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Short Communication

Effect of Biochar Application in Soil Amended with Sewage Sludge on Growth, Yield and Uptake of Primary Nutrients in Rice (*Oryza sativa* L.)

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Biochar (BC) is a charcoal which is a rich source of carbon formed by thermal degradation of organic material in a low or zero oxygen environments. Carbon in biochar is mostly recalcitrant in nature and its reactive surfaces are capable of sorbing and exchanging nutrients (Liang *et al*. 2006). Thus, there is ample scope of utilizing biochar as a soil amendment to sequester carbon and improve soil fertility. Sewage sludge (SS) is a product of sewage treatment plant and results from removal of solids and organic matter from the sewage (Kidder 2001). Sludge contains essential plant nutrients and organic matter that can enhance crop production (Latare *et al*. 2014, 2017; Jatav *et al*. 2016). Therefore, application of sewage sludge in agriculture may reduce its disposal problem, and it may serve as a source of fertilizer. The study aimed at utilizing sorption potential of biochar to enhance the availability of nutrients released from sewage sludge for increasing the productivity of rice. The present study was undertaken to evaluate the effect biochar application in soil amended with sewage sludge on rice yield, soil fertility and accumulation of nitrogen (N), phosphorus (P) and potassium (K) in grain and straw.

A pot experiment was conducted in a net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh to find out the effect of conjoint application of biochar and sewage sludge on rice. Varanasi is located between 25.14° and 25.23° N latitude and 82.56° and 83.03° E longitude, and falls in a semi-arid to sub-humid climate. The treatments consisted of six doses of biochar 1.12, 2.24, 3.36, 4.48, 6.72 and 8.96 g kg^{-1} applied to soil amended with 13.4 g kg^{-1} of sewage sludge. Fifty per cent recommended dose of N (50% RDN) was applied in each pot to provide N to plants in early growth stage. In all, there were nine treatments as T_1: without fertilizer (WF); T_2: 100% recommended dose of fertilizer (100% RDF), T_3: 13.4 g kg^{-1} SS, T_4: 1.12 g kg^{-1} biochar (BC)+13.4 g kg^{-1} SS+50% RDN, T_5: 2.24 g kg^{-1} BC+13.4 g kg^{-1} SS+50% RDN, T_6: 3.36 g kg^{-1} BC+13.4 g kg^{-1} SS +50% RDN, T_7: 4.48 g kg^{-1} BC +13.4 g kg^{-1} SS +50% RDN, T_8: 6.72 g kg^{-1} BC+13.4 g kg^{-1} SS+50% RDN, T_9: 8.96 g kg^{-1} BC+13.4 g kg^{-1} SS+50% RDN. The 100% RDF (120: 60: 60: N: P_2O_5: K_2O) were applied only in T_2. Whereas, 50% RDN *i.e.* 60 kg N ha^{-1} was applied in all treatments except in T_1 (WF) and T_2 (RDF). The experiment was laid out in a completely randomized design (CRD) with three replications taking rice cv. Swarna as test crop.

Dry plant samples were finely ground and digested with di-acid mixture (HNO_3: $HClO_4$ :: 3:1, v/v) for analyzing P and K and in H_2SO_4 for N following standard procedures (Tandon 2001). The soil samples were analyzed for pH in 1:2.5 soils: water suspension, organic carbon (OC) and available N, P and K in the soil by following standard procedure (Sparks *et al*. 1996). The data were subjected to one way analysis of variance (ANOVA, P=0.05) using SPSS version 22 software. Duncan's multiple range test (Duncan 1955) was performed to test the significance of difference between the treatments.

The experimental soil (0-15 cm) had alkaline pH 7.4 and was low in OC 3.1 g kg^{-1}. The initial available N, P and K values were 56.3, 8.26 and 61.3 mg kg^{-1}, respectively. Biochar was obtained from a rice mill of village Kollana, Mirzapur, Uttar Pradesh, where it is a waste emitting from gasifire plant which utilizes rice husk as fuel. The rice husk biochar had

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bulk density 0.40 Mg m^{-3}, porosity 72%, water holding capacity (WHC) 218%, pH 9.5 (1:2.5 w/v in water), 9.4 (0.01 *M* $CaCl_2$), electrical conductivity (EC) 2.56 dS m^{-1}. The total of N, P and K content in biochar was 0.10, 0.15 and 0.20%, respectively. Sewage sludge was also digested in di-acid and analyzed for P and K whereas for the determination of total N in sludge was digested in concentrated H_2SO_4. The sewage sludge used as soil amendment had pH 7.2 (neutral), EC 0.35 dS m^{-1}, oxidizable OC 81.3 g kg^{-1}, total N, P and K content as 1.4, 1.3 and 0.95%, respectively.

A significant increase in plant height (Table 1) at 30, 60 and 90 days after transplanting (DAT) was found with graded application of biochar from 1.12 to 8.96 g kg^{-1} soil amended with sewage sludge @13.4 g kg^{-1}. During the initial stage (60 DAT) of experiment, the maximum plant height (61.5 cm) was noticed in T_2 (100% RDF) and the minimum (48.5 cm) in T_1 (WF). However, treatment T_9 (BC_{20}+SS_{30}+RN_{50}) showed the maximum plant height at 60 DAT (84.2 cm) and 90 DAT (133 cm). The possible explanation lies in the fact that sewage sludge decomposes slowly, thus the release of the nutrients at later growth stages encouraged the growth pattern in rice. The treatments T_4 (1.12 g kg^{-1} BC+13.4 g kg^{-1} SS+50% RDN) and T_6 (3.36 g kg^{-1} BC+13.4 g kg^{-1} SS+50% RDN) were statistically at par to each other. Significant increase in number of tillers (Table 1) was recorded with the application of graded doses of biochar. The maximum number of tillers (7.11) was obtained from treatment T_9 (BC_{20}+SS_{30}+RN_{50}) and the minimum (1.67) in T_1 (WF) at 60 DAT. The treatment T_4, T_5 and T_6 were at par with each other. The increase in number of tillers pot^{-1} might be due to the addition of NPK fertilizers along with biochar and sewage sludge which is a good source of micro and macronutrients in soil (Latare *et al*. 2014). The chlorophyll content measured as SPAD value was maximum (35.6) in leaf (Table 1) was found in treatment T_2 (100% RDF) and the minimum (25.8) was in T_1 (WF) at 30 DAT. Treatment T_4 was at par with T_3 and T_2 (100% RDF) which was 38.3 per cent higher over T_1 (WF) at 60 DAT. This observation may be attributed to supply of N by fertilizers, sewage sludge and additional dose of biochar decreased the N loss due to its sorption. The N is an integral part of chlorophyll and the basic unit of chlorophyll structure (Latare and Singh 2013). Increase in chlorophyll content of rice leaf with application of sewage sludge was also reported by Latare *et al*. (2014).

The maximum grain yield (Table 2) of rice (138 g pot^{-1}) was recorded in T_9 (BC_{20}+SS_{30}+RDN_{50}) which was 8.5 per cent higher over the T_2 (100% RDF). The minimum grain yield (19.3 g pot^{-1}) was in T_1 (WF). Lower dose of biochar did not show any significant effect on grain yield over (T_2) however, in treatment T_9 (BC_{20}+SS_{30}+RDN_{50}), the grain yield of rice was at par with T_2 (RDF). The increase in grain yield of rice may be attributed to the ability of biochar to enhance the cation exchange capacity (CEC) of soil due to its porous nature and more surface area. Thus, more nutrient supply to plant by sorbing the available nutrients released due to the decomposition of sewage sludge. Increase in grain yield of rice with application of sewage sludge had also been observed (Srivastava *et al*. 2009; Latare *et al*. 2014). The straw yield of rice (Table 2) ranged between 76.1 to 143 g pot^{-1}. Application of 100% RDF resulted significantly higher straw yield by 87.9 per cent over T_1 (WF). The straw yield of rice in T_9 (BC_{20}+SS_{30}+RDN_{50}) was at par with T_2 (100% RDF). Previous studies also reported a significant increase in straw yield of rice by application of sewage sludge (Thilagavathi and Subbiah 2006; Latare and Singh 2013).

Nitrogen uptake by rice grain (Table 2) was the maximum (1.23 g pot^{-1}) in T_2 (100% RDF), and the minimum (0.21 g pot^{-1}) in T_1. Similar trend of N uptake was recorded in straw of rice. Latare *et al*. (2014, 2017) also reported increase in uptake of N by rice with application of sewage sludge. The P uptake (Table 2) by rice grain varied from 0.03 g to 0.24 g pot^{-1} and the maximum being in T_9 (BC_{20}+SS_{30}+RN_{50}). The uptake of P was lower in grain as compared to straw. The maximum P uptake (0.49 g pot^{-1}) was found with T_2 (100% RDF) and the minimum (0.13 g pot^{-1}) was recorded in T_1 (WF). Treatments T_2 (100% RDF) showed 2.7 times more P uptake over T_1 followed by 2 times in T_9 (BC_{20}+SS_{30}+RDN_{50}). A significant increase in P uptake of grain and straw was found as the doses of biochar were increased in soil amended with sewage sludge. This was possible due to the retention of P on absorbing sites of biochar which reduce the fixation of P in soil thus increasing its availability. Lehmann *et al*. (2002) also reported that P nutrition and uptake increased when charcoal was added to the Ferralsol and Anthrosol. The K uptake by rice grain varied from 0.06 to 0.38 g pot^{-1} the maximum being with T_2 (100% RDF). Treatment T_2 registered 5.3 times more K uptake over the T_1 followed by 4.8 times in T9 (BC_{20}+SS_{30}+RDN_{50}) and 3.66 times in T_8 (BC_{15}+SS_{30}+RN_{50}). The uptake of K was lower in grain as compared to straw (Tables 2). Potassium uptake by straw varied from 0.72 to 2.04 g pot^{-1}, the maximum being in T_2 (100% RDF). Lehmann

Table 1. Effect of biochar and sewage sludge application on plant height, number of tillers and chlorophyll content in rice leaves (mean of 3 replicates ± SE)

Treatment	Plant height (cm)			Number of tillers pot^{-1}			Chlorophyll content (SPAD value)		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T_1	48.5±1.17 a	66.5±0.80 a	93.8±2.33 a	1.55±0.22 a	1.67±0.67 a	1.44±0.11 a	25.7±0.52 a	28.7±0.53 a	22.5±0.46 a
T_2	61.5±2.85 c	83.5±1.48 c	131.8±1.46 ef	5.33±0.58 d	6.88±0.78 d	5.55±0.55 cd	35.6±1.03 b	38.6±1.05 c	31.4±0.07 de
T_3	50.5±0.55 ab	75.6±0.67 b	104.5±1.35 b	3.22±0.40 b	5.00±0.19 b	3.55±0.55 b	29.9±0.72 bd	32.9±0.73 b	27.1±0.33 b
T_4	54.1±2.19 abc	73.2±0.91 b	107.1±2.63 bc	3.88±0.40 bc	5.44±0.11 b	4.33±0.19 bc	31.0±0.09 b	34.0±0.07 b	29.4±0.46 c
T_5	56.2±1.23 abc	79.1±0.99 bc	112.2±2.88 cd	4.22±0.49 bcd	5.33±0.33 b	4.66±0.38 bcd	33.3±0.75 c	36.3±0.77 d	30.2±0.62 cd
T_6	55.7±1.80 abc	78.5±0.59 bc	112.8±0.73 cd	4.44±0.22 cd	6.00±0.38 bd	4.66±0.19 bcd	33.1±0.67 c	36.1±0.66 d	29.2±0.31 c
T_7	57.6±3.33 bc	78.0±0.67 bc	116.6±1.17 d	5.11±0.29 d	5.77±0.11 bd	5.11±0.59 cd	33.6±0.64 c	34.8±1.29 b	30.9±0.48 de
T_8	57.6±3.79 bc	84.1±3.07 c	126.7±1.72 e	4.89±0.11 cd	6.33±0.19 bd	5.89±0.56 d	33.1±0.44 c	36.4±0.32 de	30.8±0.12 de
T_9	58.6±3.79 bc	84.2±5.03 c	133.0±2.08 f	5.11±0.22 d	7.11±0.45 d	6.11±0.49 d	35.0±0.32 cd	38.8±0.89 c	32.1±0.48 e

Different letters for each parameter show significant difference at $P < 0.05$. Treatments: T_1 - Without fertilizer,T_2 - 100% RDF,T_3 - 13.4 g kg^{-1}SS, T_4 - 1.12 g kg^{-1} BC+13.4 g kg^{-1}SS +50% RDN,T_5 - 2.24 g kg^{-1} BC +13.4 g kg^{-1}SS +50% RDN,T_6 -3.36 g kg^{-1} BC +13.4 g kg^{-1}SS +50% RDN,T_7 -4.48 g kg^{-1} BC +13.4 g kg^{-1}SS +50% RDN,T_8 -6.72 g kg^{-1} BC +13.4 g kg^{-1}SS +50% RDN,T_9 -8.96 g kg^{-1} BC +13.4 g kg^{-1}SS +50% RDN

Table 2. Effect of biochar and sewage sludge application on straw yield, grain yield and N, P and K uptake by rice (mean of 3 replicates ±SE)

Treatment	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})	Nutrient uptake (g pot^{-1}) by rice					
			Grain			Straw		
			N	P	K	N	P	K
T_1	19.3±1.15 a	76.1±1.73 a	0.21±0.02 a	0.03±0.01 a	0.06±0.01 a	0.34±0.02 a	0.13±0.01 a	0.72±0.02 a
T_2	67.8±1.94 f	143±5.59 e	1.23±0.04 f	0.22±0.02 e	0.38±0.01 f	1.22±0.05 g	0.49±0.03 f	2.04±0.06 g
T_3	54.9±2.33 bcd	127±1.24 bc	0.92±0.05 de	0.17±0.01 d	0.27±0.02 d	0.87±0.05 c	0.38±0.01 de	1.61±0.03 de
T_4	50.2±1.89 b	122 ±1.18 b	0.72±0.02 b	0.10±0.01 b	0.19±0.02 b	0.75±0.01 b	0.25±0.01 b	1.42±0.02 b
T_5	51.8±1.53 bc	126±2.05 bc	0.77±0.03 bc	0.11±0.01 bc	0.20±0.01 b	0.88±0.02 c	0.29±0.01 b	1.48±0.03 bc
T_6	55.5±2.06 cd	129±2.04 bc	0.84±0.04 cd	0.12±0.01 bc	0.21±0.01 b	0.90±0.03 cd	0.34±0.01 c	1.53±0.04 cd
T_7	58.0±1.09 de	131±0.88 cd	0.90±0.02 de	0.13±0.01 c	0.24±0.01 c	0.99±0.01 de	0.35±0.01 cd	1.58±0.01 cde
T_8	62.2±1.13 e	133±1.73 cd	0.98±0.03 e	0.18±0.01 d	0.28±0.02 d	1.04±0.05 ef	0.36±0.01 cde	1.65±0.02 e
T_9	74.1±0.81 g	138±1.22 de	1.21±0.01 f	0.24±0.02 e	0.35±0.01 e	1.09±0.02 f	0.40±0.01 e	1.76±0.03 f

Different letters for each parameter show significant difference at $P < 0.05$. See Table 1 for treatment details.

Table 3. Effect of biochar and sewage sludge application on pH, EC, OC and available nutrients in post-harvest soil (mean of 3 replicates ±SE)

Treatment	pH	EC ($dS\ m^{-1}$)	OC ($g\ kg^{-1}$)	Available nutrients ($kg\ ha^{-1}$)		
				N	P	K
T_1	7.3±0.02 abc	0.18±0.02 a	3.0±0.12 a	119±2.90 a	21.10±1.16 a	131±4.05 a
T_2	7.3±0.06 a	0.23±0.02 a	3.2±0.11 a	220±9.13 e	34.70±4.09 b	195±4.91 e
T_3	7.4±0.08 ab	0.21±0.05 a	3.6±0.12 b	217±2.29 de	32.90±3.14 b	174±7.68 cd
T_4	7.6±0.12 bcde	0.23±0.02 a	4.1±0.04 c	188±1.45 bc	28.90±1.93 b	159±5.76 bc
T_5	7.7±0.17 abcd	0.22±0.03 a	4.1±0.08 c	178 ±3.84 b	29.60±2.56 b	156±7.83 b
T_6	7.8±0.25 cde	0.23±0.02 a	4.4±0.04 d	184±2.88 b	27.10±1.54 ab	158±2.93 bcd
T_7	7.9±0.10 de	0.25±0.04 a	4.6±0.07 de	162±8.08 bc	30.40±2.56 b	169±4.37 bcd
T_8	7.8±0.15 de	0.22±0.01 a	4.8±0.07 f	207±4.70 de	30.20±1.15 b	173±2.99 cd
T_9	8.0 ±0.10 e	0.24±0.01 a	5.1±0.08 ef	201±2.27 cd	31.60± 1.07 b	175±1.44 d

Different letters for each parameter show significant difference at $P < 0.05$. See Table 1 for treatment details.

et al. (2003) also reported that K uptake in plant increased with biochar application. A significant increase in K uptake of grain and straw was found as the doses of biochar were increased in soil amended with sewage sludge. Thilagavathi and Subbiah (2006) also reported increase in K uptake with addition of sewage sludge.

The pH of the soil (Table 3) varied from 7.3 (T_1) to 8.0 (T_9). Application of biochar significantly increased pH of the soil which may be attributed to its alkaline nature. It has been reported that chemical properties of biochar after addition in soil cause an increase in pH, EC, CEC and nutrient levels (Warnock *et al*. 2007; Amonette and Joseph 2009). There was no significant increase in the EC of post-harvest soil with application of biochar and sewage sludge. The minimum EC (0.18 $dS\ m^{-1}$) was recorded in T_1 (WF) and the maximum (0.25 $dS\ m^{-1}$) in T_9 (BC_{20}+SS_{30}+RDN_{50}). Although an increase in EC with application of sewage sludge was reported by Jamil *et al*. (2006). But in the present study we did not find significant change in EC of soil. This may be due to the lower dose of sewage sludge application in soil along with biochar which has potential to sorb the soluble cations. Soil OC content significantly increased with the application of biochar and sewage sludge (Table 3). The minimum OC (3.0 $mg\ kg^{-1}$) was observed in T_1 and the maximum (5.1 $mg\ kg^{-1}$) in T_9 (BC_{20}+SS_{30}+RDN_{50}). The treatment T_4 and T_5 were at par with each other. Biochar and sewage sludge being rich source of carbon enhanced the OC content in the soil. The increase in OC with application of biochar might be due to the recalcitrant nature of carbon in biochar which is resistant to decomposition.

Available N, P and K contents of post-harvest soil increased with an increase in application of biochar and sewage sludge along with RDN (Table 3). Available N content of soil ranged between 119 and 220 $kg\ ha^{-1}$, the minimum being in T_1 (WF) and the maximum in T_2 (100% RDF) followed by T_3 (SS_{30}) and T_8 (BC_{15}+SS_{30}+RDN_{50}). Treatment T_8 was at par with T_9 and T_4. Available P in soil increased significantly with application of sewage sludge. Soil available P ranged between 21.1 to 34.7 $kg\ ha^{-1}$, the minimum being in T_1 (WF) and the maximum in T_2 (100% RDF). Available P content in soil was increased by 64.4 per cent over T_1 followed by T_3 (55.9%) and T_9 (49.7%). Treatment T_4 was at par with T_5 and T_6. As regards to available K content in soil (Table 3), it was minimum (131 $kg\ ha^{-1}$) in T_1 (WF) and the maximum (195 $kg\ ha^{-1}$) in T_2 (100% RDF), which was 48.8 per cent higher over T_1 followed by T_9 and T_3. A significant build-up of available soil N, P and K with increase in graded doses of biochar in soil amended with sewage sludge might be due to the higher content of N, P and K compounds in sludge and sorption potential of biochar which reduced nutrients losses from the soil. It may be concluded that biochar addition in soil amended with sewage sludge increased growth, yield and N, P and K uptake by rice and their build-up in post-harvest soil.

References

Amonette, J.E. and Joseph, S. (2009) Characteristics of biochar: microchemical properties. In *Biochar for Environmental Management Science and Technology* (J. Lehmann and S.Joseph Eds.) 3. Earthscan, London, 33-52.

Duncan, D.M. (1955) Multiple range and multiple F-test. *Biometric* **11**, 1-42.

Jamil, M., Qasim, M. and Umar, M. (2006) Utilization of sewage sludge as organic fertilizer in sustainable agriculture. *Journal of Applied Sciences* **6**, 531-535.

Jatav, H.S., Singh, S.K., Singh, Y.V., Paul, A., Kumar, V., Singh, P. and Jayant, H. (2016) Effect of biochar on yield and heavy metals uptake in rice grown on soil amended with sewage sludge. *Journal of Pure and Applied Microbiology* **10**, 1367-1377.

Kidder, G. (2001) Using waste products in forage production. In *Florida Forage Handbook* (C.G. Chambli, Ed.), University of Florida. Gainesville, FL. **142**, 88-93.

Latare, A.M., Kumar, O., Singh, S.K. and Archana, G. (2014) Direct and residual effect of sewage sludge on yield, heavy metals content and soil fertility under rice-wheat system. *Ecological Engineering* **69**, 17-24.

Latare, A.M. and Singh, S.K. (2013) Effect of sewage sludge and fertilizers application on accumulation of heavy metals and yield of rice (*Oryza sativa* L.) in an Inceptisol of Varanasi. *Journal of the Indian Society of Soil Science* **61,** 219-225.

Latare, A.M., Singh, S.K. and Omkar, K. (2017) Yield and profitability of rice-wheat sequence with conjunctive application of sewage sludge and chemical fertilizers. *Indian Journal of Fertilisers* **13**, 50-61.

Lehmann, J., da Silva, J., Steiner, C., Nehls, T., Zech, W. and Glaser, B. (2002) Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the central amazon basin: Fertilizer, manure and charcoal amendments. *Plant and Soil* **249,** 343-357.

Lehmann, J., Kern, D., German, L., Mc Cann, J., Martins, G.C. and Moreira, L. (2003) Soil fertility and production potential. In *Amazonian Dark Earths: Origin, Properties, Management* (J. Lehmann, D.C. Kern, B.Glaser and W.I. Woods, Eds.) Kluwer Academic, Dordrecht, **6**, 105-124.

Liang, B., Lehmann, J., Solomon, D., Kinyangi, J., Grossman, J., O'Neill, B., Skjemstad, J.O., Thies, J., Luizao, F.J., Peterson, J. and Neves, E.G. (2006) Black carbon increases cation exchange capacity in soils. *Soil Science Society of America Journal* **70**, 1719-1730.

Sparks, D.L., Page, A.L., Helmke, P.A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M.A., Johnston, C.T. and Sumner, M.E. (1996) *Methods of Soil Analysis*. Part 3 – *Chemical Methods*. Madison, Wisconsin, USA: Soil Science Society of America Inc., American Society of Agronomy Inc. Madison Wisconsin, USA.

Srivastava, P.C., Singh, A.P., Kumar, S., Ramachandran, V., Shrivastava, M. and D'souza, S.F. (2009) Comparative study of a Zn-enriched post methanation bio sludge and Zn sulfate as Zn sources for a rice-wheat crop rotation. *Nutrient Cycling in Agroecosystems* **85**, 195-202.

Tandon, H.L.S. (2001) *Methods of Analysis of Soils, Plants, Waters, and Fertilisers.* Fertiliser Development and Consultation Organization, New Delhi, India.

Thilagavathi, T. and Subbiah, S. (2006) Integrated management of sewage sludge and fertilizers for enhanced productivity and nutrient uptake of rice. *Advances in Plant Sciences* **19**, 551-556.

Warnock, D.D., Lehmann J., Kuyper T.W. and Rillig, M.C. (2007) Mycorrhizal responses to biochar in soil concepts and mechanisms. *Plant and Soil* **300**, 9-20.

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