Effect of Biochar on Yield and Heavy Metals Uptake in Rice Grown on Soil Amended with Sewage Sludge

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A green house experiment was conducted in the net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) during *kharif*, 2013 to find out the effect of biochar on availability of heavy metals in soil amended with sewage sludge. There were nine treatments, consisting of six different doses of biochar as 2.5, 5.0, 7.5 10, 15, 20 t ha^{-1} along with 100% RDF and sewage sludge @ 30 t ha^{-1} applied in each biochar amended pot. In order to recover plant from initial stress, 50% recommended dose of nitrogen (RDN) was applied in each pot at 45 DAT. Results of this study showed a significant increase in test weight, grain and straw yield with application of graded level of biochar along with sewage sludge. Soil pH and electrical conductivity did not show any significant change with application of sewage sludge but with increasing levels of biochar pH of soil showed a significant increase. Application of biochar @ 20 t ha^{-1} along with sewage sludge (30 t ha^{-1}) was found to increase grain yield to 2.5 times over control (T_1) and 8.5 % over 100 % RDF. Application of 20 t biochar along with 30 t sewage sludge ha^{-1} (T_9) registered lowest chromium content in grain. Uptake of Cd, Cr, Ni and Pb was found maximum both in grain and straw with application of 30 t ha^{-1} of sludge sewage (T_3) where as minimum uptake was recorded with conjoint application of 20 t biochar and 30 t sewage sludge ha^{-1} (T_9).

Keywords: Biochar, Heavy metals, Sewage Sludge, Rice, fertilizer.

India has to produce 300 Mt of food grains by 2020 to feed growing population. The net cultivated land (142.5 M ha) is limited and pressure for production of food grains is increasing, therefore, maintenance of soil fertility is a prime issue for farmers. To achieve the above food demand, 45 million tonnes nutrients are required in which 35 Mt is estimated to be supplied by chemical fertilizer and remaining by organic sources[1]. The present day agriculture is facing a problem of continuous decline in soil nutrients reserve and decrease in organic matter content of soil. This may be due to intensive cropping system coupled with limited application of FYM, green manure, vermicompost and crop residue in the field. Due to rapid urbanization and industrialization, a huge amount of inorganic and organic wastes are produced in which sewage sludge is one. In India, about 450 cities generate more than 17×10^6 m^3 of raw sewage per day. With available treatment plants, production of sewage sludge is estimated to be around 1,200 tonnes per day, although there exists a potential to produce 4,000 tonnes of sludge per day[2]. The nutrient potential of available sewage in

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India is estimated to be more than 3,50,000 tonnes N, 1,50,000 tonnes P and 2,00,000 tonnes K per year[3].

Sewage sludge and effluents from municipal origin are rich in organic matter and is a good source of plant nutrients[4]. Sewage sludge and effluents are frequently disposed off on agricultural lands for irrigation/manures purposes that may prove beneficial because of its organic matter and nutrient content and harmful as it may contain high amount of heavy metals which may limit their long term use in agriculture. The heavy metals may be present in excess amount and prove either phytotoxic *(e.g.* Zn, Cu, Ni) or hazardous for human health (Cd, Cr, Pb, Hg). For reducing the effect of these metals in food web, the biochar can play a vital role. Biochar refers to a kind of charcoal made from biomass. Unlike charcoal made for fuel, biochar has properties which make it a valuable soil amendment for mitigation of negative effects of heavy metals by sorption[5]. Biochar has been found to sorbs a variety of heavy metals, including lead (Pb), arsenic (As) and cadmium (Cd). The global production of biochar (black carbon) has been estimated to be between 50 and 270 Tg yr^{-1}, with as much as 80 % of this remaining as residues in the soil[6]. Total of 9.5 billion tonnes of carbon could potentially be stored in soils by the year 2100 using a wide variety of biochar application programmes[7].

Rice (*Oryza sativa* L.) is one of the most important staple food crop for more than half of the world population, especially for south-eastern Asia, where 90% of the world production of rice is grown and consumed. Rice covers about 158.95 Mha areas in world with annual production of 685.01 Mt of grain with average productivity of 4.31 t ha^{-1} globally [1].The country like India has biggest area under rice cultivation, as it is one of the principal food crops. In India, the rice crop occupies 44 million ha of land and produces about 104.32 million tones, which is second in the world after China. In view of increasing use of sewage sludge in crop production and associated potential risk of heavy metals uptake. The present investigation was taken up to study the effect of various levels of biochar on yield and uptake of heavy metals in rice grown soils amended with sewage sludge.

MATERIALS AND METHOD

The pot experiment was conducted on alluvial soil of Varanasi representing an Inceptisol (Typic Ustochrept) during July to November 2013, in the net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agriculture Sciences, Banaras Hindu University, Varanasi (U.P.). The experimental soil (0-15 cm) had pH 7.4, EC 0.22 dS m^{-1}, organic carbon 0.3 g kg^{-1} and available N, P, K and S to the tune of 126, 18.51, 137.30 and 12.78 kg ha^{-1}, respectively. The DTPA-extractable micronutrients Fe, Cu, Zn and Mn in soil were 22.14, 2.25, 1.65 and 8.57 mg kg^{-1} and heavy metals, Cd, Cr, Ni, and Pb were 0.752, 0.164, 2.03 and 0.087 mg kg^{-1}, respectively.

Biochar was obtained from a rice mill of village Kollana, Mirzapur (U.P.) where it is considered as a waste material coming form gasifire plant which utilize rice husk as fuel. Farmer of this district has established Rice mills as small scale industries. They burn rice husk under controlled supply of oxygen and obtained smokes are used to mix diesel to get smoke- diesel aerosol. Therefore, the fuel efficiency of diesel engine is increased. The remaining incomplete dark black material of rice husk is known as rice husk Biochar

The Biochar (figure-1, a) use as a heavy metal sorbed material had the colour 2.5 YR 2.5/0 (Black), Bulk density 0.40 (Mg m^{-3}), porosity 72 % and WHC 218 %. The Biochar (BC) had the pH 9.5 (H_2O), 9.4 (0.01M $CaCl_2$) 1:2.5, 9.3 (0.01M $CaCl_2$) 1:5, EC 2.56 (dSm^{-1}), Ca & Mg 0.21 and Na 0.35 mg kg^{-1} respectively (Table 2). The total amount of N, P, K was 0.10, 0.15, 0.20% and DTPA extractable metal was not detected. Six graded levels of biochar were taken *i.e*. 2.5, 5.0, 7.5, 10, 15, and 20 t ha^{-1} which were equivalent to 11.20 g ($BC_{2.5}$), 22.40 g ($BC_{5.0}$), 33.60 g ($BC_{7.5}$), 44.80 g (BC_{10}), 67.20 g (BC_{15}), and 89.60 g pot^{-1} (BC_{20}), respectively for 10 kg of soil.

The sewage sludge (SS) used as soil amendment had pH 7.2, EC 0.35 dS m^{-1}, organic C 8.13 %, total N, P, K and S content as 1.4, 1.3, 0.95 and 2.1%, respectively (Table 3). The DTPA-extractable Fe, Cu, Zn and Mn in SS were 49.56, 13.50, 15.24 and 21.47 mg kg^{-1} and Cd, Cr, Ni and Pb content was 3.2, 4.9, 29.34 and 7.6 mg kg^{-1}, whereas total content was 32.2, 44.3, 54.6 and 28.4 mg kg^{-1}, respectively.

The constant dose of Sewage sludge (figure-1, b) was taken *i.e.*30 t ha^{-1} (SS_{30}) which was equivalent to 131 g pot^{-1}10 for kg of soil. This constant dose of sewage sludge was applied in treatment T_3 to T_9. Required quantities of biochar, sewage sludge and fertilizer for 10 kg soil were calculated. The experiment was conducted in completely randomized block design taking rice as a test crop.

Biochar and Sewage Sludge were thoroughly mixed well with soil. Full dose of fertilizers (accept ½ dose Nitrogen) applied in solution through Urea, DAP, and MOP, as source of N, P, and K before transplanting of rice seedlings. Remaining ½ recommended dose nitrogen (RDN) fertilizer was applied in two split doses at tillering and flowering initiation stage. The detail of treatment combination is given in Table 1. The experiment was laid out in a completely randomized design with three replications taking rice cv. Swarna as test crop. Grain and straw yield pot^{-1} were recorded after harvesting of crop.

The plants were harvested at maturity, washed sequentially with 0.2% detergent solution, 0.1 N HCl and finally with double distilled water. The plant material was dried at 60+2 °C for 48 h in a hot air oven. Dry plant tissues were finely ground and digested in a di-acid mixture (HNO_3: $HClO_4$ :: 3:1, v/v) and diluted. The content of Fe, Cu, Zn, Mn, Cd, Cr, Ni and Pb in the straw and grain digest was determined by using atomic absorption spectrophotometer (UNICAM-969). Similarly, biochar was also digested and content of Fe, Cu, Zn, Mn, Cd, Cr, Ni and Pb were determined by using atomic absorption spectrophotometer (UNICAM-969). Sewage sludge was also digested in di-acid and analyzed for P, K and total micronutrients (Fe, Cu, Mn, Zn) and heavy metals (Cd, Cr, Ni and Pb), however, for the determination of total N sludge was digested in concentrated H_2SO_4. The soil samples were analyzed for pH in 1:2.5 soil: water suspension; EC (dSm^{-1}) organic carbon[8]; DTPA-extractable Cd, Cr, Ni and Pb by methodusing Atomic Absorption spectrophotometer (AAS)[9].

RESULTS AND DISCUSSION

Grain Yield

The grain yield of rice (Table 4) increased significantly by applying sewage sludge along with biochar. The application of 100% RDF (T_2) resulted in significantly higher grain yield by 23.49%, 35.05% and 2 time over T_3 (SS_{30}), T_4 ($BC_{2.5}$ SS_{30} RN_{50}) and control (T_1), respectively. The maximum grain yield was observed in T_9 (BC_{20} SS_{30} RN_{50}) which was 8.5% higher over the treatment T_2 (100% RDF). Lowest grain yield (19.3 g pot^{-1}) recorded in control which was two times lower than the T_7 (BC_{10} SS_{30} RN_{50}) and T_8 (BC_{15} SS_{30} RN_{50}). Increase in grain yield of rice with application of sewage sludge[10]. The bean yield increased by 46% and biomass production by 39% over the control at 60 g kg^{-1} biochar[11]. A signiûcant increase in straw and grain yields of rice with application of sewage sludge[12].

Table 1. Treatment combination

Treatment	Fertilizer	Applied Biochar		Applied Sewage Sludge	
		Pots (g kg^{-1} soil)	Equivalent ton ha^{-1}	Pots (g kg^{-1} soil)	Equivalent ton ha^{-1}
T_1	0	0	0	0	0
T_2	100% RDF	0	0	0	0
T_3	50% RDN	0	0	131	30
T_4	50% RDN	11.20	2.5	131	30
T_5	50% RDN	22.40	5.0	131	30
T_6	50% RDN	33.60	7.5	131	30
T_7	50% RDN	44.80	10	131	30
T_8	50% RDN	67.20	15	131	30
T_9	50% RDN	89.60	20	131	30

RDF – Recommended dose of fertilizers (N, P_2O_5, and K_2O 120:60:60)
RDN – Recommended dose of nitrogen

Straw Yield

The straw yield of rice (Table 4) ranged between 76.1 to 143 g pot^{-1}. The application of 100% RDF resulted in significantly higher straw yield by 87.91% than the straw yield obtained from T_1 (control). The maximum straw yield (143 g pot^{-1}) was recorded in the T_2 (100% RDF) which was higher than T_9 (BC_{20} SS_{30} RN_{50}) by 7.5%, T_8 (BC_{15} SS_{30} RN_{50}) by 9.1%, T_7 (BC_{10} SS_{30} RN_{50}) and T_6 ($BC_{7.5}$ SS_{30} RN_{50}) by 13.4%. The treatment T_3 (SS_{30}) was 66.8 % higher over the control (T_1) and 12.5 % lower from the T_2 (100% RDF). Significant increase in straw yield might be due to the availability of all essential elements to the rice crop in sufficient amount by the sewage sludge application. A significant increase in straw yield of wheat and rice was also reported[13].

Test Weight

The test weight of rice (Table 4) ranged from 16.5 to 22.2 g 1000 grains^{-1} and it increased significantly with application of graded level of biochar and constant level of sewage sludge. The maximum test weight (22.2 g) was recorded with treatment T_9 (BC_{20} SS_{30} RN_{50}) which was 34.54 % higher over control (T_1) followed by 33.3 % T_2 (100% RDF). Minimum test weight (16.50g) was recorded in control (T_1). The increase in test weight might be the result of improvement in the soil fertility due to sewage sludge application. Similar findings also reported[14]. The higher thousands seed weight of dry been grown at 2, 4, and 6 kg m^{-2} sewage sludge amendment rates as compared to unamended soil[15]. A significant increase in test weight, grain and straw yield of rice crop with conjoint application of sewage sludge and fertilizer [13].

Harvest Index

The highest harvest index (Table 4) was registered (34.5%) in T_9 (BC_{20} SS_{30} RN_{50}) which was 8.02% higher over 100% RDF (T_2).The harvest index ranged from 20.2 to 34.9% and the treatment T_3 (SS_{30}), T_4 ($BC_{2.5}$ SS_{30} RN_{50}), T_5 (BC_5 SS_{30} RN_{50}), T_6 ($BC_{7.5}$ SS_{30} RN_{50}), T_7 (BC_{10} SS_{30} RN_{50}) were found statistically at par to each other. The minimum harvest index was recorded in the control (T_1), which decreased 78.37% from the T_9 (BC_{20} SS_{30} RN_{50}).

Heavy Metals Concentration and Heavy Metals Uptake

Cadmium content in grain and straw

The data pertaining to Cd content in grain (Table 5) showed a significant effect with graded application of biochar and constant level of sewage

Table 2. Physico- chemical characteristics of Rice husk biochar

Properties	Biochar
Colour	2.5 YR 2.5/0 (Black)
Bulk density (Mg m^{-3})	0.40
Porosity	72%
Particle density (Mg m^{-3})	1.40
Available WHC (Using keens box)	218%
pH (H_2O) 1:2.5	9.5
pH (0.01M $CaCl_2$) 1:2.5	9.4
pH (0.01M $CaCl_2$) 1:5	9.3
EC (dSm^{-1})	2.56
Organic carbon (%)	4.80
Ca & Mg (mg kg $^{-1}$)	0.21
Na (mg kg $^{-1}$)	0.35
Total N (%)	0.10
Total P (%)	0.15
Total K (%)	0.20
DTPA Extractable Metal (mgkg^{1})	
Ni	Not Detected
Cr	Not Detected
Pb	Not Detected
Cd	Not Detected

Table 3. The physico- chemical characteristics of Sewage Sludge

Properties	Sewage sludge
Colour	7.5YR 4/2 (Light brown)
Bulk density (Mg m^{-3})	1.65
Available WHC (Using keens box)	48.37
pH (H_2O) 1:2.5	7.2
EC (dSm^{-1})	0.35
Organic carbon (%)	8.13
C/Nratio	16.03:1
Total N (%)	1.4
Total P (%)	1.30
Total K (%)	0.95
Total S (%)	2.1
DTPA Extractable Metal (mgkg^{1})	
Ni	29.34
Cr	4.9
Pb	7.6
Cd	3.2

sludge. The maximum (1.59 mg kg^{-1}) was recorded inT_3 (SS_{30}) which was 4 times higher over the T_1 (Control) followed by 3 times in T_4 and BC_5 SS_{30} $RN_{50}$$T_5$ .The minimum (0.31 mg kg^{-1}) was observed in T_1 Control. The treatment T_3 (SS_{30}) was 75.47 % higher than the T_2 (100% RDF) followed by treatment T_4 (69.04%), T_5 (68.8 %), T_6 (62.13%), T_7 (61.00%) and T9 (41%). Treatment T_4 ($BC_{2.5}$ SS_{30} RN_{50}) was found at par with T_5 (BC_5 SS_{30} RN_{50}) and T_6 ($BC_{7.5}$ SS_{30} RN_{50}). The data pertaining to Cd content in rice straw (Table 5) experienced significant decrease with graded application of biochar. The Cd content in rice straw increased from 0.69 to 2.74 mg kg^{-1}. Maximum (2.74 mg kg^{-1}) being in T_3 (SS_{30}) and minimum (0.69 mg kg^{-1}) in T_1 (Control).Treatments T_3 (SS_{30}) was almost 3 times

Table 4 . Effect of biochar application on test weight, harvest index, grain yield and straw yield of rice grown in soil amended with sewage sludge

Treatment	Test weight (Wt. of 1000 grains)	Harvest index (%)	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})
T_1	16.5	20.2	19.3	76.1
T_2	22.0	32.1	67.8	143
T_3	19.3	30.2	54.9	127
T_4	17.7	29.0	50.2	122
T_5	19.1	29.1	51.8	126
T_6	19.0	30.0	55.5	129
T_7	20.1	30.7	58.0	131
T_8	21.4	31.8	62.2	133
T_9	22.2	34.9	74.1	138
SEm±	0.74	0.67	1.63	2.38
CD (P=0.05)	2.14	1.95	4.74	6.92

Treatments: T_1 –Control, T_2 – 100% RDF, T_3 – 30 t ha^{-1} SS, T_4 – 2.5 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_5 – 5.0 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_6 –7.5 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_7 –10 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_8 –15 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN , T_9 –20 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN

Table 5. Effect of biochar application on Cd, Cr Concentration and uptake in rice grown in soil amended with sewage sludge

Treatment	Biochar (t ha^{-1})	Sewage Sludge (t ha^{-1})	Cd (mg pot^{-1}) Concentration Grain	Cd Concentration Straw	Cd Uptake Grain	Cd Uptake Straw	Cd Uptake Total	Cr (mg pot^{-1}) Concentration Grain	Cr Concentration Straw	Cr Uptake Grain	Cr Uptake Straw	Cr Uptake Total
T_1	0	0	0.31	0.69	0.01	0.05	0.06	0.92	0.80	0.02	0.06	0.08
T_2	0	0	0.39	0.85	0.03	0.12	0.15	0.88	1.11	0.06	0.16	0.22
T_3	0	30	1.59	2.74	0.09	0.35	0.43	2.15	2.37	0.12	0.30	0.42
T_4	2.5	30	1.26	2.54	0.06	0.31	0.37	1.86	1.86	0.09	0.23	0.32
T_5	5.0	30	1.26	2.51	0.07	0.32	0.38	1.43	1.43	0.07	0.18	0.25
T_6	7.5	30	1.25	2.29	0.07	0.30	0.37	1.27	1.24	0.07	0.16	0.23
T_7	10	30	1.03	2.28	0.06	0.30	0.36	0.99	1.11	0.06	0.15	0.20
T_8	15	30	1.00	1.99	0.06	0.27	0.33	0.94	1.10	0.06	0.15	0.21
T_9	20	30	0.67	1.46	0.05	0.20	0.25	0.83	1.01	0.06	0.14	0.20
SEm±			0.04	0.09	0.01	0.01	0.01	0.07	0.04	0.001	0.01	0.01
CD (P=0.05)			0.13	0.26	0.01	0.04	0.04	0.20	0.11	0.01	0.02	0.03

Treatments: T_1 –Control, T_2 – 100% RDF, T_3 – 30 t ha^{-1} SS, T_4 – 2.5 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_5 – 5.0 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_6 –7.5 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_7 –10 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_8 –15 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN , T_9 –20 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN higher than the control(T_1) followed by T_5 (2.68 times), T_6(2.63 times), T_7(2.31 times),T_8(2.30 times) and T_9(1.68 times). Treatment T_8 (BC_{15} SS_{30} RN_{50}) was at par with T_9 (BC_{20} SS_{30} RN_{50}).

The increase in Cd content of straw and grain of rice in T_3 (SS_{30}) may be due to addition of Cd present in sewage sludge, however a significant decrease in content and uptake of Cd with the application of biochar (T_4 toT_8) may be due to the adsorption of Cd by biochar.

Cadmium uptake in grain and straw

A significant variation in uptake of Cd (Table 5 & Figure 2) with the straw and grain with the application of biochar and sewage sludge was noticed. The Cd uptake by grain varied from 0.01 to 0.09 mg pot^{-1}. The maximum uptake (0.09 mg pot^{-1}) was observed in T_3 (SS_{30}) which increased by 8 times over control (T_1). The minimum Cd uptake by rice grain (0.01 mg pot^{-1}) was observed in control

Table 6. Effect of biochar application on Ni, Pb Concentration and uptake in rice grown in soil amended with sewage sludge

Treatment	Biochar (t ha^{-1})	Sewage Sludge (t ha^{-1})	Cd (mg pot^{-1}) Concentration Grain	Straw	Uptake Grain	Straw	Total	Cr (mg pot^{-1}) Concentration Grain	Straw	Uptake Grain	Straw	Total
T_1	0	0	5.00	7.10	0.10	0.54	0.64	0.10	0.46	0.01	0.03	0.04
T_2	0	0	7.99	7.90	0.54	1.13	1.67	0.27	0.49	0.02	0.07	0.09
T_3	0	30	11.01	19.61	0.61	2.48	3.09	0.63	1.15	0.03	0.14	0.18
T_4	2.5	30	9.55	14.94	0.48	1.83	2.31	0.16	0.44	0.01	0.05	0.06
T_5	5.0	30	9.80	13.95	0.51	1.76	2.27	0.14	0.37	0.01	0.05	0.05
T_6	7.5	30	7.50	13.35	0.42	1.73	2.14	0.14	0.30	0.01	0.04	0.05
T_7	10	30	6.06	14.47	0.35	1.89	2.24	0.16	0.27	0.01	0.03	0.04
T_8	15	30	5.66	11.07	0.35	1.48	1.83	0.13	0.23	0.01	0.03	0.04
T_9	20	30	5.67	10.01	0.42	1.38	1.80	0.12	0.21	0.01	0.03	0.04
SEm±			0.23	0.51	0.02	0.06	0.07	0.02	0.02	0.001	0.003	0.003
CD (P=0.05)			0.66	1.48	0.06	0.19	0.22	0.05	0.06	0.004	0.01	0.01

Treatments: T_1 –Control, T_2 – 100% RDF, T_3 – 30 t ha^{-1} SS, T_4 – 2.5 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_5 – 5.0 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_6 –7.5 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_7 –10 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_8 –15 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN , T_9 –20 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN

Table 7. Effect of Biochar application on pH, EC, Organic Carbon and Heavy metals (Cd, Cr, Ni, Pb) in post harvest soil amended with sewage sludge

Treatment	pH	EC(dS m^{-1})	OC (%)	Heavy metals in post harvest soil (mg kg^{-1}) Cd	Cr	Ni	Pb
T_1	7.3	0.18	0.30	0.64	0.15	1.80	0.19
T_2	7.3	0.23	0.32	1.09	0.25	2.59	0.29
T_3	7.4	0.21	0.36	2.59	1.00	5.19	2.04
T_4	7.6	0.23	0.41	1.36	0.38	2.93	0.77
T_5	7.7	0.22	0.41	1.11	0.47	3.09	0.91
T_6	7.8	0.23	0.44	1.14	0.51	3.22	0.88
T_7	7.9	0.25	0.46	1.57	0.60	3.19	1.10
T_8	7.8	0.22	0.48	1.85	0.72	3.92	0.87
T_9	8.0	0.24	0.51	2.00	0.84	4.19	1.16
SEm±	0.16	0.01	0.01	0.15	0.03	0.09	0.05
CD (P=0.05)	NS	NS	0.03	0.45	0.09	0.26	0.13

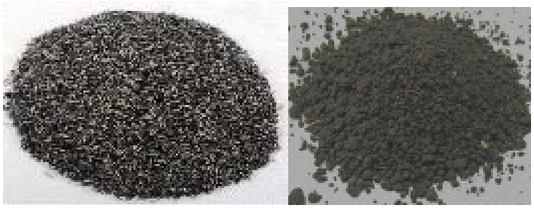
Treatments: T_1 –Control, T_2 – 100% RDF, T_3 – 30 t ha^{-1} SS, T_4 – 2.5 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_5 – 5.0 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_6 –7.5 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_7 –10 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_8 –15 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN , T_9 –20 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN

(T_1). Application of 30 t ha^{-1} sewage sludge alone resulted in 8 times increase in uptake of Cd in rice grain over control. The uptake of Cd was found maximum (0.09) in T_3 (SS_{30}) followed by T_5 (BC_5 SS_{30} RN_{50}) and T_6 ($BC_{7.5}$ SS_{30} RN_{50}). The treatment T_3 (SS_{30}) increased Cd uptake by 5 times over the T_2 (100% RDF) followed by T_5 (BC_5 SS_{30} RN_{50}) and T_6 ($BC_{7.5}$ SS_{30} RN_{50}): 57.14%, T_7 (BC_{10} SS_{30} RN_{50}) and T_8 (BC_{15} SS_{30} RN_{50}): 50% and T_9 (BC_{20} SS_{30} RN_{50}):40 %. Treatment T_8 (BC_{15} SS_{30} RN_{50}) and T_9 (BC_{20} SS_{30} RN_{50}) and T_4 ($BC_{2.5}$ SS_{30} RN_{50}) and T_5 (BC_5 SS_{30} RN_{50}) were at par. The Cd uptake by straw varied from 0.05 to 0.35 mg pot^{-1}. The maximum uptake (0.35 mg pot^{-1}) was observed in T_3 (SS_{30}) followed by T_5 (BC_5 SS_{30} RN_{50}): 0.32 mg pot^{-1} T_4 ($BC_{2.5}$ SS_{30} RN_{50}): 0.31 mg pot^{-1} and T_6 ($BC_{7.5}$ SS_{30} RN_{50}): 0.30 mg pot^{-1}. Both Chicken Manure and Green Waste were very effective in reducing Cd and Pb concentrations of Indian mustard shoots[16, 17]. Application of sewage sludge along with fertilizers also increased Cd content and uptake in rice straw and grain[13].

Chromium content in grain and straw

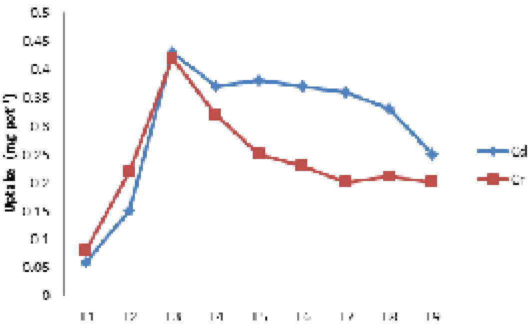
The data pertaining to of Cr content in grain (Table 5) showed a significant effect with graded application of biochar and constant level of sewage sludge. The maximum (2.15 mg kg^{-1}) was recorded inT_3 (SS_{30}) which showed an increase of 1.3 times over the T_1 (Control) followed by T_4 ($BC_{2.5}$ SS_{30} RN_{50}) and T_5 ($BC_{5.0}$ SS_{30} RN_{50}). The minimum Chromium content was in T_9 (BC_{20} SS_{30} RN_{50}) which was 9.7 % lower than control. The content of chromium in T_3 (SS_{30}) was 59.06% higher than T_2 (100% RDF).

The data pertaining to Cr content in rice (Table 5) revealed that the maximum content of chromium was (2.37 mg kg^{-1}) in T_3 (SS_{30}) which was 53.16% higher than T_2 (100% RDF) and minimum content was found in T_1 (Control). Treatment T_3 (SS_{30}) found 1.96 times higher than the T_1 (Control). The treatment T_2 (100% RDF), was at par with treatment T_8 (BC_{15} SS_{30} RN_{50}) and T_9 (BC_{20} SS_{30} RN_{50}). A significant decreased Cr content by (53.16%) in T_2 (100% RDF) over T_3 (SS_{30}) followed by T_4 (40.32%), T_5 (22.37%) and T_6 (10.48%) was noticed. The normal range of Cr in plants is considered 0.03-14.00 mg kg^{-1}, while the toxic concentrations fall between 5-30 mg kg^{-1} [18]. This



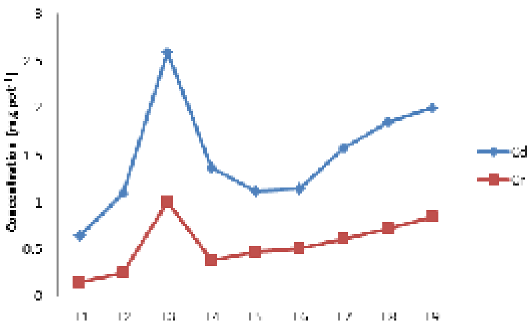
(a) Rice husk Biochar (b) Sewage Sludge

Fig. 1. Experimental material a) Rice husk Biochar and (b) Sewage Sludge



Treatments: T_1 –Control, T_2 – 100% RDF, T_3 – 30 t ha^{-1} SS, T_4 – 2.5 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_5 – 5.0 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_6 –7.5 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_7 –10 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_8 –15 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN , T_9 –20 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN

Fig. 2. Effect of biochar application on Cd and Cr uptake in rice grown in soil amended with sewage sludge



Treatments: T_1 –Control, T_2 – 100% RDF, T_3 – 30 t ha^{-1} SS, T_4 – 2.5 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_5 – 5.0 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_6 –7.5 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_7 –10 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN, T_8 –15 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN , T_9 –20 t ha^{-1} BC+30 t ha^{-1} SS +50% RDN

Fig. 3. Effect of Biochar application on Cd and Cr concentration in post harvest soil amended with sewage sludge

suggests that plant Cr in this study was in the normal range. The concentration of chromium in rice grain and straw significantly decreased due to biochar application which may be due to the slow release pattern of heavy metal adsorption biochar. Green waste-derived biochar (GW) immobilized Cd, Cu, and Pb by 30.3, 22.9 and 36.8%, respectively, for spiked soil, and by 42.7, 0.901 and 72.9% for naturally contaminated soil[16].

Chromium uptake in grain and straw

The Cr uptake in rice grain (Table 5 & Figure 2) varied from 0.02 to 0.12 mg pot^{-1}. The maximum uptake (0.12 mg pot^{-1}) was recorded in T_3 (SS_{30}) which was about 5 times higher than control (T_1). The chromium uptake by rice grain was maximum in T_3 (SS_{30}) which showed an increase of 5 times over control followed by T_4 ($BC_{2.5}$ SS_{30} RN_{50}): 3.5 times, T_5 (BC_5 SS_{30} RN_{50}) and T_6 ($BC_{7.5}$ SS_{30} RN_{50}): 2.5 times,T_7 (BC_{10} SS_{30} RN_{50}) and T_8 (BC_{15} SS_{30} RN_{50}): 2 times. Treatment T_6 ($BC_{7.5}$ SS_{30} RN_{50}) was at par with T_7 (BC_{10} SS_{30} RN_{50}), T_8 (BC_{15} SS_{30} RN_{50}) T_9 (BC_{20} SS_{30} RN_{50}).

The uptake of Cr in rice straw varied from 0.06 to 0.30 mg pot^{-1}. The maximum Cr uptake (0.30 mg pot^{-1}) was observed in T_3 (SS_{30}) and minimum 0.06 mg pot^{-1}in control. The treatment T_3 (SS_{30}) had Cr uptake 4 times higher over control (T_1) followed by T_4 ($BC_{2.5}$ SS_{30} RN_{50}): 2.8 times, T_5 (BC_5 SS_{30} RN_{50}): 2 times, T_6 ($BC_{7.5}$ SS_{30} RN_{50}) &T_2 (100% RDF): 1.6times, T_7 (BC_{10} SS_{30} RN_{50}) &T_8 (BC_{15} SS_{30} RN_{50}): 1.5 times and T_9 (BC_{20} SS_{30} RN_{50}): 1.3 times.

Nickel content in grain and straw

The Ni content in grain (Table 5) significantly affect by application of graded dose of biochar along with of sewage sludge. The maximum nickel content (7.99mg kg^{-1}) in grain was in T_3 (SS_{30}) which was 1.2 times higher than the T_1 (Control), and the minimum content (5.00 mg kg^{-1}) was in treatment T_1 (Control). The treatment T_8 (BC_{15} SS_{30} RN_{50}) and T_9 (BC_{20} SS_{30} RN_{50}) was at par with T_7 (BC_{10} SS_{30} RN_{50}). The T_2 (100% RDF), registered 59.08 % increase in Ni content over control (T_1) followed by T_9 (40.90%), T_8 (41.16%), T_7 (31.84%) and T_6 (6.5%).

Similar results were observed in Ni content of straw. It ranged from 7.10 to 19.61 mg kg^{-1}. The maximum (19.61 mg kg^{-1}) was observed in T_3 (SS_{30}) and the minimum (7.10 mg kg^{-1}) in control (T_1).Treatments T_2 (100% RDF) showed a significant decrease in Ni content by 59.71% from T_3 (SS_{30}) followed by T_4 (47.12%), T_5 (43.36%), T_6 (40.82%), T_8 (28.63%) and T_9 (21.07%). A significant decrease in Ni content was noticed with the application of biochar in combination with sewage sludge. Concentration of chromium in rice grain and straw significantly decreased by 20 to 40 % over 100% RDF which may result due to the slow release pattern of heavy metal adsorbed on biochar. Significant increase in Ni concentration in seed at 4 kg m^{-2} sewage sludge amendment in both years in dry bean[15].

Nickel uptake in grain and straw

The Ni uptake in rice grain ranged between 0.10 to 0.61 mg pot^{-1} (Table 6). The maximum uptake (0.61 mg pot^{-1}) was recorded in T_3 (SS_{30}) which was 5 times Ni uptake over control (T_1). The minimum (0.10 mg pot^{-1}) was found in control. Application of 30 t ha^{-1} sewage sludge with biochar (T_3) resulted 11.47% increase in uptake of Ni by rice grain over T_2 (100% RDF). The Treatments T_3 (SS_{30}) showed 5 times higher over control (T_1) followed by T_5 (BC_5 SS_{30} RN_{50}): 4.1times, T_4 ($BC_{2.5}$ SS_{30} RN_{50}) &T_9 (BC_{20} SS_{30} RN_{50}): 3.8 times, T_6 ($BC_{7.5}$ SS_{30} RN_{50}): 3.2 time and T_7 (BC_{10} SS_{30} RN_{50}) &T_8 (BC_{15} SS_{30} RN_{50}): 2.5 times. Thus a significant decrease in Ni uptake was noticed with increase in doses of biochar.

The Ni uptake in rice straw ranged between 0.54 to 2.48 mg pot^{-1} (Table 6). The maximum uptake (2.48 mg pot^{-1}) was recorded in T_3 (SS_{30}) and the minimum was observed in control (T_1). Treatments T_3 (SS_{30}) showed 3.5 times increase in Ni uptake over control (T_1) followed by T_7 (BC_{10} SS_{30} RN_{50}): 2.5 times, T_4 ($BC_{2.5}$ SS_{30} RN_{50}):2.3 times, T_5 (BC_5 SS_{30} RN_{50}): 2.2 times and T_6 ($BC_{7.5}$ SS_{30} RN_{50}) : 2.2 times. Treatment T_2 (100% RDF) was found 38.25 % decreased over T_4 ($BC_{2.5}$ SS_{30} RN_{50}) followed by T_5 (BC_5 SS_{30} RN_{50}): 35.79%, T_6 ($BC_{7.5}$ SS_{30} RN_{50}): 34.68%, T_7 (BC_{10} SS_{30} RN_{50}): 40.21%, T_8 (BC_{15} SS_{30} RN_{50}): 23.64 and T_9 (BC_{20} SS_{30} RN_{50}): 18.11 %. A significant decrease in Ni uptake with addition of Biochar was also reported [16].

Lead content in grain and straw

The data pertaining to Pb content in rice grain revealed that its content varied from 0.10 to 0.63 mg kg^{-1} (Table 6). The maximum (0.63 mg kg^{-1}) was observed in T_3 (SS_{30}) and minimum (0.10 mg kg^{-1}) in T_1 (Control).The Pb content in grain is increased by 5.3 times over control in T_3 (SS_{30}) followed by 1.7 times in T_2 (100% RDF), T_4 (60%)

and T_7 (60%) T_6 (40%), T_8 (30%) and T_9 (20%). The data pertaining to Pb content in rice straw also showed similar significant effect. Its content ranged from 0.21 to 1.15 mg kg^{-1}(Table 6). The maximum of 1.15 mg kg^{-1} was observed in T_3 (SS_{30}) and the minimum 0.21 mg kg^{-1} in T_9 (0.21mg kg^{-1}) followed by T_8 (0.23 mgkg^{-1}), T_7 (0.27 mg kg^{-1}),T_6 (0.30 mg kg^{-1}) and T_5(0.37 mg kg^{-1}). Chicken manure-derived biochar (CM) dramatically reduced NH_4NO_3 extractable Cd and Pb concentrations from 0.95 and 11.3 mg kg^{-1} to 0.11 (88.4%) and 0.73 (93.5%) mg kg"1, respectively[16].

Lead uptake in grain and straw

The uptake of Pb was very less in rice straw (Table 6) as well as grain. The uptake of Pb in straw and grain was increased with application of sewage sludge. The minimum Pb uptake by grain was 0.01 mg kg^{-1} in all treatment except T_2 (100% RDF), T_3 (SS_{30}) treatment and maximum uptake of lead was found in T_3 (SS_{30}) 0.03 mg kg^{-1} followed by T_2 (100% RDF) 0.02 mg kg^{-1}. The Pb uptake in rice straw ranged between 0.03 to 0.14 mg pot^{-1}. The maximum value for uptake (0.14 mg pot^{-1}) was recorded from T_3 (SS_{30}) and the minimum 0.03 mg kg^{-1} was observed in control (T_1) as well as also inT_7 (BC_{10} SS_{30} RN_{50}),T_8 (BC_{15} SS_{30} RN_{50}) ,T_9 (BC_{20} SS_{30} RN_{50}) due to the application of biochar. The treatment T_3 (SS_{30}) was increased Pb uptake by 50 % over T_2 (100% RDF).Study clearly indicated that application of sewage sludge increased the concentration and uptake of heavy metal. However addition of biochar reduced its uptake. Edible part of wheat plants (grains) from test samples presented high concentration of Cd, Cr, Cu, Ni, Pb and Zn with the application of sewage sludge[19].

Application of sewage sludge along with fertilizers also increased Ni, Cr, Cd and Pb content in rice straw and grain. There was about 7, 5, 5 and 10 times increase in Cd, Cr, Ni and Pb content, respectively, in rice grain and about 7, 3, 7 and 2 times increase in rice straw over control[13]. Sewage sludge amendment increased the content and uptake of Cd, Cr, Pb, Ni, and Zn in shoot. Some IBI[5] members (Joshep) also reported the application of biochar reduce the heavy metal content in both shoot and root [20].

Properties of post harvest soils

Soil reaction (pH)

The data pertaining to pH of the soil (Table 7) showed that it varied from 7.3 to 8.0. The maximum pH 8.0 observed in treatments T_9 (BC_{20} SS_{30} RN_{50}) and the minimum T_1 (Control) followed by T_2 (100% RDF).Application of fertilizer and sewage sludge resulted a decrease in pH T_2 (100% RDF) and T_3 (SS_{30}). The application of biochar did not show significant increase in pH. The maximum soil pH 8.0 was found in treatment T_9 (BC_{20} SS_{30} RN_{50}) followed by T_7 (BC_{10} SS_{30} RN_{50}): 7.9, T_8 (BC_{15} SS_{30} RN_{50}) & T_6 ($BC_{7.5}$ SS_{30} RN_{50}): 7.8 and T_5 (BC_5 SS_{30} RN_{50}):7.7. It has been reported that chemical properties of biochar after addition in soil cause changes in pH, electrical conductivity (EC), cation exchange capacity (CEC) and nutrient levels[21, 22, 23, & 24] .

Electrical conductivity (EC)

There was significant increase in the EC of soil with application of biochar and sewage sludge was observed (Table 7) The EC of soil ranged between 0.18 to 0.25 dS m^{-1}. The minimum of EC (0.18 dS m^{-1}) was recorded in control (T_1) and the maximum (0.25dS m^{-1}) in treatment T_7 (BC_{10} SS_{30} RN_{50}) where biochar was applied along with sewage sludge. An increase in EC was found in T_7(BC_{10} SS_{30} RN_{50}) followed by T_8 (BC_{15} SS_{30} RN_{50}) and T_6 ($BC_{7.5}$ SS_{30} RN_{50}),T_5 (BC_5 SS_{30} RN_{50}) and T_3 (SS_{30}). Sewage sludge application Increase in EC was also reorted [14, 25 & 26].

Organic Carbon

There was a significant increase in soil organic carbon content with application of biochar and sewage sludge (Table 7). The organic carbon content in soil ranged from 0.30 to 0.51 %. The minimum organic carbon content (0.30%) was observed in control (T_1) and the maximum (0.51 %) in T_9 (BC_{20} SS_{30} RN_{50}) which was 70% higher over control followed by T_8 (60%), T_7 (53.33%), T_6 (46.66%) and T_4 (36.66%). The treatment T_2 (100% RDF), had 37.25 % lower organic carbon content to T_9 (BC_{20} SS_{30} RN_{50}) followed by T_8 (33.33%), T_7 (30.48%), and T_6 (27.30 %)[27 & 28].

DTPA extractable heavy metal in post-harvest soil

The heavy metal Cd (Table 7 & figure 3) content of soil range from 0.64 to 2.59 mg kg^{-1}. The minimum content (0.64 mg kg^{-1}) was recorded in treatment where sewage sludge was not applied. However, Maximum content (2.59mg kg^{-1}) was recorded in the treatment T_3 (SS_{30}) which showed 3 times increase in DTPA extractable Cd over control (0.64 mg kg^{-1}). DTPA extractable Cr in soil ranged between 0.15 to 1.0 mg kg^{-1}. The maximum

(1.0 mg kg^{-1}) was recorded in T_3 (SS_{30}) followed by T_9 (0.84 mg kg^{-1}),T_8 (0.72mg kg^{-1}) T_7 (0.60mg kg^{-1}).The maximum chromium content in T_3 (SS_{30}) was 5 times higher over control (T_1) followed by T_9 (4.6times), T_8 (3.8times), T_7 (3.0times), T_6 (2.4 times),T_5 (2.1times) and T_4 (1.5times). The concentrations obtained in this study were very low as compared to the maximum permissible limit of 25 mg kg^{-1} set for extractable Cr in soil by UK Department of Environment (Alloway and Ayers, 1997). The DTPA extractable Ni ranged between 1.80 to 5.19 mg kg^{-1}. The maximum (5.19 mg kg^{-1}) was recorded in T_3 (SS_{30}) which showed about 3.5 times increase over control (1.80 mg kg^{-1}). Application of 30 t ha^{-1} sewage sludge with no fertilizer and biochar had shown 1.8 times increase over control (5.78 mg kg^{-1}) followed by T_9 (BC_{20} SS_{30} RN_{50})1.3times. The treatment T_5 (BC_5 SS_{30} RN_{50}) was statistically at par with T_4 ($BC_{2.5}$ SS_{30} RN_{50}). The Ni concentration in soil was lower than maximum permissible limit of 20 mg kg^{-1} for toxicity as suggested by UK Department of Environment (Alloway and Ayers, 1997). There was a significant increase in DTPA extractable Pb in soil with graded application of biochar and sewage sludge. The DTPA extractable Pb in soil varied between 0.19 to 2.04 mg kg^{-1} with the maximum (2.04 mg kg^{-1}) in T_3 (SS_{30}) which was 9.7 times more over control (0.19 mg kg^{-1}) followed by T_9 (5 times),T_7 (4.7 times), and T_2 (52.63%). The increasing levels of sewage sludge composts addition increased the extractable heavy metal status (Cd, Cr, Ni, and Pb) in the soil but did not increase to the toxic limits[29].

CONCLUSION

A significant increase in grain and straw yield of rice could be achieved by application of biochar and sewage sludge. Sole application of lower doses of biochar has no significant effect on grain yield of rice in alluvial soils of Varanasi. However, combined application of sewage sludge and biochar resulted in significant increase in yield. Among the various treatments, the highest grain yield was obtained with combined application of 20 t ha^{-1} biochar and 30 t ha^{-1} sewage sludge, which was 2.8 times higher over control (T_1) and 8.5% higher over 100% RDF. Biochar application increased the grain yield of rice, soil organic carbon content with a significant sorption of heavy metals in biochar reduced the uptake of heavy metals by rice.

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REFERENCES

1. Anonymous (2012-13) Agriculture statistics at a glance. Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India, New Delhi.
2. Bijay-Singh (2002) Soil Pollution and its control. In Fundamentals of Soil Science, *Indian Society of Soil Science* Publ. Indian Agricultural Research Institute, New Delhi, pp. 499-514.
3. Juwarkar, A.S., Asha Deshbratar, P.B. and Bal, A.S. (1997) Exploitation of nutrient potential of sewage sludge through land application, RAPA, Asian Experience in Integrated Plant Nutrition, Report of the *Expert Counsultation of the Asian Network on Bio and Organic Fertilizer*.
4. Tisdale, S.L., Nelson, W.L., Beaton, J.D. and Hevlin, J.L. (1993) Soil fertility and fertilizer. 5th ed. *Macmillian Publishing Co. New York* .
5. International Biochar Initiative http://www.biochar-international.org Organization of academic, commercial, banking, NGO, and government representatives aiming to further the use of biochar in sustainable agriculture. Westerville, OH 43081United States.
6. Jha, Pramod, B., A.K., Lakaria, B.L. and Subba Rao, A. Biochar in agriculture - prospects and related Implications. *Current Science*, 2010; **99**: 1218-1225.
7. Lehmann, J. Bioenergy in the black. *Frontiers in Ecology and Environment*, 2007; **5**:38-387.
8. Walkley, A. and Black, C.A. Estimation of organic carbon by chromic acid and titration method. *Soil Science*, 1934; **37**: 28-29.
9. Lindsay, W.L. and Norwell, W.A. Development of DTPA soil test for Zn, Iron, Manganese and Copper. *Soil Science Society of America Journal*, 1978; **42**: 421-428.
10. Srivastava, P.C., Singh, A.P., Kumar, S., Ramachandran, V., Manoj Shrivastava and D'souza, S.F. 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*. 2009; **85**(2): 195-202.

11. Rondon, M.A., Lehmann, J., Ramirez, J. and Hurtado, M. Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with bio-char additions. *Biol Fertil Soils,* 2007; **43**: 699-708.
12. Latare, A.M., Kumar, O., Singh, S.K. and Archana, G. Direct and residual effect of sewage sludge on yield, heavy metals content and soil fertility under rice-wheat system *Ecological Engineering*, 2014; **69**:17-24.
13. Latare, A.M, and Singh, S.K. 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*, 2013; **61**(3): 219-225.
14. Jamil, M., Qasim, M., Umar, M. and Rehman, K. Impact of organic wastes (sewage sludge) on the yield of Wheat (*Triticum aestivum* L.) in a calcareous soil. *International journal of Agriculture and Biology*, 2004; **6 (**3): 465-467.
15. Togay, N., Togay,Y. and Dogan,Y. Effects of municipal sewage sludge doses on the yield, some yield components and heavy metal concentration of dry bean (*Phaseolus vulgaris L.*) *Afr. J. Biotechnol*. 2008; **7**:3026-3030.
16. Jin, H.P., Choppala, G.K., Bolan, N.S., Chung, J.W. and Chuasavathi, T. Biochar reduces the bioavailability and phytotoxicity of heavy metals. *Plant Soil,* 2011; **348**: 439-451.
17. Namgay, T., Singh, B. and Singh, B.P. Influence of biochar application to soil on the availability of As, Cd, Cu, Pb, and Zn to maize (*Zea mays* L.). *Aust J Soil Res,* 2010; **48**: 638- 647.
18. Alloway, B.J. and Ayers, D.C. Chemical principles of environmental pollution. 2: 208-211. Chapman and Hall Inc.London, 1997; U.K.
19. Jamali, M.K., Kazi, T.G., Arain, M.B., Afrid, H.I., Jalbani, N., Kandhro, G.A., Shah, A.Q. and Baig, J.A. Heavy metal accumulation in different varieties of wheat (*Triticum aestivum L.*) grown in soil amended with domestic sewage sludge. *Journal of hazardous materials,* 2009; **164**: 1386-1391.
20. Singh, S.K., Singh, Y.V., Archana, and Latare, A.M. Effect of Sewage Sludge on heavy metal accumulation and response of marigold (*Tagetes Erecta).Journal of the Indian Jor of ecol,* 2012; **39**(2): 213-218.
21. 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. Black carbon increases cation exchange capacity in soils. *Soil Sci Soc Am J,* 2006; **70**:1719-1730.
22. Gundale, M.J. and DeLuca, T.H. Charcoal effects on soil solution chemistry and growth of Koeleria macrantha in the ponderosa pine/Douglas-fir ecosystem. *Biol Fertil Soils,* 2007; **43**:303-311.
23. Warnock, D.D., Lehmann, J., Kuyper, T.W. and Rillig, M.C. Mycorrhizal responses to biochar in soil-concepts and mechanisms. *Plant Soil,* 2007; **300**: 9-20.
24. Amonette, J.E. and Joseph, S. Characteristics of biochar: microchemical properties. In: Lehmann, J. and Joseph, S. (eds) Biochar for environmental management science and technology. **3**. *Earthscan, London*, 2009; pp 33-52.
25. Deshmukh, V. L., Kaswala, R. R., Patil, R. G. and Kaswala, A. R. Effect of different sludge materials on physico-chemical properties of vertisol *Journal of Maharashtra Agricultural Universities,* 2004; **29**(1): 9-11.
26. Asagi, N., Ueno, H. and Ebid, A. Effects of sewage sludge application on rice growth, soil properties, and N fate in low fertile paddy soil. *International Journal of Soil Science,* 2007; **2**(3):171-181.
27. Utomo, W.H. Rice husk biochar for rice based cropping system in acid soil. The characteristics of rice husk biochar and its influence on the properties of acid sulphate soils and rice growth in West Kalimantan, Indonesia. *Journal of Agricultural Science,* 2010; **2**(1): 68-74.
28. Sukartono U.W.H., Kusuma, Z. and Nugroho, W.H. Soil Fertility Status, Nutrient Uptake, and Maize (*Zea mays* L.) Yield Following Biochar and Cattle Manure Application on Sandy Soils of Lombok, Indonesia. *Journal of Tropical Agriculture,* 2011; **49**: 47-52.
29. Chitdeshwari, T., Savithri, P. and Raja, S.M. Effect of sewage bio-solid composts on the yield of crops and heavy metal availability. *Journal of Ecotoxicology & Environmental Monitoring.*. 2002; **12**(2): 123-128.