Short-term effect of two agricultural wastes derived biochars on some physiochemical properties of a sandy loam soil

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ABSTRACT

Biochar has not been adequately used by farmers to improve the soil properties in the world and less attention is given to effects of biochar (BC) in semi-arid and arid environments with few studies in sandy soils. So, agricultural applications of biochar (BC) to these soils should be considered as a possible way of improving productivity and sustainability. A pot experiment was conducted in winter season of 2020 (20th of November) to evaluate the effect of two different biochars derived from palm tree wastes (PTWB) and olive pomace wastes (OPWB) on some physical and chemical properties, including available nutrients (N, P and K), EC, pH and bulk density. The soil was loamy sand and collected from Elshekha Salam region, at Meet Kenana village, Tukh City, El-Qalubiea Governorate, Egypt. Treatments consisted of a factorial combination of two types of biochar (PTWB and OPWB) and three biochar levels (0, 0.5 and 1%). The experiment was arranged in a randomized complete block design with three replicates. The results showed that PTWB and OPWB led to marked changes in the studied physiochemical properties and the influence of PTWB on these properties was lower than OPWB. EC, pH and available N, P and K values were recorded as follows 5.15 dS m^{-1}, 8.29, 32.73 mg kg^{-1}, 14.28 mg $kg^{-1}$and 244.4 mg kg^{-1}, respectively, due to application of 1% OPWB, whereas the respective values in the control treatment had the lowest values of these items and were as follows 3,76 dS m^{-1}, 8.03, 23.13 mg kg^{-1}, 11.99 mg $kg^{-1}$and 132.0 mg kg^{-1} . Application of PTWB and OPWB in the sandy loam soil decreased its bulk density and the use of 1% of OPWB was responsible for its lowest value (1.36 g cm^{-1}). Our results concluded that both PTWB and OPWB could be recommended as promising amendments for improving

the physiochemical properties of sandy loam soils.

1. Introduction

In most arid and semi-arid regions, large areas of cultivated and non-cultivated soils are characterized by low organic matter contents (<1%) due to rapid decomposition mineralization process, which can adversely affect physicochemical soil properties [1]. Sandy soils are characterized by high infiltration rate, low water holding capacity, high evaporation, low fertility, and deep percolation resulting in low water availability and use efficiency [2-3]. Generally, the low organic matter content in sandy soils could result in low available water, weak structure and low nutrient holding capacity [1-5]. Attempts have been made to improve the physicochemical properties of such soils having coarse texture by the incorporation of organic amendments.

The application of organic matter (i.e. manure, mulches and composts) has frequently been shown to increase soil fertility, the benefits are generally short-lived, especially in sandy soils because of the rapid decomposition (mineralization) of organic matter under high temperature and aeration even during the cropping season [1]. This has made the practice expensive, and therefore, the farmers refrain from organic fertilizers addition to crops. For this reason, organic amendments must be applied every year to sustain soil productivity. An alternative to this practice could be the use of more stable compounds such as biochar (BC) instead of the ordinary degradable organic manures [3].

The use of BC as a soil amendment is not a new concept, but it has received growing attention in the last few years, generally due to its role in improving soil properties and quality, and increasing nutrient use efficiency and crop production [6-7]. Biochar is a carbon-rich material produced through the heating of any organic materials through pyrolysis process under low or absence of oxygen at high temperatures (250–700°C) [4]. Moreover, biochar is highly porous with high surface area and charge density, which contributes to its high capacity to adsorb cations compared with traditional soil organic matter [2]. Application of biochar soils improves a range of soil properties such as aggregate stability, porosity, soil bulk density and water holding capacity. Key soil chemical properties, such as pH, OM content, and CEC are also influenced by BC addition, thus affecting soil fertility and productivity [9]. Moreover, the controlling of soil nutrients in plant root zone following biochar addition is possible and could be directly as biochar being as a nutrient source or indirectly by altering soil nutrient content and availability [8]. The incorporation of biochar into soil has been also shown to enhance soil capacity to retain plant nutrients and decrease the nutrient losses by leaching resulting in a significant increase in agricultural productivity [10-13]. Impact of BC addition on crop yield is more pronounced in infertile and degraded soils compared to that in the soils of high fertility [9,14]. The effects vary with feedstock type, pyrolysis conditions (temperature and residence time) as well as soil type and environment [4,8].

There are few literature studies which demonstrate the effect of biochar application on physical and chemical properties of sandy soils in Egypt. Therefore, there is a need to evaluate the potential benefits of biochar as soil amendment for sandy soils. The main objective of this study was to evaluate the effect of two types of biochar on selected physical and chemical properties of a sandy loam soil under a greenhouse experiments.

2. Materials and Methods

2.1. Soil sampling and preparation

The soil samples for this study were obtained from El-Sheikha Salma region at Meet Kenana village, Tukh City, El-Qalubiea Governorate, Egypt. The composite soil samples were collected from the surface soil layer (0–20 cm) from the plough horizon. All soil samples were brought to the laboratory, crushed, and then air-dried. In addition, the soil samples were sieved passing through a 2-mm screen for further analyses and experiments.

2.2. Biochar preparation

Palm trees wastes (PTW) were collected from the fruit farm of Faculty of Agriculture, Benha University, Moshtohor village, Tukh City, El-Qalubiea Governorate. However, olive pomace wastes (OPW) were collected from a local factory for pressing olive at Mersa Matruh City, Matrouh Governorate, Egypt. Both of PTW and OPW were used individually in this experiment to produce the biochar. PTW and OPW were oven dried at 105 C^{o} (moisture content was nearly 5.1% in each waste) and then converted into biochar by the pyrolysis process at 400-450 C º for 1h in the Training for Center Recycling the Agriculture Residues and Biogas Technology (TCRAR), Moshtohor village, Tukh City, Kalubia Governorate, Agricultural Research Center (ARC), Egypt. The obtained biochars of PTW and OPW were crushed by an electrical mill and then kept for the experimental work.

2.3. Pot experiment and design

Pot experiment was conducted under natural conditions in the greenhouse of Soils and Water Sciences Department at Faculty of Agriculture, Benha University, Moshtohor village, Tukh City, El-Qalubiea Governorate, Egypt. The experiment aimed to study the effects of PTW and OPW biochar individually on growth of two crops on a sandy soil and also to determine their influences on some chemical and physical properties of this sandy soil. The experiment was factorial with two factors. The first one was biochar's type and the second one was biochar's level. So, the experiments consisted of six treatments, which were resulted from combination of two types of biochar (PTW and OPW) and three levels of biochar (0, 0.5 and 1%). The treatments were arranged in a randomized complete block design (RCBD) with three replicates. Both of PTW biochar and OPW biochar were individually spread on the soil in each experimental pot and then manually incorporated into the soil two weeks before starting the experiments.

Barley (*Hordeum vulgare* L) variety Giza (123) was used as an indicator plant. Barley grains were sown in November 20, 2020. Each pot contained 5 kg air-dreid soil. The pots were sown with 15 grains and then thinned to 10 plants after two weeks from the sowing process. Barley plants were fertilized with 0.325 g N/pot in a form of urea (N= 46.5%), 1 g/pot calcium super phosphate (P_2O_5 15.5%) and 0.25 g/pot potassium sulfate (K_2O 24%). Nitrogen and potassium fertilizers were added at two equal doses (the first dose 50% after thinning process and the second one after 30 days from the thinning process), while phosphors fertilizer was added one time and mixed well in the soil two weeks before starting the experiment. The experimental pots were regularly irrigated with tap water at 70% from the water holding capacity.

2.٤. Soil and biochar analyses

Particle size distribution of the soil samples was carried out by using the international standard pipette method, as described by Gee and Baudee [15]. Bulk density was then determined according to the method as described by Blake and Hartge ([16]. Soil EC was determined in soil paste extract, while soil pH was determined in a suspension of 1:2.5 soil:water. Biochar EC and pH were determined in extract of 1:10 biochar:water. Values of pH were measured using a digital pH meter (6173 pH, USA) but EC values were measured using a digital EC meter (Jenway 4510 conductivity meter, UK). Organic matter of biochar and soil was determined according to the wet combustion as described by Nelson and Sommers [17]. Soil available N, P and K were extracted by KCl (1M), $NaHCO_3$ (0.5 M) and ammonium acetate (1M) according to Jackson [18] and then determined by Kjeldahl (Mod.DNP.1500MP, Spain), spectro-photometer (Spectronic 20 D, USA), and flame-photometer (FP 6410), respectively. Physicochemical characteristics of soil and biochar were presented in Tables 1 and 2.

Table 1. Physiochemical properties of the soil before planting.

Parameters	Values
Coarse sand (%)	76.46
Fine Sand (%)	4.31
Total Sand	80.77
Silt (%)	7.73
Clay (%)	11.5
Texture class	Sandy loam
Bulk density (g cm^{-3})	1.58
Particle density (g cm^{-3})	2.59
Total Porosity (%)	38.99
EC (dS m^{-1})*	3.91
pH**	8.15
CaCO3 (g kg^{-1})	33.70
Organic matter (g kg^{-1})	10.48
Available N (mg kg^{-1})	21.45
Available P (mg kg^{-1})	9.85
Available K (mg kg^{-1})	103.6

EC= Electrical conductivity, * in soil paste extract, ** in a suspension of 1:2.5 (soil:water)

Table 2. Some chemical and physical properties of the used biochars

Properties	PTW*	OPW**
EC dS m^{-1} at (1:10 ext	**4.50**	**2.40**
pH at biochar:wate spension)	**8.62**	**8.12**
Organic matter (%)	**69.3**	**68.51**
ASH %	**25.57**	**36.39**
Total nitrogen (%)	**0.325**	**1.241**
Total P (%)	**0.112**	**0.549**
Total K (%)	**0.283**	**0.958**
Saturation (%)	**152.91**	**237.37**
Bulk density (g cm^{-3})	**0.182**	**0.536**

Palm trees wastes (PTW) * Olive pomace wastes (OPW)**

2.٥. Data analysis

Data collected was subjected to analysis of variance (ANOVA) using with SPSS 20.0 (SPSS Inc., Chicago, USA) software. The differences between the treatment means were compared using the least significant difference at $P \leq 0.05$.

3. Results and Discussion

Data in Tables 3 and 4 showed the effect of palm tree waste biochar (PTWB) and olive pomace waste biochar (OPWB) and their different rates on some physiochemical properties of the loamy sand soil. Application of PTWB and OPWB caused marked changes in available nutrients (N, P and K), EC, pH and bulk density and the effect of OPWB is more notable than that of PTWB, especially at its highest applied rate (1%). Soil available N was 23.13 mg kg^{-1} in the control and increased to 25.08 and 29.84 mg kg^{-1} when the soil treated with 0.5 and 1% PTWB, while it was 23.12 mg kg^{-1} in the control and enhanced to 26.95 and 32.73 mg kg^{-1} when the soil amended with 0.5 and 1% OPWB. There is no significant alterations were found the effect of PTWB and OPWB on available N when they added individually in to the soil at a rate of 0.5%. Soil available P significantly varied from 11.99 mg kg^{-1} in the control to 12.56 and 13.65 mg kg^{-1} due to application of PTWB at rates of 0.5 and 1% but to 12.94 and 14.28 mg kg^{-1} as results of OPWB application at rates of 0.5 and 1%. The results of available P indicated that effects of PTWB and OPWB were similar at the chosen applied rates (0.5 and 1%). Soil available K significantly increased from 132 mg kg^{-1} to 155.85 and 174.65 mg kg^{-1} in pots treated with 0.5 and 1% of PTWB, and to 211.8 and 244.4 mg kg^{-1} in those pots incorporated with 0.5 and 1% of OPWB. Significant changes were found between the effects of the different rates of PTWB and OPWB on available K. Biochar improves soil chemical properties with low and high application rate depending on the type of biochar [19]. Indeed, biochar feedstock type determined the chemical compositions of the final biochar and the resulting effect in the soil as observed in this study. Our results agree with the observations of Zhang [20] who reported that soil pH under different application levels of biochar increased by 0.20~0.36 pH units over that in their control treatment. Also, Pandey [21], who reported that soil pH after oil crop cultivation ranged from 7.95~8.09 for biochar treatments, but the pH was 7.8 in the control treatment. The application of wood biochar at 10–20 t ha^{-1} has been previously reported to increase exchangeable K, Ca and Mg on clay and sandy textured soils [22-23]. The increase in K and Mg with biochar application on a loamy sand soil was probably due to the high concentration of these nutrients in the used biochar [1]. It was indicated that the soil fertility was improved at a certain extent by biochar application and this reflected on contents of available P and K in the soils [13]). The reason of these differences in nutrient results is assumed to be related to the slow release of nutrients from biochar [21].

Table 3. Available nutrients of a loamy sand soil treated with biochar after harvesting of barley

Bio-Char type	Bio-Char rate	N (mg kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})
Palm Tree waste biochar (BTWB)	0	23.13d	11.99b	132.00e
	0.5%	25.08c	12.56ab	155.85d
	1%	29.84b	13.65a	174.65c
Olive pomace biochar (OPWB)	0	23.12d	11.99d	132.00e
	0.5%	26.95c	12.94ab	211.80b
	1%	32.73a	14.28a	274.40a

Different letters within the same column indicated the significant differences between treatments at p ≤0.5 according to Duncan's Multiple Range Test

Soil EC and pH were changed from 3.76 dS m^{-1} and 8.03 for the control to 3.88 dS m^{-1} and 8.03, and 4.53 dS m^{-1} and 8.21 in 0.5 and 1% PTWB treatments, and to and 4.59 dS m^{-1} and 8.07 and 5.15 dS m^{-1} and 8.29 in 0.5 and 1% OPWB treatments, respectively. These results indicated that no significant effects between the control treatment and PTWB and OPWB when they individually added in the soil at a rate of 0.5%. However, application of 1% PTWB and 1% OPWB individually was markedly responsible for the highest changes in pH and EC of the sandy soil. Peng [24] reported that biochar application could increase pH because biochar not only has a high pH but also has a high level of exchangeable cations, resulting in high surface and charge densities. This indicates that biochar has a liming potential but depends on the application rate and the type of soil [1]. The increase in pH as a result of biochar application is due to its high liming potential (pH 7.62) and Ca content [3].

Application of 1% PTWB and 1% OPWB individually decreased the values of soil bulk density to 1.36 and 1.43 g cm^{-3}, in comparison to the control 1.58 g cm^{-3} but these decreases generally were not significant. However, the use of OPWB at a rate of 1% only led to the lowest and significant value of soil bulk density (1.36 g cm^{-3}) in compassion to other treatments. Bulk density in soil is a basic soil physical parameter that depends on soil amendment application levels [25]. Among the various soil amendments, biochar can change soil status, leading to a dilution effect due to its low density. These trends agree with results reported by Burrell [26], which showed that a lower bulk density of soil was the result of direct dilution of soil by biochar application. In addition, Głąb [27] reported that biochar application resulted in lower bulk density under different rates of biochar application in sandy soil. The change in soil physical properties on a loamy sand soil with biochar application could be attributed to the high carbon content, porosity and possibly large surface area of the added biochar [28]. Biochar, due to its porous nature, may improve soil physical properties through direct contribution of new pores [29]. The decrease in bulk density after biochar incorporation partly relates to the smaller bulk density of the porous biochar than that of the soil through the dilution effect [30].

Table 4. Physiochemical properties a sandy loam soil treated with biochar after harvesting of barley

Bio-Char type	Bio-Char rate	pH	EC dS m^{-1}	Bulk density g/cm3
Palm tree waste biochar (PTWB)	0	8.03b	3.76c	1.58a
	0.5%	8.07b	3.88c	1.43ab
	1%	8.21a	4.79b	1.36b
Olive pomace wastes (OPW)	0	8.03b	3.76c	1.58a
	0.5%	8.07b	4.59b	1.53ab
	1%	8.29a	5.15a	1.47ab

Different letters within the same column indicated the significant differences between treatments at p ≤0.5 according to Duncan's Multiple Range Test

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