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EFFECT OF PINE AND BAGASSE BIOCHAR ON PHYSICAL PROPERTIES OF SOIL

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KEYWORDS

Biochar

Bagasse

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Physical properties of soil

C sequestration

ABSTRACT

Biochar is the by-product of pyrolysis that has been produced for the amendment of soil profile as well as soil biota. At present waste is generated in agriculture, forests and related agro-industries is in tremendous amount. Biochar could provide a key solution by converting these wastes (biomass) into biochar for soil amendment. Biochar is a paradigm shift from chemical view to biological insight into fertility and soil food web which in-turn depends on soil physical properties. Present study was conducted to investigate the effect of pine and bagasse biochar samples on physical properties of soil. After application of these two biochar, soil samples were analyzed for moisture content, BD and WHC of soil. The data were analyzed by applying Tukey HSD test of post hoc treatment in SPSS 16.00 software. Results of study clearly signify the importance of bagasse biochar and it was followed by the pine biochar, both biochar greatly improves the physical properties of soil.

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1 Introduction

Fertility of soil is the nation most important assets. In the present century the trend of agriculture has shifted from mixed cropping and crop rotation to the addition of chemical fertilizers that may compensate the decrease in fertility but may not affect the physical properties of soil much. Soil functions mainly depend on three prominent properties viz., physical, chemical and biological (Sassenrath et al., 2018). According to the recent research, the application of carbonization products may effectively enhance the physico-chemical characteristics of soils and improve the fertility of poor soils (Saletnik et al., 2019). Soil health is the foundation of a vigorous and sustainable food system. The continuous farming in agriculture disturbs the natural soil system including nutrient cycling along with the release and uptake of nutrients (Bot & Benites, 2005). Plants obtain their nutrition from organic matter and mineral found in soil. Due to the increased use of chemical fertilizers and highly inefficient use of water, increases the non-profit pollution in agricultural areas around the world (EPA, 2005). With the world's population set to increase by 65% (i.e., 3.7 billion people) by 2050, the additional food required to feed future generation will put further pressure on natural soil system and in-turn agriculture. To rectify the issues of chemical fertilizers and inefficient water uses, the biochar could be use as an alternative to enhance the soil properties. The focus of past studies was limited to nutritional status of treated soil whereas biochar is widely considered as a soil conditioner. Biochar showed positive effects on nutritional status of soil and C-sequestration (Glaser et al., 2002), microbial community or soil biota (Lehmann et al., 2011) and GHG emissions (Lehmann et al., 2006; Fowles, 2007; Lehmann, 2007) which are directly or indirectly related to physical properties of soil (Berglund & Berglund, 2011). There is little published information available about the relation between biochar treatments and physical properties of soil (Hammes & Schmidt, 2009; Atkinson et al., 2010).

Clearly there is a knowledge gap in understanding how biochar alters physical properties of soil and the mechanism responsible for GHG emission. Thus, this work aims to study the effect of pinus and bagasse biochar on the physical properties of soil. Biochar, the solid product formed by the heating of biomass (Plant/Animal material) in an oxygen deficient environment and this is known as pyrolysis. Pyrolysis is the clean waste management process to convert biomass to solid (biochar), liquid (bio-oil) and gas. Biochar, the solid product of biomass carbonization intended as a soil amendment, has attracted attention due to its ability for long term improvements in soil physical and chemical properties with potentially important effects on soil biota. Biochar offers multitude of benefits in terms of agronomical and environmental management. The waste generated in agriculture, forests and related agro-industries has the potential to supply feedstock for biochar production.

Understanding the action of biochar is a paradigm shift from chemical views to biological insight into fertility and soil food web which in-turn depends on soil physical properties (Marjenah et al., 2016). The application of carbonized organic wastes to soil improves the physical properties of soil, soil fertility and nutrient retention (Sombroek et al., 1993; Lehmann & Rondon, 2005; Tagoe et al., 2008). On the basis of recommendations from recent review studies (Verheijen et al., 2010; Sohi et al., 2010; Atkinson et al., 2010; Jeffery et al., 2011; Kookana et al., 2011; Barrow, 2012; Xu et al., 2012; Gurwick et al., 2013; Liu et al., 2013; Huang et al., 2013; Biederman & Harpole, 2013; Ameloot et al., 2013; Verheijen et al., 2014), it is quite evident that effects of biochar feedstock and production process (pyrolysis conditions) on the physical, chemical and biological properties of soil must be better understood to devise effective management strategies for achieving agricultural benefit.

2 Materials and Methods

2.1 Feedstock Selection

The feedstocks used in present investigation are pine needles and sugarcane derived bagasse (SCB). The pine needles were collected from different forest areas of Dehradun and bagasse was collected from sugar mill company limited Doiwala, Dehradun. The feedstock was air dried for 24 hours and then crushed into small pieces.

2.2 Biochar Production

Slow pyrolysis is the most common referred method for biochar production (Yadav & Jagadevan, 2019). Feedstock is the most important factor that controls the properties of resulting biochar. Ligno-cellulosic feedstocks with high content of alkalines (Na, K, Mg and Ca) resulted higher yields of biochar and relatively low yields of quality bio-oil. Feedstock rich in cellulose produced rich pyrolytic sugars, low molecular weight organic acids and water; whereas feedstock high in lignin produced high energy bio-oils enriched with mono and oligo phenols. The feedstock was pyrolysed at 500°C under the recommendation of Lehmann (2007). The pine needles were pyrolysed for 20 minutes and bagasse was pyrolysed for 30 minutes. After the biochar was taken out from muffle furnace the biochar was allowed to cool. This biochar was crushed with mortar and pestle and sieved with 4mm mesh.

2.3 Soil Sampling

The soil used in the experiment was collected from Botanical garden of government P.G College Rishikesh. A composite sample was collected 10cm below the top soil layer. The soil was dried for 24 hours. Prior to potting the soil was sieved through 4mm mesh to remove the plant debris, stones and other unwanted material. Biochar was applied @ 10% (w/w) according to big biochar

experiment of IBI. Thus, in each pot 100gm biochar is mixed with 900gm soil and pots were kept for 4-5 months.

2.4 Experimental Plot and Treatments

Pot trials were conducted for the comparative study of effect of different types of biochar on the physical properties of soil. This study was carried out for two consecutive years i.e. 2014 and 2015. Study was conducted in RBD with three treatments viz., Untreated soil (Control), Pine biochar treatment (PB), Bagasse biochar treatment (BB) with three replicates.

2.5 Experimental Analysis

2.5.1 Determination of Moisture Content

The moisture content of the soil samples was calculated as per standard method given by Mishra (1968).

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

2.5.2 Determination of BD

It was calculated as the dry weight of soil divided by its volume. This volume includes the volume of soil particles and its pores among soil particles. It is an indicator of soil compaction.

$$\text{Bulk density} = \frac{W_2 - W_1}{V}$$

Whereas, W_2 = weight of bottle containing dry soil, W_1 = weight of empty bottle and V = volume of bottle

2.5.3 Determination of WHC of soil

For measuring water holding capacity of soil, first of all dry watch glass + kee box + filter paper were weighed. This was followed by the filling kee box with fine grinded soil and saturated with water. The soil was allowed to absorb moisture. The excess water was removed from saturated soil and weighed again. The kee box with saturated soil was placed in oven for 24 hours to dry up and was weighed again. Collected data were calculated by following

1 Weight of dry filter papers say -0.20,0.18,0.16,0.20 - Total weight - A

2. Weight of wet filter papers say -0.40,0.48,0.48 - Total weight - B

3 Average weight of water held by one filter paper = $\frac{B-A}{\text{No. of filter papers}}$ - C

$$\text{WHC} = \frac{(\text{WSS} + \text{KB} + \text{FP}) - (\text{WODS} + \text{KB} + \text{AWWHFP}) \times 100}{(\text{WWG} + \text{KB} + \text{FP})}$$

Where WWS – Weight of saturated soil; KB – Kee box; FP – Filter Paper; WODS – Weight of oven dry soil; AWWHFP -

Average weight of water hold by one filter paper and WWG – Weight of watch glass

2.6 Statistical Analysis

For analyzing the data obtain through experiment on effect of pine and bagasse biochar on physical properties of soil, ANOVA for one way classification was applied and the data was analyzed using SPSS software. For comparison of pine and bagasse in order to assess their performance regarding physical parameters of soil i.e., WHC, BD and moisture Tukey's HSD test was applied.

3 Results

The data obtained from the study of effect of two biochar on physical properties of soil were given in table 1.

3.1 Effect of Biochar on Bulk Density of Soil

The data obtain from mean values revealed that biochar have reducing effect on the bulk density (BD) of soil. The BD of soil was reported from 0.68 (BB) to 1.32 (Control) in 2014 while it was reported from 0.67 (BB) to 1.32 (Control) in 2015, while this value was reported 0.68 (BB) to 1.32 (Control) in pool analysis. Further, the BD for Control, PB, and BB are reported 1.32, 0.89 and 0.68 respectively in 2014 while this was reported 1.32, 0.88, 0.67 in 2015 and 1.32, 0.88 and 0.68 respectively in pool analysis. Both the biochar treatments (PB and BB) were found to decrease BD of soil. Further, bagasse biochar was found more effective in decreasing the BD of soil as compare to pine biochar (Table 1).

3.2 Effect of Biochar on WHC of Soil

The water holding capacity (WHC) of soil ranges from 15.80 (Control) to 22.14 (BB) in 2014, 16.05 (Control) to 22.13 (BB) in 2015 and 15.93 (Control) to 22.14 (BB) in pool analysis. Further, results of study revealed that WHC for control, PB, and BB was reported 15.80, 18.32 and 22.11 respectively in 2014 while this was reported 16.05, 18.30, 22.13 in 2015 and 15.93, 18.28 and 22.12 respectively in pool analysis. Results of study suggested that both biochar treatments (PB and BB) were effective in increasing WHC of soil for both the study years. No significant difference was reported in the data obtained for both the studied years for both the biochar while among the both tested biochar, bagasse biochar was found more effective in increasing the WHC of soil and it was significantly different from the pinus biochar (Table 1).

3.3 Effect of Biochar on Moisture Content of Soil

The moisture content of soil ranges from 8.37 (Control) to 33.47 (BB) in 2014 while it range from 8.27 (Control) to 33.30 (BB) in 2015 and 8.32 (Control) to 33.38 (BB) in pool analysis (Table 1). The moisture content for all soil samples are 8.37 (Control), 13.37

Table 1 Effect of biochar incorporation on physical properties of soil.

Treatments	2014			2015			Pool Analysis		
	WHC (%)	BD (g/cm ³)	Moisture (%)	WHC (%)	BD (g/cm ³)	Moisture (%)	WHC (%)	BD (g/cm ³)	Moisture (%)
Control	15.80 ± 0.360	1.32 ± 0.024	8.37 ± 0.230	16.05 ± 0.185	1.32 ± 0.025	8.27 ± 0.208	15.93 ± 0.27	1.32 ± 0.025	8.32 ± 0.175
PB	18.32 ± 0.011	0.89 ± 0.011	13.37 ± 0.058	18.32 ± 0.025	0.88 ± 0.153	13.03 ± 0.152	18.32 ± 0.006	0.88 ± 0.018	13.20 ± 0.1
BB	22.14 ± 0.040	0.68 ± 0.002	33.47 ± 0.152	22.13 ± 0.025	0.67 ± 0.007	33.30 ± 0.264	22.14 ± 0.029	0.68 ± 0.003	33.38 ± 0.202

CONTROL - Untreated soil ; PB - Pine biochar treatment; BB - Bagasse biochar treatment.

Table 2 Effect of biochar incorporation on physical properties of soil leveled by Tukey's HSD test of post-hoc treatment.

Treatments	2014			2015			Pool Analysis		
	WHC (%)	BD (g/cm ³)	Moisture (%)	WHC (%)	BD (g/cm ³)	Moisture (%)	WHC (%)	BD (g/cm ³)	Moisture (%)
Control	15.80 ^a	1.32 ^c	8.37 ^a	16.05 ^a	1.32 ^c	8.27 ^a	15.93 ^a	1.32 ^c	8.32 ^a
PB	18.32 ^b	0.89 ^b	13.37 ^b	18.32 ^b	0.88 ^b	13.03 ^b	18.32 ^b	0.88 ^b	13.20 ^b
BB	22.14 ^c	0.68 ^a	33.47 ^c	22.13 ^c	0.67 ^a	33.30 ^c	22.14 ^c	0.68 ^a	33.38 ^c

(PB) and 33.47 (BB) in 2014, whereas in it was recorded as 8.27 (Control), 13.03 (PB), 33.30 (BB) respectively in 2015 and 8.32 (Control), 13.20 (PB) and 33.38 (BB) in pool analysis. Like WHC, biochar amended soil have higher moisture content and bagasse biochar was found significantly different that the all tested treatments.

3.4 Statistical Analysis of Data

The results of biochar incorporation on physical parameter of soil leveled by tukey's HSD test of post hoc treatment are given in table 2. Analysis of data suggested the significant effect of biochar on the physical properties of soil and among the tested biochar, bagasse biochar was found significantly different that the other treatments.

4 Discussion

From the perusal of results it was reported that biochar application statistically increases WHC and moisture content. The bagasse biochar treatment was found statistically superior than pine treatment. It was also clear from the study that biochar treatment decreases BD and it has been found that lower BD increases the soil aeration and better in the movement of water and ions. Further, bagasse treatment is found to decrease BD more than pine treatment however WHC and Moisture follows the same trend. These findings are in line with the findings of Yu et al. (2013), Laird et al. (2010), Jones et al. (2010) and Chen et al. (2011). The highest WHC and moisture content has been found in bagasse biochar due to its high porosity than pine biochar. Sohi et al. (2009) showed that soil with a high WHC increases crop yields and decreases irrigation needs. Soil

hydrological properties (WHC and Moisture content) are directly related to surface area, porosity, BD and aggregate stability. The decrease in BD in biochar treated soil is one of the most important indicator of enhancement in soil structure. Biochar application increases the water retention capacity of soil as it increases soil porosity and due to adsorptive nature of biochar (Herath et al., 2013). In general, it can be concluded that biochar amendment to soil increase the porosity, availability of water, nutrient retention capacity and decreased the soil BD (Lei & Zhang, 2013). However Dume et al. (2016) reported that biochar cannot change the texture of soil, this is also in agreement with the findings of present study.

Conclusion

The achieved results of current investigation has shown that bagasse biochar is more suitable for improving soil physical properties and suggesting it superior than pine biochar. No doubt crop yield depend on the functioning of standard soil *i.e.* the yield of a crop depends on both the physical and chemical properties of soil. The chemical properties of soil or ions alone can't do anything until physical properties will improve. If WHC, moisture content of soil and movement of water soluble ion is better then only the chemical ions from biochar will pass to the soil and enhance its chemical status. The biochar is more stable than compost and livestock manure as it has higher capacity to hold nutrients. Thus, this development mechanism can be adopted to achieve the goal of maintaining the fertility of soil in urbanization as it is cost effective and environment friendly practice which is the need of hour in this world of science and technology.

Conflict of Interest

Author hereby declare no conflict of interest

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