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Influence of Biochar on Physical Properties of Rice Soil under Two Moisture Regimes

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In the present investigation, a biochar was produced from prosopis wood, characterized and its effect on physical properties of rice soil under different moisture conditions *viz.,* intermittent wetting and drying and continuous submergence were examined. Examination of soil core samples (undisturbed) collected from rice field showed marked reduction in soil bulk density (from 1.23 to 1.13 Mg m$_{-3}$) due to biochar application. The porespace was also increased, when biochar was applied along with vermicompost. There was significant improvement in the hydraulic conductivity (from 6.5 to 18.5 cm h$_{-1}$) in rice soil due to biochar application. The application of biochar (5 t ha$_{-1}$) along with vermicompost (5 t ha$_{-1}$) and NPK fertilizer in soil recorded higher hydraulic conductivity. The structural indices *viz.,* stability index, aggregate stability, mean weight diameter and structural coefficient of rice soil were appreciably improved by the application of biochar.

Key words: biochar, rice soil, hydraulic conductivity, structural indices

Biochar is a charcoal produced from the thermal decomposition of biomass in a low- or zero-oxygen environment (Lehmann and Joseph, 2009). During pyrolysis, at low temperatures, cellulose and hemicellulose are lost in the form of volatile organics leading to mass loss and shrinkage. The mineral and Carbon skeleton formed retains the structure of the original material. The molecular structure of biochar is of high porosity and a large surface area. Soil micropores contribute most to surface area and are responsible for the high absorptive capacity; mesopores are important for liquid-solid adsorption processes; and macropores are important for aeration, hydrology, movement of roots and bulk soil structure. Application of biochar to soil also changes the physical nature of soil, causing a net increase in the total soil-specific surface, improving soil structure and aeration (Kolb, 2007). Based on the above findings a field experiment has been conducted with the application of different levels of biochar, to study the potential of biochar on physical properties of soil under rice cultivation.

Materials and Methods

Biochar was prepared from the pyrolysis of prosopis wood log. The pyrolysis stove consisted of a cylindrical drum made up of zinc alloy sheet. It consisted of combustion chamber, ventilation cone, outer tin and lid. The biochar was powdered, sieved through < 2mm sieve, characterized and then used for field experiment. The biochar had a bulk density and particle density of 0.45 mg m$_{-3}$ and 0.54 mg m$_{-3}$, respectively, with a pore space of about 48 per cent. SEM analysis of powdered sample of prosopis wood biochar also indicated the porous structure (Fig.1). It had very low moisture content (1.21%), but high water holding capacity (131%).

A field experiment was conducted at Wetland Farm, Tamil Nadu Agricultural University, Coimbatore, TamilNadu, India. The experimental soil was clay loam belonging to Noyyal series. The soil is classified taxonomically as *Typic haplustalf* according to USDA classification. The bulk and particle densities of initial soil were 1.22 and 2.58 mg m$_{-3}$. The experiment was laid out in split plot design with following treatments which were replicated three times.

Main plot Treatments

M$_1$ - Alternate wetting and drying; M$_2$ – Complete submergence

Subplot Treatments

T$_1$ – Recommended dose of NPK (150: 50: 50kg ha^{-1}); T$_2$ – NPK + biochar (2.5 t ha^{-1}); T$_3$ – NPK + biochar (5 t ha$_{-1}$); T$_4$ – NPK + Vermicompost (5 t ha$_{-1}$); T$_5$ – NPK + Vermicompost (5 t ha$_{-1}$) + biochar (2.5 t ha$_{-1}$); T$_6$ – NPK + Vermicompost (5 t ha$_{-1}$) + biochar (5 t ha$_{-1}$)

The medium duration rice cultivar ADT 43 was tested during *Kharif* season (June – September 2010) . The plots were irrigated with one cm of water for one week after transplanting. The depth of water was increased from one cm to five cm as the crop advanced in age in the case of submerged condition; whereas, in the intermittent wet and dry condition, irrigation was given with five cm depth of water after the establishment stage one day after the disappearance of ponded water. The undisturbed surface core soil samples were collected from the field after the harvest of rice crop.

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Soil analyses

The bulk density and particle density of the soils were determined by cylindrical method as suggested by Gupta and Dakshinamoorthi (1981). The per cent pore space, moisture content, water holding capacity, apparent density, absolute specific gravity and volume expansion were determined by using Keen Raczkowski brass cup method suggested by Richards (1954). Mechanical composition of soil like coarse sand, fine sand, silt and clay were determined by the International pipette method (Piper, 1966). Soil samples were analysed for hydraulic conductivity and aggregate parameters as per the procedure given by Gupta and Dakshinamoorthi (1981). The statistical analysis of data was carried out as per Gomez and Gomez (1984).

Results and Discussion

Effect of biochar on physical properties of soil under different moisture regime

The bulk density of soil was reduced from 1.23 to 1.13 mg m$_{-3}$ due to the application of biochar, particularly under intermittent wetting and drying condition. However, it was slightly increased under submerged condition (Table 1). Similar effect was also observed when biochar was applied at 2.5 t ha$_{-1}$ along with vermicompost. Whereas at the higher rate (5 t ha$_{-1}$) a small increase in bulk density was observed under both moisture conditions. Biochar had a bulk density (0.45 mg m$_{-3}$) much lower than that of mineral soil and therefore, its application to soil can reduce the bulk density of soil, although increase in bulk density is also possible. (Sohi *et al.,* 2009; Lehmann *et al.,* 2007).

Table 1. Effect of levels of biochar on physical properties of soil under two moisture regimes

Treatment	Bulk density (Mg m$_{-3}$)			Pore space (%)			Hydraulic conductivity (cm h$_{-1}$)		
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
T_1 – NPK alone	1.23	1.19	1.21	70.6	55.9	63.2	6.5	5.3	5.9
T_2 –NPK+BC 2.5 t ha$_{-1}$	1.15	1.2	1.18	70.6	41.2	55.9	8.7	7.2	8.0
T_3 –NPK+BC 5 t ha$_{-1}$	1.13	1.25	1.19	64.7	64.7	64.7	12.0	10.6	11.3
T_4 –NPK+VC 5 t ha$_{-1}$	1.20	1.18	1.21	67.6	50.0	58.8	13.1	12.9	13.0
T_5 – NPK + VC 5t ha$_{-1}$ + BC 2.5t ha$_{-1}$	1.17	1.17	1.17	70.6	41.2	55.9	15.4	13.8	14.6
T_6 – NPK + VC 5t ha$_{-1}$+ BC 5t ha$_{-1}$	1.19	1.21	1.25	52.9	50.0	51.5	18.5	15.4	17.0
Mean	1.18	1.22	1.20	66.2	50.5	58.3	12.4	10.9	11.6

	SEd	CD (0.05)	SEd	CD (0.05)	SEd	CD (0.05)
T	0.17	0.35	0.70	1.42	0.10	0.22
M	0.16	0.71	0.13	0.59	0.06	0.28
M x T	0.27	0.80	0.16	0.53	0.15	0.38
T x M	0.24	0.50	0.09	0.20	0.14	0.31

BC – biochar VC- Vermicompost M_1-Intermitant Wetting and drying M_2- Submerged condition

The decrease in soil bulk density in the study could be the result of incorporation of biochar particles which improved the total porespace and hydraulic conductivity. The improvement in soil aggregation also might have contributed toward the decrease in the soil bulk density. Similar results were reported by Harris *et al.* (1966) and Chan *et al.* (2007).

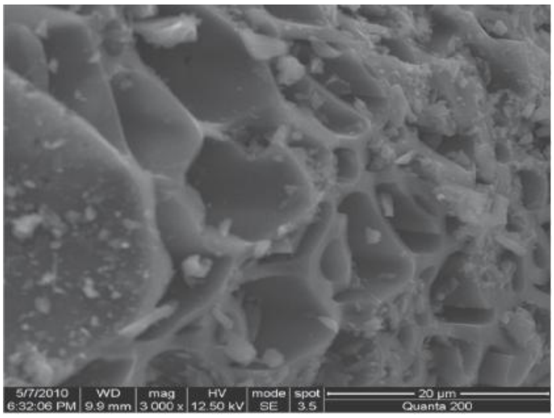

Fig. 1. SEM images of prosopis wood biochar with porous structure

The pore space differed significantly in soil under two moisture conditions. Soil, under the intermittent wetting and drying, contained more porespace than under submerged condition. Application of biochar (2.5 t ha$_{-1}$) along with vermicompost and NPK fertilizer markedly increased the porespace of rice soil. At its higher rate (5 t ha$_{-1}$) reduced the porespace, under intermittent wetting and drying but increased the porespace under submerged condition. There was a marked improvement in the hydraulic conductivity of rice, from 6.5 to 18.5 cm h$_{-1}$, due to biochar application (Fig.2). Increase in the rate of biochar significantly improved the hydraulic conductivity and this change was observed under both moisture conditions. The application of biochar (5 t ha$_{-1}$) along with vermicompost (5 t ha$_{-1}$) and NPK fertilizer (T_6) in soil recorded higher hydraulic conductivity. In several studies, biochar application was found to improve soil aggregation which may lead to an increase in the soil; water infiltration capacity, hydraulic conductivity and porespaces (Ayodele *et al.,* 2009; Verhejen *et al.,* 2010)

The structural indices *viz.,* stability index, aggregate stability, mean weight diameter and structural coefficient were significantly influenced by the application of biochar and vermicompost. Application of biochar, irrespective of its rate of addition, appeared to have significantly increased the stability index and stability of the soil aggregates (Table 2). Such improvement was more significant due to the combined application of biochar and

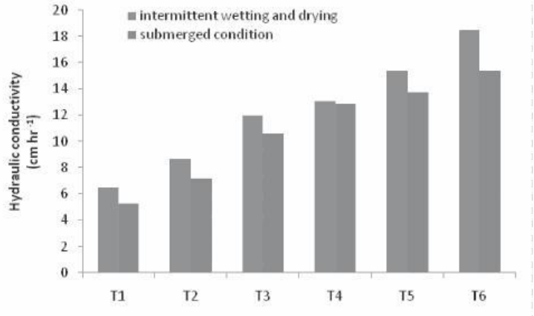

Fig. 2. Effect of biochar on hydraulic conductivity of soil

Table 2. Effect of biochar on structural indices of rice soil

Treatment	Stability Index			Aggregate stability (%)			Mean weight diameter (mm)			Structural coefficient		
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
T_1 – NPK alone	53	56	55	82	88	85	0.32	0.55	0.44	0.53	0.56	0.55
T_2 – NPK + BC 2.5 t ha^{-1}	64	59	61	71	94	85	0.56	0.45	0.51	0.64	0.59	0.61
T_3 – NPK + BC 5 t ha^{-1}	71	74	72	90	97	94	0.83	0.52	0.68	0.71	0.74	0.72
T_4 – NPK + VC 5 t ha^{-1}	64	68	66	75	86	81	0.57	0.47	0.52	0.64	0.68	0.66
T_5 – NPK + VC 5 t ha^{-1} + BC 2.5 t ha^{-1}	74	83	79	91	93	92	0.62	0.58	0.60	0.74	0.83	0.79
T_6 – NPK + VC 5 t ha^{-1}+ BC 5 t ha^{-1}	78	70	74	93	98	96	0.85	0.54	0.70	0.78	0.70	0.74
Mean	67	68	68	84	93	89	0.63	0.52	0.57	0.67	0.68	0.68
	SEd	CD (0.05)		SEd	CD (0.05)		SEd	CD (0.05)		SEd	CD (0.05)	
T	0.08	0.17		0.06	0.13		0.29	0.63		0.21	0.45	
M	0.92	0.33		0.08	0.36		0.14	0.61		0.56	0.23	
M x T	0.10	0.22		0.12	0.38		0.40	0.96		0.28	0.62	
T x M	0.11	0.24		0.09	0.19		0.41	0.87		0.31	0.64	

BC – biochar VC- Vermicompost M_1-Intermitent Wetting and drying M_2- Submerged condition

vermicompost along with the recommended dose of NPK fertilizer (T_6).

There was a significant improvement in the mean weight diameter of soil aggregates and structural coefficient. The mean weight diameter of soil aggregate was increased in soil with the application of biochar under intermittent wetting and drying as well as under submerged conditions. Similar effect was also observed in soil with the combined application of biochar and vermicompost. The mean weight diameter of the aggregate was greater (0.85 mm) in soil due to the application of biochar along with vermicompost and NPK fertilizer (T_6) and it was about 53 per cent increase over the soil aggregates under control (T_1).

The structural coefficient was also remarkably improved due to the application of biochar with and without vermicompost. The effect was more significant under intermittent wetting and drying. Increase in the rate of biochar significantly increased the structural coefficient by about 47 (M_1) to 49% (M_2). Improvement in structural coefficient was also resulted due to the application of biochar along with vermicompost. Similar result was reported by Prasad *et al.* (1993) in red loam soil due to the application of organic manures.

The improvement in aggregate stability could possibly be due to the formation of organo mineral complexes by functional groups of the humic acids. The hydrophobic poly aromatic backbone reduces the entry of water into the aggregate pore, leading to an increased aggregate stability and water availability (Glaser *et al.,* 2002).

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