stage. However, at harvest stage of crop with levels of FYM with higher dose of CS-biochar, significantly higher labile carbon pools of PPOC (996.67 mg kg^{-1}) and SMBC (709.30 mg kg^{-1}) was recorded especially in treatment, T_{16} (CS-biochar 8 t ha^{-1} + FYM 10 t ha^{-1} + RDF) over all other treatments. With regard to CWEC pool was found by non-significant at harvest stage of crop. However, increased trend of CWEC pool was noticed with increased levels of FYM (5 to 10 t ha^{-1}) with higher dose of CS-biochar (2 to 8 t ha^{-1}).

Over all, labile soil carbon pools increased with increased in levels of CS-biochar and FYM addition. Maximum amount of labile carbon pools was noticed at harvest stage of crop over panicle initiation stage in soil. Among different labile pools, PPOC (996.67 mg kg^{-1}) was found dominant pool in soil followed by SMBC (709.30 mg kg^{-1}) and CWEC (475.0 mg kg^{-1}) especially in the treatment, T_{16} (CS-biochar 8 t ha^{-1} + FYM 10 t ha^{-1} + RDF).

The labile pool of carbon is the fraction of SOC that has the most rapid turnover rates (Verma *et al*. 2011) [12] and therefore its oxidation drives the flux of carbon dioxide from soils to atmosphere. Further, the labile carbon pool is one which is readily decomposable, easily oxidizable and susceptible to microbial attack and is sensitive to management induced changes in soil organic carbon. This pool is very important as it fuels the soil food web and greatly influences the nutrient cycling for maintaining the quality and productivity of soil in accordance with Majumder *et al.* (2008) [15].

The data presented in a Table 2 shows PPOC of different levels of CS-biochar and FYM treatments, revealed that the highest value of PPOC was observed in combined CS-biochar and FYM plots and lowest value was observed in absolute control treatment at both panicle initiation and at harvest stage, this might be due to changes in soil organic carbon due to management practices are difficult to quantify as these changes occur slowly or relatively small compared to vast soil organic carbon pool size and vary both spatially and temporally as studied by Paustian *et al.* (1997) [18]. In recent times, the certain fractions of SOC are sensitive indicators of the effects of management practices compared to SOC in accordance with Cambardella and Elliott (1992) [17]. The increase of PPOC value suggests that PPOC content increased at the beginning which decreased progressively with time. Such behavior indicates that this fraction changes with time because of its dynamic nature.

Soil microbial biomass carbon is an important ecological indicator and acts as a source and sink of available nutrient for plant growth. Soil microorganisms play a crucial role in ecosystem functions such as organic matter decomposition, nutrient cycling, transformation, mineralization *etc*. The microbial biomass is a living component of soil organic matter constituting ***one*** to ***five*** per cent of total organic matter content and it responds more quickly to the changes in soil conditions, this results are in accordance with Brookes *et al*. (2008) [18]. Any changes in microbial biomass ultimately affect the nutrient cycling of soil organic matter. Therefore estimation of microbial biomass carbon can provide useful information on the changes in soil biological properties.

The data presented in Table 2 shows significant differ in SMBC content at different levels of biochar and FYM revealed that among different levels CS-biochar and FYM combination, the highest values of SMBC were observed in 8 t ha^{-1} CS-biochar + 10 t ha^{-1} FYM with RDF. Due to the supply of additional mineralizable and readily hydrolysable carbon sources, resulted in higher microbial activity and higher soil microbial biomass carbon (SMBC) in CS-biochar and FYM received plots as compared to RDF alone. The variations in soil SMBC among different treatments may be attributed to variation in the microbial activity and addition of biochar. The addition of larger quantity of CS-biochar and FYM had a positive effect on soil organic matter content which in turn decides the content of SMBC these results are supported by Collins *et al*. (2008) [16]. The SMBC decreased substantially in paddy land use system. The variation could be attributed to the difference in microbial population which was influenced by soil organic carbon content.

CWEC is considered to be the most active component of soil organic matter (McGill *et al.,* 1986) [20]. It is the main energy source for soil microorganisms and is a primary source of mineralizable nitrogen, phosphorus and sulphur and it influences the availability of metal ions in soils by forming soluble complexes as studied by (Stevenson, 1994). Understanding the role of CWEC in nutrient cycling is an important factor for sustainable ecosystem management, in accordance with Silveira (2005) [22]. The term water soluble carbon is defined as the entire pool of water soluble organic carbon either be sorbed on soil or sediment particles or dissolved in interstitial pore water. The present study also found that CWEC content varied among the different levels of CS-biochar and FYM application and also show that it increased with increase in levels of biochar and FYM at both panicle initiation and at harvest of aerobic rice crop. However, it was statistically non-significant. Perusal of the present study, CWEC fraction in soil is lower as compared other labile fractions of carbon. The lower per cent of CWEC in arable land due to evaporation of soil moisture. These results are in line with the findings of Zaimenko *et al*. (2014) [23].

3.1.3 Total soil carbon pools

Results given in Table 3 indicate the effect of CS-biochar and FYM with their combination on the distribution of total carbon pools *viz.,* total organic carbon (TOC), total carbon (TC) and total inorganic carbon (TIC) in soil at panicle initiation and at harvest stage of aerobic rice.

Application of CS-biochar and FYM with their combination increased the soil total organic carbon (TOC) at both panicle initiation and harvest stage over absolute control (T_1). However, the increased in TOC was found to be non-significant at both panicle initiation and harvest stage of crop. TOC distribution in soil, varied from 7.64 to 9.70 g kg^{-1} and 8.24 to 14.60 g kg^{-1} at panicle initiation and at harvest stage, respectively. However, the treatment, T_{16} (CS-biochar 8 t ha^{-1} + FYM 10 t ha^{-1} + RDF) recorded higher amount of TOC (9.70 and 14.60 g kg^{-1}) at both stages of crop, respectively over all other treatments. Even in total carbon (TC) pool the same trend was noticed in soil. Here also the treatment, T_{16} (CS-biochar 8 t ha^{-1} + FYM 10 t ha^{-1} + RDF) recorded higher value (9.95 and 14.81 g kg^{-1}) and lower value of TC (7.90 and 8.45 g kg^{-1}) was registered at both panicle initiation and harvest stage of crop, respectively compared to all other treatments.

Total inorganic carbon (TIC) content in soil did not differ significantly due to application of CS-biochar and FYM at panicle initiation and at harvest stage. However, TIC content of soil in experimental plots varied from 0.17 to 0.38 mg kg^{-1} and 0.21 to 0.38 mg kg^{-1} at panicle initiation and at harvest, respectively.

The results of TOC of soil under different levels of CS-biochar and FYM are presented in Table 3, revealed that among the different levels of CS-biochar and FYM, didn’t show significant differ at both panicle initiation and at harvest of aerobic rice crop. TOC pool per cent in soil increased with increased levels of CS-biochar and FYM. The highest TOC content was observed in 8 t ha^{-1} CS-biochar and 10 t ha^{-1} FYM combined applied plots, it might be due to application of higher levels of CS-biochar and FYM under aerobic rice improves total organic carbon in the soil. These results of present study corroborate with Manna *et al*. (2008) [24]. The lowest TOC content was observed in absolute control treatment, this might be due to the variation of TOC content due to the continuous cropping and soil cultivation has caused loss of soil organic carbon in the surface layer which is probably due to the rapid decomposition of native soil organic matter. These results are agreement with findings of Fayez (2006) [25].

The TC in soil includes both organic and inorganic form. The inorganic carbon is mainly in the form of $CaCO_3$. However, the soils of the study area are unlikely to have $CaCO_3$ as it is situated in moderate rainfall area and the soil pH is also acidic. Thus**,** the total carbon in these soils in all probability represents organic form only (Table 3). The total carbon in soils of different treatments not differed significantly at both panicle initiation and at harvest of aerobic rice crop. However, the soil samples from combined biochar and FYM treatments plots recoded higher total carbon content in the treatment received 8 t ha^{-1} biochar and 10 t ha^{-1} FYM and lower content was recorded in the treatment received only 2 t ha^{-1} CS-biochar as compared to only RDFYM (10 t ha^{-1}) applied plots. The higher TC content might be due to higher application of organic amendments (biochar and FYM) and fertilizer. These results are in line with the findings of Syed (2010) [26].

Table 1: Methodology used for analysis of soil carbon pools

Sl. No.	Soil carbon pools	Methodology and references
1.	PDOC or SOC g kg^{-1}	Determination of potassium dichromate oxidizable carbon was carried out by wet oxidation method by (Walkley and Black, 1934).
2.	PPOC mg kg^{-1}	Potassium permanganate oxidizable carbon was carried out as per the procedure described by Blair *et al.* (1995).
3.	SMBC mg kg^{-1}	Estimation of cold water extractable carbon (CWEC) was carried out as per the method described by McGill *et al*. (1986) [20].
4.	CWEC mg kg^{-1}	The microbial biomass carbon was analyzed by following chloroform fumigation method (Vance *et al.*, 1987) [29].
5.	TOC g kg^{-1}	Estimation of total carbon, total inorganic carbon and total organic carbon was carried out using total organic carbon (TOC) analyzer. The commonly used method is the catalytic combustion or oxidation method.
6.	TIC g kg^{-1}	
7.	TC g kg^{-1}	

Table 2: Effect of levels of biochar on labile soil organic carbon pools at panicle initiation stage and harvest under aerobic rice cultivation

Treatments	PDOC (g kg^{-1})		PPOC (mg kg^{-1})		SMBC (mg kg^{-1})		CWEC (mg kg^{-1})	
	Panicle initiation	Harvest	Panicle initiation	Harvest	Panicle initiation	Harvest	Panicle initiation	Harvest
T_1: Absolute Control	4.10	5.00	431.86	369.10	269.50	212.61	164.34	243.43
T_2: 100:50:50 NPK kg ha^{-1} (Only RDF)	4.15	5.40	429.12	356.41	236.70	191.67	210.14	297.68
T_3: FYM @ 5 t ha^{-1}	7.12	5.93	639.43	686.39	479.40	496.78	332.41	373.17
T_4: FYM @ 10 t ha^{-1} (POP)	7.37	6.10	710.61	690.41	494.50	507.71	363.17	397.08
T_5: CS - Biochar @ 2 t ha^{-1}	4.90	7.39	467.38	621.38	312.70	529.79	263.67	330.61
T_6: CS - Biochar @ 4 t ha^{-1}	5.60	7.47	498.21	676.43	329.40	546.79	278.67	347.83
T_7: CS - Biochar @ 6 t ha^{-1}	5.90	7.63	563.89	717.34	336.70	576.08	309.41	360.03
T_8: CS - Biochar @ 8 t ha^{-1}	6.12	7.98	584.09	768.41	358.80	580.81	310.96	390.96
T_9: CS - Biochar @ 2 t ha^{-1} + FYM @ 5 t ha^{-1}	6.28	8.07	681.40	786.31	381.40	598.61	316.61	408.63
T_{10}: CS - Biochar @ 4 t ha^{-1} + FYM @ 5 t ha^{-1}	6.63	8.29	693.07	841.36	409.40	603.09	320.43	416.18
T_{11}: CS - Biochar @ 6 t ha^{-1} + FYM @ 5 t ha^{-1}	6.92	8.58	709.36	873.12	439.30	618.13	361.67	435.61
T_{12}: CS - Biochar @ 8 t ha^{-1} + FYM @ 5 t ha^{-1}	7.05	8.92	718.01	891.43	440.67	671.01	368.18	457.31
T_{13}: CS - Biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1}	7.14	8.97	723.61	901.63	477.61	656.41	393.17	445.00
T_{14}: CS - Biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1}	7.21	9.21	738.37	928.18	485.30	673.73	395.63	449.00
T_{15}: CS - Biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1}	7.42	9.36	757.46	941.67	494.50	680.09	401.43	455.18
T_{16}: CS - Biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1}	7.62	9.79	773.43	996.67	512.61	709.30	403.71	475.00
S. Em±	0.99	0.14	85.35	12.22	63.87	8.85	51.09	45.38
C.D. (p=0.05)	NS	0.40	NS	35.28	NS	25.56	NS	NS

Note: CS: Coconut shell, RDF: Recommended dose of fertilizer - [Common for all except absolute control treatment (T_1)], POP: Package of practice PDOC: Potassium dichromate oxidizable carbon, PPOC: Potassium permanganate oxidizable carbon, SMBC: Soil microbial biomass carbon, CWEC: Cold water extractable carbon

Table 3: Effect of levels of biochar on soil total carbon pools at panicle initiation stage and harvest under aerobic rice cultivation

Treatments	TOC (g kg^{-1})		TC (g kg^{-1})		TIC (g kg^{-1})	
	Panicle initiation	Harvest	Panicle initiation	Harvest	Panicle initiation	Harvest
T_1: Absolute Control	4.64	5.24	7.90	8.45	0.25	0.21
T_2: 100:50:50 NPK kg ha^{-1} (Only RDF)	5.08	5.31	8.34	8.54	0.26	0.23
T_3: FYM @ 5 t ha^{-1}	8.29	8.74	8.61	8.97	0.32	0.23
T_4: FYM @ 10 t ha^{-1} (POP)	8.36	8.95	8.46	9.19	0.17	0.23
T_5: CS - Biochar @ 2 t ha^{-1}	8.48	9.90	8.85	10.12	0.37	0.22
T_6: CS - Biochar @ 4 t ha^{-1}	8.70	9.94	9.00	10.21	0.30	0.25
T_7: CS - Biochar @ 6 t ha^{-1}	8.80	10.90	9.03	11.21	0.23	0.25
T_8: CS - Biochar @ 8 t ha^{-1}	8.87	13.21	9.21	13.85	0.33	0.25
T_9: CS - Biochar @ 2 t ha^{-1} + FYM @ 5 t ha^{-1}	8.94	11.17	9.18	11.46	0.23	0.29
T_{10}: CS - Biochar @ 4 t ha^{-1} + FYM @ 5 t ha^{-1}	8.93	11.78	9.25	12.08	0.31	0.30
T_{11}: CS - Biochar @ 6 t ha^{-1} + FYM @ 5 t ha^{-1}	9.04	12.13	9.28	12.45	0.23	0.32
T_{12}: CS - Biochar @ 8 t ha^{-1} + FYM @ 5 t ha^{-1}	9.42	13.90	9.80	14.22	0.38	0.32
T_{13}: CS - Biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1}	9.49	12.70	9.80	13.12	0.30	0.33
T_{14}: CS - Biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1}	9.54	13.28	9.77	13.54	0.22	0.25
T_{15}: CS - Biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1}	9.64	13.75	9.89	14.12	0.25	0.38
T_{16}: CS - Biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1}	9.93	14.87	9.95	15.97	0.24	0.21
S. Em±	1.35	1.55	1.37	1.55	0.05	0.04
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS

Note: CS: Coconut shell RDF: Recommended dose of fertilizer - [Common for all except absolute control treatment (T_1)] POP: Package of practice TOC: Total organic carbon, TC: Total carbon TIC: Total inorganic carbon

4. Conclusion

This study has demonstrated that C pools in the soil can be enhanced by the biochars through stimulating soil microorganisms. Carbon storage in the soil is improved after biochar addition. Plantation-waste (e.g., coconut shell) biochar associated with fertilizer can amend degraded soils (e.g., acidic soil). Therefore, double benefits of C sequestration and soil amendment can be enhanced by adding biochar with fertilizer and FYM. The study area is located in the southern transition zone of Karnataka state, India with *Typic haplusdalf* with sandy loam texture, where soils are infertile, acidic and drastically mineralized. Based on the findings in this study, chemical fertilizer application to soils could be associated with biochar and FYM, through which multi-benefits (e.g., soil amendment, environment protection, and C sequestration) could be obtained simultaneously. And thus, additional experiments are recommended using biochar associated with different amendments to determine whether or not the effects of biochar on C sequestration are more permanent.

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