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Effect of Microbial Enriched Biochar with Fertilizer Doses on Soil Properties and Yield under Soybean (*Glycine max*) –Wheat (*Triticum aestivum*) Cropping Sequence

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To find out the Effect of different levels of microbial enriched biochar with fertilizer doses on soil properties and yield under Soybean (*Glycine max*) –Wheat (*Triticum aestivum*) cropping sequence.
Study Design: Randomized Block Design (RBD).
Place and Duration of Study: The study was carried out at BAIF-Central Research Station, Urulikanchan, Ta. Haveli, Dist. Pune Maharashtra, India, during July 2021 to April 2022.
Methodology: The charcoal powder is treated with the different bio fertilizers viz. *Rhizobium*,

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Phosphate Solubilizing Bacteria (PSB), and *Trichoderma.* The farmyard manure at the rate of 10 tons per ha was mixed equally in all the treatments.The reduced recommended dose of chemical fertilizers in Soybean and wheat was 50% and 75%, where the microbial enriched biochar was applied to the soil at the rate of 5, 7.5, 10, and 15 tha^{-1} (Table-1). In the *Kharif*, the *var. JS 335* (Soybean) and in the *Rabi* season, Wheat (*var. Ankur Kedar*) was sown in the same field. The charcoal was prepared and this wet microbial-enriched Biochar was used as per the treatment combinations in both the crops (Table 1).

Results: In Soybean crop all the growth parameters recorded highest readings and also a higher grain yield (25.89 qha^{-1}) and straw yield (27.49 qha^{-1}) and in Wheat all the growth parameters recorded highest readings and also higher grain yield of (43.19 qha^{-1}) and straw yield of (45.78 qha^{-1}) was recorded (Table 2 & 4) in treatment T_3 (Biochar @ 7.5 t ha^{-1} + 75 % GRDF) and it is at par with GRDF.

Conclusion: It is concluded that in (T_3) the application of microbial-enriched Biochar @ 7.5 t ha^{-1} + 75 % GRDF has given significantly higher grain yield (Soybean: 25.89 qha^{-1} and Wheat: 43.19 qha^{-1}) and straw yield (Soybean: 27.49 qha^{-1} and wheat: 45.78 qha^{-1}) over the GRDF in both Soybean and Wheat cropping sequence.

Keywords: Biochar; growth; nutrient and cropping sequence.

1. INTRODUCTION

Biochar is a carbon-rich organic material, an organic amendment, and a by-product derived from biomass by pyrolysis under high-temperature and low oxygen conditions. Biochar is produced through a process called pyrolysis, which involves the heating of biomass (such as wood, manure, or leaves) in the complete or almost complete absence of oxygen. However, the quantity and quality of these produced depend on the type of crop residues used.

Biochar has great potential in mitigating greenhouse gases and is capable of preserving carbon in the soil for long periods [1]. Recently, it has been reported that biochar obtained from the carbonization of organic wastes can be a substitute that not only influences the sequestration of soil carbon but also modifies its physicochemical and biological properties [2]. Additionally, biochar is produced and applied to achieve optimal management of agricultural waste.

There have been many studies that have reported the benefits of applying biochar as a soil ameliorant, such as mitigating climate change [3], improving soil fertility [4], and increasing plant productivity [5]. The potential benefits of biochar application in soils include decreasing the salinity and pH, improving the soil properties, increasing soil nutrient availability, enhancing plant growth [6] and potentially toxic element adsorption, and climate change mitigation [7]. The literature shows the study carried out on the use of biochar is limited to a few crops. Therefore, it needs to be conducted a study to investigate the effect of biochar levels of application on soil fertility management under different crop sequences.

Therefore, the field experiment was conducted, to study the effect of microbial-enriched biochar levels and fertilizer doses on soil chemical properties and yield potential under the Soybean-Wheat cropping sequence. This could help to overcome the constraints related to nutrient uptake, moisture retention, soil organic matter, and microbial population under this cropping sequence. The Biochar was prepared from subabul wood (*Leucaena leucocephala*) using a kiln and the powder prepared using pulverizer machine.

2. MATERIALS AND METHODS

The study was carried out at BAIF-Central Research Station, Urulikanchan, Ta. Haveli, Dist. Pune Maharashtra, India, The Soybean was cultivated during July 2021 to Oct 2021 and Wheat from Nov 2021 to April 2022. The average annual rainfall is 450 mm and the average annual temperature varies from 14 °C to 35 °C. The land has a black type of soil with properly managed cultivable land that had been selected for the field trial. The chemical properties of soil were analyzed before sowing and after harvesting of each crop. The land was ploughed and the Randomized Block Design (RBD) was laid with a plot size of 4 x 3 m^2. The Farm yard Manure (FYM) is prepared basically using cow dung, cow urine and other agricultural crop residues and it was used at the rate of 10 tons per ha was mixed equally in all the treatments.

The reduced recommended dose of chemical fertilizers in Soybean and wheat was 50% and 75%, where the microbial enriched biochar was applied to the soil at the rate of 5, 7.5, 10, and 15 tha^{-1}. In the *Kharif*, the *var. JS 335* (Soybean) were sown at the row-to-row distance of 30 cm and in the *Rabi* season, Wheat (*var. Ankur Kedar*) in the distance of 22 cm in the same field. The residual effect in the treatments T4, T5, T8, T9, and T12, T13 was recorded in wheat crop (Table 1).

Cropping sequence: Soybean-Wheat.

Biochar can be produced with raw materials such as grass, cow manure, wood chips, rice husk, wheat straw, cassava rhizome, and other agricultural residues [8]. In study, the Subabul (*Leucaena leucocephala*) of small branches were used for the preparation of charcoal as it is generally available in farms and other open lands. The charcoal was prepared through the combustion method using a kiln and powdered in a pulverizer using an 8 mm sieve. The charcoal powder is treated with the mother culture each of 10% *Rhizobium*, *Phosphate Solubilizing Bacteria (PSB),* and *Trichoderma* was mixed in 100 liter of water and kept for overnight. This wet microbial-enriched Biochar was partially dried under the shade for 2 days retaining 8-10 percent moisture. The microbial-enriched biochar was broadcasted on the surface of the soil at the level of 5, 7.5, 10, and 15 tha^{-1} and mixed properly in the soil. The different treatment combinations of biochar and chemical fertilizers levels were applied before sowing the crops and in absolute control plot application of fertilizers and Biochar was not applied (Table 1).

The treatment-wise yield and growth parameters (Plant height, number of branches, no. of pods per plant, the test weight of 100 grain, and grain and straw yield were recorded in Soybean crop and plant height, no of fertile tillers, spike length, no of grains per spike, No. of spikelet's, test weight of 100 grain, straw and grain yield in Wheat) were recorded in wheat. The change in the soil chemical properties before and after the harvest of the crop was analyzed in the laboratory from the collected soil samples. The data was statistically analyzed using MS Excel (2010) and OPSTAT software [9]. The plant samples were collected during the initial stage of flowering and grain samples were collected after the harvest of the crop. The treatment-wise NPK content in plant biomass and grain was analyzed to calculate the nutrient uptake status of each crop. The Nitrogen uptake was estimated by Kjeldahl's method as described by piper [10]. Total Phosphorous was determined by Vanadomolybdate Phosphoric yellow color method and total Potassium was estimated by flame photometer method as described by Jackson, [11].

Table 1. Treatment details

Tr.	Soybean	Wheat
1.	GRDF (50:75:45 N, P_2O_5 & K_2O ha^{-1}) + 10 t ha^{-1} FYM)	GRDF (120:60:40 N, P_2O_5 & K_2O ha^{-1}) + 12 t ha^{-1} FYM)
2.	Biochar @ 5 t ha^{-1} + 75 % GRDF	Biochar @ 5 t ha^{-1} + 75 % GRDF
3.	Biochar @ 7.5 t ha^{-1} + 75 % GRDF	Biochar @ 7.5 t ha^{-1} + 75 % GRDF
4.	Biochar @ 10 t ha^{-1} + 75 % GRDF	Biochar @ 0 t ha^{-1} + 75 % GRDF
5.	Biochar @ 15 t ha^{-1} + 75 % GRDF	Biochar @ 0 t ha^{-1} + 75 % GRDF
6.	Biochar @ 5 t ha^{-1} + 50 % GRDF	Biochar @ 5 t ha^{-1} + 50 % GRDF
7.	Biochar @ 7.5 t ha^{-1} + 50 % GRDF	Biochar @ 7.5 t ha^{-1} + 50 % GRDF
8.	Biochar @ 10 t ha^{-1} + 50 % GRDF	Biochar @ 0 t ha^{-1} + 50 % GRDF
9.	Biochar @ 15 t ha^{-1} + 50 % GRDF	Biochar @ 0 t ha^{-1} + 50 % GRDF
10.	Biochar @ 5 t ha^{-1} + 100 % GRDF	Biochar @ 5 t ha^{-1} + 100 % GRDF
11.	Biochar @ 7.5 t ha^{-1} + 100 % GRDF	Biochar @ 7.5 t ha^{-1} + 100 % GRDF
12.	Biochar @ 10 t ha^{-1} + 100 % GRDF	Biochar @ 0t ha^{-1} + 100 % GRDF
13.	Biochar @ 15 t ha^{-1} + 100 % GRDF	Biochar @ 0 t ha^{-1} + 100 % GRDF
14.	Absolute Control	Absolute Control

Note: General Recommended Dose of Fertilizer (GRDF)

3. RESULTS AND DISCUSSION

3.1 Influence of Microbial Enrich Biochar on Growth and Yield on Soybean and Wheat Cropping Sequence

3.1.1 Soybean crop

The growth and yield parameter in Soybean crop shows a higher plant height (61.8 cm) and maximum branches (06), maximum no. of pods per plant (59), and highest test weight (12.3 g of 100 grains), grain yield (25.89 qha^{-1}) and straw yield (27.49 qha^{-1}) were recorded in treatment T_3 (Biochar @ 7.5 t ha^{-1} + 75 % GRDF) and it is at par with GRDF (Table 2). The study by Liu et al. [12] reveals that, the highest yield was obtained at the 5% biochar loading, whereas the 10% biochar loading level slightly decreased soybean seed and biomass yields. Therefore the use of biochar @ 7.5 t ha^{-1} + 75 % GRDF and this study has near to the observations recorded by Liu et al. 2020. The number of pods per plant is one of the most important components of grain yield, making up the largest contribution to the variation of grain yield [13].

3.1.2 Wheat crop

The use of a higher dose of microbial enriched Biochar leads to an increase in the cost of cultivation. Therefore, higher dose of biochar levels i.e. 10 and 15 t ha^{-1} did not apply again in the treatments T4, T5, T8, T9, T12 and T13 and their residual effect on growth and yield were recorded. The results in treatment T_3 (Biochar @ 7.5 t ha^{-1} + 75 % GRDF shows again significantly higher grain yield of 43.19 qha^{-1} and straw yield of 45.78 qha^{-1} and growth parameters like higher plant height (81.6 cm), maximum fertile tillers (9), Spike Length (9.88 cm), more number of grains Spike^{-1} (43), more spikelet's spike $^{-1}$ (17) and highest test weight (6.00 g of 100 grain) was recorded (Table 4). The results shows that the residual treatments (T_4, T_5, T_8, T_9, T_{12} and T_{13}) are also at par with the treatments T_3. But in absolute control plot, growth and yield, parameters were recorded minimum values over all the treatments. The combined effect of biochar and fertilizers on wheat yield shows [14] that the application of biochar @ 6 t ha^{-1} improved grain yield. The findings were closely consistent with those of the current study.

Biederman and Harpole [15] argued that one of the main practical advantages of biochar is to enhance grain yield and reduce the leaching of soil nutrients (2012). Soil was amended with biochar, compost, and their mixture at field level is higher benefit in terms of growth and yield, pod number per plant, number of soybean seeds per plant, 100-seed weight, and seed yield [16].

3.2 Nutrient Uptake by Soybean-wheat Cropping Sequence

The highest uptake of nitrogen (211.56 kg ha^{-1} and 124.06 kg ha^{-}), Phosphorus (78.60 kg ha^{-1} and 81.27 kg ha^{-1}) and Potash (35.46 kg ha^{-1} and 62.02 kg ha^{-1}) was observed in T_3 (Biochar @7.5 t ha^{-1} + 75 % GRDF) in soybean and wheat respectively (Table 6). The use of biochar levels in this study is near to the results of Chan et al. [17] in which they reported that application of biochar 6 tha^{-1} significantly increased nitrogen uptake by the plant.

3.3 Change in the Soil Properties

The Soil Organic Carbon (SOC) content was slightly increased in all the levels of biochar application in which the highest soil organic carbon content under Soybean (0.80 %) and Wheat (0.87 %) was recorded in T3 (Biochar @ 7.5 tha^{-1} + 75 % GRDF). Similarly the increase of Nitrogen (379 kg ha^{-1} and 378 kg ha^{-1}) and Potassium (368 kg ha^{-1} and 385 kg ha$^{-1)}$ in Soybean and Wheat respectively (Tables 3 and 5).

The residual effect of biochar under Wheat, that is in treatments T_4, T_5, T_8, T_9, T_{12} and T_{13} the organic carbon values shows near to the treatment T_3 (Biochar @ 7.5 tha^{-1} + 75 % GRDF) (Table 5). Therefore, the result indicates that the application of biochar for every cropping season is not much useful to increase soil organic carbon.

3.4 Benefit Cost Ratio for Soybean and Wheat Cultivation

The data pertaining to economics of each treatment viz., cost of cultivation, gross income, net income and benefit: cost ratio has shown in (Tables 2 and 4). The maximum grain yield 25.89 and 43.19 qha^{-1} and highest gross monetary return of Rs. 1, 81,222/- and Rs. 1, 51,181/- ha^{-1} was recorded in T_3 (microbial enriched Biochar @ 7.5 t ha^{-1} + 75 % GRDF) of soybean and wheat respectively. But the net monitory return is lesser wherever the biochar is applied,

Table 2. Effects of different microbial enrich biochar levels in combination with NPK on growth, yield, and economics of Soybean

Tr #	Treatment details	Plant Height (cm)	No. of branches	No. of pods per plant	Test Weight (100-grain wt. in g)	Yield (q/ha)	Straw Yield (q/ha)	Gross Monetary Returns (Rs/ha)	Cost of cultivation (Rs/ha)	Net Monetary Returns (Rs/ha)	Benefit : cost
T1	GRDF (50:75:45 N, P_2O_5 & K_2O ha^{-1}) + 10 t ha^{-1} FYM)	59.9	5	54	11.7	23.78	26.07	166444	73136	93308	2.28
T2	Biochar @ 5 t ha^{-1} + 75 % GRDF	50.7	5	48	11.2	19.97	22.89	139806	125872	13934	1.11
T3	Biochar @ 7.5 t ha^{-1} + 75 % GRDF	61.8	6	59	12.3	25.89	27.49	181222	156322	24900	1.16
T4	Biochar @ 10 t ha^{-1} + 75 % GRDF	59.8	5	49	10.6	23.36	25.41	163528	186772	-23244	0.88
T5	Biochar @ 15 t ha^{-1} + 75 % GRDF	46.2	4	50	10.4	21.69	23.89	151861	247672	-95811	0.61
T6	Biochar @ 5 t ha^{-1} + 50 % GRDF	56.4	4	50	10.3	18.72	21.31	131056	117708	13348	1.11
T7	Biochar @ 7.5 t ha^{-1} + 50 % GRDF	54.3	5	53	10.6	19.25	21.86	134750	148158	-13408	0.91
T8	Biochar @ 10 t ha^{-1} + 50 % GRDF	56.7	5	51	11.1	18.08	20.74	126583	178608	-52025	0.71
T9	Biochar @ 15 t ha^{-1} + 50 % GRDF	50.7	4	48	11	18.06	20.53	126389	239508	-113119	0.53
T10	Biochar @ 5 t ha^{-1} + 100 % GRDF	57.9	5	51	10.9	21.14	23.8	147972	134036	13936	1.1
T11	Biochar @ 7.5 t ha^{-1} + 100 % GRDF	59	5	56	11.4	24.03	26.36	168194	164486	3708	1.02
T12	Biochar @ 10 t ha^{-1} + 100 % GRDF	54.3	5	51	10.7	23.11	25.18	161778	194936	-33158	0.83
T13	Biochar @ 15 t ha^{-1} + 100 % GRDF	54.8	5	49	10.7	19.03	21.63	133194	255836	-122642	0.52
T14	Absolute Control	45.9	3	40	10.4	9.58	12.89	67083	40480	26603	1.66
	SE(m)$\pm$	2.36	0.36	2.01	0.2	1.31	1.3				
	CD at 5 %	6.91	1.07	5.89	0.61	3.85	3.81				

Table 3. Soil chemical analysis before and after harvest Soybean

Tr. No	Treatment details	pH	EC	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
	Before sowing of crop	7.43	0.44	0.61	131.79	32.14	230.00
	After harvesting						
1	GRDF (50:75:45 N, P_2O_5 & K_2O ha^{-1}) + 10 t ha^{-1} FYM)	7.92	0.44	0.65	305	42	298
2	Biochar @ 5 t ha^{-1} + 75 % GRDF	7.95	0.48	0.61	352	55	296
3	Biochar @ 7.5 t ha^{-1} + 75 % GRDF	7.89	0.49	0.80	379	68	368
4	Biochar @ 10 t ha^{-1} + 75 % GRDF	7.31	0.5	0.74	368	72	346
5	Biochar @ 15 t ha^{-1} + 75 % GRDF	8.12	0.42	0.71	345	65	308
6	Biochar @ 5 t ha^{-1} + 50 % GRDF	8.44	0.4	0.73	349	61	306
7	Biochar @ 7.5 t ha^{-1} + 50 % GRDF	8.13	0.55	0.70	361	68	341
8	Biochar @ 10 t ha^{-1} + 50 % GRDF	8.22	0.43	0.69	372	70	321
9	Biochar @ 15 t ha^{-1} + 50 % GRDF	8.4	0.48	0.68	375	54	309
10	Biochar @ 5 t ha^{-1} + 100 % GRDF	7.98	0.53	0.63	362	61	344
11	Biochar @ 7.5 t ha^{-1} + 100 % GRDF	8.16	0.52	0.70	369	73	340
12	Biochar @ 10 t ha^{-1} + 100 % GRDF	8.14	0.51	0.69	367	69	324
13	Biochar @ 15 t ha^{-1} + 100 % GRDF	7.92	0.49	0.67	370	67	310
14	Absolute Control	7.64	0.42	0.56	275	38	273

Table 4. Effects of different microbial enrich biochar levels in combination with NPK on growth, yield and economics of Wheat

0	Treatment details (Wheat)	Plant Height (cm)	No. of fertile tillers	Spike Length (cm)	No of Grains Spike^{-1}	No of spikelet's spike $^{-1}$	Test weight 100-grain (g)	Yield (qha^{-1})	Straw Yield (qha^{-1})	Gross Monetary Returns (Rsha^{-1})	Cost of cultivation (Rsha^{-1})	Net Monetary Returns (Rsha^{-1})	Benefit :cost (B:C)
1	GRDF (120:60:40 N, P_2O_5 & K_2O ha^{-1}) + 12 t ha^{-1} FYM)	80.1	8	9.58	42	16	5.5	40.82	42.45	142868	65942	76926	2.17
2	Biochar @ 5 t ha^{-1} + 75 % GRDF	77.9	6	8.62	38	14	5.17	34.71	36.69	121489	119214	2275	1.02
3	Biochar @ 7.5 t ha^{-1} + 75 % GRDF	81.6	9	9.88	43	17	6	43.19	45.78	151181	149664	1517	1.01
4	Biochar @ 0 t ha^{-1} + 75 % GRDF	76.1	6	8.48	37	15	5.33	38.61	40.92	135139	58314	76825	2.32
5	Biochar @ 0 t ha^{-1} + 75 % GRDF	75.8	5	8.2	37	14	5.33	36.16	38.48	126544	58314	68231	2.17
6	Biochar @ 5 t ha^{-1} + 50 % GRDF	72.4	6	7.39	38	13	5.17	31.61	34.94	110619	111586	-966	0.99
7	Biochar @ 7.5 t ha^{-1} + 50 % GRDF	74.3	6	7.82	38	14	5.33	33.86	35.94	118504	142036	-23532	0.83
8	Biochar @ 0 t ha^{-1} + 50 % GRDF	74.1	6	7.63	36	14	5.17	32	34.78	112000	50686	61314	2.21
9	Biochar @ 0 t ha^{-1} + 50 % GRDF	72.2	5	7.39	37	12	5.33	30.77	33.19	107693	50686	57007	2.12
10	Biochar @ 5 t ha^{-1} + 100 % GRDF	79.7	7	8.75	40	15	5.17	38.38	40.95	134322	126842	7480	1.06
11	Biochar @ 7.5 t ha^{-1} + 100 % GRDF	80.3	8	9.29	42	16	5.83	41.92	44	146708	157292	-10584	0.93
12	Biochar @ 0t ha^{-1} + 100 % GRDF	76.6	6	8.81	37	14	5.33	38.56	41.53	134964	65942	69022	2.05
13	Biochar @ 0 t ha^{-1} + 100 % GRDF	73.2	6	8.62	39	13	5.67	36.31	39.33	127069	65942	61128	1.93
14	Absolute Control	57.2	4	7.81	30	12	4.83	19.74	21.81	69086	35430	33656	1.95
	SE(m)$\pm$	1.32	0.26	0.16	0.96	0.32	0.17	0.96	2.2				
	CD at 5 %	3.87	0.78	0.47	2.81	0.95	0.52	2.82	6.45				

Table 5. Soil chemical analysis before and after harvest of Wheat

Tr	Treatment Details (Wheat)	pH	EC	OC (%)	N	P	K
						(kg/ha)	
	Initial Soil Status	8.02	0.48	0.68	352.43	61.64	321.79
	After harvesting						
1	GRDF (120:60:40 N, P_2O_5 & K_2O ha^{-1}) + 12 t ha^{-1} FYM)	7.82	0.48	0.71	334	51	334
2	Biochar @ 5 t ha^{-1} + 75 % GRDF	7.91	0.46	0.75	351	59	315
3	Biochar @ 7.5 t ha^{-1} + 75 % GRDF	7.76	0.48	0.87	378	68	385
4	Biochar @ 0 t ha^{-1} + 75 % GRDF	7.71	0.51	0.85	342	67	348
5	Biochar @ 0 t ha^{-1} + 75 % GRDF	7.92	0.43	0.83	340	61	351
6	Biochar @ 5 t ha^{-1} + 50 % GRDF	7.81	0.44	0.84	351	63	355
7	Biochar @ 7.5 t ha^{-1} + 50 % GRDF	7.93	0.42	0.82	342	70	364
8	Biochar @ 0 t ha^{-1} + 50 % GRDF	8.11	0.42	0.83	360	65	361
9	Biochar @ 0 t ha^{-1} + 50 % GRDF	8.21	0.46	0.8	343	58	342
10	Biochar @ 5 t ha^{-1} + 100 % GRDF	7.85	0.51	0.73	351	60	356
11	Biochar @ 7.5 t ha^{-1} + 100 % GRDF	8.1	0.5	0.84	362	62	364
12	Biochar @ 0t ha^{-1} + 100 % GRDF	7.85	0.41	0.82	365	58	353
13	Biochar @ 0 t ha^{-1} + 100 % GRDF	7.91	0.49	0.82	353	59	356
14	Absolute Control	7.42	0.41	0.58	289	35	281

Table 6. NPK uptake after harvest of soybean and wheat crop

Tr #	Treatment Details in Soybean	Nutrient uptake (kgha^{-1})			Treatment Details in Wheat	Nutrient uptake (kgha^{-1})		
		N	P	K		N	P	K
1	**GRDF (50:75:45 N, P_2O_5 & K_2O ha^{-1}) + 10 t ha^{-1} FYM)**	**195.26**	**47.01**	**29.43**	**GRDF (120:60:40 N, P_2O_5 & K_2O ha^{-1}) + 12 t ha^{-1} FYM)**	**119.65**	**80.99**	**53.10**
2	Biochar @ 5 t ha^{-1} + 75 % GRDF	158.2	47.31	25.85	Biochar @ 5 t ha^{-1} + 75 % GRDF	93.89	61.88	50.09
3	Biochar @ 7.5 t ha^{-1} + 75 % GRDF	211.56	78.6	35.46	Biochar @ 7.5 t ha^{-1} +75% GRDF	124.30	81.27	62.02
4	Biochar @ 10 t ha^{-1} + 75 % GRDF	191.51	57.68	34.68	Biochar @ 0 t ha^{-1} + 75 % GRDF	118.96	71.22	52.07
5	Biochar @ 15 t ha^{-1} + 75 % GRDF	191.32	52.92	24.94	Biochar @ 0 t ha^{-1} + 75 % GRDF	97.23	64.56	48.46
6	Biochar @ 5 t ha^{-1} + 50 % GRDF	156.1	48.76	20.56	Biochar @ 5 t ha^{-1} + 50 % GRDF	100.04	61.67	44.82
7	Biochar @ 7.5 t ha^{-1} +50 % GRDF	160.27	46.9	23.4	Biochar @ 7.5 t ha^{-1}+ 50% GRDF	88.94	61.42	48.63
8	Biochar @ 10 t ha^{-1} + 50 % GRDF	140.34	45.98	20.72	Biochar @ 0 t ha^{-1} + 50 % GRDF	87.48	66.15	37.24
9	Biochar @ 15 t ha^{-1} + 50 % GRDF	148.11	47.39	23.07	Biochar @ 0 t ha^{-1} + 50 % GRDF	79.81	55.48	45.05
10	Biochar @ 5 t ha^{-1} + 100 % GRDF	192.43	50.14	26.25	Biochar @ 5 t ha^{-1} + 100 %GRDF	112.77	77.43	52.84
11	Biochar @ 7.5 t ha^{-1}+100 % GRDF	198.4	55.15	28.78	Biochar @7.5 t ha^{-1}+100% GRDF	116.91	78.00	60.19
12	Biochar @ 10 t ha^{-1}+ 100 % GRDF	194.14	57.24	27.15	Biochar @ 0t ha^{-1} + 100% GRDF	99.64	59.24	61.05
13	Biochar @ 15 t ha^{-1}+ 100 % GRDF	169.75	47.76	23.87	Biochar @ 0 t ha^{-1}+ 100% GRDF	99.03	69.92	51.28
14	Absolute Control	79.96	28.29	12.98	Absolute Control	50.86	36.22	29.17
	SE(m)±	8.22	2.48	1.31	SE(m)±	4.56	2.98	2.28
	CD at 5 %	24.03	7.26	3.85	CD at 5 %	13.34	8.72	6.68

it is mainly due to the major cost involved for the Biochar. The study shows that the benefit cost ratio in all the biochar applied treatments shows lower income in the initial stage of cropping but in the next wheat at *rabi* season benefited the residual effect of biochar for growth, yield and which leads to reducing the cost of cultivation (Tables 2 and 4).

4. CONCLUSION

It is concluded that in (T_3) the application of microbial-enriched Biochar @ 7.5 t ha^{-1} + 75 % GRDF has given significantly higher grain yield (Soybean: 25.89 qha^{-1} and Wheat: 43.19 qha^{-1}) and straw yield (Soybean: 27.49 qha^{-1} and wheat: 45.78 qha^{-1}) over the GRDF in both Soybean and Wheat cropping sequence. In the absolute control plot application of fertilizers and Biochar was not applied and due to this growth and yield, parameters were recorded minimum values over all the treatments.

Considering soil health, the consistent use of chemical fertilizer alone will not be recommended. Use of recommended dose of chemical fertilizer, FYM along with the Microbial enriched biochar will have more benefit in terms of increased soil organic carbon and uptake of nutrients for better crop growth and yield. However, the study need to be continued for at least three seasons to draw a detailed conclusion allied to yield and soil properties.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Lehmann CJ, Rondon M. Biochar soil management on highly weathered soils in the tropics. In: Uphoff NT (ed) Biological approaches to sustainable soil systems. CRC Press, Boca Raton. 2006;517–530.
2. Zhang R, Zhang Y, Song L, Song X, Hanninen H, Wu J. Biochar enhances nut quality of Torreya grandis and soil fertility under simulated nitrogen deposition. Forest Ecology and Management. 2017;391:321-329.
3. Zhang C, Zeng G, Huang D, Lai C, Chen M, Cheng M, Tang W, Tang L, Dong H, Huang B, et al. Biochar for environmental management: Mitigating greenhouse gas emissions, contaminant treatment, and potential negative impacts. Chem. 2019;335: 391-398.
4. Yang C, Lu S. Straw and straw biochar differently affect phosphorus availability, enzyme activity and microbial functional genes in an Ultisol. Sci. Total Environ. 2022;805:150325.
5. You X, Suo F, Yin S, Wang X, Zheng H, Fang S, Zhang C, Li F, Li Y. Biochar decreased enantioselective uptake of chiral pesticide metalaxyl by lettuce and shifted bacterial community in agricultural soil. J. Hazard. Mater. 2021;417:126047.
6. Zhao W, Zhou Q, Tian Z, Cui Y, Liang Y, Wang H. Apply biochar to ameliorate soda saline-alkali land, improve soil function and increase corn nutrient availability in the Songnen Plain. Sci. Total Environ. 2020;722:137428.
7. Ennis CJ, Evans AG, Islam M, Ralebitso-Senior TK, Senior E. Biochar: carbon sequestration, land remediation, and impacts on soil microbiology. Critical Reviews in Environmental Science and Technology. 2012;42(22): 2311–2364.
8. Ronsse F, van Hecke S, Dickinson D, Prins W. Production and characterization of slow pyrolysis biochar: Influence of feedstock type and pyrolysis conditions. GCB Bioenergy. 2013;5:104-115.
9. Sheoran OP, Tonk DS, Kaushik LS, Hasija RC, Pannu RS. Statistical software package for agricultural research workers. Recent Advances in information theory, Statistics & Computer Applications by D.S. Hooda & R.C. Hasija Department of Mathematics Statistics, CCS HAU, Hisar. 1998;139-143.
10. Piper CS. Soil and plant analysis 4th Edn. Inc. Pub., New York. 1996;135-200.
11. Jackson ML. Soil chemical analysis. Prentice Hall, Inc. Englewood, Cliffs.U.S.A. Indian Ed.1962, Asia Publication House; 1967.
12. Liu Defu, Zhenyue Feng, Hongde Zhu, Lihe Yu,a Kejun Yang, Song Yu, Yifei Zhang, Wei Guo. Effects of corn straw biochar application on soybean growth and alkaline soil properties. Peer revied article, Bio Resources. 2020;15(1):1463-1481.
13. Caliskan S, ArsalanM, Urimis I. The effect of row spacing on yield and yield components of full season and double-cropped soybean. Turk J. 2007;3:147–154.
14. Solaiman ZM, Blackwell P, Abbott LK, Storer P. Direct and residual effect of

biochar application on mycorrhizal root colonization, growth and nutrition of wheat. Aust J Soil Res. 2010;48:546–554.

15. Biederman LA, Stanley Harpole W. Biochar and its effects on plant productivity and nutrient cycling: a meta-analysis. GCB Bioenergy. 2013;5(2): 202–214.
16. Agegnehu G, Bass AM, Nelson PN, Bird MI. Benefits of biochar, compost and biochar–compost for soil quality, maize yield and greenhouse gas emissions in a tropical agricultural soil. Sci Total Environ. 2016;543:295–306.
17. Chan K, VanZwieten L, Meszaros I, Downie A, Josph S. Using poultry litter biochars as soil amendments. Australian Journal of Soil Research. 2008;46:437–444.

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