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Effect of Biochar Application on Performance of Rice in a Vertisol of Central India

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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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Original Research Article

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ABSTRACT

The present investigation was carried out at the Research Farm of ICAR- Indian Institute of Soil Science (ICAR-IISS), Bhopal (M.P.) during the Kharif seasons of 2021 and 2022 and performance of rice crop under the application of biochar in combinations of farm yard manure and chemical fertilizers was studied. The field experiment consisted of 12 treatments involving three doses of biochar (0, 4 and 8 tha^{-1}) with and without fertilizer (0 or 120:60:40 kg N, P_2O_5, K_2O ha^{-1}) and manure (0, 5 t ha^{-1}) in four replications. Rice (cv. PB 1121) was grown consecutively for two years

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and various parameters viz., plant height, green seeker, number of tillers, earhead length, grains per earhead, seed index and grain yield, straw yield, total biomass and harvest index were evaluated. The results revealed that, among the parameters studied except harvest index, all parameters were influenced positively upon biochar application.

Keywords: Biochar; rice; farm yard manure; chemical fertilizers; crop performance.

1. INTRODUCTION

Rice (*Oryzasativa* L.) is one of the most important cereal crop belonging to genus Oryza of family Poaceae, ranking first among the three major cereals followed by wheat and maize. It provides more than 50% calorie intake for one-third population on the earth. Rice provides 21% of global human per capita energy and 15% of per capita protein [1]. About 33% of Asia's rice production is from China and one fifth from India. Among the rice developing nations on the planet, India has the biggest zone under rice (around 45 million ha.) and positions second underway beside China, [2]. Rice is grown in many states India, yet significant rice production is from lower Gangetic and front marshes of peninsular India. Uttar Pradesh produces around 12.5 million tonnes of rice which is second biggest rice maker in India following West Bengal (14.6 million tonnes). Madhya Pradesh, the central state of India also contributes significantly towards rice production.

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 [3,4]. This process is called slow pyrolysis, which basically involves heating of biomass (such as wood, manure, or leaves) in complete or almost absence of oxygen. The properties of biochar material produced through pyrolysis process are a function of the biomass used and temperature, conditions at which these are pyrolyzed. Biochar application into the soil as an amendment may improve soil physical, chemical and biological properties and thereby provide many solutions of the ecosystem related issues [5]. Jha et al, 2010). It has been reported that biochar has major benefits like improving soil fertility, soil structure, water holding capacity, organic carbon content, increased biological activities, thereby, resulting in improved crop yield in a sustainable manner [6]. Therefore, considering the importance biochar in enhancing the productivity, present investigation was carried out.

2. MATERIALS AND METHODS

The field experiment was conducted at the Research Farm of ICAR- Indian Institute of Soil Science (ICAR-IISS), Bhopal (M.P.) during the Kharif seasons of 2021 and 2022. The soil of the experimental site is clayey in texture (Typic Haplusterts) with 25.2%, 18.0% and 56.8% of sand, silt and clay, respectively (Table 1). The data pertaining to various chemical components clearly exhibit that soil of the experimental field was rich in potassium, low in phosphorus and nitrogen and medium in organic carbon content.

Table 1. Physico-chemical characteristics of experimental soil

Soil parameter	Status
Sand	25.2%
Silt	18.0%
Clay	56.8%
Textural class	Clayey
pH	8.07
Electrical Conductivity (EC)	0.19 dS m^{-1}
Organic Carbon (OC)	0.56%
Available Nitrogen (N)	220 kg ha^{-1}
Available Phosphorus (P)	5.15 kg ha^{-1}
Available potassium (K)	388 kg ha^{-1}

The experiment consisted of 12 treatments for biochar involving three doses (0, 4 and 8 tha^{-1}) with and without fertilizer (0 or 120:60:40 kg N, P_2O_5, K_2O ha^{-1}) and manure (0, 5 t ha^{-1}) in four replications (Table 2). The wood biochar was tested in randomized block design. Rice (cv. PB 1121) crop was grown with identified treatments. Rice nursery was sown on 15 June and transplanted on 22-24 July in 2021 and 14-15 July in 2022. Before transplanting total quantities of phosphorous and potassium fertilizers, FYM and biochar were applied and mixed thoroughly in surface soil treatment wise. Split dose of nitrogen was applied to rice in the form of urea as per treatment details after 10, 45 and 55 days after transplanting. The observations such as plant height (cm) at 30, 60 DAS and at maturity, the number of tillers at 30, 60 DAP and at maturity, the earhead length, grains per earhead, test weight and grain yield were recorded. All the data for field experiment was subjected to statistically analysis as per method described by Fisher [7] for randomized block design. Treatment means were compared using least significant differences.

Table 2. Treatment details

Treatment	Details
T1	Absolute control
T2	FYM @ 5t ha^{-1} Control
T3	Fertilized control (Recommended dose of fertilizer- RDF)
T4	RDF + FYM (@ 5t ha^{-1})
T5	Biochar 4 t ha^{-1}
T6	Biochar 4t ha^{-1} + FYM5 t ha^{-1}
T7	Biochar 4t ha^{-1} + RDF
T8	Biochar 4t ha^{-1}+ RDF +FYM 5 t ha^{-1}
T9	Biochar 8 t ha^{-1}
T10	Biochar 8 t ha^{-1} + 5t ha^{-1} FYM
T11	Biochar 8 t ha^{-1} + RDF
T12	Biochar 8t ha^{-1} + RDF + FYM 5 t ha^{-1}

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

The plant height of rice measured at 50 DAT during 2021, 2022 and pooled of two years ranged 46.3-73.3 cm, 55.2-91.9 cm and 50.8-82.6 cm with a mean of 60.6 cm, 75.3 cm and 68.0 cm, respectively. Further, the plant height of rice at 70 DAT ranged 60.8-99.0 cm, 72.6-101.4 cm and 66.7-100.2 cm during 2021, 2022 and pooled of two years, respectively. The plant height of rice measured at 90 DAT during 2021, 2022 and pooled of two years ranged 65.3-110.0 cm, 81.3-113.7 cm and 73.3-111.8 cm, respectively. The mean plant height of rice at 90 DAT were found 85.7 cm, 97.1 cm and 91.4 cm, during 2021, 2022 and pooled of two years, respectively (Table 3). The highest and lowest plant height of rice at 90 DAT was recorded in the treatment T12 (Biochar 8t + RDF + FYM) and T1 (Absolute control).

The various treatments under study had a significant effect on plant height of rice. In general, the combined application of biochar, RDF and FYM showed better plant height among the various treatments studied. The plant height of the rice was found up to 9% higher in biochar applied treatments as compared to the treatments without biochar.

3.2 Number of Tillers

The number of tiller m^{-1} in rice during 2021, 2022 and pooled of two years ranged 30.5-77.3, 33.5-90.5 and 32.0-83.9, respectively. The mean number of tiller m^{-1} in rice across the treatments was found 54.4, 60.0 and 57.2, during 2021, 2022 and pooled of two years, respectively (Table 4). The treatment receiving biochar in combination with RDF and FYM showed higher number of tillers in rice. The biochar application also showed a significant effect on the tillering in rice. The treatments receiving biochar showed 4-17% higher tillers as compared to the treatments without biochar.

Table 3. Plant height of rice as influenced by biochar application

Treatment	Rice plant height 50 DAT			Rice plant height 70 DAT			Rice plant height 90 DAT		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T1	46.3	55.2	50.8	60.8	72.6	66.7	65.3	81.3	73.3
T2	50.9	66.1	58.5	68.5	77.2	72.8	69.2	86.5	77.8
T3	69.4	83.4	76.4	92.3	91.1	91.7	97.4	102.1	99.7
T4	70.8	88.8	79.8	95.8	96.7	96.3	100.3	108.4	104.3
T5	48.2	56.1	52.1	65.5	73.4	69.4	68.2	82.3	75.2
T6	55.2	72.9	64.0	73.8	82.6	78.2	77.5	92.6	85.0
T7	69.5	84.0	76.7	94.6	94.6	94.6	98.5	106.1	102.3
T8	71.8	91.8	81.8	97.2	99.7	98.5	101.9	111.8	106.9
T9	50.2	56.9	53.5	67.1	75.2	71.1	69.2	84.3	76.7
T10	52.1	71.7	61.9	70.4	79.1	74.7	72.6	88.6	80.6
T11	69.9	85.2	77.5	94.6	95.8	95.2	98.6	107.4	103.0
T12	73.3	91.9	82.6	99.0	101.4	100.2	110.0	113.7	111.8
SEm±	1.86	2.30	1.53	2.52	2.89	1.90	5.29	3.24	2.93
CD (5%)	5.34	6.61	4.41	7.24	8.31	5.47	15.23	9.33	8.44

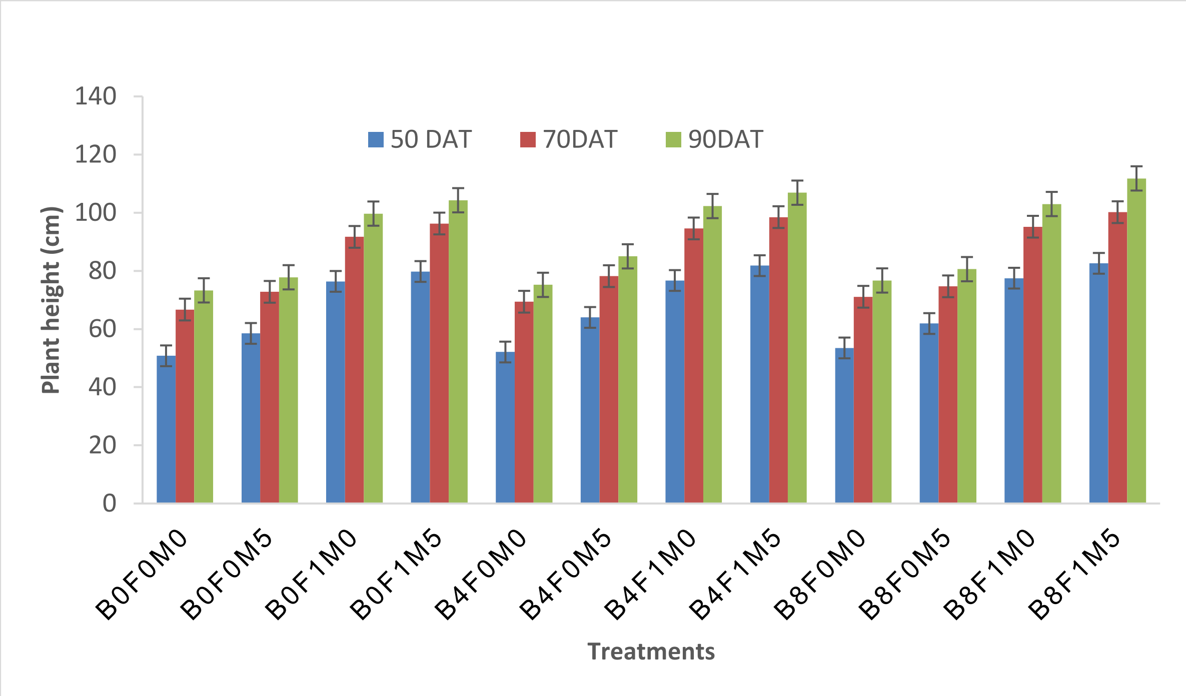

Fig. 1. Effect of different level of biochar, manure and fertilizer applications on pooled plant height of rice

Table 4. Influence of biochar application on tillering and earhead length in rice

Treatment	Rice No. of tillers/m			Rice Earhead length (cm)		
	2021	2022	Pooled	2021	2022	Pooled
T1	30.5	33.5	32.0	17.6	18.1	17.9
T2	41.0	44.0	42.5	19.7	20.3	20.0
T3	63.8	68.3	66.0	21.2	21.8	21.5
T4	70.5	74.8	72.6	22.4	22.8	22.6
T5	35.5	39.3	37.4	17.7	18.1	17.9
T6	46.8	48.3	47.5	20.6	21.4	21.0
T7	65.8	71.8	68.8	21.6	21.9	21.7
T8	75.8	87.8	81.8	22.5	23.0	22.7
T9	35.5	43.5	39.5	19.2	19.7	19.4
T10	41.8	47.0	44.4	20.2	20.8	20.5
T11	69.0	72.0	70.5	22.4	22.8	22.6
T12	77.3	90.5	83.9	23.7	24.1	23.9
SEm±	4.86	4.49	3.47	1.14	1.11	1.00
CD (5%)	13.97	12.92	9.98	3.29	3.19	2.87

3.3 Earhead Length (cm)

The earhead length of rice during 2021, 2022 and pooled of two years ranged 17.6-23.7- cm, 18.1-24.1 cm and 17.1-23.9 cm, respectively (Table 4). Though the difference in ear head length of rice was marginal but found statistically significant. The treatment T1 (Absolute control) and T5 (biochar 4t) showed lower earhead length in rice. The earhead length also found increased (up to 5%) under the treatments receiving the biochar as compared to non-biochar treatments.

3.4 Number of Grains Per Earhead

The grains earhead^{-1} in rice during 2021, 2022 and pooled of two years ranged 110.8-184.0, 113.0-170.5 and 111.9-177.3, respectively (Table 5). The studied treatment showed significant effect on number of grains per earhead in rice. The effect was more visible in second year of study as compared to previous year. The number of grains per earhead also found increased by up to 6% whereas the seed index did not influence by the application of biochar.

Table 5. Number of grains per earhead and grain yield of rice under various biochar treatments

Treatment	No. of grains/earhead			Rice Grain yield		
	2021	2022	Pooled	2021	2022	Pooled
T1	110.8	113.0	111.9	1263	1223	1243
T2	132.8	115.5	124.1	1649	2055	1852
T3	167.3	119.5	143.4	2901	4222	3561
T4	178.3	147.8	163.0	3284	4807	4045
T5	112.3	114.3	113.3	1275	1225	1250
T6	145.8	116.5	131.1	1573	2301	1937
T7	168.3	120.3	144.3	2923	4312	3617
T8	181.5	153.5	167.5	3424	5276	4350
T9	113.8	115.0	114.4	1279	1290	1285
T10	143.8	115.8	129.8	1563	2227	1895
T11	170.5	142.3	156.4	3008	4361	3684
T12	184.0	170.5	177.3	3539	5314	4426
SEm±	4.54	4.57	3.20	106.1	83.9	79.4
CD (5%)	13.06	13.15	9.60	305.3	241.5	228.4

3.5 Grain Yield

The grain yield of rice during 2021, 2022 and pooled of two years ranged 1263-3539 kg ha^{-1}, 1223-5314 kg ha^{-1} and 1243-4426 kg ha^{-1} with a mean of 2307 kg ha^{-1}, 3218 kg ha^{-1} and 2762 kg ha^{-1}, respectively (Table 5). The treatment T12 found significantly superior over all other treatment under study. The treatments receiving combined application of biochar, RDF and FYM showed significantly higher grain yield as compared to other treatments. A maximum of 8% higher grain yield of rice was recorded under biochar treatments as compared to the treatments without receiving the biochar.

The study indicated that the application of biochar positively influenced the growth and yield parameters in rice. Further, the application of biochar with higher magnitude i.e. 8t as compared to 4t did not show positive impact on the growth and yield of either crop. Yeboah et al. [8] reported that the biochar application significantly promoted the performance of maize. The enhanced crop performance upon biochar application is attributed to the various soil benefits of biochar such as biochar reduces the soil bulk density and increase the soil's total porosity due to its porous structure and large specific surface area, it also improves the root system development, enhanced the plant nutrient uptake ability, and promotes the growth and yield of crops [9,10]. The application of biochar in soil can also improve soil structure, promote the agglomeration of soil mineral particles, and enhance the stability of aggregates [11,12]. Most biochars are made from crop stalks, so it contains a lot of nutrients. A large number of studies have confirmed that the application of biochar can significantly increase the content of nutrients in the soil, thus affecting the growth of crops [13-17].

4. CONCLUSION

The study revealed that application of biochar @ 8 t ha^{-1} along with RDF and FYM @ 5 t ha^{-1}, emerged as viable treatment to achieve better yield of rice. The treatment receiving the combined application of biochar, FYM and RDF (T12) performed superior whereas the treatment absolute control (T1) was performed poor. The treatments receiving combined application of biochar, RDF and FYM showed significantly higher grain yield as compared to other treatments. Biochar application @ 4 & 8 t/ha along with NPK+FYM resulted in only 7.5 and 9.4% higher rice grain yield over no biochar + NPK+FYM .Thus, among the various treatments studied, the application of biochar @8t ha^{-1} along with RDF and FYM@5t ha^{-1}, emerged as potentially viable treatment to achieve better yield of rice. Thus, the application of biochar is recommended for better yield of rice in a vertisol in central India.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. FAO Rice information. Rome, Italy: FAO; 2002.

2. IRRI. Leading innovations, Annual Report 2016. International Rice Research Institute, Los Banos, Laguna, Philippines; 2016.
3. Jha DP, Sharma SK, Amarawat, T. Effect of organic and inorganic sources of nutrients on yield and economics of blackgram (*Vigna mungo* L.) grown during Kharif. Agricultural Science Digest. 2015; 35(3):224-228.
4. Panwar NL, Pawar A, Salvi BL. Comprehensive review on production and utilization of biochar. SN Applied Sciences. 2019;1:1-19.
5. Singh BP, Cowie AL, Smernik RJ. Biochar carbon stability in a clayey soil as a function of feedstock and pyrolysis temperature. Environmental Science & Technology. 2012;46(21): 11770-11778.
6. Masto RE, Kumar S, Rout TK, Sarkar P, George J and Ram LC. Biochar from water hyacinth (Eichornia crassipes) and its impact on soil biological activity. Catena. 2013;111:64-71.
7. Fisher RA. Statistical methods for research workers (No. 5). Oliver and Boyd; 1928.
8. Yeboah E, Asamoah G, Kofi B, Abunyewa AA. Effect of biochar type and rate of application on maize yield indices and water use efficiency on an ultisol in Ghana. Energy Proc. 2016;93:14–18.
9. Oguntunde PG, Abiodun BJ, Ajayi AE, Giesen N. Effects of charcoal production on soil physical properties in Ghana. J. Plant Nutr. Soil Sci. 2008;171:591–596.
10. Ibrahim A, Marie H, Elfaki J. Impact of biochar and compost on aggregate stability in loamy sand soil. Agric. Res. J. 2021; 58:34–44.
11. Liu Z, Chen X, Jing Y, Li Q, Zhang J, Huang Q. Effects of biochar amendment on rapeseed and sweet potato yields and water stable aggregate in upland red soil. Catena. 2014;123:45–51.
12. Dong X, Guan T, Li G, Lin Q, Zhao X. Long-term effects of biochar amount on the content and composition of organic matter in soil aggregates under field conditions. J. Soils Sediments. 2016;16:1481–1497.
13. Liang B, J. Lehmann, D. Solomon J. Kinyangi J. Grossman B. O'Nell JO. Skjemstad J. Thies, FJ. Luizao J. Petersen EG. Neves. Black carbon increases cation exchange capacity in soils. Soil Sciences Society of America J. 2006;70: 1719-1730.
14. Cheng C, Lehmann J, Engelhard MH. Natural oxidation of black carbon in soils: changes in molecular form and surface charge along a climosequence. Geochimica Cosmochimica Acta. 2008;72: 1598–1610.
15. Lehmann J, Joseph S. Biochar for environmental management: science and technology. Taylor Francis. 2009;11:535–536.
16. Rogovska N, Laird DA, Karlen DL. Corn and soil response to biochar application and stover harvest. Field Crops Res. 2016; 187:96–106.
17. Amin AEAZ. Phosphorus dynamics and corn growth under applications of corn stalks biochar in a clay soil. Arabian J. Geosciences. 2018;11:379.

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