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Biochar and Compost Increase N- Use Efficiency and Yield for Sudangrass *(Sorghum bicolor* Var. Sudanese) Grown on a Sandy Soil

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ABSTRACT

In 2017 and 2018 summer seasons, two field experiments were conducted at, EL-Qantara East, Ismailia Governorate, Egypt to study the addition effect of biochar and compost in increasing N-fertilizer efficiency for *Sorghum bicolor* grown on a sandy loam. Four N-fertilization rates of *0*, 60, 120, 180 kg N ha^{-1} (i.e. N_0, N_{60}, N_{120} and N_{180} respectively) and three organic sources 2 biochars and compost (i.e. BA, BB and Co, respectively) each applied at 24 Mg ha^{-1}. Highest yield was by BB+ $N_{180.}$ Highest chlorophyll, protein and protein yield contents (41.3 mg g^{-1} fw., 118 g kg^{-1} and 2053 kg ha^{-1}, respectively were obtained due to CoN_{180}. Available N, P, K, Fe, Mn and Zn increased due to added treatments and highest was by CoN_{180}. Soil pH decreased due to organic amendments while EC slightly increased owing to biochar addition. Maximum N, P, K, Fe, Mn and Zn content and uptake by plants were by CoN_{180}. Highest Nitrogen Use Efficiency, was by CoN_{120}. The CoN_{180} had superior effect on improving soil properties and increasing sorghum traits.

Keywords: Biochar, compost, sorghum N-fertilization, sandy soil.

INTRODUCTION

Sorghum (*Sorghum bicolor* L.), belongs to the Tribe Andropogonae of the grass family Poacae, cultivated for its grains, which is used for human food and animal feed, as well as other uses and is the world's fifth most important cereal crop after rice), Wheat, maize and barley (Berenji and Dahlberg, 2004).

Sorghum grains contain ranges of each of the followings (g kg^{-1}) 700-800 starch, 110-1300 protein, 20-50 fat, 10-30 fiber and 10-20 ash, (Adebiyi, *et al.*, 2016).

It has a high water use efficiency and could be a good alternative to maizeunder limited water in the semi-arid conditions (Marsalis *et al.*, 2010) , and requires modest rates of N (Olanite *et al.*, 2010) and grows well under stress conditions of heat (Yan *et al.*, 2012) and high salinity (Saberi, 2013). It is as suitable for making silage as maize (Qu *et al.*, 2014).

Nitrogen is a major plant nutrient since it is a constituent of all proteins and nucleic acids (Russell, 1973, Osman *et al.*, 2000 and Fathi *et al.*, 2003).It is applied to crops in various types of fertilizers and amendments (Johnston *et al.*, 2009) especially on sandy soils which suffer from low fertility (Jaiarree *et al.*, 2011.Crop residues and organic manures have traditionally been applied to soils as a means for maintaining and increasing their fertility (Senesi *et al.*, 2007 and increase crop production (Cleveland and Townsend, 2006).

Biochars are charred organic materials, mostly of plant origins obtained through pyrolysis of wood, straw or other crop residues. Pyrolysis produces energy efficient materials (Verheijen, *et al.*, 2010; Woolf *et al.*, 2010; Lehmann and Joseph, 2012; Njenga *et al.*, 2016). On the other hand, they can be useful organic amendments for soils and crops improving soil chemical, physical and biological properties (Scholz *et al.*, 2014; Cernansky, 2015). Positive effects on crop growth and yield have been reported due to the use of biochar (Jeffery *et al.*, 2011and Liu *et al.*, 2013). For high productivity and forage quality of sorghum, mineral N is most important (Marsalis *et al.*, 2010 and Sawargaonkar *et al.*, 2013). Complementary use of organic and biochar may be a practical way of reducing the cost of amendments and fertilizers for some crops (Patil, 2013).

The aim of the current experiment is to assess the effect of using biochar and compost in increasing yield and N use efficiency for Sudan grass *(Sorghum bicolor* var Sudanese) grown on a sandy soil.

MATERIALS AND METHODS

The present study was carried out under sandy soil condition at El-Qantra East, Ismailia Governorate, Egypt, during the 2017 and 2018 summer seasons. The soil was a sandy-loam. Table 1 shows the main properties of the soil.

Table 1. Main physical and chemical properties of the studied soil.

Sand	**Silt (%)**		**Clay (%)**		**Texture**	**O.M (g kg^{-1})**		**$CaCO_3$ (g kg^{-1})**
80.3	6.8		12.9		Sandy loam	5.52		18.5
Soluble ions (mmolc L^{-1})								
pH**	EC* (dSm^{-1})	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO^{-}_{3}	Cl^{-}	$SO^{=}_{4}$
7.92	1.42	4.65	2.18	6.52	0.85	1.20	7.78	5.22
Available nutrients (mg kg^{-1})								
N	P	K		Fe		Mn		Zn
29	5	121		1.89		0.93		0.59

***EC in soil paste extract.; *pH in soil suspension 1:2.5 w/v .No $CO_3^{=}$ was detected.**

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The aim of this study is to study the effect of adding biochar and compost, with and without mineral fertilizer N, to Sudan grass (*Sorghum bicolor* var Sudanese) hybrid 102 grown on a light textured soil. There were 2 biochars i.e, biochar A (BA) and biochar B (BB) and compost (Co). BA was made from maize straw + rice straw + faba bean straw; BB was made from cotton fire wood + tree branches; Co was made from plant residues + FYM. The application rate was 24 Mg ha^{-1} for each biochar as well as the compost. Main properties of the biochars and the compost are given in Table 2. The experimental design was of split-plot with 3 replicates. The main plots were assigned to the organic fertilization and the subplots were assigned to the mineral N fertilization. The organic fertilization was 3, i.e. BA, BB and Co. The fertilizer N treatments were 4, i.e. 0, 60, 120 and 180 kg Nha^{-1} (designated N_0, N_{60}, N_{12}, and N_{180} respectively), with ammonium nitrate (335 g N kg^{-1}) being the source, in three equal splits: immediately after thinning (20 days after sowing), 30 and 45 days later. Therefore, the treatment combinations were 12. The plot size was 12 m^2 and consisted of five rows 60 cm apart and 4 m long. Organic amendments were added 15 days before seeding and mixed with the surface layer. The analysis of biochar types and compost were shown in Table 2.

Table 2. Analysis of biochar and compost sources used in this study.

Parameter	pH (1:2.5) suspension	EC (dSm^{-1})	C ($g\ kg^{-1}$)	C/N ratio	N	P	K	Fe	Mn	Zn
					($g\ kg^{-1}$)			($mg\ kg^{-1}$)		
Biochar A (BA)	8.40	4.85	289	23.1	12.5	1.55	60.3	230	165	11.8
Biochar B (BB)	8.45	6.12	314	23.1	13.6	2.18	78.0	258	178	13.9
Compost (Co)	7.89	3.10	272	31.9	8.51	6.65	54.0	248	190	22.0

All plots received P at 17 kg P ha^{-1} during soil preparation as superphosphate (68 g P kg^{-1}) and K at 40 kg K ha^{-1} as K-sulphate (400 g K kg^{-1}) in two equal splits, 30 and 45 days after sowing. Agricultural practices were carried out as recommended by the Egyptian Ministry of Agriculture.

Measured traits, N parameters and methods of analysis:

At maturity, plants of the middle three rows of each plot were harvested and air dried to determine the following characteristics (Means of 2 seasons 2017 and 2018): Plant height, Number of branches $plant^{-1}$; forage fresh yield; Forage dry yield; Protein content (N content multiplied by 5.75, FAO, 2003). A line was left for each treatment until fully matured to calculate the weight of 1000 seeds.

Apparent N recovery (ANR) was calculated by the following equation (Echeverria and Videla, 1998):

ANR = {(N uptake in fertilized– N uptake in non-fertilized) ÷ N fertilizer rate} X 100.

Nitrogen agronomic efficiency (NAE) was calculated according to the following equation (Creswell and Godwin,1984):

(grain yield of fertilized - grain yield of non-fertilized) ÷ N fertilizer applied (all expressed as kg ha^{-1}).

Nitrogen use efficiency (NUE) is calculated as follows (Angas *et al*. ,2006):

kg of grain yield kg^{-1} ÷ kg N applied.

Laboratory analysis

Plant analysis was done in a mixture of concentrated sulfuric and perchloric acids H_2SO_4 + $HClO_4$ acids as described by (Ryan et al., 1996). The analyses for soils and plants were done by methods described by Chapman and Pratt (1961), Jakson (1973) , Brunner and Wasmer (1978), Klute (1986) and Page et al. (1982). Chlorophyll content of leaf tissue was determined by method of Saric et al., (1967).

Statically analysis.

Data was statically analyzed for analysis of variance (ANOVA) and test significant difference (LSD) at 0.05 probability level which applied to make comparisons among treatment means according to Snedecor and Cochran (1990).

RESULTS AND DISCUSIONS

Effect of biochar types and compost on some chemical properties of soil after harvest.

Soil pH.

Data in Figure 1 show that soil pH tended to slightly decrease from 7.86 to 7.79 due to biochar A + N_{180}, from 7.92 to 7.85 under addition of biochar B + N_{180} and from 7.85 to 7.75 by compost + N_{180}. Siam *et al.* (2013) reported a decrease in pH upon applying N and compost fertilization. The lowest pH (7.75) was obtained owing to treating the soil by Co+N_{180}. This Fig (1) show that the soil pH was might be attributed to the effect of microorganisms on decomposing organic matter releasing organic acids (Ashmaye et al. 2008 and Abdel-Fattah 2012). Also, there was a low pH with treatment of 180 kg N ha^{-1} compared with pH of the other N treatments. Concerning the effect of the treatments on soil salinity in the rhizosphere

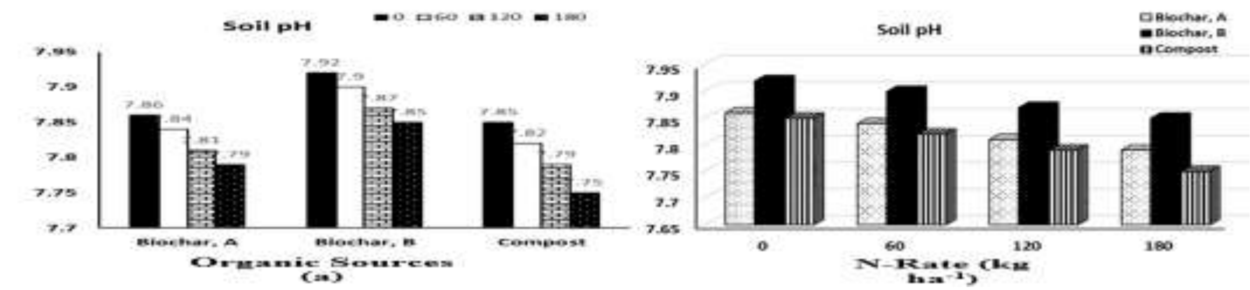

Fig. 1. Soil pH after sorghum harvest as affected by different soil amendments and different N-rates (Means of 2 seasons 2017 and 2018)

Soil Salinity (EC_e)

Data in Figure 2 reveal that the EC was lower in soil of compost addition in combination with N, especially at 180 kg N ha^{-1} as compared with biochar A and biochar B which showed increased soil EC. Increased porosity and aggregation in soil due to organic amendments were reported by Zaka *et al.,* (2005) and Shaban and Omar (2006) due to compost addition and hence enhanced the leaching of salts. Such changes reduce the deleterious effect of Na-salts, and improve soil structure, increasing aggregate stability and drainable pores. The effect is more pronounced in soil when treated with $Co+N_{180}$ caused a decreases of -46.4% and -44.6% as compared with $BA+ N_{180}$ and $BB + N_{180}$, respectively.

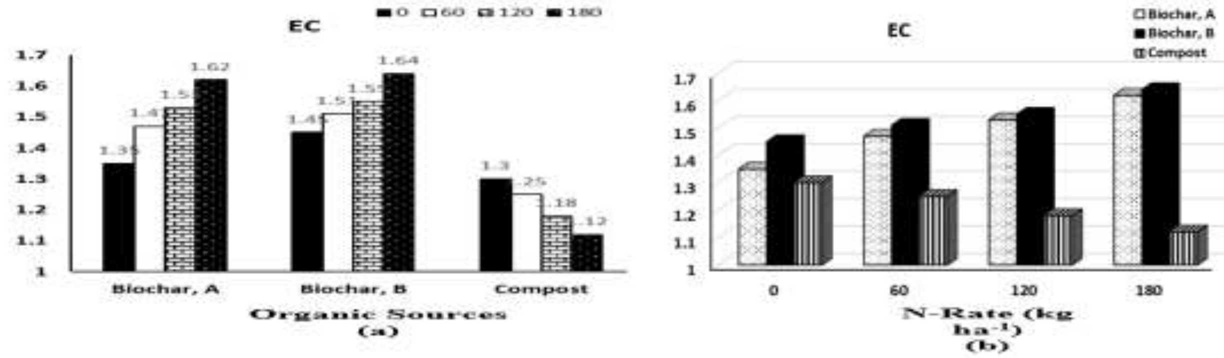

Fig. 2. Soil EC after sorghum harvest as affected by different organic sources and different N-rates.

The effect of soil amendments sources could be arranged regarding reducing soil EC as follows: Co > B A > B B, while, the effect of N-rates was in order: $N_{180} > N_{120} > N_{60} > N_0$.

The EC decreased with increasing N-addition when combined with compost and the sequence was: $N_{180} < N_{120} < N_{60} < N_0$. The lowest EC (1.12 dSm^{-1}) was recorded due to the treatment ($Co+ N_{180}$) while the highest (1.64 and 1.62 dSm^{-1}) was obtained with $BA + N_{180}$ as well as $BB + N_{180}$.

Available macro and micronutrients in soil after harvest

Data of Figures 3,4 and 5 reveal that available N, P and K increased by addition of organic amendments in combination with mineral-N. Available N ranged between 30.9 to 41.2 mg kg^{-1}. Available P ranged between 5.01 to 5.38 mg kg^{-1} and available K ranged between 121 to 138 mg kg^{-1}. The soil of $Co+N_{180}$ gave the highest values of available N, P and K. The corresponding relative increases were 33.3%, 7.38% and 14.0%, respectively as compared with lowest values.

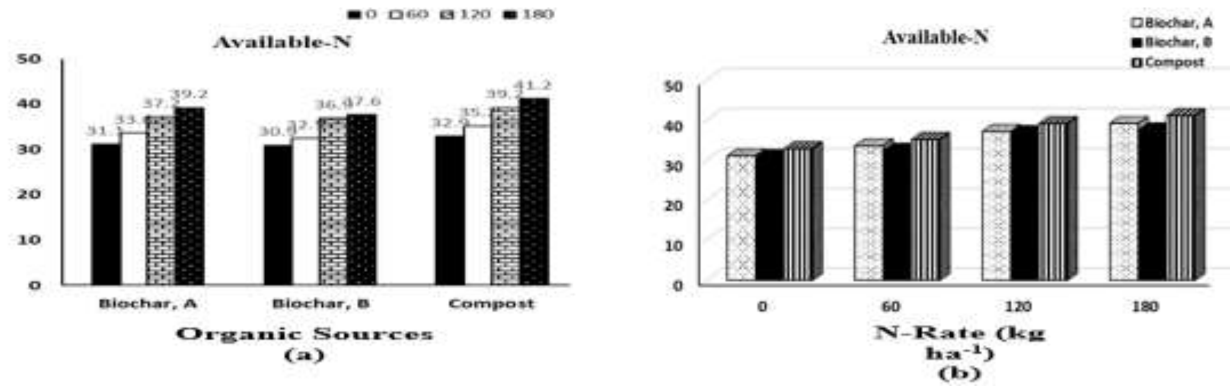

Fig. 3. Available-N (mg kg^{-1}) in soil after sorghum harvest as affected by different organic sources and different N-rates (Means of 2 seasons 2017 and 2018)

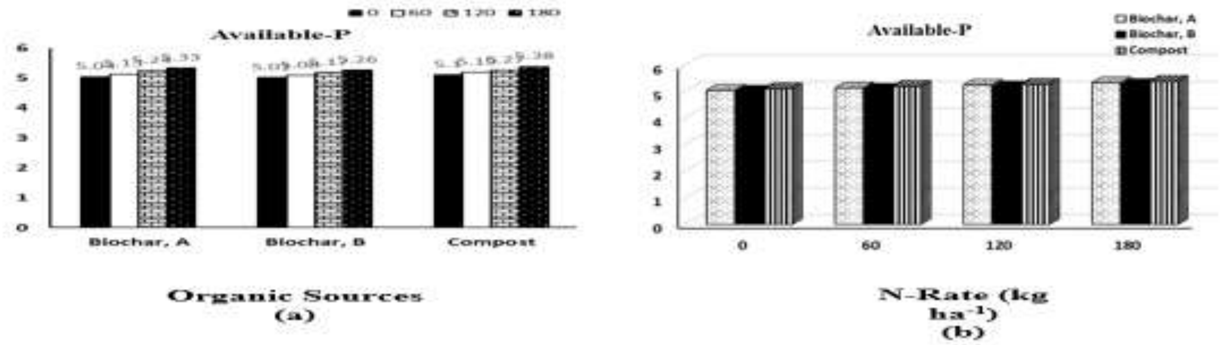

Fig. 4. Available-P (mg kg^{-1}) in soil after sorghum harvest as affected by different organic sources and different N-rates

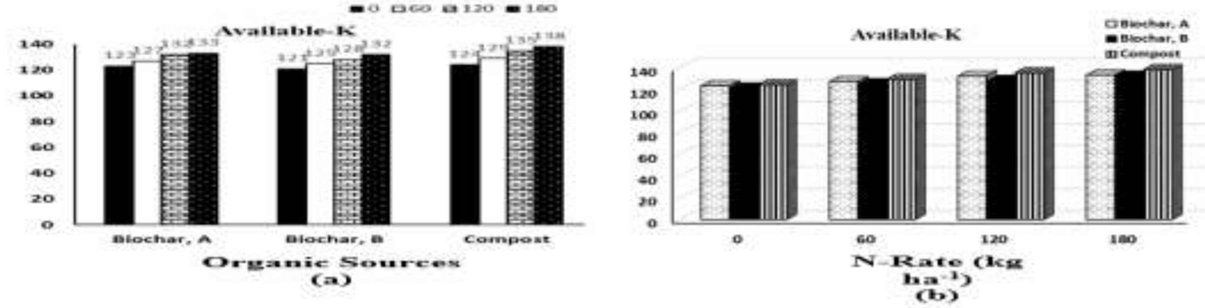

Fig. 5. Available-K (mg kg^{-1}) in soil after sorghum harvest as affected by different organic sources and different N-rates.

As for available Fe, Mn and Zn in soil after harvest, data in Figures 6, 7 and 8 illustrate that the content of these elements in soil after harvest increased as affected by the treatments. The highest values were 2.17, 1.18 and 0.77 mg kg^{-1} for Fe, Mn and Zn, respectively due to the treatment of (Co+ N_{180}) causing increases of 13.0%, 24.2% and 26.2%, respectively over the lowest values given by BB+N_0.

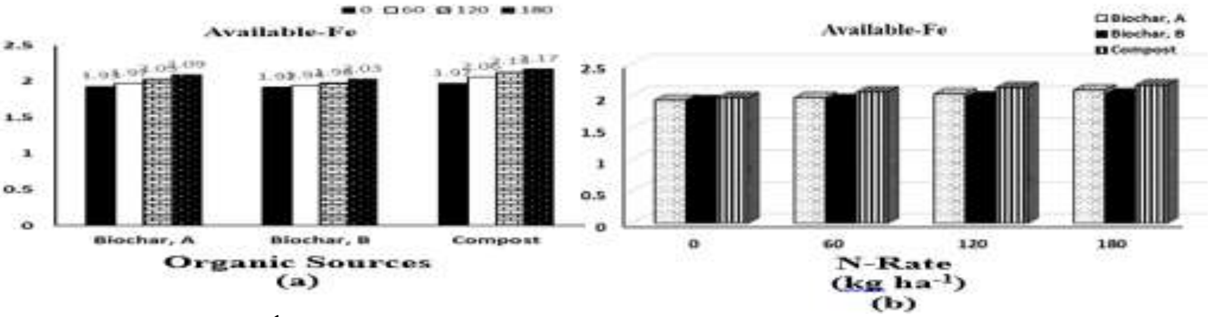

Fig. 6. Available-Fe (mg kg^{-1}) in soil after sorghum harvest as affected by different organic sources and different N-rates .

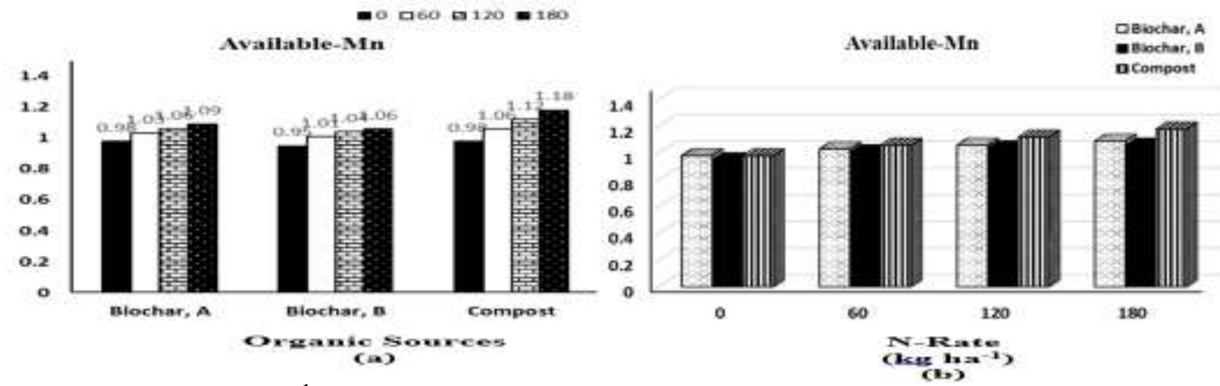

Fig. 7. Available-Mn (mg kg^{-1}) in soil after sorghum harvest as affected by different organic sources and different N-rates.

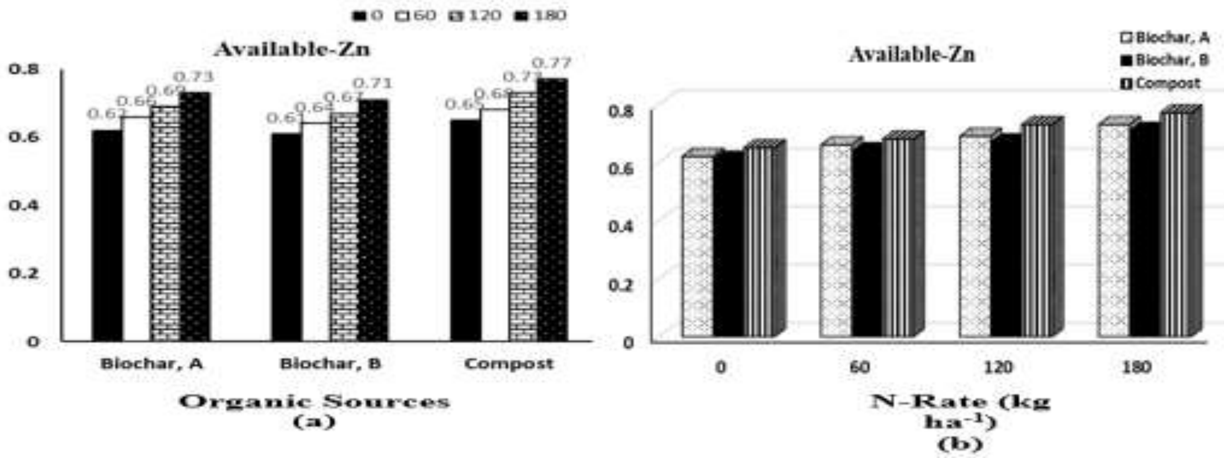

Fig. 8. Available-Zn (mg kg^{-1}) in soil after sorghum harvest as affected by different organic sources and different N-rates.

Forage Quality

Table 3 shows the effect of different organic sources and N-addition rates on protein content and yield as well as total chlorophyll content in fresh leaves. All of these quality parameters were increased by addition of organic or inorganic sources.

Table 3. Effect of organic amendments and N-addition rate on some sorghum forage quality.

Organic sources (OS)	N-Rate, kg ha^{-1} (NR)	Protein (g kg^{-1})	Protein yield (kg ha^{-1})	Total Chlorophyll (mg g^{-1} f.w)
Biochar (A)	0	79.4	497	29.1
	60	94.9	996	33.7
	120	103	1349	36.5
	180	112	1669	38.2
Mean		97.3 ab	1128 b	34.4 b
Biochar (B)	0	77.6	414	23.9
	60	88.6	772	28.0
	120	95.5	1108	31.9
	180	102	1367	33.2
Mean		90.9 b	915 b	29.3 c
Compost	0	82.8	631	31.9
	60	102	1010	35.8
	120	113	1661	38.9
	180	118	2053	41.3
Mean		104 a	1339 a	37.0 a
Mean of N-rate	0	79.9 c	514 d	28.3 d
	60	95.2 b	926 c	32.5 c
	120	104 ab	1373 b	35.8 b
	180	111 a	1696 a	37.6 a
F-test	OS	*	**	**
	NR	**	**	**
	OSxNR	ns	ns	ns

Protein content and protein yield in forage.

The pattern of response to treatments on protein content is as follow: Co ≥ BA ≥ BB for organic amendments and $N_{180} \geq N_{120} \geq N_{60} > N_0$ for N-addition. The pattern for protein yield was: Co > BA ≥ BB for organic sources and $N_{180} > N_{120} > N_{60} > N_0$ for N-addition rate. The relative protein content increases for addition N-rates over N_0 were 38.9, 30.2 and 19.1% for N_{180}, N_{120} and N_{60}, respectively. Highest protein content and protein yield (118 g kg^{-1} and 2053 kg ha^{-1}, respectively) were obtained by Co+ N_{180} causing 52.1% and 396% increases, compared with BB treatment. Increasing protein content and yield in crops due to organic amendments is related to improving the nutrients availability and uptake (Khan *et al.,* 2008 and Abd El-Lattief, 2011). Mahfouz *et al.* (2015) reported that application of N fertilizer significantly increased crude protein content particularly at high rates of N.

Data also show that chlorophyll content was increased with N application and the increase was progressive with the increase in N-rate. The pattern of response was increases of 32.9, 26.5, and 14.8% for $N_{180,}$ N_{120}, and N_{60}, respectively. The pattern of response to organic addition was Co > BA > BB. Highest chlorophyll content 41.3 mg g^{-1} f.w was obtained by Co +180 kg N ha^{-1} representing 72.8% increase over the lowest value obtained by BB treatment.

Effect on plant height, number of branches plant^{-1}, 1000-seed weight and fresh and dry weight.

Table 4 shows that organic amendments and N-fertilization increased plant height, 1000-seed weight, total fresh weight and total dry weight of sorghum plants. The effect of N followed a pattern of $N_{180} > N_{120} > N_{60} > N_0$; and the effect of organic sources was Co > BA > BB for all traits. The relative increases of total dry weight as affected by N-addition rates were 138, 105 and 51.6% due to $N_{180,}$ N_{120} and N_{60} respectively. Increases due to the organic amendments were 27.0 and 14.8% due to BA and BB respectively.

Highest values of plant height, number of branches plant^{-1}, 1000- seed weight and total dry weight were obtained due to Co+N_{180} representing increases of 21.4, 93.8, 45.2 and 227%, respectively compared with BB. Sohi (2012) obtained positive response to biochar regarding environmental quality and plant nutrition. The positive response obtained in the current study by the organic amendments suggests major benefits due to increased N retention and N-use efficiency (Hossain *et al.,* 2010; Van Zwieten *et al.,* 2010a; Zhang *et al.,* 2010), increased enzymatic activity (Paz-Ferreiro *et al.,* 2012) and improvement of soil moisture regime (Zhang *et al.,* 2012 a, b and c).

The favorable effect of nitrogen fertilizer indicates stimulation of plant growth, which would increase photosynthetic pigments and photosynthesis (Wortman *et al.,* 2011). The effects of biochar in regulating soil hydrological, physical and chemical properties were stated by Hill *et al.* (2007). Von Glisczynski *et al.* (2016) reported that biochar can affect the colonization of roots by beneficial microorganisms; and Biederman and Harpole (2013) showed that biochar increased growth and crop yield as well as soil microbial biomass, rhizobia nodulation, and plant nutrient s in plant. Studies by Chan *et al.,* (2007), Alburquerque, *et al. (*2013), Abbasi and Anwar (2015), Van Zwieten, *et al.* (2010b) Li and Shang guan (2018), Asia, *et al.* (2009) and (Schulz and Glaser) 2012) showed that biochar was most effective in crop yield particularly when applied with mineral fertilizers.

Table 4. Yield and yield component of sorghum plants as affected by organic amendments and N-addition rate

Organic Sources (OS)	N-Rate, kg ha^{-1} (NR)	Plant height (cm)	Number of branches $plant^{-1}$	1000 -grain weight (g)	Fresh yield ($Mg\ ha^{-1}$)			Dry yield ($Mg\ ha^{-1}$)		
					Cut 1	Cut 2	Total	Cut 1	Cut 2	Total
Biochar (A)	0	178	3.25	33.3	30.6	25.0	55.6	3.43	2.83	6.26
	60	185	4.30	35.2	46.0	34.8	80.9	6.86	3.64	10.5
	120	193	5.18	38.2	53.8	46.2	100	8.45	4.64	13.1
	180	198	5.44	40.1	69.9	55.8	126	9.76	5.10	14.9
Mean		189 b	4.54	36.7 b	50.1	40.5	90.6 b	7.13	4.05	11.2 b
Biochar (B)	0	173	3.20	30.5	24.9	20.9	45.8	2.71	2.62	5.33
	60	178	4.00	33.0	37.9	30.6	68.5	5.29	3.43	8.71
	120	184	5.10	35.9	43.7	37.2	80.9	7.55	4.00	11.6
	180	190	5.17	38.1	53.5	45.2	98.8	9.33	4.40	13.4
Mean		181 c	4.37	34.4 c	40.0	33.5	73.5 c	6.22	3.61	9.76 c
Compost	0	180	3.36	35.4	30.9	26.7	57.6	4.48	3.14	7.62
	60	188	4.88	38.2	53.2	41.3	94.5	5.62	4.29	9.90
	120	195	5.77	42.2	60.5	52.1	113	9.48	5.19	14.7
	180	210	6.20	44.3	71.7	65.9	138	10.8	6.60	17.4
Mean		193 a	5.05	40.0 a	54.1	46.5	101 a	7.60	4.81	12.4 a
Mean of N-rate	0	177 d	3.27 c	33.1 d	28.8	24.2	53.0 d	3.54	2.86	6.40 d
	60	184 c	4.39 b	35.5 c	45.7	35.6	81.3 c	5.92	3.79	9.70 c
	120	191 b	5.35 a	38.8 b	52.7	45.2	97.8 b	8.49	4.61	13.1 b
	180	199 a	5.60 a	40.8 a	65.0	55.6	121 a	9.96	5.37	15.2 a
F-test	OS	**	ns	**			**			**
	NR	**	**	**			**			**
	OSxNR	ns	ns	*			**			**

Macronutrients content and uptake by sorghum

Data in Table 5 show that N, P and K contents and uptake increased due to addition of compost and biochar as well as mineral-N. This positive effect could be related to N effect on plants and improving the availability of soil nutrients (Kandil *et al.,* 2011, Namvar *et al.,* 2012 and Daneshmand *et al.*, 2012) as well as the increased N uptake increases N use efficiency (Maral 2012).

The effect of mineral-N followed the pattern of $N_{180} > N_{120} > N_{60} > N$. The effect of organic amendments was Co>BA > BB. Highest N, P and K uptake showed increases of 396, 457 and 318%, respectively by Co+N_{180} as compared with BB+N_0.

Table 5. Macronutrients content and uptake by sorghum plants as affected by organic amendments and N-addition rate

Organic sources (OS)	N-Rate, kg ha^{-1} (NR)	Macronutrients content ($g\ kg^{-1}$)			Macronutrients uptake ($kg\ ha^{-1}$)		
		N	P	K	N	P	K
Biochar (A)	0	13.8	3.41	23.0	86.4	21.3	144
	60	16.5	3.72	26.6	173	39.1	279
	120	17.9	4.22	27.5	235	55.3	360
	180	19.5	4.61	28.3	291	68.7	422
Mean		16.9 b	3.99 b	26.4 a	196	46.1 b	301 b
Biochar (B)	0	13.5	3.11	22.5	72.0	16.6	120
	60	15.4	3.52	25.5	134	30.7	222
	120	16.6	3.93	26.4	193	45.6	306
	180	17.8	4.32	26.9	239	57.9	361
Mean		15.8 c	3.72 b	25.3 b	159	37.7 c	252 c
Compost	0	14.4	3.71	23.5	110	28.3	179
	60	17.7	4.42	26.1	175	43.8	258
	120	19.6	4.82	27.8	288	70.9	409
	180	20.5	5.31	28.8	357	92.4	501
Mean		18.1 a	4.57 a	26.6 a	232 a	58.9 a	337 a
Mean of N-rate	0	13.9 d	3.41 d	23.0 d	89.4 b	22.1 d	148 d
	60	16.5 c	3.89 c	26.1 c	161 ab	37.9 c	253 c
	120	18.0 b	4.32 b	27.2 b	238 a	57.3 b	358 b
	180	19.3 a	4.75 a	28.0 a	295 a	73.0 a	428 a
F-test	OS	**	**	**	ns	**	**
	NR	**	**	**	*	**	**
	OSxNR	ns	ns	ns	ns	*	**

Micronutrients content and uptake by sorghum

Table 6 shows contents and uptake of Fe, Mn and Zn by sorghum. Such increases may be attributed to the role of organic amendments in: *i*) Releasing of these nutrients through microbial decomposition of organic matter; *ii*) Enhancing the chelation of metal ions *iii*) Lowering the redox statues of iron and manganese, leading to reduction of higher Fe^{3+} and Mn^{4+} to Fe^{2+} and Mn^{2+} and / or transformation of insoluble chelated forms into more soluble ions (Nasef *et al*., 2009).

Organic manures would cause favorable soil physical conditions, increasing availability and uptake of nutrients (Rashed *et al.*, 2011). Increased uptake on nutrients upon adding organic manures were reported by Hegazi (2004) on maize and Joshi *et al.*, (2012) on wheat. These results are in agreement with those obtained by Berhanu *et al.* (2013) and Namvar and Teymur (2013).

Table 6. Micronutrients content and uptake by sorghum as affected by organic amendments and N-addition rate

Organic sources (OS)	N-Rate, kg ha^{-1} (NR)	Micronutrients content (mg kg^{-1}) Fe	Mn	Zn	Micronutrients uptake (g ha^{-1}) Fe	Mn	Zn
Biochar (A)	0	59.3	34.9	18.4	371	218	115
	60	64.7	38.5	20.4	679	404	214
	120	69.4	41.3	22.7	909	541	297
	180	73.0	44.9	26.4	1088	669	393
Mean		66.6	39.9	22.0	762	458	255
Biochar (B)	0	54.3	32.4	15.3	289	173	82
	60	58.1	35.1	18.8	506	306	164
	120	64.2	39.2	21.9	745	455	254
	180	68.9	42.5	23.9	923	570	320
Mean		61.4	37.3	20.0	616	376	205
Compost	0	64.0	36.0	20.8	488	274	158
	60	68.2	40.1	23.8	675	397	236
	120	74.0	45.6	27.3	1088	670	401
	180	76.9	49.4	29.7	1338	860	517
Mean		70.8	42.8	25.4	897	550	328
Mean of N-rate	0	59.2	34.4	18.2	383	222	118
	60	63.7	37.9	21.0	620	369	205
	120	69.2	42.0	24.0	914	555	317
	180	72.9	45.6	26.7	1116	700	410
F-test	OS	**	**	**	**	**	**
	NR	**	**	**	**	**	**
	OSxNR	*	ns	ns	**	**	**

The Co+N_{180} superior to the other treatments giving 41.6, 52.5 and 94.1% increases for Fe, Mn and Zn contents, respectively as well as 363, 397 and 530% for Fe, Mn and Zn-uptake as compared with the BBN_0. Mineral-N treatments followed an order of $N_{180} > N_{120} > N_{60} >$ N while organic amendments followed a pattern of Co > BA> BB.

Effect of the treatments on N utilization efficiency ((NUE) Nitrogen Use Efficiency kg kg^{-1}

The value of NUE was increased by combination mineral –N with compost (Table 7). Application of biochar decreased NUE probably due to nitrogen in biochar B was not readily available for plant and NUE increased as the nitrogen addition rate increased up to 120 kg N ha^{-1} and then slightly decreased. The NUE ranged from 22.7 to 45.5 kg kg^{-1}. The highest NUE was obtained Co+N_{120} and the lowest was by Co+N_{120}.

Nitrogen Agronomic Efficiency (NAE) kg kg^{-1}

The NAE parameter (the plants ability to increase the yield in response to N fertilization levels) is expressed as kg grain per kg of applied N. It followed the same pattern shown by NUE and apparent nitrogen recovery (ANR). The increase of N rate increased the NAE values. The above three traits which behaved similarly, show that plants absorb more N when it is of high level in the soil. As the level of N increased the relative absorption of N increased. The highest NAE value of 34.56 kg kg^{-1} was obtained by Co+ N_{180} which resulted in 298% increase compared with Co+$N6_0$.

Table 7. NUE, NAE (kg kg^{-1} N) and ANR (%) of sorghum as affected by biochar and compost as well as N-rates.

N-rate Organic sources	Nitrogen Use Efficiency, NUE (kg kg^{-1} N) N0 (0 kg N ha^{-1})	N1 (60 kg N ha^{-1})	N2 (120 kg N ha^{-1})	N3 (180 kg N ha^{-1})	Nitrogen Agronomic Efficiency, NAE (kg kg^{-1} N) N0 (0 kg N ha^{-1})	N1 (60 kg N ha^{-1})	N2 (120 kg N ha^{-1})	N3 (180 kg N ha^{-1})	Apparent Nitrogen Recovery, ANR (%) N0 (0 kg N ha^{-1})	N1 (60 kg N ha^{-1})	N2 (120 kg N ha^{-1})	N3 (180 kg N ha^{-1})
Biochar A	0.0	29.3	31.3	31.2	0.0	11.8	16.4	18.1	0.0	24.2	35.6	42.8
Biochar B	0.0	22.7	26.1	26.6	0.0	8.80	14.1	16.0	0.0	16.1	27.3	33.1
Compost	0.0	37.6	45.5	45.4	0.0	8.70	21.9	34.6	0.0	24.7	55.1	64.5

Apparent Nitrogen Recovery (ANR)

The ANR parameter, which is the proportions of fertilizer N recovered by the crop was greatest when 180 kg N ha^{-1} was added in combination with compost, giving 64.5% recovery. This shows that the application of the high rate of nitrogen caused an enhancement of plant growth, causing the roots to explore a greater soil volume and absorb more N from the soil lower N recovery was by by N_{60}. Combined application of organic amendments and mineral fertilizer may provide more favorable conditions for plant growth. The use of organic sources provides not only nutrients in available forms but also organic matter, which is as an ecological method of sustaining soil productivity.

CONCLUSION

Application of compost and biochar increased soil fertility, particularly the light textured soils. Such practice enhances physiological and biochemical aspects of plant growth. Under the current experimental conditions, it could be concluded not application of 24 Mg ha^{-1} biochar or compost combined with 120 kg N ha^{-1} as ammonium nitrate gave the highest positive effects in terms of N use efficiency saving about 33 to 65 % of, the recommended rate of N.

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البيوشار و الكمبوست ورفع كفاءة التسميد النيتروجيني و محصول حشيشة السودان (*Sorghum bicolor* var. Sudanese) النامي في أرض رملية

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تم إجراء تجربتين حقليتين خلال موسم الصيف لعامين متتالين هما 2017 و 2018 بالقنطرة شرق - محافظة الأسماعيلية ، مصر و ذلك لدراسة تأثير إضافة كلا من البيوشار و الكمبوست علي رفع كفاءة أستخدام التسميد النيتروجيني وجودة الأرض الرملية وكذلك إنتاجية و جودة محصول حشيشة السودان صنف هجين 102. (*Sorghum bicolor* var. Sudanese). تم أستخدام 4 معدلات من النيتروجين المعدني وهي (0 ، 60 ، 120 و 180 كجم ن هكتار$^{-1}$) علي صورة نترات الأمونيوم (330 جم ن كجم$^{-1}$) وثلاث مصادر عضوية (نوعين من البيوشار و الكمبوسبت) و التي أضيفت بمعدل 24 ميجاجرام هكتار$^{-1}$. يمكن تلخيص أهم النتائج المتحصل عليها فيما يلي: تم زيادة المحتوي الميسر من عناصر ن، فو ، بو ، حديد ، منجنيز و زنك بالتربة بعد الحصاد نتيجة لإضافة المعاملات المستخدمة بالتجربة وكانت أعلي القيم المتحصل عليها نتيجة إضافة الكمبوست + 180 كجم ن هكتار$^{-1}$. أنخفضت درجة حموضة التربة نتيجة للإضافات العضوية للتربة بينما حدثت زيادة طفيفة في قيم التوصيل الكهربي نتيجة إضافة مصادر البيوشار. أعلي القيم لمحتوي الكلوروفيل الكلي ، البروتين والمحصول وجدت نتيجة أستخدام الكمبوست + 180 كجم ن هكتار$^{-1}$ والتي أعطت أيضاً أعلي قيم لتركيزات عناصر ن، فو ، بو ، حديد ، منجنيز و زنك بالنبات وكذلك الكميات الممتصة منها. أعلي كفاءة للنيتروجين المستخدم تم التوصل إليها نتيجة معاملة الإضافة الكمبوست + 120 كجم ن هكتار$^{-1}$. كانت أفضل معاملة علي الأطلاق من حيث تحسين خواص التربة ، زيادة إنتاجية حشيشة السودان وجودتها من حيث محتوي البروتين و الكلوروفيل وكذلك تركيزات العناصر الممتصة بواسطة النباتات كمقارنة بباقي المعاملات تحت الدراسة هى معاملة الكبوست + 180 كجم لكل هكتار.