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Using Biochar as a Soil Conditioner for Improving Chemical Properties of Sandy Soil, Nutritional Status and Wheat Yield Productivity

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ABSTRACT

Two field experiments were carried out during two successive winter seasons 2014/2015 where wheat plants (*Triticum aestivum* L., CV. Giza 168) was cultivated in sandy soil under sprinkler irrigation system at Ismaillia Agric. Res. Station, ARC. Combined thoroughly mixed biochar , sulfur and organic materials (compost) as soil conditioner along with different rates of nitrogen and phosphorus comprising 18 treatments were applied in a split split design. Chemical properties of sandy soil as well as its nutrients availability, nutritional status, Apparent Nutrients Recovery Efficiency (ANRE) and wheat yield productivity were evaluated. Biochar was added with three rates 1, 2 and 4 ton fed^{-1}. Nitrogen was applied with three rates 50%,75% and 100%, where phosphorus rates were 75% and 100% of the recommended dose for wheat. Soil pH was slightly decreased by increasing the rate of biochar application ,while the values of EC, O.M, CEC and availability of N, P and K nutrients increased significantly by increasing the rate of biochar amendment . The application of high rates of biochar along with high rates of both N and P significantly increased the availability of N, P and K as compared to control (without biochar) and other treatments. Similar results were obtained for both tested seasons. All applied treatments increased significantly the total contents of macronutrient over control. Moreover, biochar application combined with N and P rates has a positive effect on plant growth and crop yields. The yield components increased gradually by increasing the rate of N and P application in presence of biochar as compared to control (without biochar), especially in case of the second rate of biochar (2 ton fed^{-1}) along with the high rate of N and P (100%) from the recommended dose. Application of second rate of biochar (2 ton fed^{-1}) in presence of high rate of N and P (N3 combined with P2) significantly increased wheat straw and grains. This increase was higher than that existing in case of applying the high rate of biochar (4 ton fed^{-1}) . On the other hand, the lowest straw and grains yield was recorded in case of the control treatment (without biochar), similar results were recorded for both tested seasons. Moreover, the calculation of Apparent Nutrients Recovery Efficiency values by wheat crop increased due to the presence of biochar as a soil conditioner as compared to control (without biochar) especially in presence of the second rate of biochar (2 ton fed^{-1}).Finally, the obtained results indicate that blending biochar with organic materials (compost) along with sulfur in sandy soils prevents the loss of nutrients, improves the soil chemical properties , holds nutrients against leaching , increases the availability of nutrient to plants, increases nutrient use efficiency, maintains the surface sorption and increases the wheat yield productivity.

Keywords: Biochar-Nitrogen- Phosphorus-Potassium- Nutritional-Status – ANRE -Wheat-Yield

INTRODUCTION

Biochar is the carbon-rich product obtained by heating organic materials in a closed system under conditions of limited or no oxygen. Biochar analyzed using solid-state nuclear magnetic resonance (NMR) analysis was shown to be composed of a highly heterogeneous mixture of organic structures. The structural form of C in biochar depends on the biogeochemistry of the biomass feedstock and the conditions under which it was pyrolyzed. Biochars composed primarily of condensed aromatic C are known to persist in soil environments, whereas biochars with higher levels of single ring aromatic and aliphatic C will mineralize more rapidly (Lehmann, 2007 and Novotny et al., 2007). Surface area and surface charge density of biochar will have a large influence on soil CEC and the ability of biochar additions to ameliorate soil fertility problems. We hypothesize that biochar additions to the sandy soil, would increase the soil organic carbon content and CEC and improve the fertility status. Because of these properties, biochar is both more recalcitrant in soils and contributes a higher capacity to sorb cations per unit mass than does biogenic soil organic matter (Liang et al., 2006). Biochar contains large amounts of charred materials most likely added by farmers who practiced a form of slash and char agriculture (Sombroek et al., 2003). The biochar acts as a soil conditioner, improving soil physical properties and nutrient use efficiency, thereby increasing plant growth.

Moreover, biochar acts as a stable C compound being degraded slowly. The most important measures of biochar quality appear to be high adsorption and it has synergistic benefits effects. Biochar can increase microbial activity and reduce nutrient losses during composting (Dias et al. 2010). In the process, the biochar becomes “charged” with nutrients, covered with microbes and pH-balanced. Also, burned residues cleared the agricultural field and add nutrients to soil resulting in increased nutrient availability during the first cropping seasons (Sanchez et al., 1983). Moreover, at high temperature, biochar usually become more alkaline as compared to the lower temperature (Mukherjee et al., 2011). This alkalinity is provided by presence of organic and inorganic ions in biochar. The anions (chlorides, sulphates, carbonates and bicarbonates) presence in the soils also enhanced the soil salinity level (Tavakkoli et al., 2011). Among cations, Ca^{+2} ions are rich part of biochar (Yuan and Xu, 2011). Plants which are cultivated in the BC amended soils response better in growth through modifications in soil CEC and nutrients retention (Peng et al., 2011). Glaser et al., (2002) found that a direct nutrient additions via ash or organic fertilizer amendments, nutrient retention and nutrient availability were reported being enhanced after biochar application.

Biochar has been reported to boost soil fertility and improve soil quality by added a sequester ring carbon to the soil, increasing moisture holding capacity, improving cation exchange capacity (CEC) and retaining nutrients in soil (Lehmann, 2007). Another major benefit associated with the use of biochar as a soil amendment is its ability to sequester carbon from the atmosphere-biosphere pool and transfer it to soil (Laird, 2009).

Sorption capacity is a key indicator of uptake ability. So, biochar usually has greater sorption ability than natural soil organic matter due to its greater surface area, negative surface charge and charge density (Liang et al., 2006). Biochar can not only efficiently remove many cationic chemicals ions, but also sorb anionic nutrients such as phosphate ions (Lehmann, 2007). Thus, the addition of biochar to soil offers a potential environmental benefit by preventing the loss of nutrients and thereby protecting water resources. Studies showed that biochar addition increased crop yields and improved soil quality (Chan et al., 2007). Also, the use of biochar as a soil amendment could reduce chemical fertilizer use due to a reduced percolation of water and nutrients. Biochars would be able to hold nutrients and increase its availability to plant if they are applied in agricultural fields (Zhang et al., 2010)

Lehmann et al., (2003 a) found that char can increase the nutrient use efficiency by plants of applied N and P this could be explained by char has a surface sorption nutrients maintaining them in the root zone and maintaining leaching, especially in sandy soil because of its low fertility, low retention capacity of nutrient and rapidly leached of mineral fertilizers. Also, char is influencing the physical and/or chemical structure of the tested soil. Synergisms recorded as a combination of organic fertilizers (compost, manure) or inorganic fertilizers and biochar for sustainable soil amelioration and fertilization (Schulz and Glaser, 2012).

The objectives of the present study is to investigate the effect of combined application of biochar, sulfur and organic materials as a soil conditioners along with nitrogen and phosphorus rates on chemical properties of sandy soil as well as its nutrients availability, nutritional status , apparent nutrient recovery and wheat yield productivity.

MATERIALS AND METHODS

A field experiment was carried out on wheat plants (*Triticum aestivum* L., CV. Giza 168) cultivated in sandy soil under sprinkler irrigation system at Ismaillia Agric. Res. Station, ARC, located at 30° 35´41.9" N Latitude and 32° 16´ 45.8" E longitude during two successive winter seasons 2014/2015. The impact of applying combined application of biochar, sulfur and organic materials as soil conditioners along with different rates of nitrogen and phosphorus on chemical properties of sandy soil as well as its nutrients availability, nutritional status, apparent nutrient recovery and wheat yield productivity is considered. The experiment was designed in a split- split plot design with three replications, the main plot for biochar, the sub plot for phosphorus fertilizers rates and the sub sub plot for nitrogen fertilizers rates.

Some physical and chemical properties of the tested soil sample are shown in Table (1), while biochar and compost composition are presented in Table (2).

Table 1. Some physical and chemical properties of the experimental soil before wheat cultivation

Soil characteristics	Values	Soil characteristics	Values
Particle size distribution %		**Soluble cations and anions (meq/l)**	
Coarse Sand	58.40	Ca^{++}	
Fine Sand	27.20	Mg^{++}	0.84
Silt	6.40	Na^{+}	0.78
Clay	8.00	K^{+}	1.32
Texture class	Sandy	CO_3^{--}	0.39
		HCO_3^{-}	-
		Cl^{-}	1.34
		SO_4^{-}	1.02
			0.97
Chemical properties		**Available nutrients (ppm)**	
$CaCO_3$ %	1.40	N	38
pH(Suspension 1: 2.5)	7.92	P	12
EC dS m^{-1} (saturated past extract)	0.33	K	33
Organic matter %	0.30		
CEC (meq $100g^{-1}$)	5.00		

Table 2.Some chemical characteristics of biochar and composted rice straw used in the present study.

Determination	Biochar	Compost
pH(1:2.5)	8.12	6.70
EC dSm^{-1}	1.20	5.21
Organic carbon %	23.00	19.70
Organic matter %	39.65	33.96
Total Nitrogen	0.70	1.92
C/N Ratio	1:32	1:10
CEC (meq $100g^{-1}$)	55.0	40.0
Available nutrients (%)		
N	0.224	0.512
P	0.341	0.503
K	3.500	0.632

Every rate of biochar (1, 2 and 4 tons fed^{-1}) was prepared by blending biochar, thoroughly, with compost and sulfur at rates of 6 ton fed^{-1} and 125 kg fed^{-1}, respectively along with phosphorus treatments. The mixture was broadcasted and mixed with the soil surface two weeks before sowing.

All experimental treatments received 50 kg $fed.^{-1}$ of potassium sulfate (48 % K_2O) as a recommended potassium dose. Nitrogen was added at rates of 50, 75 and 100 % from the recommended nitrogen dose (N1, N2, N3) as ammonium sulphate (20.5 % N); while phosphorus as superphosphate (15.5 % P_2O_5) was added at rates of 75 and 100 % from the recommended phosphorus dose (P1, P2) as a mixture with biochar two weeks before sowing, at both tested seasons. Ammonium sulfate was added in four split equal doses after 2, 4, 6 and 8 weeks from sowing. While potassium was divided into two equal doses, after two weeks and five weeks from sowing.

Plants were harvested at maturity and the yield components (straw and grains) were recorded and subjected to oven drying at 70° C, up to a constant dry weight, ground and prepared for digestion using a mixture of H_2SO_4 and H_2O_2 as described by Page et al., (1982). The digests were then subjected to the evaluation of plant nutrients (N, P and K contents) according to procedures described by Cottenie et al. (1982). Furthermore, three soil samples were taken from each treatment after wheat harvesting for chemical analysis to evaluate the values of soil pH, EC and availability of nutrients (N, P and K) which are determined according to Page et al., (1982). Results were subjected to statistical analysis according to Snedecor and Cochran (1982); the treatments were compared using the least significant difference (L.S.D) at 0.05 level of probability.

Apparent Nutrients Recovery Efficiency (ANRE) was calculated according to Quanbao et al., (2007).

ANRE = (Uptake in fertilized plot, kg fed $^{-1}$- Uptake in control plot, kg fed $^{-1}$) / quantity of fertilizer nutrient applied (kg fed^{-1})*100

RESULTS AND DISCUSSION

1-Effect of biochar amendment on the soil chemical characteristics and soil nutrients availability after wheat harvesting.

a. Soil reaction (pH), electrical conductivity (EC), organic matter (O.M) and cation exchange capacity (CEC).

Data presented in Table (3) show the changes of soil chemical properties in response to application of biochar rates along with different rates of nitrogen and phosphorus fertilization.

Table 3.Effect of biochar amendments along with N and P rates on some soil chemical characteristics and soil nutrients availability (ppm) after harvesting wheat crop.

		First season					Second season				
Treatments		**pH (1:2.5)**	**E.C (dS^{-1})**	**N**	**P**	**K**	**pH (1:2.5)**	**E.C(dS^{-1})**	**N**	**P**	**K**
Without Biochar											
P1	N1	7.38	0.158	77.0	16.5	46.4	7.38	0.160	70.0	17.2	50.0
	N2	7.25	0.167	85.0	21.7	47.0	7.40	0.170	79.2	19.5	52.0
	N3	7.45	0.180	95.0	22.1	47.2	7.42	0.179	89.7	22.0	52.3
P2	N1	7.31	0.117	81.3	21.0	46.3	7.33	0.120	79.5	19.7	54.2
	N2	7.46	0.129	88.7	23.0	52.0	7.41	0.130	88.3	20.0	55.1
	N3	7.35	0.137	86.7	25.3	53.3	7.44	0.140	90.0	22.0	55.0
With Biochar I											
P1	N1	7.31	0.165	78.0	26.0	62.6	7.34	0.170	74.6	20.2	66.0
	N2	7.34	0.170	98.0	42.3	76.2	7.33	0.182	82.4	24.2	67.0
	N3	7.35	0.175	99.7	45.0	77.0	7.34	0.190	94.2	27.3	79.1
P2	N1	7.32	0.127	80.7	42.6	72.3	7.36	0.162	80.0	33.0	74.2
	N2	7.34	0.175	90.3	44.4	72.7	7.38	0.176	92.0	32.0	80.0
	N3	7.35	0.178	109	44.5	74.7	7.40	0.190	99.4	39.2	80.4
With Biochar II											
P1	N1	7.30	0.144	89.3	36.0	78.1	7.33	0.150	90.0	30.3	70.1
	N2	7.30	0.170	94.7	40.3	86.2	7.34	0.176	97.2	39.2	89.5
	N3	7.32	0.190	98.3	45.6	87.0	7.39	0.178	105	41.0	86.2
P2	N1	7.17	0.207	103	47.0	77.0	7.29	0.270	110	49.2	80.5
	N2	7.33	0.251	118	55.9	82.3	7.27	0.300	122	57.2	87.2
	N3	7.28	0.246	140	57.0	91.5	7.30	0.320	149	59.1	95.0
With Biochar III											
P1	N1	7.31	0.130	80.7	33.3	72.2	7.39	0.127	92.3	34.2	70.0
	N2	7.30	0.227	91.7	42.0	74.4	7.37	0.211	95.2	44.2	76.2
	N3	7.23	0.325	95.3	43.0	76.3	7.30	0.220	97.2	47.6	79.3
P2	N1	7.21	0.291	79.0	40.5	59.0	7.30	0.281	97.2	40.7	62.2
	N2	7.17	0.305	87.3	45.0	64.0	7.27	0.310	98.3	44.2	66.4
	N3	7.14	0.376	89.7	48.7	65.0	7.29	0.390	102	44.3	63.2
Means values of biochar rates											
Without		7.366	0.148	85.611	21.594	48.700	7.40	0.15	82.78	20.07	53.10
Char I		7.335	0.165	92.611	40.783	72.561	7.36	0.18	87.10	29.32	74.45
Char II		7.280	0.201	107.27	46.950	83.678	7.32	0.23	112.20	46.00	84.75
Char III		7.225	0.276	87.275	42.078	70.136	7.32	0.26	97.03	42.53	69.55
Means values of P rates											
P1		7.318	0.183	90.222	34.476	69.964	7.36	0.18	88.92	30.58	69.81
P2		7.284	0.211	96.167	41.226	67.574	7.34	0.23	100.64	38.38	71.12
Means values of N rates											
N1		7.288	0.167	83.667	32.854	65.403	7.34	0.18	86.70	30.56	65.90
N2		7.310	0.199	94.250	39.306	69.403	7.35	0.21	94.33	35.06	71.68
N3		7.307	0.226	101.67	41.394	71.500	7.36	0.23	103.31	37.81	73.81
LSD at 5%											
Rates of biochar (A)		0.03	0.02	3.85	2.64	1.43	0.02	0.02	3.65	2.20	1.46
Rates of P(B)		0.03	0.01	3.14	1.67	1.01	0.02	0.01	3.00	1.32	1.00
Rates of N (C)		0.02	0.01	2.10	1.14	1.06	0.01	0.01	2.04	1.00	1.02
A*B		0.05	0.02	9.13	3.35	2.01	0.04	0.02	6.20	2.33	1.98
A*C		0.03	0.02	4.21	2.29	2.13	0.02	0.02	3.86	2.10	1.78
B*C		0.05	0.01	2.97	1.62	1.50	0.04	0.01	2.52	1.22	1.03
A*B*C		0.10	0.03	5.95	3.24	3.01	0.12	0.03	4.59	2.98	3.20

Regarding soil pH, the statistical interaction analysis showed that, the values of pH slightly decreased by increasing the rate of biochar as compared to control treatment (without biochar), the same trend was observed for both tested seasons. This may be due to the presence of compost and sulfur combined with char which governs the soil pH values (Nigussie and Kissi, 2011) according to the production of organic acids formed as a result of compost decomposition. Moreover, increasing P rates caused a significant decrease in the soil pH values, while the changes did not show any obvious trend at both tested seasons due to different rates of Nitrogen application.

With regard to electrical conductivity (EC) the obtained results showed that the application of biochar rates caused a significant increase in EC as compared to control treatment. Moreover, the values of EC increased gradually by increasing the rate of biochar amendment, this may be due to presence of ash which is rich in basic cations during the production of char; also because of the positively and significant relationship between EC and exchangeable bases (Nigussie and Kissi, 2011), the same trend was observed for both tested seasons. Moreover, a significant increase in EC was recorded due to the increase the of nitrogen and phosphorus application rates along with biochar.

Concerning the organic matter content in soil after harvesting wheat crop at both tested seasons, data presented in Fig. (1) show that a significant increase in O.M values exist due to application of biochar compared to control treatment (without biochar) .This may be due to the high organic carbon content of biochar , similar results were obtained by Schahczenski (2010). Moreover, this explanation was confirmed by Uzoma et al. (2012) who reported that biochar provided a significant portion of carbon returned to soil for enhancing future soil fertility and health. Generally, increasing the rate of biochar caused a significant increase in organic carbon values.

With respect to the changes in cation exchange capacity (CEC) due to applied biochar along with different rates of N and P, data presented in Fig. (1) show a significant positive effect of applied different rates of biochar on CEC as compared to the control treatment. Biochar has a high concentration of acidic and basic functional groups which results in high CEC (Major, 2010). Also, these explanations were confirmed by Lehmann (2010) who reported that biochar has a large specific surface area of organic matter and negatively charged functional groups which increased the exchange points of soil colloid, thus increasing the CEC values, but, a slightly changes in CEC values was observed at both tested seasons due to different rates of application of N and P along with biochar .

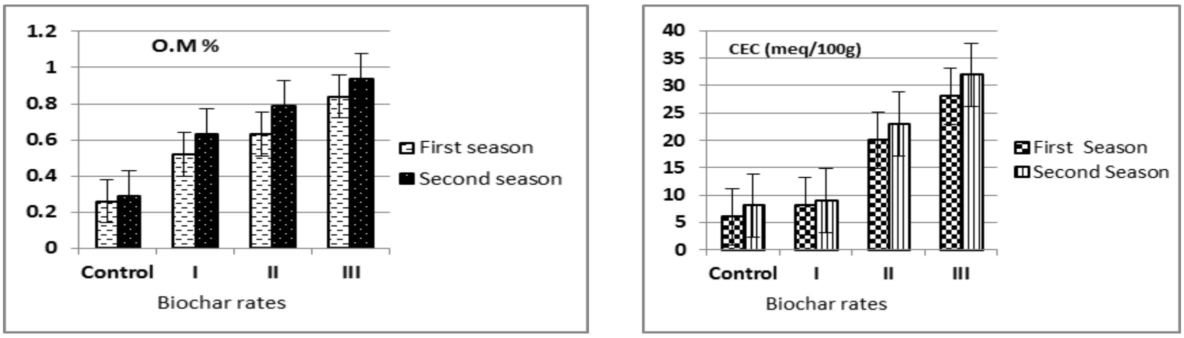

Fig. 1 .Effect of biochar rates amendment on cation exchange capacity (CEC) as well as O.M for both tested seasons. Error bars represented standard error of the means.

b. Effect of biochar amendment along with N and P rates on availability of some macronutrients in soil after wheat harvesting for both tested seasons.

Data in Table (3) showed that the application of biochar increases significantly the availability of N, P and K soil content as compared to control treatment (without biochar); this trend was true for both tested seasons.

Generally, increasing the application of biochar to soil up to second rate caused a significant increase in nutrient availability, through increasing the adsorption sites and nutrient availability also to the impact of adding the compost to the char which enhanced the nutrient availability. Similar results were obtained by Major (2009) who found that blending biochar with organic materials (compost) enhance its nutrients values as a soil amendment; furthermore, biochar retain nutrients against leaching. Moreover, burned residues added nutrients to soil which results in increasing nutrient availability (Sanchez et al., 1983).

Furthermore, biochar has low nutrients content but acts more as a soil conditioner by making nutrients more available to plants and improving soil structure. Moreover, pore structure of biochar likely provides a habitat for soil microorganisms, which in turn may aid in making nutrients available to crops,(Schahczenski, 2010). Also, the availability of N, P and K increased significantly, as expected, by increasing the rates of N and P fertilizers in presence of biochar.

Again, the application of second rate of biochar (2 ton fed^{-1}) along with high rates of both N and P (100 %) from the recommended dose was significantly superior in increasing the availability of N,P and K as compared to control (without biochar) and other treatments, similar results were obtained for both tested seasons. This may be due to minimizing the leaching of N and K due to the presence of biochar which has a negative charge; beside an electrostatic attraction process. The strong sorption of N as NH_4 by biochar is expected to retain and makes ammonium available to plants, these explanation was confirmed by Lehmann (2003 a). Biochar can act also as a slow release fertilizer and / or as a catalyst to estimate microbial growth.

2. Effect of applying biochar amendment along with N and P rates on total contents of macronutrients in wheat straw and grains.

Data in Table (4) and Fig.(2) show that all applied treatments increased significantly the wheat total contents of macronutrient over control; this may be due to application of biochar along with N and P rates. The second rate of biochar in presence of high rates of N and P were significantly superior in increasing either straw or grains for both tested seasons. The corresponding increase as compared to control for N, P and K plant content were 98.2,62.4 and 91.1 % for straw as well as 71.4 , 65.1 and 61.5% for grains in the first season where it reached 85.2 , 26.3 and 115.8% for straw as well as 66.7 , 50.5 and 96.6% for grains as compared to control, in the second season. Such results are confirmed by those of Adriano et al., (2005) who found that increasing the addition of char can certainly have a positive influence on N and P nutrient uptake by increasing the sorption capacity.

Table 4. Effect of biochar amendments along with N and P rates on total contents of some macronutrients for wheat crop (kg fed^{-1}).

First season:

Treatments		Straw			Grains		
		N	P	K	N	P	K
	Without Biochar						
P1	N1	16.8	8.67	14.2	17.5	5.15	15.6
	N2	23.1	12.3	21.9	24.4	7.17	20.4
	N3	24.3	13.9	22.3	25.1	7.41	21.2
P2	N1	26.4	13.6	18.9	19.6	7.38	19.2
	N2	27.3	15.9	21.1	25.8	7.86	25.2
	N3	28.3	15.7	21.3	26.6	9.39	26.5
	With Biochar I						
P1	N1	25.9	10.7	22.9	25.4	7.95	21.9
	N2	27.8	14.6	22.8	26.8	8.93	24.2
	N3	28.5	14.0	23.2	27.8	6.12	26.0
P2	N1	27.7	15.1	19.7	26.0	7.70	24.2
	N2	30.8	16.0	21.4	29.5	8.30	25.8
	N3	31.4	16.0	22.7	30.1	8.56	27.4
	With Biochar II						
P1	N1	33.9	14.7	27.9	32.5	8.31	28.7
	N2	39.1	16.2	30.3	44.1	14.6	42.2
	N3	40.7	18.4	30.4	44.4	13.3	45.1
P2	N1	38.0	17.2	27.4	33.1	8.30	28.4
	N2	49.4	21.4	35.8	45.1	14.2	41.6
	N3	56.1	25.5	40.7	45.6	15.5	42.8
	With Biochar III						
P1	N1	32.5	13.9	22.6	29.1	9.53	26.3
	N2	40.3	14.3	27.9	35.8	10.7	33.5
	N3	42.8	11.8	29.5	36.4	11.0	34.7
P2	N1	33.8	11.8	17.9	34.5	10.8	31.6
	N2	43.2	13.5	22.5	36.1	12.2	35.2
	N3	53.5	17.8	34.0	37.6	11.5	37.7
Means values of biochar rates							
Without		24.369	13.236	19.927	23.171	7.394	21.322
CharI		28.666	14.019	22.109	27.592	7.927	24.910
Char II		44.494	18.896	32.094	40.800	12.365	38.111
Char III		42..708	13.869	25.723	34.908	10.950	33.173
Means values of P rates							
P1		31.296	13.623	24.652	30.769	9.181	28.310
P2		38.823	16.386	25.275	32.466	10.137	30.448
Means values of N rates							
N1		29.365	13.208	21.434	27.207	8.145	24.470
N2		35.516	15.543	25.445	33.440	10.482	31.002
N3		40.298	16.263	28.010	34.207	10.350	32.665
LSD at 5%							
Rates of biochar (A)		6.84	2.56	3.85	2.54	1.67	2.85
Rates of P(B)		3.07	1.47	1.64	0.45	0.75	1.37
Rates of N (C)		1.98	1.57	1.85	1.11	0.73	1.32
A*B		1.20	1.11	1.20	1.00	0.65	2.74
A*C		3.97	1.54	3.71	2.21	1.45	2.64
B*C		2.81	1.09	2.62	0.77	0.98	0.92
A*B*C		5.61	2.18	5.24	1.54	1.95	2.80

Second season:

Treatments		**Straw**			**Grains**		
		N	**P**	**K**	**N**	**P**	**K**
	Without Biochar						
P1	N1	18.2	9.22	13.2	19.2	5.30	12.5
	N2	27.2	13.2	18.2	25.4	7.00	19.5
	N3	28.3	13.9	20.4	26.4	7.36	22.5
P2	N1	24.2	14.5	17.4	22.5	7.40	15.5
	N2	28.3	16.3	20.1	26.0	7.90	17.0
	N3	32.4	16.0	20.9	28.2	7.84	17.8
	With Biochar I						
P1	N1	27.2	11.3	15.7	27.3	6.21	23.0
	N2	32.2	14.9	24.8	30.0	7.33	27.0
	N3	33.7	15.2	24.7	33.5	7.34	27.2
P2	N1	33.4	16.5	20.2	29.1	7.35	25.2
	N2	37.5	16.2	24.0	33.5	7.90	27.9
	N3	40.1	17.2	24.9	38.4	7.91	30.0
	With Biochar II						
P1	N1	37.5	16.3	27.0	35.2	8.30	25.0
	N2	44.2	20.2	32.5	45.3	8.35	27.2
	N3	47.2	21.2	32.9	47.2	9.00	29.8
P2	N1	39.2	18.0	33.0	39.1	10.2	25.2
	N2	58.3	19.2	35.7	45.2	11.2	27.2
	N3	60.0	20.2	45.1	47.0	11.8	35.0
	With Biochar III						
P1	N1	37.3	18.0	25.2	32.2	8.20	24.5
	N2	45.0	19.3	30.4	40.2	9.22	25.0
	N3	47.0	19.0	31.2	44.5	9.20	25.9
P2	N1	44.0	18.0	27.0	37.3	8.22	25.7
	N2	51.2	20.0	28.5	39.1	9.00	26.1
	N3	55.1	20.0	28.3	42.5	9.24	27.5
Means values of biochar rates							
Without		26.43	13.85	18.37	24.62	7.13	17.47
CharI		34.02	15.22	22.38	31.97	7.34	26.72
Char II		47.73	19.18	34.37	43.17	9.81	28.23
Char III		46.60	19.05	28.43	39.30	8.85	25.78
Means values of P rates							
P1		35.42	15.98	24.68	33.87	7.73	24.09
P2		41.98	17.68	27.09	35.66	8.83	25.01
Means values of N rates							
N1		32.63	15.23	22.34	30.24	7.65	22.08
N2		40.49	17.41	26.78	35.59	8.49	24.61
N3		42.98	17.84	28.55	38.46	8.71	26.96
LSD at 5%							
Rates of biochar(A)		4.72	2.57	3.48	3.24	1.42	2.71
Rates of P(B)		2.98	1.39	1.26	0.50	0.68	1.35
Rates of N (C)		1.30	1.63	1.62	1.09	0.74	1.14
A*B		1.12	0.98	1.11	0.99	0.45	2.62
A*C		3.85	1.42	2.98	1.25	1.26	2.45
B*C		2.64	1.00	2.70	1.20	0.88	0.82
A*B*C		4.86	2.00	4.82	1.26	1.20	2.07

Moreover, the obtained results were confirmed by Warnock et al.,(2007) who found that biochar serves as a catalyst that enhances plant uptake of nutrient and water compared to other soil amendments due to its high surface area and porosity which enable it to adsorb or retain nutrients and water and increasing plant uptake of nutrients . On the other hand, application of the high rate of biochar caused a significant decrease in the total contents, of N, P and K for straw and grains, this may be due to the high C/N ratio of the biochar used in this investigation, where its addition to soil did not provide sufficient additional of N to plants and therefore did not result in increasing the total contents of N . This causes imbalance in the uptake of P and K even at rate of 2 ton fed^{-1}, this response agree with Chan *et al*.(2007). In other words, under high rate of biochar, nitrogen was likely immobilized as evident from the low N concentrations and reducing N uptake. Moreover, the most inferior treatments for total contents of both yield components were recorded for control treatment without biochar.

First season

Total contents of Nitrogen **Total contents of Phosphorus**

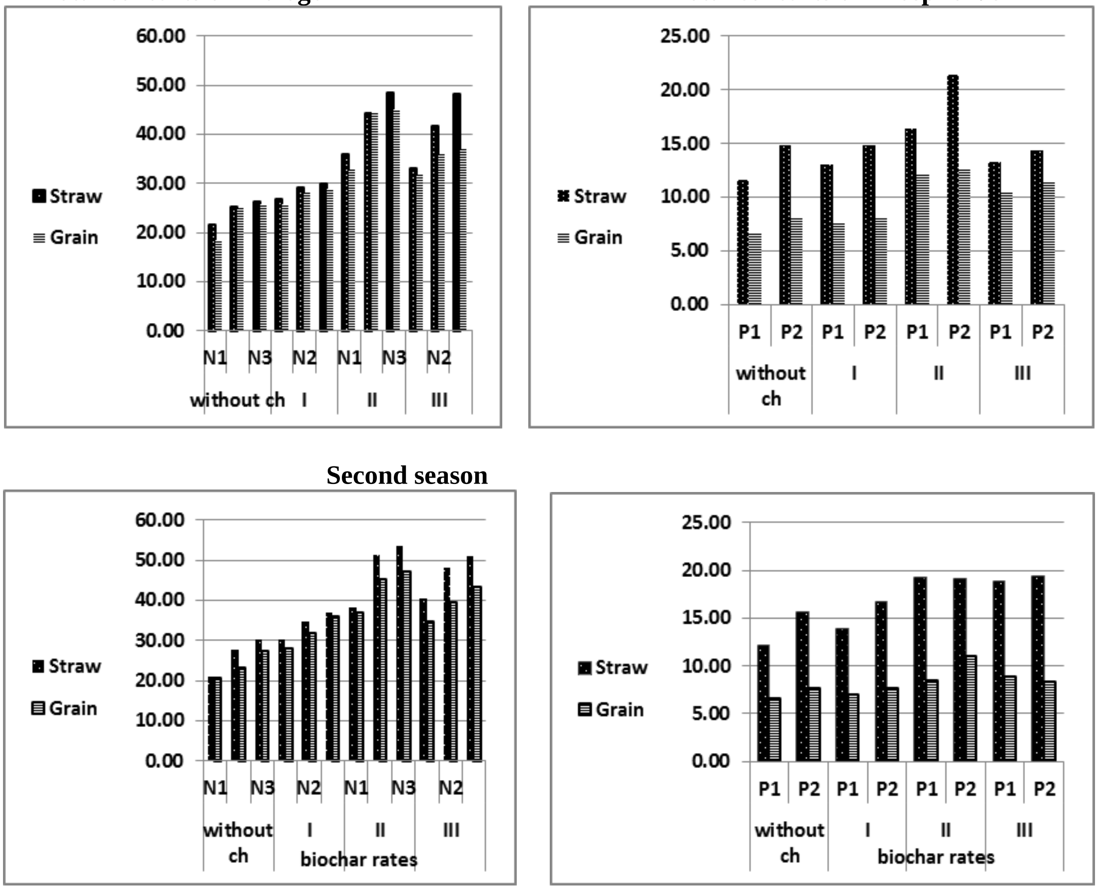

Fig. 2.Effect of biochar amendments along with N and P rates on total contents of nitrogen and phosphorus for both straw and grains of wheat crop (kg fed^{-1}).

3- Effect of biochar amendment on Apparent Nutrients Recovery Efficiency (ANRE) of wheat crop.

The values of Apparent Nutrients Recovery Efficiency (ANRE) was calculated for wheat crop as presented in Table (5) and Fig. (3). Values show that a significant increase exists in N,P and K (ANRE) due to the presence of biochar as a soil conditioner. Increasing biochar amendment gradually increases the (ANRE) especially in presence of the second rate of biochar (2 ton fed^{-1}), then the opposite trend was obtained in presence of the third rate of biochar (4 ton fed^{-1}) in both tested seasons. Moreover, increasing the rates of both nitrogen and phosphorus caused a positive increase in N, P and K (ANRE), especially in presence of the second rate of biochar. Finally, it could be concluded that the addition of biochar combined with compost and sulfur as a soil conditioner is more useful in improving the (ANRE) of N, P and K because of its effect in enhancing the nutrients availability, nutritional status and wheat crop in sandy soil. Similar results were obtained by Reddy (2014) who found that the addition of biochar combined with compost is more useful in improving the ANRE.

Table 5. Effect of biochar amendment along with N and P rates on ANRE for N, P and K (%) of wheat crop.

Treatments		First season			Second season		
		N	P	K	N	P	K
With Biochar I							
P1	N1	34.0	4.83	30.0	34.2	3.99	26.0
	N2	9.47	4.06	9.40	12.8	2.71	28.2
	N3	6.90	2.71	11.4	12.5	1.71	18.0
P2	N1	15.4	1.21	11.6	31.6	1.95	25.0
	N2	9.60	1.36	1.80	22.3	0.70	29.6
	N3	6.60	1.31	4.60	17.9	1.27	32.4
M.		13.7	2.41	11.5	21.9	2.05	26.5
With Biochar II							
P1	N1	64.2	9.19	53.6	70.6	13.44	52.6
	N2	47.6	11.3	60.4	49.2	11.13	44.0
	N3	35.7	10.4	60.4	39.7	11.92	39.6
P2	N1	50.2	3.01	35.4	63.2	6.30	50.6
	N2	55.2	7.89	62.2	65.6	6.20	51.6
	N3	46.8	11.0	71.4	46.4	8.16	82.8
M.		50.0	8.80	57.2	55.8	9.53	53.5
With Biochar III							
P1	N1	54.6	9.61	38.2	64.2	15.8	48.0
	N2	38.1	5.53	38.2	43.5	11.1	35.4
	N3	29.8	1.49	41.4	36.8	11.0	28.4
P2	N1	44.6	1.08	22.8	69.2	6.52	39.6
	N2	34.9	1.29	22.8	48.0	7.50	35.0
	N3	36.2	3.21	47.8	37.0	7.40	34.2
M.		39.7	3.70	35.2	49.8	9.89	36.8

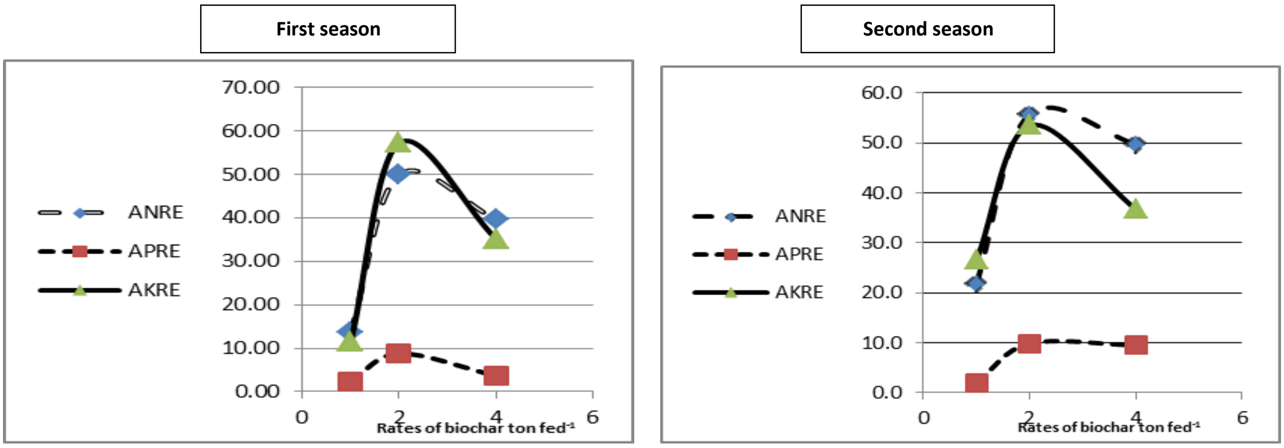

Fig. (3): Effect of biochar amendment on Apparent Nutrients Recovery Efficiency (ANRE) of wheat crop.

4- Effect of biochar amendment along with N and P rates on yield components of wheat crop.

Data presented in Table (6) revealed that the crop yield components of wheat increased significantly by increasing the rate of biochar from (1 ton fed^{-1}) up to (2 ton fed^{-1}) then significantly decreased by increasing the rate of biochar (4 ton fed^{-1}). The best suited biochar rate and materials for application be considered before crop yields decline or its soil properties diminished. Barrow (2012) and Gaskin et al. (2010) found a positive effect of biochar on plant growth and biomass yield only when biochar is applied along with supplement nutrient source. Moreover, Chan et al.(2007) attributed the low response to the high C/N ratio of the biochar used in this investigation, as its addition to soil did not provide sufficient additional N to plants and therefore did not result in yield increase even at rate of 2 ton fed^{-1}.

Also, biochar application combined with N and P rates has a positive effect on plant growth and crop yields compared to control. In this respect, Barrow (2012) pointed out that applied biochar has a positive effect on growth and yield components. With respect to different application rates of N and P(100%), data indicate that yield components increased gradually by increasing the rate of N and P application in presence of biochar as compared to control (without biochar), especially in presence of biochar (2 ton fed^{-1}) along with the high rate of N and P. Biochar application give a favorable condition as it acts as a slow release fertilizer and / or as a catalyst which activate microbial growth. Moreover, biochar acts as a soil conditioner, improve soil physical properties and nutrient use efficiency, thereby increasing plant growth and yield.

The application of second rate of biochar (2 ton fed^{-1}) in presence of high rate of N and P(100%).(N3 combined with P2) was significantly superior in increasing either straw or grains of wheat crop as compared to control. On the other hand, the most inferior treatments for both straw and grains were recorded for the control treatment (without biochar), similar results are being recorded for both tested seasons.

Finally, we can conclude that applying blended biochar with organic materials (compost) and sulfur to sandy soil is of beneficial impact by preventing the loss of nutrients, improves the soil chemical properties, hold nutrients against leaching, increases the availability of nutrient to plants, maintains the surface sorption and increases the wheat yield components.

Table 6. Effect of biochar amendment along with N and P rates on yield components of wheat crop(kg fed^{-1})

Treatments		First season Straw	First season Grains	Second season Straw	Second season Grains
	Without Biochar				
P1	N1	1831	1358	1900	1090
	N2	2073	1700	2940	1570
	N3	2359	1847	2990	2110
P2	N1	2467	1590	2010	1550
	N2	2665	1800	2680	1062
	N3	2645	1917	2700	1670
	Biochar I				
P1	N1	2213	1767	2380	1540
	N2	2445	1859	2940	1900
	N3	2719	2044	3430	2170
P2	N1	2572	1810	2800	1840
	N2	2834	2032	3290	2000
	N3	2800	2199	3640	2140
	Biochar II				
P1	N1	3414	2181	3002	2000
	N2	3609	2971	3400	2390
	N3	3685	3160	3830	2780
P2	N1	3499	2320	3800	2510
	N2	4508	3220	4000	3020
	N3	5199	3373	5420	4002
	Biochar III				
P1	N1	3080	2097	2980	1800
	N2	3342	2468	3400	2.122
	N3	3386	3308	3540	2173
P2	N1	2360	1844	2450	1987
	N2	2442	2330	3010	2000
	N3	3373	2460	3220	2155
Means values of biochar rates					
Without		2340	1702	2537	1509
CharI		2597	1952	3080	1932
Char II		3986	2871	3909	2784
Char III		2997	2418	3100	1686
Means values of P rates					
P1		2846	2230	2061	1794
P2		3114	2241	3252	2161
Means values of N rates					
N1		2680	1871	2665	1780
N2		2990	2297	3208	1843
N3		3271	2538	3596	2400
LSD at 5%					
Rates of biochar (A)		318.6	75.59	290.2	62.40
Rates of P(B)		86.08	8.00	72.20	20.40
Rates of N (C)		55.09	53.73	40.20	30.50
A*B		172.2	131.2	154.3	112.0
A*C		110.2	107.4	92.00	82.60
B*C		77.91	75.99	72.50	62.50
A*B*C		155.82	151.98	142.7	168.2

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استخدام البيوتشار كمحسن للتربة لتحسين الخواص الكيميائية للاراضى الرملية والحالة الغذائية وانتاجية محصول القمح

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اقيمت تجربة حقلية بمحطة البحوث الزراعية بالإسماعيلية خلال موسمين شتويين متتالين2015/2014 بأرض رملية على محصول القمح تحت نظام الرى بالرش لتقييم استخدام الفحم النباتى مختلطا مع الكمبوست والكبريت كمحسن للأراضى الرملية واضافته مع معدلات مختلفة من النيتروجين والفوسفور وتأثير ذلك على بعض الخواص الكيميائية للأرض الرملية وكذلك تيسر العناصر والحالة الغذائية وكفاءة الاستخدام للعناصر (النيتروجين والفوسفور والبوتاسيوم) وانعكاس ذلك على انتاجية محصول القمح . تم اضافة الفحم النباتى بثلاث معدلات (1 و 2و 4 طن/ فدان) , وأضيف النيتروجين بثلاث معدلات (50 و75 و100%) من المعدل الموصى به بينما اضيف الفوسفور بمعدلين (75 و100%) من المعدل الموصى به لمحصول القمح.أوضحت النتائج ان : هناك انخفاض معنوى فى قيم الحموضة بالتربة نتيجة زيادة معدل الاضافة للفحم مع الكمبوست والكبريت بالمقارنة بالكنترول (عدم اضافة فحم) و حدثت زيادة معنوية فى قيم التوصيل الكهربى والمادة العضوية والسعة التبادلية الكاتيونية وكذلك تيسر العناصر (النيتروجين , الفوسفور , البوتاسيوم) بزيادة معدل الاضافة من الفحم بالمقارنة بالكنترول وكان لاضافة المعدل العالى من الفحم النباتى مع المعدل العالى من النيتروجين والفوسفور تاثير ايجابى معنوى لزيادة تيسر عناصر(النيتروجين , الفوسفور , البوتاسيوم) فى التربة حيث سجلت اعلي قيم لتيسر العناصر فى التربة بالمقارنة بالكنترول والمعاملات الاخرى فى كلا الموسمين. أوضحت النتائج أيضا زيادة معنوية فى الأمتصاص ومكونات محصول القمح (قش وحبوب) نتيجة لوجود الفحم النباتى بالمقارنة بالكنترول فى كلا الموسمين , وبصفة عامة كان لاضافة الفحم النباتى وفى وجود معدلات مختلفة من (النيتروجين , الفوسفور) أدى الى حدوث تأثير ايجابى على النمو والمحصول بالمقارنة بالكنترول وبصفه عامة حدثت زيادة تدريجية فى محصول القمح بزيادة معدل الاضافة من (النيتروجين , الفوسفور) وفى وجود الفحم بالمقارنة بالكنترول وبصفة خاصة مع المعدل الثانى(2 طن/ فدان), بينما اوضحت النتائج انخفاض معنوى فى المحصول نتيجة زياده المعدل المضاف من الفحم الى 4 طن/فدان.أوضحت النتائج أيضا, أن هناك زيادة واضحة فى كفاءة الاستخدام للعناصر(نيتروجين , فوسفور , بوتاسيوم) نتيجه لوجود الفحم بالمقارنة بالكنترول وخصوصا مع المعدل الثانى (2 طن/فدان) وبالتالى فوجوده مفيد جدا فى تحسين كفاءة الاستخدام للعناصر وكذلك محصول القمح.واخيرا يمكن استنتاج أن اضافة الفحم النباتى مع الكمبوست للأراضى الرملية مفيد لأنه يمنع العناصر من الفقد ويحسن الخواص الكيميائية للتربة ويعمل على زيادة تيسر العناصروكفاءة استخدامها فى التربة وبالتالى زيادة محصول القمح.