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Effect of Plant Residues Derived Biochar on Fertility of a new Reclaimed Sandy Soil and Growth of Wheat (*Triticum aestivum* L.)

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TWO TYPES of biochar , rice straw biochar (RSB) and soybean straw biochar (SSB) at four rates (0, 4.20, 8.40 and 16.80 g kg^{-1}) for each were used to evaluate their effects on the fertility of a new reclaimed sandy soil and on the growth of wheat. The results showed that incorporation of RSB and SSB caused significant enhancements in soil physical properties through decreasing bulk density and increasing porosity, water-holding capacity and volumetric water. Moreover, soil chemical properties, including pH, organic carbon, cation exchange capacity, electrical conductivity and nutrients availability were markedly affected by RSB and SSB additions, especially at their highest applied rates (16.80 g kg^{-1}). The biochar type had an important impact on soil properties and the effect of SSB was more pronounced than RSB. Data also indicated that the use of RSB and SSB led to increase the growth of wheat plants, as presented by dry weights of their straw and grains. The highest effects of RSB and SSB on straw (3.05 and 3.73 g pot^{-1}) and grains (2.72 and 3.25 g pot^{-1}) of wheat were recorded at the addition of 16.80 g RSB or SSB kg^{-1}, respectively. Concentrations of N, P and K were markedly increased in RSB and SSB treatments as compared with the control (no biochars addition). Both RSB and SSB had valuable influences on growth and nutrients content in wheat due to their efficient effects in improving physical and chemical properties of the used sandy soil. This study demonstrated that converting plant residues to biochars through the pyrolysis process could be recommended in the agricultural management of sandy soil and had an important role in enhancing their qualities and productivities.

Key words: Biochar, Plant residues, Sandy soil, Soil quality, Wheat growth

Wheat (*Triticum aestivum* L.) is highly cultivated in large areas in the world with an annual production of 650 million tons and its cultivated area and production come after maize and rice (FAO, 2012). In Egypt, wheat is considered as one of the most vital cereal crops in the human life because it is rich in mineral, gluten and fiber contents. In 2011, the total production of wheat in Egypt was 8.4 million ton from a land area of 1.28 million hectare (FAO, 2011). The cultivated area of wheat in Egypt reached 1.43 million hectare in 2015. Recently, a great attention is going to increase the productivity of wheat (Helmy and Shaban, 2013).

Sandy soils in Egypt are characterized by poor fertility (low retention capacity for water and nutrients) and limited crop productivity. Searching for natural organic amendments to improve their fertilities is one of the vital tasks in the Egyptian agriculture system. In recent years, addition of biochar as an organic amendment is becoming one of the practical strategies to improve soil fertility and crop production.

In arid and semi-arid regions, soil organic matter (SOM) is highly oxidized and degrade, so improving SOM contents gains high attention to keep the quality and productivity of soils under these conditions (Lal, 2008 and Papathanasiou *et al*., 2012). Addition of organic amendments to sandy soils is an eco-friendly, cost-effective and common practice and is still a desirable way to enhance their fertilities. Crop residues can be used as an important management strategy to enrich the soil with nutrients through their decomposition and then maintain soil fertility and crop production. However, farmers do not know the best ways to manage these residues such as rice straw and soybean straw and they are usually burned them

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to clean the fields after crop harvesting. So, searching for a good way to recycle the crop residues through biochar production become a vital task. Recently, recycling organic residues through thermal modification process to produce the biochar as a soil amendment is considered as a beneficial way and popular approach in improving soil properties (Chan et al., 2008, Al-Wabel et al., 2015 and El-Mahrouky et al., 2015).

Biochar (BC) is produced by the pyrolysis process of different biomass materials such peanut hulls, wood, grass, coffee husks and animal wastes in the absence of oxygen or under limited oxygen (Chan et al., 2008). Biochar is one of the most stable carbon forms and can resist in soils for hundreds to thousands years (Kuzyakov et al. 2009). Properties of biochar are generally depended on the type of biomass materials and conditions of pyrolysis process (Bonelli et al., 2010 and Singh et al., 2010). It has been shown in many researches that biochar has an important role in keeping soil fertility at high level and also may improve the sequestration of soil carbon (Lehmann et al., 2003, Steiner *et al*., 2007, Chan et al., 2008 and Lehmann et al., 2008). Biochar can enhance nutrients availability and their retention (reduce the loss of nutrients through leaching), moisture content, cation exchange capacity, porosity and microbial activity of the soil as a result of its high surface area and porosity (Laird et al., 2010, Uzoma et al., 2011 and Reverchon et al., 2014). Incorporation of biochar in the presence of nitrogen fertilizer into the soil causes marked increases in plant growth and yield, and also in nitrogen use efficiency (Lehmann et al., 2003, Downie et al., 2009, Kammann et al., 2010, Singh et al., 2010 and Widowati et al., 2012). So, biochar can be used as a good soil amendment with high potential to improve crop yields and quality of degraded soils.

To the best of our knowledge, there is no sufficient information about effect of biochar on soil properties and plant growth in the new reclaimed sandy soils in Egypt. Therefore, the aim of this study is to determine the efficiency of two types of biochar (rice straw biochar and soybean straw biochar) on physical and chemical properties of the studied sandy soil as well as on the growth and yield of wheat (*Triticum aestivum* L.).

Materials and Methods

Soil sampling and biochar production

Surface Soil samples (0-30 cm) were collected from Borg Al-Arab, Alexandria Governorate, Egypt. The samples were mixed, air-dried, passed throw a 2mm sieve and finally kept for further using and analysis. Some physical and chemical properties of the studied soil are presented in Table 1.

Two types of plant residues, namely rice straw and soybean straw were collected from the Agronomy farm at Faculty Agriculture, Benha University, Egypt. The straw samples were air-dried and cut to small pieces (1-2 cm), and then converted to biochars through the continuous low pyrolysis process at a temperature of 400-500 °C for 30 minutes as a retention time (Lu et al., 2014). The obtained biochars were crushed and sieved to a fine size (< 2 mm) for the chemical analysis and experimental using. The chemical characteristics of biochar samples are shown in Table 2.

Experimental work

A pot experiment was conducted in the greenhouse of the Soils and Water Department at Faculty of Agriculture, Benha University, Egypt. In 10th November 2013 .The experiment was set up in a Randomize Complete Block design in three replicates. Four rates of biochar (0, 4.20, 8.40 and 16.80 g kg^{-1}) of two types of biochar (rice straw biochar and soybean straw biochar) were used. Soil samples of 4 kg (< 2mm size) were placed in plastic pots (20 cm diameter x 20 cm height). Biochars were mixed with the soil 15 days before sowing of wheat grains. Ten grains of wheat (*Triticum aestivum* L. var. Sakha 93) were sown in 10th of November in each pot and thinned to five plants after ten days. Wheat plants were fertilized with the recommended doses of N (215 kg N ha^{-1} = 0.36 g N pot^{-1}), P (36.9 kg P_2O_5 ha^{-1} = 0.06 g P_2O_5 pot^{-1}) and K (57 kg K_2O ha^{-1} = 0.096 g K_2O pot^{-1}) as described by Ministry of Agriculture. Urea, Calcium superphosphate and potassium sulfate were the sources of N, P and K in the experiment. N fertilizer was added in two times (firstly at 20 days and the other one at 50 days from sowing), while K fertilizer was added after 60 days from sowing). Moreover, P fertilizer was added during mixing soil with biochar. Soil water contents were adjusted every 3-4 days at 60% of water-holding capacity.

TABLE 1. Some Physical and chemical properties of the used soil

Properties	Value
EC (dS m^{-1})*	1.16
pH**	7.53
Organic carbon (g kg^{-1}) $CaCo_3$ (g kg^{-1})	8.14 28.45
CEC ($cmol_+$ kg^{-1})	6.25
WHC (%)	14.31
VW (%)	7.30
PO (%)	44.15
Total N (%)	0.12
Total P (%)	0.07
Total K (%)	0.26
Total Ca (%)	0.11
Total Mg (%)	0.09
Available N (mg kg^{-1})	14.7
Available P (mg kg^{-1})	3.37
Available K (mg kg^{-1})	56.9
Exchangeable Ca (mg kg^{-1})	39.6
Exchangeable Mg (mg kg^{-1})	21.5
Bulk density (g cm^{-3})	1.48
Sand (%)	87.07
Silt (%)	9.58
Clay (%)	3.35
Texture	Sandy

* Extraction of 1:2 soil: water (w/v). ** Suspension of 1:2 soil: water (w/v).
CEC= cation exchange capacity.

TABLE 2. Some chemical characteristics of the prepared biochars

Properties	RSB	SSB
EC (dS m^{-1})*	2.51	2.97
pH*	8.30	8.46
Organic carbon (g kg^{-1})	438	487
CEC ($cmol_+$ kg^{-1})	38.4	52.6
Total N (%)	0.68	1.12
Total P (%)	0.46	0.63
Total K (%)	1.26	1.52
Total Ca (%)	0.62	0.84
Total Mg (%)	0.31	0.52
Bulk density (g cm^{-3})	0.59	0.47

*Suspension of 1:5 biochar: water ratio (w/v)
CEC= cation exchange capacity.

Methods of analyses

Total N, P and K of soil and biochar were determined after their digestion using a mixture of concentrated H_2SO_4 and $HClO_4$ at a ratio of 1:1 (v:v) by micro Kjeldhal, spectrophotometer and flame photometer, respectively. Available N, P and K of the used soil were extracted by KCl (2M), $NaHCO_3$ (0.5 M) and CH_3COONH_4 (1M), respectively. Total and available N, P and K were determined according to the method of A.O.A.C. (1995). Carbonate El-Calcium was determined by using calcimeter according to Balazs *et al*. (2005). Total Organic carbon of soil and biochars were determined according to page et al (1982). Soil texture was determined using the pipette method (Sheldrick and Wang, 1993). Cation exchange capacity (CEC) of the soil and biochars were determined in the presence of ammonium acetate (pH 7) followed by sodium acetate (pH 8.2), while the exchangeable Ca and Mg in the used soil were determined in the extracts of ammonium acetate (pH 7) as described by Van Reeuwijk (1995). Total and exchangeable Ca and Mg were measured by atomic absorption spectrophotometry (Perkin-Elmer, Model 3110) as described in Tejada et al. (2008). Soil bulk density was determined according to the method of Blake and Hartage (1986). Soil volumetric water content was determined through drying 10 g soil at a temperature of 105 °C and then multiplying the obtained result with the bulk density (Cassel and Nielsen, 1986). The total porosity was estimated using values of bulk density and particle density (2.65 g cm^{-3}) and was calculated according to the formula: soil porosity = 1- (bulk density/particle density) x100 (Blake and Hartage, 1986)

Plant analysis

At the end of the experiment in mid May 2014, wheat plants were harvested and divided into two parts (straw and grains). Samples of straw and grains were oven-dried at 60-70 °C for 48 h to record their dry weights and then crushed to powder using an electrical mill. Sub-samples of grinding straw and grains were digested using a concentrated mixture of H_2SO_4 and H_2O_2 (1:1, v: v) according to Horneck and Miller (1998). Concentrations of N, P and K were determined in the digested solution. Grain protein content = grain N concentration x 6.25, while protein yield = protein content x grain yield.

Statistical analysis

Data were statistically analyzed using MSTATC 98 for windows, and the significant differences between treatments were evaluated by Duncan Test at $p < 0.05$ according to Snedecor and Cochran (1991).

Results and Discussion

Effect of biochars on soil chemical properties

Incorporation of rice straw biochar (RSB) and soybean straw biochar (SSB) significantly increased soil EC, OC and CEC (Table 3). However, no significant increase was recorded in soil pH values due to application of RSB at rates of 4.20 and 8.40 g kg^{-1} and 4.20 g kg^{-1} for SSB. Under untreated soils, values of soil EC, pH, OC and CEC were 1.18 dS m^{-1}, 7.48, 7.03 g kg^{-1} and 5.87 $cmol_+$ kg^{-1}, respectively. These values increased to 1.52 dS m^{-1}, 7.61, 15.48 g kg^{-1} and 12.72 $cmol_+$ kg^{-1}, respectively in soil treated with RSB at rate of 16.80 g kg^{-1}. The corresponding values were 1.76 dS m^{-1}, 7.73, 18.23 g kg^{-1} and 15.65 $cmol_+$ kg^{-1}, respectively in soils treated with SSB at rate of 16.80 g pot^{-1}. Our results are in agreement with findings of Kamara et al. (2015) who indicated that addition of rice straw biochar (15 g kg^{-1}) to a sandy loam soil increased soil CEC from 7.40 to 10.20 $cmol_+$ kg^{-1}. Usman et al. (2016) studied the effect of Conocarpus wood waste biochar at rates of 4% and 8% on a sandy soil irrigated with un-saline water and found that EC and organic matter values increased from 2.29 dS m^{-1} and 2.70 g kg^{-1} in the control treatment to 2.54 dS m^{-1} and 9.40 g kg^{-1} at rate of 4% and to 3.26 dS m^{-1} and 13.49 g kg^{-1} at rate of 8%, respectively. Moreover, they reported that the increase of soil EC after addition of biochar might be resulted from the release of soluble cations through its mineralization. The highest effects of RSB and SSB on the chosen chemical properties were recorded due to addition of 16.80 g kg^{-1}. SSB was more effective than RSB in increasing soil chemical properties because of its higher EC, CEC, pH and OC values (Table 2). Although addition of RSB and SSB caused increases in soil EC, the salinity was low and did not reach the limited value of saline conditions (EC > 4 dS m^{-1}) . The increase of soil pH values due to application of RSB and SSB might be explained by the alkaline nature of biochar (Houben et al., 2013). The increase of soil pH after addition of biochars could be resulted from the dissolution of OH^- and $CO_3^=$ ions that presented in them and the release of some cations such as Ca and Mg through their decomposition process (Nguyen & Lehmann, 2009, Lucchini et al., 2014 and Al-Wabel et al., 2015). The enhancement of soil

CEC could be resulted from the high surface area and negative charges of biochar (Peng et al., 2011 and Laghari et al., 2015).

Soil physical properties as affected by biochars addition

Data presented in Table 4 showed that both rice straw biochar (RSB) and soybean straw biochar (SSB) had significant impact on soil bulk density (BD), porosity (PO), water-holding capacity (WHC) and volumetric water (VW). Soil bulk density decreased due to application of RSB and SSB to sandy soil and this decrease increased with increasing applied rates. Increasing application rates of RSB and SSB to 16.80 g kg^{-1} significantly decreased soil BD to 1.21 and 1.10 g cm^{-3}, respectively. The lower bulk density of SSB more than that of RSB (Table 2) might be used to explain the lower soil BD after treating the soil with SSB. Also, the higher organic carbon contents that recorded after using SSB compared with those of RSB (Table 3) might be responsible for lower soil BD when the soil amended with SSB. Similar findings were shown by Zhang *et al*. (2014) who showed that using wheat straw biochar amendment at a rate 40 t ha^{-1} caused a consistent reductions in soil BD by 0.10 g cm^{-3} and 0.06 g cm^{-3} in years of 2009 and 2010, respectively as compared to the control soil. The lower values of soil BD, which were shown in the current study, could be used as a good indicator for the higher soil capacity to absorb and keep more water content (Aslam *et al*., 2014).

Values of soil porosity PO, WHC and VW showed increased due to addition of RSB and SSB to the sandy soil. The highest values of PO, WHC and VW (58.49%, 27.25% and 13.70%) were resulted from application of SBB at a rate of 16.80 g kg^{-1}, respectively. These values were 54.34%, 24.03% and 11.58%, respectively with application of 16.80 g kg^{-1} RSB. The results indicated that SSB was more effective than RSB in improving soil physic properties. This could be resulted from higher organic carbon contents (Table 3) and lower soil BD in SSB treatments than in RSB treatments (Table 4), and this could lead to higher increases in soil pores and water retention capacity. In this concern, Briggs *et al*. (2005) indicated that the decrease of soil BD had important role in improving soil porosity and water holding capacity. The observed increases in soil porosity due to application of biochar were highly related to the decrease of bulk density in biochar amended soil (Herath etal., 2013). Moreover, Mukherjee and Lal (2013) reported that the decrease of soil BD could be used as a good indicator for soil fertility through enhancing soil aeration, structure and aggregation. It is worthy to indicate that biochar type could highly affected soil PO, WHC and VW. Similarly, Herath *et al*. (2013) indicated that porosity of soil enhanced by addition of biochar and was highly related to its type.

TABLE 3. Effect of rice straw and soybean straw biochars on soil chemical properties after harvesting of wheat

Biochar type	Biochar rate (g kg^{-1})	EC (dS m^{-1})	pH	OC (g kg^{-1})	CEC ($cmol_+$ kg^{-1})
RSB	0	1.18d	7.48c	7.03f	5.87e
	4.20	1.24cd	7.50c	8.19e	7.38d
	8.40	1.37c	7.54c	11.34d	9.54c
	16.80	1.52b	7.61b	15.48b	12.72b
SSB	0	1.18d	7.48c	7.03f	5.87e
	4.20	1.32c	7.53c	9.48e	8.93c
	8.40	1.50b	7.61b	13.61c	11.76b
	16.80	1.76a	7.73a	18.23a	15.65a

Different letters (a-f) indicate the significant difference between treatments
RSB= rice straw biochar, SSB= soybean straw biochar, EC= electrical conductivity, OC= organic carbon and CEC= cation exchange capacity

TABLE 4. Effect of rice straw and soybean biochars on physical properties after harvesting of wheat

Biochar type	Biochar rate ($g\ kg^{-1}$)	BD ($g\ cm^{-3}$)	PO (%)	WHC (%)	VW (%)
RSB	0	1.48a	44.15d	14.31f	7.30f
	4.20	1.43a	46.04d	16.34e	8.24e
	8.40	1.35b	49.06c	19.61d	9.37d
	16.80	1.21d	54.34b	24.03b	11.58b
SSB	0	1.48a	44.15d	14.31f	7.30f
	4.20	1.36b	48.68c	17.28e	9.39d
	8.40	1.22d	53.96b	21.11c	10.88c
	16.80	1.10c	58.49a	27.25a	13.70a

Different letters (a-f) indicate the significant difference between treatments
RSB= rice straw biochar, SSB= soybean straw biochar, BD=bulk density, PO=porosity, WHC=water-holding capacity and VW=volumetric water.

Effect of biochars on soil nutrient contents

Marked increases in N, P, K, Ca and Mg contents (Table 5) were noticed due to using RSB and SBB in the chosen sandy soil. Increasing of biochars application rates led to high improvements in nutrient concentrations. SSB was more efficient than RSB in enhancing soil nutrient contents. The highest concentrations of available soil N, P, K, Ca and Mg (37.52, 13.00, 89.28, 61.22 and 36.00 mg kg^{-1}, respectively) were obtained when the soil treated with 16.80 g kg^{-1} SSB, whereas the lowest ones (17.23, 4.16, 63.52, 45.01 and 24.65 mg kg^{-1}, respectively) were recorded with the untreated soil. The release of nutrients due to the decomposition process of biochars in the soil could be highly responsible for enriched the soil with nutrients. Similar results were found by Uzoma et al. (2011) who showed that exchangeable K, Ca and Mg were markedly enhanced after application of cow manure biochar to a sandy soil. It was demonstrated by Inal et al. (2015) that poultry manure biochar addition at 20 g kg^{-1} caused significant increases in available p, exchangeable K and Ca concentrations. Laghari et al. (2015) found that application of pine sawdust biochar increased soil P, K and Ca contents in sandy soils. In the current study, the higher concentrations of K, Ca and Mg were achieved in biochar amended soil as compared with the untreated one. Such results could be interpreted due to higher CEC values of the amended soil. Moreover, higher amounts of N, P, K, Ca and Mg, which were observed in SSB than in RSB (Table 2) could be used as a good reason to explain the higher efficient of SSB than RSB in improving soil nutrient contents.

TABLE 5. Effect of rice straw and soybean straw biochars on soil nutrient amounts (mg kg^{-1}) after harvesting of wheat

Biochar type	Biochar rate ($g\ kg^{-1}$)	N	P	K	Ca^{2+}	Mg^{2+}
RSB	0	17.23e	4.16g	63.52e	45.01e	24.65e
	4.20	20.58d	6.07f	70.34d	49.23d	26.74d
	8.40	26.04c	9.28d	75.41c	52.84c	30.16c
	16.80	31.19b	11.82b	81.69b	56.11b	33.93b
SSB	0	17.23e	4.16g	63.52e	45.01e	24.65e
	4.20	22.46d	7.21e	72.23d	52.46c	27.61d
	8.40	30.15b	10.48c	78.19c	56.93b	31.84c
	16.80	37.52a	13.00a	89.28a	61.22a	36.00a

Different letters (a-g) indicate the significant difference between treatments
RSB= rice straw biochar and SSB= soybean straw biochar .

Effect of biochars on wheat growth and Yield efficiency

Wheat growth

The results presented in Table 6 showed that dry weights of wheat straw and grains were significantly increased after application of RSB and SSB and the effect of SSB was more pronounced than that of RSB. In the absence of biochar (untreated), dry weights of wheat straw and grains were 2.11 and 1.73 g pot^{-1} , respectively and reached the highest values (3.05 and 2.72 g pot^{-1}, respectively) with application of the highest rate of RSB (16.80 g kg^{-1}) .These corresponding values at the same rate of SSB were 3.73 and 3.25 g pot^{-1}, respectively .

Yield efficiency

Values of yield efficiency are presented also in Table 6, and they were calculated by dividing grain yield (g pot^{-1})/ total biological yield (g pot^{-1}) x 100. Yield efficiency increased with increasing rates of applied biochar. Percentage of yield efficiency increased from 45.05 % in the untreated soil to 47.14% and 46.56% with application rate 16.80 g kg^{-1} of RSB and SSB, respectively. The highest percentage of yield efficiency was obtained with application of SSB at a rate of 8.40 g kg^{-1}.

TABLE 6. Effect of rice straw and soybean straw biochars on dry weights of wheat straw and grains (g pot^{-1}) and its yield efficiency (%) in the sandy soil

Biochar type	Biochar rate (g kg^{-1})	Wheat grains	Wheat straw	Yield efficiency
RSB	0	1.73e	2.11f	45.05d
	4.20	2.15d	2.39e	47.36b
	8.40	2.40c	2.63d	47.71b
	16.80	2.72b	3.05b	47.14b
SBB	0	1.73e	2.11f	45.05d
	4.20	2.31c	2.54e	47.63b
	8.40	2.67b	2.81c	48.72a
	16.80	3.25a	3.73a	46.56c

Different letters (a-f) indicate the significant difference between treatments
RSB= rice straw biochar and SSB= soybean straw biochar.

Effect of biochars on concentrations of N, P and K

Concentrations of N, P and K in wheat straw as presented in Table 7 ranged from 1.34%, 0.41% and 1.58% at the control (no biochar addition) to 1.63%, 0.59% and 2.01% in RSB treatments and to 1.98%, 0.72% and 2.23% in SSB treatments, respectively. In wheat grains, N, P and K concentrations were enhanced from 2.14, 0.56 and 2.42% in the control to 2.21-2.32%, 0.59-0.64% and 2.60-2.73% at the lowest rates (4.20 g kg^{-1} of RSB or SSB, respectively. At the highest rates of RSB and SSB, these values increased to 2.56-2.70%, 0.82-0.91% and 3.03-3.37%, respectively. The higher effect of SSB than that of RSB on wheat growth and its nutrient contents could be related to the greater amounts of N, P and K in SSB than in RSB (Table 2) and also to the more efficient influence of SSB on availability of soil nutrients (Table 5) and soil physical properties than RSB (Table 4). These results are in harmony with findings of Alburquerque *et al*. (2014) who showed that application of pine-woodchip biochar and olive-tree-pruning biochar increased sunflower growth due to the high releasing of available nutrients in the soil. Agegnehu *et al*. (2015) indicated that higher maize growth after application of willow biochar as compared with acacia biochar might be illustrated by its larger effect on nutrient retention capacity, pore spaces and nutrients supplement for maize plants. Kamara et al. (2015) found that incorporation of rice straw to infertile soil had remarkable influence on rice shoots and roots and their dry weights were higher at 5 g biochar kg^{-1} soil than at the control (0 g kg^{-1}). Moreover, they mentioned that the improvement of soil physicochemical properties in response to biochar addition could be used to reflect the higher rice growth in poor fertile soil.

TABLE 7. Macro-nutrient concentrations (%) in wheat plants as influenced by biochars addition

Biochar type	Biochar rate ($g\ kg^{-1}$)	Wheat straw			Wheat grains		
		N	P	K	N	P	K (%)
RSB	0	1.34e	0.41e	1.58e	2.14f	0.56c	2.42f
	4.20	1.42d	0.47d	1.67d	2.21e	0.59d	2.60e
	8.40	1.58c	0.52c	1.84c	2.45c	0.65c	2.75d
	16.80	1.63c	0.59b	2.01b	2.56b	0.82b	3.03b
SSB	0	1.34e	0.41e	1.58e	2.14f	0.56e	2.42f
	4.20	1.66c	0.53c	1.73d	2.32d	0.64c	2.73d
	8.40	1.74b	0.60b	1.90c	2.59b	0.78b	2.96c
	16.80	1.98a	0.72a	2.23a	2.70a	0.91a	3.37a

Different letters (a-f) indicate the significant difference between treatments
RSB= rice straw biochar and SSB= soybean straw biochar.

Protein content and protein yield of wheat grains

Data presented in Table 8 reflected that both grain protein contents or protein yield were enhanced with increasing rate of applied biochar in the form of RSC or SSB. Values of protein contents were increased from 13.38% (control treatment) to 16.00% and16.88% after application of the highest rate of RSB and SSB (16.80 $g\ kg^{-1}$) , respectively. Similar trends were observed for protein yield and their values were increased from 23.15 $g\ pot^{-1}$ (control treatment) to 43.52 and 54.86 $g\ pot^{-1}$ due to application of the highest rate of RSB and SSB (16.80 $g\ kg^{-1}$), respectively. These results confirmed the positive effect of biochar in enhancing metabolic processes, dry matter accumulation and higher uptake of N and other nutrients, which were finally increased amounts of protein in grains and consequently total protein yield.

TABLE 8. Protein content (%) and protein yield ($g\ pot^{-1}$) of wheat grains as influenced by biochars addition

Biochar type	Biochar rates ($g\ kg^{-1}$)	Protein content	Protein yield
RSB	0	13.38d	23.15e
	4.20	13.81d	29.69d
	8.40	15.31c	36.74c
	16.80	16.00b	43.52b
SSB	0	13.38d	23.15e
	4.20	14.50b	33.50c
	8.40	16.19b	43.23b
	16.80	16.88a	54.86a

Different letters (a-e) indicate the significant difference between treatments
RSB= rice straw biochar and SSB= soybean straw biochar

Conclusion

This study indicated that using rice straw biochar (RSB) and soybean straw biochar (SSB) had promising effects in improving soil fertility. obtained results showed that RSB and SSB had vital effects on soil physical properties, including bulk density, soil porosity and water-holding capacity. They also caused high increases in availability of N, P and K and high enhancements in exchangeable Ca and Mg, CEC and organic carbon. Application of RSB and SSB at a rate of 16.80 $g\ kg^{-1}$ was responsible for the highest growth and production of wheat in the used sandy soil. Biochar derived from plant residues such as rice straw and soybean straw could be highly recommended to improve the quality of sandy soils. So, spot-lights should be focused on the importance of biochars in improving fertility and productivity of Egyptian Sandy soils under short-term or long-term field conditions.

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تأثير البيوشار الناتج من المخلفات النباتية علي خصوبة ارض رملية حديثة الاستصلاح ونمو نبات القمح

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تم استخدام نوعين من البيوشار وهما بيوشار قش الارز وبيوشار قش فول الصويا تحت اربع مستويات لكل منهما لتقدير تاثيرهم علي خصوبة ارض رملية حديثة الاستصلاح وعلي نمو القمح في هذة الارض. اوضحت النتائج ان دمج كل من بيوشار قش الارز وبيوشار قش فول الصويا أدي الي تحسينات معنوية في خواص التربة الطبيعية وذلك من خلال خفض الكثافة الظاهرية للتربة ورفع المسامية وسعة الاحتفاظ بالماء وايضا الماء الحجمي. أيضا الخواص الكيميائية للتربة والتي تشمل رقم الحموضة والتوصيل الكهربي وتيسر المغذيات قد تأثرت بوضوح نتيجة اضافة بيوشار قش الارز وبيوشار قش فول الصويا. وقد اوضحت الدراسة ان نوعية البيوشار لها تأثيرا مهما علي خواص الارض وقد كان تأثير بيوشار قش فول الصويا اكثر وضوحا من بيوشار قش الارز. وقد اشارت النتائج ايضا الي ان استخدام بيوشار قش فول الصويا وبيوشار قش الارز قد أدي الي تحسينات مرتفعة في نمو نباتات القمح والذي عبر عنة بالوزن الجاف للقش والحبوب وكان أعلي تاثير لكل من بيوشار قش الارز وبيوشار قش فول الصويا علي قش القمح (3.05 و 3.73 جم/اصيص) وعلي حبوب القمح (2.72 و 3.25 جم/اصيص) علي التوالي عند اضافه كل منهم بمعدل 16.80 جم/اصيص. كما أن تركيزات النتروجين والفوسفور والبوتاسيوم قد ازدادت بشكل ملحوظ عند استخدام معاملات بيوشار قش فول الصويا وبيوشار قش الارز مقارنة بالكنترول (بدون اضافة بيوشار). كما أوضحت الدراسه ان اضافه كل من بيوشار قش فول الصويا وبيوشار قش الارزكان له تأثيرات ملحوظه علي نمو نبات القمح ومحتواة من العناصر الغذائية وذلك نتيجه لتأثيرهم الفعال علي الخواص الطبيعية والكيميائية للتربة تحت الدراسه.

هذا ولقد أوضحت الدراسة انه يمكن التوصيه بالأستفاده من المخلفات النباتية بتحويلها الي بيوشار عن طريق عملية التحلل الحراري واضافته الي التربه أثناء عمليات خدمة الاراضي الرملية لتحسين خواصها وزياده انتاجها.