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Impacts of Biochar in Different Sizes on Sandy Soil Physical and Biological Properties

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ABSTRACT

Sandy soils occupied a considerable area of marginal lands in arid and semi-arid regions. Previous studies on biochar paid rare attention of its particle size effect on soil properties, usually used biochar of < 2 mm size. The aim was to focus on the impact of biochar in different sizes on some sandy soil physical and biological properties and barely growth. This was to develop a management strategy for using biochar as a soil conditioner in sandy soil. Laboratory experiments were conducted to evaluate the possibility of using biochar in two different particle sizes (< 2 mm and 2-5 mm) at two different application rates, 1% and 1.5% (w/w), with an incubation time of 60 days. The results showed that applying biochar in a range 2 - 5 mm as well as < 2 mm size improved the physical properties of sandy soil, including either significant decreases such as in bulk density, saturated hydraulic conductivity (K_{sat}) and the evaporated water or significant increases such as in porosity and water holding capacity (wt. %) at different matric potentials. Applying biochar in size 2 – 5 mm to sandy soil significantly ($p < 0.05$) improved all studied physical properties more than finer biochar particles (< 2 mm), except for K_{sat} and barely growth, the results were better with applying biochar in size < 2 mm. Soil microbial biomass C and N, and soil enzymes (urease and β-glucosidase) were significantly improved by both particle sizes biochar. This research enhances the information about biochar application to sandy soil with positive effects in terms of soil physical and microbial properties following biochar addition in different particle sizes and with different ways of application.

Keywords: Biochar, physical properties, sandy soil, enzyme activities, barley

INTRODUCTION

Sandy soils generally have poor physical properties such as bulk density, total porosity, water holding capacity and hydraulic conductivity. Therefore, the demand for optimizing properties and maximizing the productivity of newly reclaimed soils especially sandy soils became one of the most essentials aims in the agriculture in Egypt. This necessitates the expansion of agricultural production on the marginal lands with unfavorable physical properties such as desert sandy soils. Maintenance of farming in these areas is impossible without improving the productive capacity of sandy soil and irrigation. An increase of arable area on such soils is difficult because the lack of irrigation water. Therefore, the problem of rational use of irrigation water is urgent agenda.

The idea of applying biochar in agriculture originated in Latin America. Farmers in the Brazilian Amazon region commonly use slash and burn method for agricultural production. Regular and long-time burning of grassy and shrubby vegetation has resulted in the formation of Terra Prata soil that is highly cultured (Lehmann, *et al.,* 2003). Lehmann and Joseph (2009), motioned that biochar can be well-defined as “a carbon rich product when biomass such as wood, manure or leaves is heated in a closed container with little or unavailable air”. Biochar due to its inherent properties, scientific consensus exists that application to soil at a specific site is expected to sustainably sequester carbon and concurrently improve soil functions, while avoiding short- and long-term detrimental effects to the wider environment as well as human and animal health (Verheijen *et al.,* 2009).

Improving physical properties of sandy soil with biochar applications will enhance water use efficiency in dry land agricultural systems (Basso *et al.,* 2013). Many studies proved that biochar application enhanced soil physical properties e.g. bulk density, water holding capacity and saturated hydraulic conductivity (Glaser *et al.,* 2002; Chan *et al.,* 2007; Asai *et al.,* 2009; Novak *et al.,* 2009; Laird *et al.,* 2010; Brockhoff *et al.,* 2010; Jun *et al.,* 2016 and Obia *et al.,* 2017).

Biochar has many possible benefits, improves moisture retention which may reduce the demand for irrigation and make cropping more secure, enhances plant growth, raise and sustain crop yields, also help improve good and problematic nutrient-poor soils (Barrow, 2012). Understanding soil hydraulic properties is crucial for planning effective soil and water management practices (Bayabil *et al.,* 2013). Application of wood biochar on highly weathered soils enhanced the soil physical properties and reduced the soil loss (Jien and Wang, 2013). Biochar derived from birch and aspen wood applied to loamy sand spodosol soil resulted in a significant increase of the soil water content in the range of soil-water potential from –5 to –50 kPa (Rizhiya *et al.,* 2015).

Microbial biomass and enzyme activities are considered as indicators of the change in soil physical and chemical properties following biochar application to soil. The impacts of biochar on soil microbial properties are related to the improvement in soil structure and soil water holding capacity (Lehmann *et al.,* 2011; Plaza *et al.,* 2015; Liang *et al.,* 2016; Khadem and Raiesi, 2017). Enzyme activities in soil play an important role because: (1) all biochemical alterations in soil are dependent on, or related to, the presence of enzymes, (2) enzyme activities are related to soil fertility and may influence soil productivity, and (3) the measurement of specific enzymatic activities may back to the understanding of themetabolic processes involved in the biogeochemical cycles of nutrients. In principle, it is assumed that high values of enzymatic activity are indication of good quality of soil, while low values indicate an incorrect run of biological processes in the soil (Gianfreda *et al.,* 2005).

It was hypothesized that addition of biochar in size > 2 mm to sandy soil could improve some physical properties related to water use efficiency. The main aim of this research was to develop best management strategy of using biochar in different sizes at different application rates as a soil conditioner for sandy soil to improve its physical, biological properties and agronomic benefits. Most previous studies were paid attention to the impact of biochar in size < 2 mm on soil properties. In this study, the objectives were to determine whether the addition of biochar produced from the pyrolysis of birch and aspen wood trees residues feedstock at 550°C of two different particle sizes affects water holding capacity (WHC) at different pressures, bulk density, saturated hydraulic conductivity (K_{sat}) and evaporation rate of sandy soil, microbial biomass C, microbial biomass N, enzyme activities and plant growth.

MATERIALS AND METHODS

Some laboratory experiments were conducted to study the impact of biochar of different sizes at two different application rates on sandy soil physical properties. The study was carried out at the Department of Soil Science, faculty of Soil Sciences and Agroecology, Saint-Petersburg State Agrarian University, Saint-Petersburg, Russia and at departments of soil science and Agricultural Microbiology, Faculty of agriculture, Minia University, Minia, Egypt.

- **Soil preparation and biochar characterization:**

Sandy soil was used and washed with diluted hydrochloric acid (1 HCl: 10 distilled water), then washed from the acid with distilled water, air-dried and passed through a 2-mm sieve. By the end of this process the percentage of sand was 98.85% in the soil sample.

Biochar, produced from pyrolysis of birch and aspen wood trees residues feedstock at 550°C, was ground to pass through two different sizes of sieves 5 and 2 mm (Fig 1.). Some physiochemical characteristics of biochar and soil were studied according to Page, 1982; Carter and Gregorich, 2007 (Table, 1).

Biochar < 2 mm

Biochar 2-5 mm

Table 1. Soil properties and some characteristics of biochar in size <2 mm and 2-5 mm.

Soil	Particle size distribution		bulk density ($g\ cm^{-3}$)	Total porosity volumetric %	pH (1:2.5)					
	Sand%	Silt and Clay %								
	98.85	1.15	1.64	38.1	6.9					
	bulk density ($g\ cm^{-3}$)	Water holding capacity (volumetric %) under different pressures: 0.1 bar	0.3 bar	0.6 bar	1.0 bar	3.0 bar	Total C ($g\ kg^{-1}$)	Total N ($g\ kg^{-1}$)	C/N ratio	pH (1:10)
biochar < 2 mm	0.29	43.48	25.83	23.41	22.34	22.28	782	2.4	325.8	8.1
biochar 2-5 mm	0.19	29.79	25.73	24.48	23.73	23.50				

- **Determination of soil physical properties:**

(1) Determination of bulk density, total porosity and water holding capacity:

Incubation experiment was conducted to evaluate the effects of biochar on bulk density, total porosity and water holding capacity of sandy soil. Samples (6.5 kg) of the washed sandy soil were placed in plastic containers (20 cm - width and 15 cm - depth) and then mixed with biochar in two different sizes < 2 mm and 2-5 mm at two different application rates, 1% and 1.5% (w/w).

Biochar was mixed thoroughly with the soil, and then wetted with deionized water to approximately 60% water content of the saturation point of the soil. The experiment was carried out for 60 days under controlled conditions of temperature and relative humidity (24 – 25°C and 55 – 60 % RH). The containers were weighed every 3 days to keep constant moisture content. Treatments were control, soil-biochar < 2 mm at application rate 1%, soil-biochar 2-5 mm at application rate 1%, soil-biochar < 2 mm at application rate 1.5% and soil-biochar 2-5 mm at application rate 1.5%, with three replications.

After the incubation undisturbed samples were taken from the containers using rings (3 cm - height and 4 cm - diameter) to determine bulk density and water holding capacity. Moisture contents of the samples were measured at different matric potentials of 0.1, 0.3, 0.6, 1.0 and 3.0 bars. Five-bar pressure plate apparatus was used to measure the water contents (Dane and Hopmans, 2002). Readily available water content (RAWC) calculated as the difference in water holding capacity (wt. %) at 0.3 and 1 bar. Total porosity was calculated from bulk density using the formula: total porosity = $100(1 – D_b/ D_p)$; where D_b = Bulk density, D_p = Particles density and D_p is assumed to be $2.65 gcm^{-3}$ (Carter and Gregorich, 2007).

(2) Determination of evaporation rate:

Samples (600 g) of washed sandy soil were placed in plastic containers (10 cm - diameter and 5 cm - depth) and then mixed with biochar at the same rates with the same application method as mentioned in experiment (1). The samples were kept saturated with deionized water for 60 days under controlled conditions of temperature and relative humidity (24 – 25°C and 55 – 60 % RH). After the incubation time the evaporated water % every 6 hours was measured until the full evaporation of water from the control.

(3) Determination of saturated hydraulic conductivity:

Separately in columns (25 cm height and 5 cm external diameter) the biochar fractions were applied by mixing thoroughly with sandy soil (applying method, 1) (AM1), in another group of columns biochar applied as a thin layer beneath the sandy soil, 5cm of soil was placed under the biochar (applying method, 2) (AM2). Treatments were control (T0), soil-biochar < 2 mm at application rate 1% (AM1) (T1), soil-biochar < 2 mm at application rate 1% (AM2) (T2), soil-biochar 2-5 mm at application rate 1% (AM1) (T3), soil-biochar 2-5 mm at application rate

1% (AM2) (T4), soil-biochar < 2 mm at application rate 1.5% (AM1) (T5), soil-biochar < 2 mm at application rate 1.5% (AM2) (T6), soil-biochar 2-5 mm at application rate 1.5% (AM1) (T7) and soil-biochar 2-5 mm at application rate 1.5% (AM2) (T8) with three replications. The columns were kept wet with deionized water at approximately 60% water content of the saturation point of the soil for 60 days, then saturated with a constant head permeater of water and saturated hydraulic conductivity was measured according to Israelsen and Hansen (1962).

(4) Growth experiment:

Growth of barley experiment was carried out in pots (radius, 7.5 cm and depth, 17 cm) and the amount of sandy soil per pot was calculated regarding that depth is 15 cm. In this experiment, two biochar application methods were used, one of them was by mixing biochar with 15 cm of soil (AM1) and the other was by butting biochar in a thin layer above 5 cm and beneath 10 cm of sandy soil (AM2). Treatments were control (T0), soil-biochar < 2 mm at application rate 1% (AM1) (T1), soil-biochar < 2 mm at application rate 1% (AM2) (T2), soil-biochar 2-5 mm at application rate 1% (AM1) (T3), soil-biochar 2-5 mm at application rate 1% (AM2) (T4), soil-biochar < 2 mm at application rate 1.5% (AM1) (T5), soil-biochar < 2 mm at application rate 1.5% (AM2) (T6), soil-biochar 2-5 mm at application rate 1.5% (AM1) (T7) and soil-biochar 2-5 mm at application rate 1.5% (AM2) (T8) with three replications. All pots of all treatments were incubated as mentioned in experiment (1). Complex fertilizers were applied 7 days before sowing of the plants in an amount of 1.37 g/pot, after dissolving them in distilled water. The dry weight of 10 barley's plants/pot after 30 days of sowing was recorded.

(5) Biological analyses

After the growth experiment microbial biomass C (MBC) was determined by fumigation extraction (Vance *et al.,* 1987). The difference in organic C of fumigated and unfumigated K_2SO_4 extracts was converted to MBC using a factor $K_C = 0.45$. Also, microbial biomass N (MBN) was determined by chloroform fumigation-extraction method described by Moore *et al.,* (2000), the MBN was calculated as follow: $MBN = EN/K_N$, where EN – the difference between flush of NH_4-N due to fumigation and NH_4-N produced in non-fumigated soil, and K_N – a factor of 0.54. Both MBC and MBN were expressed in mg kg^{-1}. Enzyme activity of urease in soil samples was analyzed as described by Tabatabai (1994) and enzyme activity of β-glucosidase (βG) was assayed using ρ-nitrophenyl-β-D-glucopyranoside as substrate (Eivazi and Tabatabai, 1988).

- **Statistical analysis**

The analysis of variance (ANOVA) was used to determine the statistical differences between the studied treatments using the MSTATC program Ver. 4.0 (Michigan University, USA) according to Gomez and Gomez (1984). The means were compared using the Duncan Multiple Range test at p=0.05.

RESULTS AND DISCUSSION

This research enhances the information about biochar application to sandy soil with positive effects in terms of soil physical properties, microbial biomass and enzyme activities following biochar addition in different particle sizes and with different ways of application.

- **The changes in bulk density and total porosity**

The results of this research show that bulk density was significantly ($p<0.05$) decreased from 1.64 gcm^{-3} to 1.53 g cm^{-3} by treating sandy soil with biochar in two different sizes compared to untreated sandy soil, (Table 2). There was no significant difference among biochar-sandy soil treatments at all application rates and different biochar sizes except for sandy soil treated with biochar 2-5 mm at application rate 1.5%. This was related to the lower bulk density of the biochar 2-5 mm (Table 1). The opposite relationship was observed with the total porosity where the soil total porosity significantly increased ($p<0.05$) with the addition of biochar compared with the control. No significant differences among biochar-sandy soil treatments were observed except for sandy soil treated with biochar 2-5 mm at application rate 1.5%, (Table 2). The effect of biochar on the porosity of the treated sandy soil after 60 days of incubation was attributed to the contribution of biochar to micro-porosity as suggested by Tseng and Tseng (2005) and Novak et al. (2009), and attributed to dilution effect of a low bulk density of biochar (Bhogal *et al.,* 2009).

Table 2. Soil physical properties as affected by biochar application:

Treatments	bulk density (g cm^{-3})	Total porosity volumetric %	Water holding capacity (wt. %) at matric potentials					RAWC[a]
			0.1 bar	0.3 bar	0.6 bar	1.0 bar	3.0 bar	
Control	1.64 a	38.11 a	9.66 c[b]	6.66 d	5.03 d	4.40 d	3.22 d	2.26 d
Sand-biochar < 2 mm (1%)	1.59 b	40.00 b	11.05 b (14.39)[c]	7.48 c (12.31)	5.78 c (14.91)	5.12 c (16.36)	3.90 c (21.12)	2.36 bc
Sand-biochar 2-5 mm (1%)	1.57 b	40.75 b	11.12 b (15.11)	7.94 b (19.22)	6.26 b (24.45)	5.60 b (27.27)	4.41 b (36.96)	2.34 c
Sand-biochar < 2 mm (1.5%)	1.57 b	40.75 b	11.73 a (21.43)	7.88 b (18.32)	6.15 b (22.27)	5.48 b (24.55)	4.29 b (33.23)	2.40 a
Sand-biochar 2-5 mm (1.5%)	1.53 c	42.26 c	11.83 a (22.46)	8.57 a (28.68)	6.86 a (36.38)	6.18 a (40.45)	4.99 a (54.97)	2.39 ab

[a] RAWC: readily available water content [b] the relative increase in WHC comparing to control treatment
[c] Different letters in the same column indicate significant differences (p < 0.05) between the treatments

The impacts of biochar on soil physical properties i.e. porosity and bulk density depend on several factors, such as biomass or feedstock type, pyrolytic condition and application rate. Soil porosity is an important physical property which controls soil fertility utilities such as water and nutrient holding capacity, aeration and microbial activity. High porosity and low bulk density of biochar amended sandy soil, may be provide space for formation of ponds and complexes with cations and ions on surface of soil elements which improves retention capacity of soil nutrients.

Results of this experiment indicated that incorporation of biochar can enhance soil porosity and decrease bulk density of amended sandy soil. Thus, the decrease in bulk density and the increase in total porosity of biochar amended sandy soil could be an indicator of enhancement of soil structure, aeration and aggregation. The higher the total porosity (micro- and macro-pores) the higher is soil physical quality because micro-pores are involved in molecular adsorption and transport while macro-pores affect aeration and hydrology (Atkinson *et al.,* 2010).

- **Water holding capacity**

Application of biochar to the investigated sandy soil at all treatments increased significantly the water holding capacity (WHC) (w %) compared to control at specific matric potentials (0.1, 0.3, 0.6, 1.0 and 3.0 bar), (Table, 2). Results of this research show that at 0.1 bar matric potential there was no significant difference between treated soil with biochar in both two sizes at rate 1% and between treated soil with biochar in both two sizes at rate 1.5%. However, at matric potentials from -0.3 to -3.0 bars there was always no significant difference between soil-biochar 2-5 mm at a rate of 1% and soil-biochar < 2 mm at a rate of 1.5% treatments (Table, 2). Comparing to control treatment, the relative increase in water holding capacity of the treated soil with coarse biochar (2-5 mm) at a rate of 1.5% at matric potentials range from 0.1 to 3.0 bar varied from 22.46% to 54.97% and was significantly higher (p<0.05) than the soil treated with fine biochar (< 2 mm), where WHC of the soil treated with fine biochar (< 2 mm) varied from 21.43% to 33.23% at the same range of matric potentials (Table, 2). Herath *et al.,* (2013) revealed that the observed increase in the water holding capacity (wt %) at any matric potential after the addition of biochar compared to the control is to a large extent related to the increase of macro-porosity caused by the dilution effect. Applying biochar to soil could increase water content either by holding water in its pores with capillary force or by changing soil hydraulic properties (Pietikäinen *et al.,* 2000 and Jun *et al.,* 2016).

In agreement with our results water-holding capacity of medium textured, boreal agricultural soil was increased by 11% with biochar addition (Karhu et al. 2011). Biochar addition at a rate of 3%, and 6% w/w to sandy loam soil increases water-holding capacity and might increase water available for crop use (Basso *et al.,* 2013). Biochar produced from black locust increased the available water capacity (AWC) by 97%, and saturated water content by 56%, however, reduced hydraulic conductivity (Uzoma *et al.,* 2011).

- **The change in the evaporated water % as affected by biochar**

Both studied sizes of the used biochar at the application rates of 1% and 1.5% caused a significant (p<0.05) decrease in the percentage of the evaporated water from the soil-biochar treatments in comparison with the control. In the observations after 42, 48 and 54 hours the lowest evaporated water % was from the soil treated with biochar 2-5 mm at a rate of 1.5% followed by the treatments soil-biochar < 2 mm at a rate of 1.5%, soil-biochar 2-5 mm at a rate of 1% and soil-biochar < 2 mm at a rate of 1% in ascending manner (Table 3).

Table 3. The effect of biochar application on the evaporated water %:

The observation every 6 hours	the evaporated water %				
	Control	Sand-biochar < 2 mm @ 1%	Sand-biochar 2-5 mm @ 1%	Sand-biochar < 2 mm @ 1.5%	Sand-biochar 2-5 mm @ 1.5%
After 6 hours	26.16 a	25.34 b	25.22 b	24.85 c	24.69 c
After 12 hours	42.54 a	41.97 b	41.76 c	41.59 d	41.35 e
After 18 hours	53.22 a	52.22 b	52.02 c	51.67 d	51.29 e
After 24 hours	61.69 a	60.72 b	60.54 b	60.30 c	59.92 d
After 30 hours	67.74 a	66.75 b	66.59 b	66.15 c	65.90 c
After 36 hours	78.93 a	77.81 b	77.52 c	77.35 c	76.91 d
After 42 hours	88.87 a	87.36 b	87.03 c	86.58 d	86.10 e
After 48 hours	97.85 a	95.88 b	95.55 c	94.81 d	94.41 e
After 54 hours	100.0 a	98.11 b	97.80 c	97.14 d	96.68 e

Biochar ground to fine particles < 2 mm demolished the pore structure, which simultaneously decrease the WHC and would not decrease the water evaporation loss from the soil, this phenomenon was in agreement with the obtained results by Jun *et al.,* 2016.

- **Effect of biochar application method on saturated hydraulic conductivity (K_{sat})**

In this trail the hypothesis was that biochar application in different sizes and at both rates in a thin layer under the sandy soil is more effective in improving saturated hydraulic conductivity than applying biochar by mixing thoroughly with sandy soil. All treatments significantly (p<0.05) improved K_{sat} after 60 days of incubation in comparison with control except for treatment T3 had no significant effect as shown in Fig 2. The higher effect of biochar application on saturated hydraulic conductivity of the investigated soil was observed in treatments T6 and T2 where K_{sat} decreased from 0.851 to 0.257 and 0.311 cm min.$^{-1}$, respectively. This gave us two notes, first, applying fine biochar (< 2-mm) beneath sandy soil was more effective in improving K_{sat} and second, increasing ratio of applied fine biochar decreased K_{sat}. The same was observed with treatments T4 and T8 regardless, those were less effective in improving K_{sat}. On the other hand, applying biochar by mixing either its fine particles or coarse with sandy soil had the lowest improve of K_{sat}, that was observed in treatments T1, T5 and T7.

The reason of the greatest decrease in K_{sat} as a result of applying fine biochar (< 2 mm) as a thin layer under the sandy soil could be due to the small size of biochar particles, which have a high-water retention forming a layer stands against water movement.

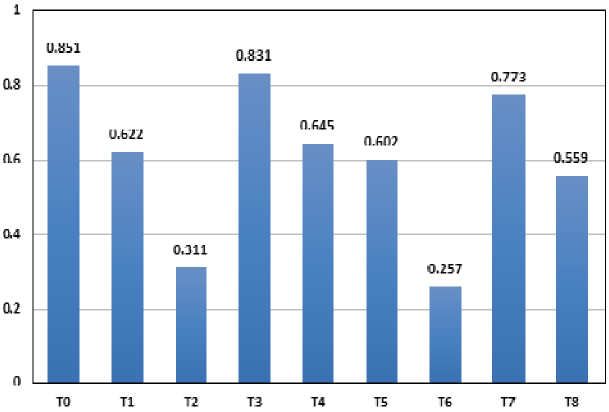

Fig 2. biochar treatments effect on Saturated hydraulic conductivity (K_{sat}), cm min^{-1}

Biochar particle sizes <0.5 and 1–5 mm significantly reduced K_{sat} ($p < 0.05$) in sandy loam below the crust by 0.17 ± 0.07 cm h^{-1} per percent BC added. However, this reduction in K_{sat} may be explained by clogging of soil pores by BC or by collapse of soil structure near water saturation (Obia *et al.,* 2017). When biochar is water saturated, hydrogen bonding between hydrogen atoms on biochar surface and the oxygen of water forms (Conte *et al.,* 2013).

5. The effect of biochar applications on barley growth

The results shown by Fig 3. illustrate that all treatments with biochar significantly (p<0.05) caused an increase in the dry weight of 10 plants of barley/pot in comparison with the control. Applying biochar in size < 2 mm at a rate of 1% and 1.5% as a thin layer under the soil slightly increased, but not significantly, the dry weight of 10 plants of barley/pot in comparison with mixing the biochar with the soil. In general, the fine biochar (< 2 mm) significantly increased the dry weight of 10 plants of barley/pot much higher than the coarse biochar (2-5 mm) at the both application rates 1% and 1.5%. An exception was observed with the treatment T8 in which the dry weight of 10 plants of barley/pot significantly decreased comparing with the treatment T7, this was maybe due to the higher water holding capacity of coarse biochar against plant when applied in a thin layer under the soil.

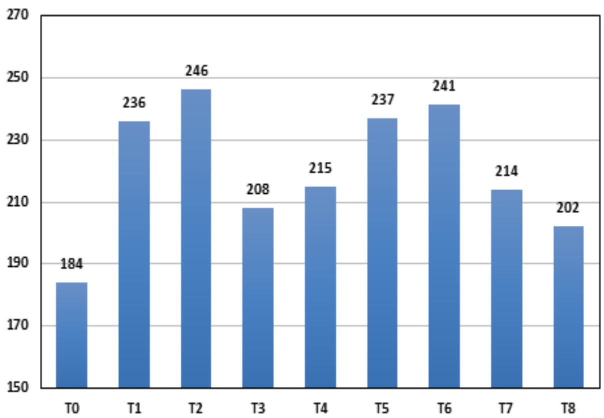

Fig 3. The dry weight of barley/pot after 30 days of sowing (mg) as affected by biochar treatments

Application of rice-husk biochar in a sandy, acidic soil typical for Cambodia at rates between 50–150 g kg^{-1} in pot experiment caused a highly positive effect on lettuce and cabbage growth (Carter et al, 2013). Also, biochar application could optimize water use and consequently improve plant growth, this seems a conceivable result for farmers suffered from scarce water resource (Nabahungu and Visser, 2013; Masood *et al.,* 2014; de Melo Carvalho *et al.,* 2014).

6. Soil microbial biomass and enzyme activities response to biochar application

The properties of biochar itself such as porosity and surface area contribute to increase sand water holding capacity as the obtained results showed. These results reflected in soil microbial biomass and enzyme activities.

Soil microbial biomass (MBC and MBN) significantly increased as affected by biochar application in all treatments comparing with control. The obtained results in Table (4) showed that treatments T1, T2, T5 and T6 recorded the most higher values and followed by treatments T3, T4, T7 and T8. Microbial biomass C and N were increased by 29.2% and 8.8% in treatments amended with biochar < 2 mm in comparison with coarser particle size biochar (2 – 5 mm). These results agree with those obtained by Zhang *et al.,* (2014) who concluded that MBN was less responsive to biochar application than MBC. Overall, MBC and MBN were not significantly affected by the higher dose of biochar excluding T5. Also, the way biochar applied with did not affect significantly soil microbial biomass, that means applying biochar as a thin layer beneath 10 cm of sandy soil has almost the same effect of applying biochar by mixing thoroughly with the sandy soil.

With respect to soil enzyme activity, soil microbial biomass enzymes involved in carbon (β-glucosidase) and nitrogen (urease) in sandy soil amended with biochar were activated as indicators of enzyme activity, the obtained results in Table (4) presented that biochar application either with particle size < 2 mm or 2-5 mm significantly increased urease and β-glucosidase in comparison with untreated sand (T0). It is important to notice that biochar with finer particles improved enzyme activities higher than biochar with particles 2-5 mm at the both rate of application. Urease and β-glucosidase average values in treatments with coarser biochar were respectively 73.6 and 70% of their values in treatments with finer biochar.

Table 4. The effect of biochar application on soil microbial biomass (MBC and MBN) and enzyme activities (urease and β-glucosidase):

Treatments	MBC (mg kg^{-1})	MBN (mg kg^{-1})	Urease (mg NH_4-N kg^{-1} h^{-1})	β-glucosidase (mg ρ-nitrophenol kg^{-1} h^{-1})
T0	35.64 d	15.37 d	3.52 f	4.21 d
T1	53.90 b	34.87 b	9.26 bc	8.31 b
T2	55.18 b	34.37 b	8.79 cd	7.94 b
T3	42.98 c	31.88 c	6.88 e	6.08 c
T4	42.38 c	32.49 c	6.65 e	5.68 c
T5	60.19 a	37.79 a	10.55 a	9.53 a
T6	54.52 b	36.66 a	10.12 ab	9.23 ab
T7	44.23 c	32.81 c	7.83 d	6.51 c
T8	43.81 c	31.81 c	7.75 de	6.34 c

In this study, was found that soil microbial biomass (MBC and MBN) and enzyme activities (urease and β-glucosidase) values in treatment T5 were significantly higher than the rest of treatments. The contact between sand and biochar in treatments with finer particle size biochar suggested to be more effective in microbial activities than in those treatments with coarser particle size biochar.

Used biochar in this research improved a serious of physical properties such as porosity and water holding capacity causing changes in microbial properties. On the other hand, the dark color of biochar causes a decrease in soil albedo resulting in enhancing soil microbial activities.

CONCLUSIONS

Sandy soil physical properties such as bulk density, total porosity, water holding capacity, evaporation rate and saturated hydraulic conductivity compared to control, were affected by biochar particle size regardless the application rates, and also barely vigorous growth was stimulated. Applying biochar as a thin layer under surface layer of sandy soil keep water from missing because of the high drainage capacity of such soils with sand texture. Biochar in both studies sizes stimulated soil microbial activities. In this study, it could be concluded that application of coarse biochar (2-5 mm) to sandy soil has a best management strategy practice to reach optimum improvements in sandy soil physical and biological properties and barely growth.

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تأثيرات الفحم الحيوى بأحجام مختلفة على الخواص الطبيعية والحيوية للأرض الرملية

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تشغل الأراضى الرملية مساحة كبيرة من الأراضى الثانوية فى المناطق الجافة وشبه الجافة. قليل من الدراسات السابقة على الفحم الحيوى اهتمت بتأثير حجم حبيبات الفحم على خواص التربة وغالبا ما كان التركيز على حجم الحبيبات أصغر من ٢ مم. ولذلك كان الهدف من هذا البحث دراسة تأثير الفحم الحيوى بأحجام مختلفة على خواص الأراضى الرملية الطبيعية والحيوية ونمو نباتات الشعير بهدف تطوير استراتيجية لاستخدم الفحم الحيوى كمحسن للأراضى الرملية. ولهذا الهدف تم اجراء بعض التجارب المعملية بغرض تقييم إمكانية اضافة الفحم الحيوى بأحجام حبيبات مختلفة (<٢مم، ٢-٥ مم) وبمعدلى اضافة (١، ١.٥ % وزنا) مع التحضين لمدة ٦٠ يوم. هذا وقد أظهرت نتائج هذه الدراسة أن اضافة الفحم باحجام مختلفة كان له تأثير ايجابى على خواص التربة الطبيعية متمثلا فى انخفاض الكثافة الظاهرية والتوصيل الهيدروليكى ومعدل البخر وزيادة المسامية وقدرة التربة على الاحتفاظ بالماء تحت جهود ضغط مختلفة. كان لحجم حبيبات الفحم ٢-٥ مم أفضل التأثيرات على الخواص الطبيعية بالمقارنة مع حجم حبيبات الفحم أقل من ٢ مم فيما عدا التوصيل الهيدروليكى ونمو نباتات الشعير. الكتلة الميكروبية لكربون ونيتروجين التربة وكذلك النشاط الانزيمى (انزيم اليوريز وانزيم البيتا-جلوكوسيديز) تحسنت معنويا نتيجة اضافة الفحم بكلا الحجمين. هذه الدراسة تعزز المعلومات حول اضافة الفحم الحيوى للأراضى الرملية لما له من آثار ايجابية فيما يخص خصائص التربة الطبيعية والحيوية نتيجة اضافته بأحجام مختلفة وبطرق مختلفة.