Effects of biochar on soil physico-chemical properties

Mishra, Anand
Nepal Agricultural Research Council : Researcher

Shinogi, Yoshiyuki
Laboratory of Irrigation and Water Management, Faculty of Agriculture, Kyushu University : Professor

https://doi.org/10.15017/1961296

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 4, pp.102-105, 2018-10-18. 九州大学大学院総合理工学府
バージョン：

Effects of biochar on soil physico-chemical properties

Anand Mishra[1], Yoshiyuki Shinogi[2]
Corresponding Author Email:anandhansy@yahoo.com
[1]Researcher, Nepal Agricultural Research Council, [2] Professor, Laboratory of Irrigation and Water Management, Faculty of Agriculture, Kyushu University

Abstract

The experiment was conducted with an aim to know the effect of biochar on soil physico-chemical properties. Two types of soil namely clayey loam and sandy soil and four types of biochars namely, pine wood, bermuda grass, rice husk, and bamboo saw dust were used. All biochars were applied at the rate of 5% (w/w). The application of biochar to both soil types increased field capacity, permanent wilting point, and plant available water but decrease the bulk density. Among them, pine wood biochar was best in terms of plant available water (PAW). The PAW was increased by 22% in the clay loam soil. On the other hand, in the sandy soil, the pine wood biochar has pronounced effect to increase PAW by about 37%. Hence, pine wood biochar can be used in the drought-prone areas for both clayey loam as well as sandy soil.

Keywords: Biochar, plant available water, soil physico-chemical properties, soil types

1. INTRODUCTION

Population growth increases the competition for use of fresh water. Agriculture shares about 70% of the freshwater [1]. Nowadays there is competition among the various users of fresh water. Therefore, judicious utilization of fresh water needed in the coming future. The water use efficiencies of the crop needs to be increased to feed ever growing population.

Biochar is produced from biomass by the process of pyrolysis in the oxygen-free environment. The residence time of biochar in soil is more than 10000 years as reported in the literature [2]. Biochar is highly porous in nature. Biochar application to soil can enhance the crop production by enhancing the soil physico-chemical properties.

Plant available water (PAW) is the difference between the field capacity (FC) and permanent wilting point (PWP). Since biochar is highly porous in nature, the application of biochar to soil increases the soil water holding capacity as well as the PAW. The increase in PAW by addition of biochar amendment to soil can help the plant to cope with the adverse condition such as drought. However, soil physical properties depend on the feedstock and pyrolysis temperature of biochar. Also, the soil physical properties vary with the soil types. Thus, the objective of this research was to investigate the effect of biochar types on soil physico-chemical properties in two soil types.

2. MATERIALS AND METHODS

2.1 Feedstock collection and biochar preparation

Pinewood and bermuda grass were collected from the Hakozaki campus, Kyushu University. The bamboo sawdust and rice husk were collected from local market of Fukuoka. They were firstly sun-dried for one week and afterward were oven dried at 70°C for 24 hours. The feedstocks were burnt in limited oxygen environment by the FM 48 furnace for one hour at 500°C for the biochar preparation. The biochar yield was determined as the difference in weight of the feedstock after pyrolysis to the original weight of the feedstock. Fig. 1 shows the feedstock and biochar used in this experiment.

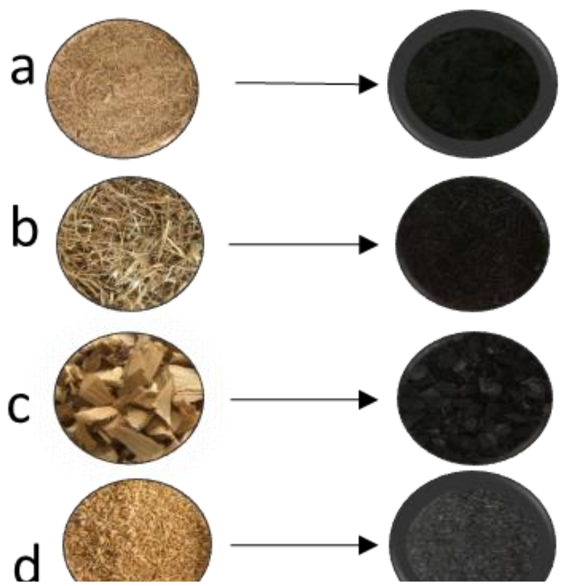

Fig. 1 a) Bamboo sawdust and biochar b) Bermuda grass and biochar c) Pine wood and biochar d) Rice husk and biochar

2.2 pH and EC measurement of biochar

pH_{H20} was measured by pH meter (HORIBA LAQUA twin B-712) (1:5 biochar: H_2O, (w/v)). EC was measured by the electrical conductivity meter (HORIBA LAQUA twin B-771) (1:5 biochar: H_2O, (w/v)).

2.3 Soil sampling and analysis

The soil samples were collected from the Kyushu university experimental farm from a depth of top 30 cm. The soil samples were air-dried, crushed and passed through 2mm sieve prior to analysis. A laboratory experiment was conducted by a completely randomized design with three replications. Two types of soils were sandy and clayey loam soil as identified by the pipette method and four types of biochars rice husk, pinewood, bermuda grass, and bamboo sawdust were used in this experiment. They were mixed at the rate of 5%, hereafter called as RHC5, PWB5, BG5 and, BSDB5, respectively. The soil without biochar amendment serves as a control.

2.4 Soil physico-chemical properties

Samples were prepared by mixing biochar and soil. The prepared samples were packed in soil core rings of 100 cm^3 manually. Samples were submerged in deionized water overnight before starting the water retention experiment. Moisture contents at field capacity (-33 kPa) and permanent wilting point (-1500 kPa) were determined by the centrifuge machine according to Richards *et al.* (1938) [3]. PAW was calculated as the difference between volumetric water content at field capacity and permanent wilting point. Bulk density was determined as the ratio of oven dry weight at 105 °C for 24 hours to the total volume of the sample. Soil organic matter was determined by the ignition method (Storer, 1984) [13]. Particle size distribution was determined using the pipette method. The textural class was identified from the Marshal triangle (Konert and Vandenberghe, 1997) [4].

2.5 Data analysis

Analysis of Variance (ANOVA) was used to know the statistical difference between the treatments. Turkey's HSD (honestly significant difference) was performed by using Statistix 8 Software. All statistical analysis were compared at $p<0.05$.

3.RESULTS

3.1 Biochar yield, pH and EC

The yield, pH and EC of biochar are shown in Table 1. The biochar yield was highest for the rice husk biochar 43.75% followed by the bermuda grass biochar 33.16%, pinewood biochar 28.87% and the least was found for the bamboo sawdust biochar 28.29%. The biochar yield is greatly dependent on the feedstock used and the pyrolysis temperature. As the pyrolysis temperature increases, the yield decreases and vice versa. The pH was the highest for the rice husk biochar followed by the bermuda grass biochar, bamboo sawdust biochar and the least was found for the pinewood biochar. The electrical conductivity (EC) was highest for the bermuda grass followed by the pinewood biochar, bamboo saw dust biochar and the least was found for the rice husk biochar.

Table 1. Biochar Yield, pH and EC

Feed Stock type	Yield (%)	pH	EC (µS/cm)
Bermuda grass biochar (BGB)	33.16	8.32	0.237 (mS/cm)
Bamboo saw dust biochar (BSDB)	28.29	8.14	97.1
Pine wood biochar (PWB)	28.87	7.72	107.5
Rice husk biochar (RHB)	43.75	9.41	23.4

3.2 Soil organic matter and bulk density

The effects of biochar on soil organic matter (SOM), and bulk density (BD) in sandy and clayey loam soil are shown in Table 2. The application of biochar to soil significantly increased the soil organic matter for both soil types ($p < 0.05$). The increase in the organic matter in soil by addition of biochar may be due to increase in the organic carbon in the soil.

Table 2. Effects of biochar application on SOM and BD in sandy and clayey loam soil

Soil type	Treatments	BD (g cm^{-3})	SOM (%)
Sandy	Control	1.53a	2.41
	RHC5	1.35b	5.46
	BG5	1.31bc	6.49
	BSDB5	1.24d	7.13
	PWB5	1.28cd	7.29
Clayey loam	Control	1.25a	6.13
	RHC5	1.13b	8.76
	BG5	1.05c	10.18
	BSDB5	1.03c	11.16
	PWB5	1.03c	11.39

The bulk density (BD) of the sandy and clayey loam soils significantly decreased ($p < 0.005$) by the application of biochar. In sandy soil, the bulk density decreased by 11.76 %, 14.38%, 18.95% and 16.33 % for RHC5, BG5, BSDB5, and PWB5 compared to that of the control soil, respectively. On the otherhand, for the clayey loam soil the bulk density decreased by 11.71 %, 17.97%, 19.53% and 19.53 % for RHC5, BG5, BSDB5 ,and PWB5 compared to that of the control, respectively. Biochar has low density but the high surface area. When it is mixed with the denser particle such as soil; the bulk density and particle density of the biochar mixed soil is reduced.

3.3 Field capacity, permanent wilting point and plant available water

The effect of biochar on field capacity in both soils is shown in Fig. 2. The addition of biochar significantly increased the FC in both soil types. The FC in the clayey loam soil increased by 6.2 %, 12.59 %, 10.90% and 8.62% for RHC5, BG5, BSDB5, and PWB5 compared to that of the control, respectively.

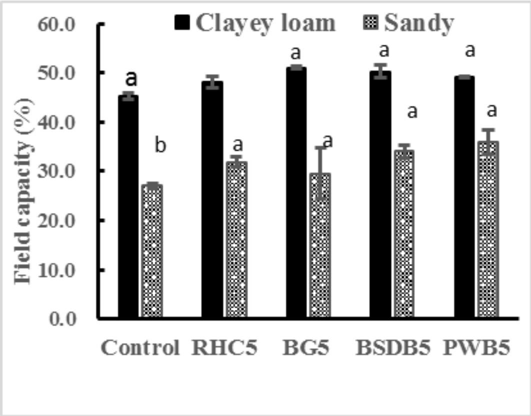

Fig. 2. Effect of biochars on FC of two soil. Error bars represents the standard deviation.

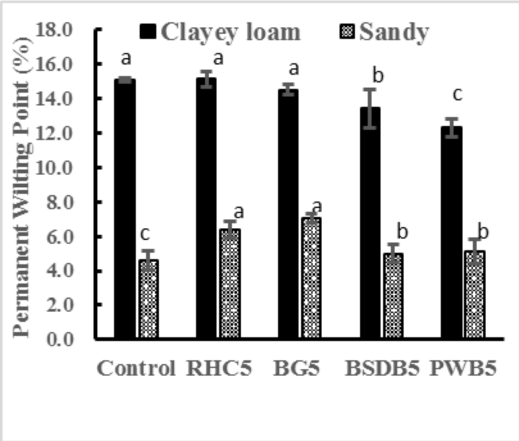

Fig. 3. Effect of biochars on PWP of two soil. Error bars represents the standard deviation.

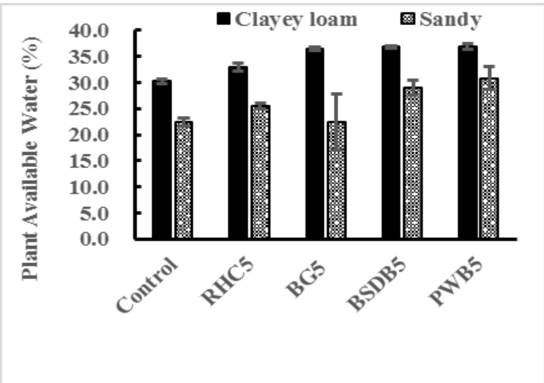

Fig. 4. Effect of biochars on PAW of two soil. Error bars represents the standard deviation.

On the other hand, in sandy soil the FC increased by 17.93 %, 9.25 %, 26.02% and 32.92% for RHC5, BG5, BSDB5, and PWB5 compared to that of the control, respectively.

The effect of biochar on PWP in both soils is shown in Fig. 3. PWP increased by the application of all biochar types in sandy soil.

The effect of biochar on the PAW in both soils is shown in Fig. 4. The PAW also increased by the application of all types of biochar for both clayey loam as well as sandy soil types. The PAW in the clayey loam soil increased by 9.16 %, 20.86 %, 21.85% and 22.18% for RHC5, BG5, BSDB5, and PWB5 compared to that of the control, respectively.

On the other hand, in sandy soil the PAW increased by 13.60 %, 0.13 %, 29.54% and 37.27% for RHC5, BG5, BSDB5, and PWB5 compared to that of the control, respectively.

4. DISCUSSION

4.1 The effect of biochar on water retention in clayey loam soil

In clayey loam soil, the addition of biochar increased water content at field capacity and PAW. (Abel *et al*., 2013; Peake *et al*., 2014) [5,6] also reported that biochar amendment to loamy sand and sandy loam soils increased the field capacity and the PAW. In contrast, no effect of biochar amendment on the field capacity and the permanent wilting point were observed by Hardie *et al.* (2013) [7]. The increase in water content in soil by application of biochar dependents on soil texture, soil organic matter, physicochemical biochar characteristics and biochar application rate. Abel *et al.* (2013) [5] observed that there was an increase in the PAW by biochar application in sandy soils and no effect on soils with high organic matter content.

4.2 The effect of biochar on water retention in sandy soil

In sandy soil, the addition of biochar increased water content at field capacity and PAW. Similar results have also been documented in other studies on sandy soils (Uzoma *et al*., 2011; Abel *et al*., 2013; Barnes *et al*., 2014) [8,5,9]. Carvalho *et al.* (2014) [10] also reported that the PAW was increased by biochar application due to an increase in the porosity of the soil matrix. Cornelissen *et al.* (2013) [11] and Martinsen *et al.* (2014) [12] reported similar findings where the addition of 5% biochar significantly increased the PAW of three sandy soil in West Zambia, from 9% to 15% in sandy soil. We also found similar increase in the PAW in our experimental results.

5. CONCLUSIONS

Biochar amendment to soil increased the FC and the PAW for all types of biochar and both soil types used in this experiment. Among them, pinewood biochar was best in terms of the PAW. Rice husk biochar had the least impact on the increase in the water holding capacity of both soil types. The PAW was increased by 22% in the clay loam soil for pine wood biochar. On the other hand, it has pronounced effect in sandy soil to increase PAW. PAW was increased by about 37% in sandy soil by the application of PWB5. Hence, pinewood biochar can be used in the drought-prone areas for both clayey loam as well as sandy soil types.

REFERENCES

[1] WRI, (2005) World Resource Institute: Freshwater Resources.

[2] Lehmann, J. (2007). A handful of carbon. Nature, **447**(7141), 143-144.

[3] Richards, L. A., Russell, M. B., & Neal, O. R. (1938). Further Developments on Apparatus for Field Moisture Studies 1. *Soil Science Society of America Journal*, **2**(C), 55-64.

[4] Konert, M., & Vandenberghe, J. E. F. (1997). Comparison of laser grain size analysis with pipette and

sieve analysis: a solution for the underestimation of the clay fraction. *Sedimentology*, **44**(3), 523-535.
[5] Abel, S., Peters, A., Trinks, S., Schonsky, H., Facklam, M., & Wessolek, G. (2013). Impact of biochar and hydrochar addition on water retention and water repellency of sandy soil. *Geoderma*, **202**, 183-191.
[6] Peake, L. R., Reid, B. J., & Tang, X. (2014). Quantifying the influence of biochar on the physical and hydrological properties of dissimilar soils. *Geoderma*, **235**, 182-190.
[7] Hardie, M., Clothier, B., Bound, S., Oliver, G., & Close, D. (2014). Does biochar influence soil physical properties and soil water availability? *Plant and Soil*, **376**(1-2), 347-361.
[8] Uzoma, K. C., Inoue, M., Andry, H., Fujimaki, H., Zahoor, A., & Nishihara, E. (2011). Effect of cow manure biochar on maize productivity under sandy soil condition. *Soil Use and Management*, **27**(2), 205-212.
[9] Barnes, R. T., Gallagher, M. E., Masiello, C. A., Liu, Z., & Dugan, B. (2014). Biochar-induced changes in soil hydraulic conductivity and dissolved nutrient fluxes constrained by laboratory experiments. *PLoS One*, **9**(9), e108340.
[10] De Melo Carvalho, M. T., de Holanda Nunes Maia, A., Madari, B. E., Bastiaans, L., Van Oort, P. A. J., Heinemann, A. B., & Meinke, H. (2014). Biochar increases plant-available water in a sandy loam soil under an aerobic rice crop system. *Solid Earth*, **5**(2), 939-952.
[11] Cornelissen, G., Martinsen, V., Shitumbanuma, V., Alling, V., Breedveld, G., Rutherford, D., & Mulder, J. (2013). Biochar effect on maize yield and soil characteristics in five conservation farming sites in Zambia. *Agronomy*, **3**(2), 256-274.
[12] Martinsen, V., Mulder, J., Shitumbanuma, V., Sparrevik, M., Børresen, T., & Cornelissen, G. (2014). Farmer-led maize biochar trials: Effect on crop yield and soil nutrients under conservation farming. *Journal of Plant Nutrition and Soil Science*, **177**(5), 681-695.
[13] Storer, D. A. (1984). A simple high sample volume ashing procedure for determination of soil organic matter. *Communications in Soil Science and Plant Analysis*, **15**(7), 759-772.