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Behavior of Biochar on Alkaline Soil and its Impact on Tomato Growth and Productivity

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ABSTRACT

Biochar is projected as a soil conditioner to amend soil physical and chemical properties. However, behavior of biochar in alkaline soils under arid and semi-arid conditions in Egypt not much investigated. In this study, field experiments were carried out under greenhouse conditions to explore the effect of applying biochar and sugarcane bagasse with two different ways and at three different rates (10, 20 and 30 ton ha^{-1}) on some properties of alkaline clay loam soil and tomato growth and yield. The experiments were conducted for two successive seasons of 2015 and 2016. Mixing biochar with top surface soil at rates of 20 and 30 ton ha^{-1} reduced particle and bulk density and increased the porosity and water holding capacity. The results indicated that biochar application did not affect soil pH, however, decreased EC_e and increased soil organic carbon, exchangeable cations and cation exchange capacity. Addition of biochar by mixing through the top-twenty-centimeters of soil surface was more effective than applying as a thin layer under the top-twenty-centimeters of soil surface on improving tomato growth. Application of organic residues such as sugarcane bagasse caused limited positive effects on soil physical-chemical properties. In comparison, this shows the benefit effect of pyrolysis for organic residues on soil properties. Tomato growth and yield only was affected significantly ($P < 0.05$) by biochar application at a rate of 20 ton ha^{-1}.
Keywords: biochar; alkaline soil; bagasse; tomato

INTRODUCTION

By 2050 the world human population is projected to reach 9.2 billion. Projected population growth rates for the next 30 years will require an increase in food production equal to 20% in developed countries and 60% in developing countries to maintain present levels of food consumption (USDA, 2013).

Land resources in Egypt are limited and always there is a need for contentious improving soil workability and productivity to guaranty the rapidly increase in population. One of the Egyptian farmer's traditions, was and still burning the agricultural wastes over the soil surface and then ploughing the derived ash into the top-soil to enrich the soil quality and fertility.

Using biochar as a soil amendment has been suggested as a sustainable approach in achieving soil workability and enhancing crop productivity along with other environmental benefits (Chen *et al*., 2007; Mulabagal *et al*., 2017). Biochar addition to soil is a hopeful option for climate change mitigation and has many benefits on soil properties and plant growth (Vaccari *et al*., 2015). The positive impacts of biochar application on soil workability and crop productivity have been mostly investigated in experiments under humid and tropical environments, on soils with low fertility and acid soils (Glaser *et al*., 2002; Van Zwieten *et al*., 2010; Carter *et al*., 2013; Jien and Wang, 2013; Wan *et al*., 2014).

The most common definition for the biochar is: "biochar is a black carbon produced through pyrolysis of biomass" (Lehmann *et al*., 2006). Also, biochar can be defined as a solid material obtained from the thermo-chemical alteration of biomass in an oxygen-limited environment (IBI, 2012; Mulabagal *et al*., 2017). Biochar could be produced from vary biomass sources including woody residues (Van Zwieten *et al*., 2010). Biochar produced from wood materials has a large surface area and cation exchange capacity (CEC) and therefore its addition to soils increases the CEC of the soil (Yanai *et al*., 2007; Joseph *et al*., 2009; Blackwell *et al*., 2010; Van Zwieten *et al*., 2010).

It has been found in a review from 634 publications that: a) the majority of published investigations about biochar have been carried out in developed countries; b) studies on biochar produced in small kilns are more common in developed countries than biochar produced at a commercial scale; c) in developing countries biochar produced using traditional techniques is more commonly used than biochar produced in modern pyrolysis units; d) laboratory and greenhouse studies are more common than field experiments; and e) biochar mostly derived from wood and municipal wastes in comparison with crop residues and manures (Agegnehu *et al*., 2017).

In a pot experiment with wheat, the obtained results showed that biochar application caused a reduction in plant sodium uptake and increased the growth of wheat under salinity stress, which was due to the high adsorption capacity of the biochar and decreasing osmotic stress by enhancing soil moisture content and by releasing mineral nutrients (K^+, Ca^{++}, Mg^{++}) into soil solution (Akhtar *et al*., 2015).

Sugarcane residues such as straw and bagasse were used as a low-cost soil amendment to enhance soil organic matter and improve soil hydro-physical properties (Leal *et al*., 2013; Abd El-Halim and Kumlung, 2015). Bagasse is a fibrous residue derived from sugarcane after extraction of sugar juice at local sugarcane mills in Egypt.

Studies about biochar application to alkaline soil under aired and semi-aired conditions still rare especially in Egypt. Therefore, this study was to stand on the effects of biochar and bagasse on tomato growth and yield characteristics and some soil properties under field conditions.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at a greenhouse of the Vegetables Scientific Experimental Farm, Faculty of Agriculture, Minia University, El-Minia, Egypt. The study site is located at latitude 28°7' N and longitude 30°43' E. The experiment was conducted for two successive seasons of 2015 and 2016. Tomato transplants were transplanted on 15 and 17 of February in the first and second seasons, respectively. The investigated soil is clay loam, classified as Alluvial soil according to Hamdi and Abdelhafez (2001) and its basic physiochemical properties are shown in Table 1.

Biochar and bagasse characterizations

The biochar (BC) that was used in this study was produced from mango wood in a local kiln. This kind of kilns is using usually for manufacturing charcoal for cooking and smoking purposes. Biochar was ground well and sieved through a 2-mm sieve. Sugarcane bagasse (SCB) was collected from local markets, then washed, sun-dried and ground to a size < 1 cm. The physicochemical properties of biochar and SCB are shown in Table 1.

Table 1. Some physicochemical properties of biochar and bagasse used in this study.

	Sand	Silt	Clay	Class	Soluble cations ($cmol_c\ kg^{-1}$)				Exchangeable cations ($cmol_c\ kg^{-1}$)				CEC ($cmol_c\ kg^{-1}$)	pH	EC_e	OC	N %	K %	Na %	D_p Mg m^{-3}	D_d Mg m^{-3}
					Ca	Mg	Na	K	Ca	Mg	Na	K									
Soil	32.82	29.97	37.21	Clay loam	0.9	0.23	0.75	0.048	38.62	7.78	0.6	0.95	47.95	8.13 (1:2.5)	1.48 (1:2.5)	9.1 (SOC g kg^{-1})	-	-	-	2.55	1.23
*BC	-	-	-	-	0.35	0.10	8.22	3.15	32.41	2.63	9.89	1.71	49.13	9.02 (1:10)	5.15 (1:2.5)	70.89% (TC)	0.45	-	-	1.12	0.29
*SCB	-	-	-	-	-	-	-	-	-	-	-	-	-	3.85 (1:10)	1.05 (1:2.5)	41.26% (TC)	0.62	1.12	0.22		-

*** BC: biochar, SCB: sugarcane bagasse**

Experimental setup

The experiment consisted of 13 treatments representing combinations of two organic amendments (biochar and sugarcane bagasse) and two ways of soil application (first way was by mixing the biochar or bagasse through the top-twenty-centimeters of soil surface, and the second way was by applying the biochar or bagasse as a thin layer under the top-twenty-centimeters of soil surface) at four rates (0.0, 10, 20, and 30 ton ha^{-1}). The experimental design was a split-plot system in a randomized complete block design with three replicates. Organic amendments with two ways of soil application allocated to the main and sub-plots, respectively. The sub-plot was 7.65 m^2 in area including 15 plants to make up a total of 585 plants in the experiment. Abbreviations of the studied treatments are shown in Table (2).

Table 2. Abbreviations of the studied treatments

Biochar levels	Bagasse levels	Application method	Abbreviation
-	-	-	Control
10 ton ha^{-1}	-	Method 1	T1 = BC1-10
10 ton ha^{-1}	-	Method 2	T2 = BC2-10
20 ton ha^{-1}	-	Method 1	T3 = BC1-20
20 ton ha^{-1}	-	Method 2	T4 = BC2-20
30 ton ha^{-1}	-	Method 1	T5 = BC1-30
30 ton ha^{-1}	-	Method 2	T6 = BC2-30
-	10 ton ha^{-1}	Method 1	T7 = SCB1-10
-	10 ton ha^{-1}	Method 2	T8 = SCB2-10
-	20 ton ha^{-1}	Method 1	T9 = SCB1-20
-	20 ton ha^{-1}	Method 2	T10 = SCB2-20
-	30 ton ha^{-1}	Method 1	T11 = SCB1-30
-	30 ton ha^{-1}	Method 2	T12 = SCB2-30

Method1: mixing the biochar or bagasse through the top-twenty-centimeters of soil surface
Method2: applying the biochar or bagasse as a thin layer under the top-twenty-centimeters of soil surface

Biochar and bagasse were randomly applied 15 days before the beginning of first season. For second season, all treatments were applied with the same inorganic fertilizers as in the first season but without addition of biochar or bagasse.

At the fifth leaf stage, tomato (*Solanum lycopersicum* L.) cv. Indiana seedlings were transplanted at greenhouse which was 9 m width x 40 m length x 3.2 m height as the normal house, covered with thiram film. The greenhouse soil was divided into 5 ridges (170 cm width). The space between transplants was 30 cm, one row of plants on each ridge. The drip irrigation system consisted of polyethylene hoses GR (4 L h^{-1}) of 16 mm in diameter, allocating one hose for each ridge. Irrigation frequency was every 2 days to maintain soil moisture according to Qassim and Ashcroft (2002), which is the optimum moisture level of tomato plants.

All plots received a recommended dose of NPK fertilizers (300-110-115 kg ha^{-1}) according to Ministry of Agriculture and Land Reclamation (2009) as ammonium sulfate (20.5%N), phosphoric acid (58% P_2O_5) and potassium sulfate (48% K_2O). The fertilizer solutions were injected directly into the irrigation water using a venture injector at two doses weekly. Other recommended agricultural practices were followed as commonly used in the commercial production of tomato.

Soil properties measurement

Soil samples were collected from the top-twenty-centimeters. The samples were air-dried, ground and sieved through 2 mm sieve to determine the investigated soil properties. Particle density (D_p) was measured with the pycnometric method (Blake and Hartge, 1986). Undisturbed soil samples were collected using core method to determine bulk density (D_b) and water holding capacity (WHC) (Blake and Hartge, 1986). The porosity was calculated using the formula:

Total porosity = 100(1 – D_b/ D_p)

where D_b = Bulk density, D_p = Particles density.

The particle size distribution was determined by the pipette method (Sheldrick and Wang, 1993). The pH and electrical conductivity (EC) were determined at 1:2.5 w/v by pH meter (Jenway, 3020 pH meter) and EC meter (Jenway, 470 cond. meter). The soil organic carbon (SOC) was determined using wet oxidation method (Nelson and Sommers, 1982). Soluble cations (Ca^{++}, Mg^{++}, Na^{+}, and K^{+}) were extracted with distilled water and then Ca^{++}, Mg^{++} were determined by titration with versene and Na^{+}, K^{+} were analyzed by Flame Photometer (Jenway, Model PFP7). Extractable cations (Ca^{++}, Mg^{++}, Na^{+}, and K^{+}) were extracted with 1N ammonium acetate at pH 7 and then determined as mentioned above. Exchangeable cations were calculated by subtracting the soluble cations from the extractable. Cation exchange capacity (CEC) was determined using 1 M sodium acetate pH 8.2. Soil properties analyses were in accordance with Page *et al*., 1982 and Black *et al*., 1965.

Growth and fruit yield

After 60 days from transplanting, five plants from each replicate were randomly chosen to measure shoot fresh and dry weight. At the maturity stage, tomato fruit were harvested and number of fruits and fruit fresh weight was immediately taken. Total yield per plant was recorded accumulatively after each harvesting.

Statistical analysis

Data obtained in the two seasons of study was subjected to analysis using MSTATC software version 4 (1996). For treatments that were significant, mean separation was done using the Least Significant Differences (LSD) test at 0.05 probability level (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of treatments on soil physical properties

Particle density (D_p) of the investigated soil significantly influenced by biochar application at a rate 20 and 30 ton ha^{-1} recording 2.51 and 2.50 Mg m^{-3} for T3 and T5 treatments compared to 2.55 Mg m^{-3} for control (Table 3). No other significant changes in soil particle density were observed for the rest of treatments. Bulk density decreased with mixing biochar and bagasse thoroughly with the soil, accompanied by an increase of porosity (Table 3). Significant decreases of D_b or increases of porosity were noticed only for T3, T5, T9 and T11 treatments. Concerning WHC of soil, mixing biochar with the soil at rates of 20 and 30 ton ha^{-1} significantly increased WHC by 4.97 and 7.06% relatively to control. The response of WHC to bagasse application was not statistically significant.

Table 3. Effect of biochar and bagasse applications on some soil physical properties:

Treatment	D_p* Mg m^{-3}	D_b* Mg m^{-3}	Porosity, m^3 m^{-3}	WHC% *
Control	2.55	1.22	0.524	41.22
T1	2.53	1.21	0.523	41.40
T2	2.54	1.21	0.525	41.64
T3	2.51	1.18	0.531	43.27
T4	2.56	1.20	0.529	42.15
T5	2.50	1.16	0.535	44.13
T6	2.54	1.21	0.526	41.79
T7	2.55	1.19	0.535	41.26
T8	2.56	1.22	0.525	41.87
T9	2.54	1.15	0.549	42.04
T10	2.55	1.21	0.527	41.82
T11	2.53	1.14	0.551	42.60
T12	2.56	1.21	0.530	42.10
LSD_{05}	0.025	0.03	0.011	1.93

* **D_p: particle density, D_b: bulk density, WHC: water holding capacity**

Under conditions of this study, the most positive effect of biochar on the estimated physical properties was observed at the higher application rates. The biochar used in this study characterized by low particle density (1.12 Mg m^{-3}) and bulk density (0.29 Mg m^{-3}), which caused noticeable changes in soil physical properties. These results are consistent with studies of Busscher *et al*. (2011); Mukherjee and Lal (2013); Hammam and Mohamed, (2018). Also, application of biochar resulted in increasing soil WHC depending on its ability to retain water as an organic amendment and in soil pores with capillary forces (Tryon, 1948; Karhu *et al*., 2011). Application of sugarcane bagasse at a rate of 30, 45, 75 t/ha to clay soil at experimental farm resulted in significant reduction in soil bulk density and accordingly high porosity (Muhieldeen *et al*., 2014).

Generally, applying either biochar or bagasse beneath a 20-cm-layer of soil had no significant effect on the estimated soil physical properties of this layer. We suggest that, locating the applied amount of biochar or bagasse beneath a 20-cm-layer of soil retains more water with nutrients.

Effect of treatments on soil pH and EC_e

Biochar after being applied to soil for two seasons did not affect significantly the pH of the investigated soil, while soil pH values increased from 8.17 in the control to 8.24 and 8.25 in the treatments T3 and T5, respectively (Table 4). It was observed that the applied amount of biochar did not affect the pH in the same manner. Although the application rate of biochar in T5 was 1.5 times that in T3, there was no significant difference between T3 and T5.

Table 4. Effect of biochar and bagasse applications on some soil chemical properties:

Treatment	pH	EC_e * dS m^{-1}	SOC * g kg^{-1}	Soluble cations (cmolc kg^{-1})				Exchangeable cations (cmolc kg^{-1})				CEC * (cmolc kg^{-1})
				Ca	Mg	Na	K	Ca	Mg	Na	K	
Control	8.16	1.42	9.2	0.87	0.19	0.78	0.043	38.99	7.56	0.54	0.99	49.32
T1	8.17	1.17	11.0	0.69	0.20	0.99	0.055	38.91	8.20	0.96	1.15	50.51
T2	8.18	1.20	10.2	0.77	0.13	0.82	0.046	39.08	8.65	0.65	1.14	50.52
T3	8.24	1.13	11.2	0.69	0.26	0.93	0.053	39.96	8.73	1.00	1.28	52.42
T4	8.17	1.18	9.9	0.77	0.14	0.88	0.043	39.08	9.73	0.70	1.13	51.66
T5	8.25	1.15	11.3	0.77	0.30	0.91	0.048	40.66	8.66	0.95	1.19	52.75
T6	8.19	1.20	10.4	0.84	0.14	0.89	0.048	38.97	9.45	0.71	1.14	51.07
T7	8.17	1.29	10.3	0.81	0.29	0.77	0.057	38.43	7.97	0.51	1.18	48.54
T8	8.16	1.28	10.3	0.82	0.21	0.74	0.048	38.50	8.15	0.52	1.17	49.23
T9	8.16	1.22	10.5	0.82	0.30	0.82	0.059	38.26	8.56	0.52	1.18	49.37
T10	8.17	1.28	10.0	0.83	0.20	0.77	0.046	38.85	8.43	0.54	1.12	49.73
T11	8.15	1.20	10.5	0.85	0.30	0.90	0.050	39.14	7.74	0.64	1.13	49.46
T12	8.18	1.26	10.1	0.81	0.19	0.79	0.048	39.14	7.96	0.56	1.11	49.57
LSD_{05}	0.11	0.163	0.53	0.119	0.064	0.141	0.011	0.630	0.876	0.153	0.087	0.727

*** EC: electrical conductivity, SOC: soil organic carbon, CEC: cation exchange capacity**

Soil buffering capacity stood against changing soil pH in most treatments. Nevertheless, soil pH values increased in T3 and T5 as a function of pyrolysis temperature and biochar application rate. Most of reported data in many previous studies about biochar effect on soil pH have been achieved on acidic soils characterized by low pH compared to biochar with high pH (Carter *et al*., 2013; Wan *et al*., 2014; Shi *et al*., 2017, 2018). However, it was stated that pH buffering capacity (pHBC) chiefly affected by CEC of soils in tropical and subtropical regions (Nelson and Su, 2010; Xu *et al*., 2012; Shi *et al*., 2018). Our obtained results showed a significant increase in cation exchange capacity (CEC) of treated soil with biochar.

The effect of investigated treatments on EC_e is presented in Table (4). The EC_e of the studied soil decreased significantly in treatments T1, T2, T3, T4, T5 and T6 in comparison with the control ($p \leq 0.05$). In addition, there were no significant difference between treatments where biochar applied by mixing through the top 20 cm of soil and those where biochar applied as a thin layer under the top 20 cm of soil.

The higher relative decrease in EC_e compared to control was observed in biochar treatments T1, T3, and T5.

The EC_e decreased by 18%, 20%, and 19% for T1, T3, and T5, respectively. These results were opposite to those data obtained after rice husk-derived biochar application on an alkaline soil at Karaj, Iran (Abrishamkesh *et al*., 2015) and during lab incubation experiment as biochar derived from branches and trunks of Acacia applied to calcareous soil, where soil EC was increased (Shah *et al*., 2017).

Probable explanations for the reduction of the EC_e as the obtained results showed may be: 1. improvements in soil porosity due to the biochar application, which resulted in enhancing leached salts; 2. soil EC_e values were measured by the end of second season which could be gave chance for biochar lose its EC high value effect with time.

Effect of treatments on SOC

The obtained results showed that in comparison with control, treatments T1, T3, and T5 caused a significant increase in SOC, Table (4). However, there was a relative increase in SOC but not significant in treatments with bagasse compared to control. The relative increase in SOC in comparison with control was notable for treatments T1, T3, and T5, which recorded 12.24%, 14.29%, and 15.31%, respectively. The increase in SOC in treatments, where biochar was mixed with the soil, was due to the rich biochar in organic carbon as shown in Table 1. Several studies have reported that biochar application causes an increase in SOC (Carter *et al*., 2013; Abujabhah, *et al*. 2016; Agegnehu *et al*., 2016; Agegnehu *et al*., 2017; Hammam and Mohamed, 2018). Also, many reports presented that biochar considers as a source of stabile carbon (Joseph *et al*., 2010; Agyarko-Mintah *et al*., 2017).

Soluble and exchangeable cations and CEC

The response of soluble and exchangeable cations to investigated treatments was changeable (Table 4). Soluble Ca^{2+} significantly decreased in treatments T1 and T3, however there was no significant response in the rest of treatments. On a different manner in treatments where biochar and bagasse were mixed thoroughly with top soil, soluble Mg^{2+} significantly increased excluding T1, however the way of application in treatments T2, T4 and T6 has no significant effect on soluble Mg^{2+} comparing with control. The obtained data showed a significant increase in soluble Na^+ in treatments T1 and T3 compared to control. A tendency of decrease for soluble Na^+ and K^+ was observed by increasing the applied amount of biochar in treatments T1, T3 and T5, but without significant difference. Mixing bagasse with soil caused an increase in soluble K^+. Also, applying biochar or bagasse as a thin layer beneath the top soil did not affect significantly the soluble Na^+ and K^+. The chemical composition of the used biochar was the reason of increasing the amount of some soluble cations.

Generally, only biochar treatments affected exchangeable cations and CEC. Biochar application in treatments T1, T3 and T5 significantly increased exchangeable Ca^{2+}, Mg^{2+}, Na^+ and K^+, except for $Ca^{2+}$and Mg^{2+} were not statistically affected in treatment T1. Applying biochar as thin layer beneath the top soil in treatments T2, T4 and T6 did not affect exchangeable Ca^{2+}, nevertheless significantly increased the rest of exchangeable cations. Cation exchange capacity (CEC) significantly increased as a result of biochar application.

Proportional to biochar application rate CEC increased linearly in treatments T1, T3 and T5. This phenomenon was also stated by Sun *et al.* (2016) when applied wheat straw biochar at different rates (5, 10 and 20 g/kg) to saline soil in Yellow River Delta. Similar trends were observed in other studies and reports (Glaser *et al.* 2002; Rondon *et al.* 2007; Blackwell *et al.* 2010; Van Zwieten *et al*. 2010; Ullah *et al*. 2018). On the other hand, all treatments of bagasse application only significantly increased exchangeable K^+.

The increase in exchangeable cations and consequently CEC in treatments T1, T3 and T5 was a result of considerable high CEC of used biochar. However, the evidence increases in most of exchangeable cations and CEC in treatments T2, T4 and T6 may be caused by movement of colloidal biochar particles from the thin layer upward the top soil.

Tomato growth and fruit yield response to treatments

Application of biochar as mentioned above improved soil physical and chemical properties and consequently changed soil water and nutrient conditions affecting tomato growth. Recorded data showed no significant (p=0.05) difference in number of fruits/plant and fruits fresh wt./plant between control and biochar treatments except for T3 treatment (Fig. 1. a, b, c, d). For the latter, number of fruits/plant and fruits fresh wt./plant were higher than the other treatments at the first and second season. Plant fresh and dry weights were significantly increased at biochar application rate of 20 ton ha^{-1} relatively to control (Fig. 2. a, b, c, d). Regardless the biochar application way, there was a tendency of decrease in all growth parameters as the application rate increased to 30 ton ha^{-1} relatively to T3 and T4 treatments. With few exceptions, application of sugarcane bagasse significantly decreased all growth parameters at the first season relatively to control, however, no significant differences were observed at the second season. Addition of biochar by mixing through the top-twenty-centimeters of soil surface was more effective than applying as a thin layer under the top-twenty-centimeters of soil surface on improving tomato growth.

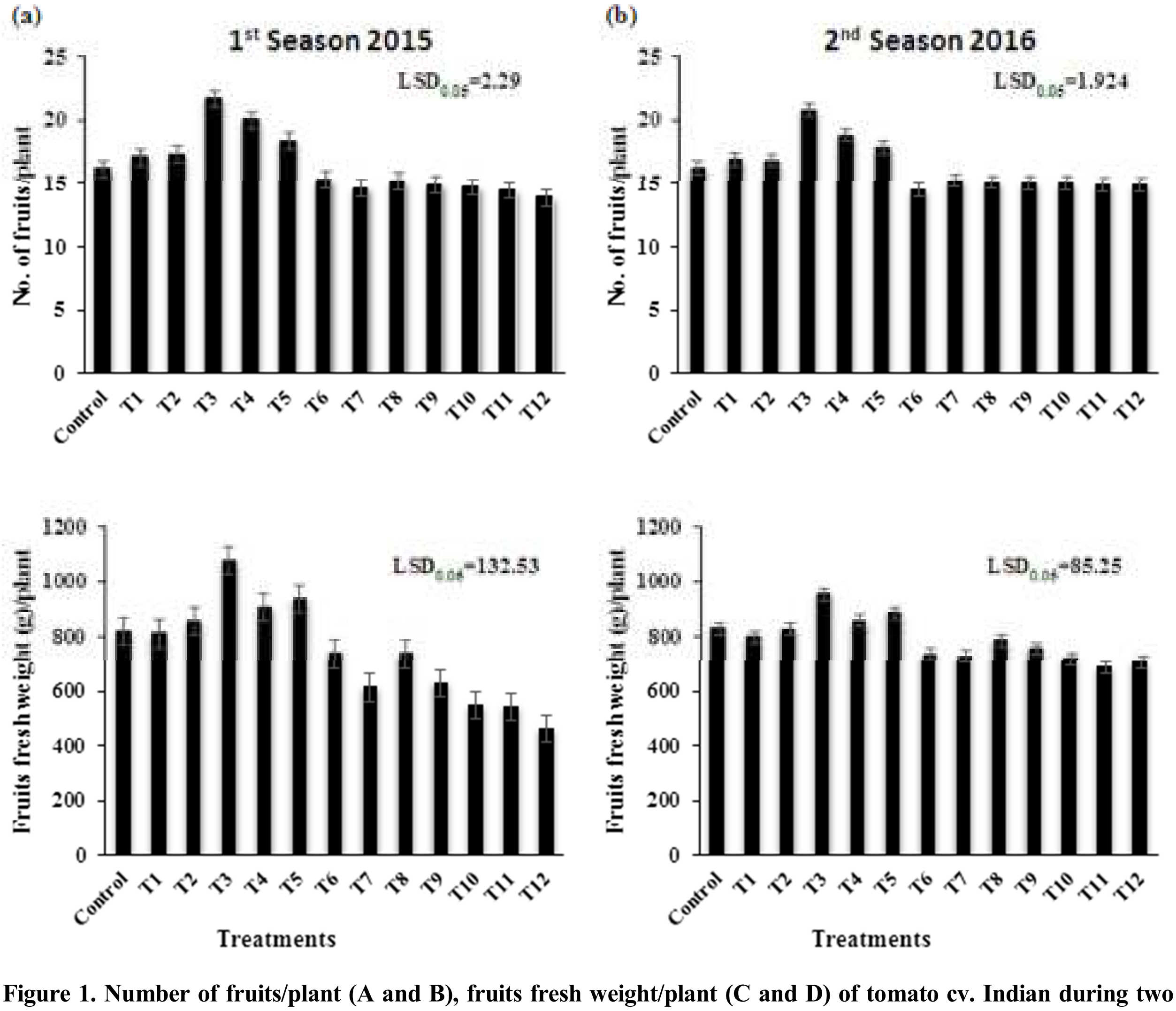

Figure 1. Number of fruits/plant (A and B), fruits fresh weight/plant (C and D) of tomato cv. Indian during two seasons of 2015 and 2016

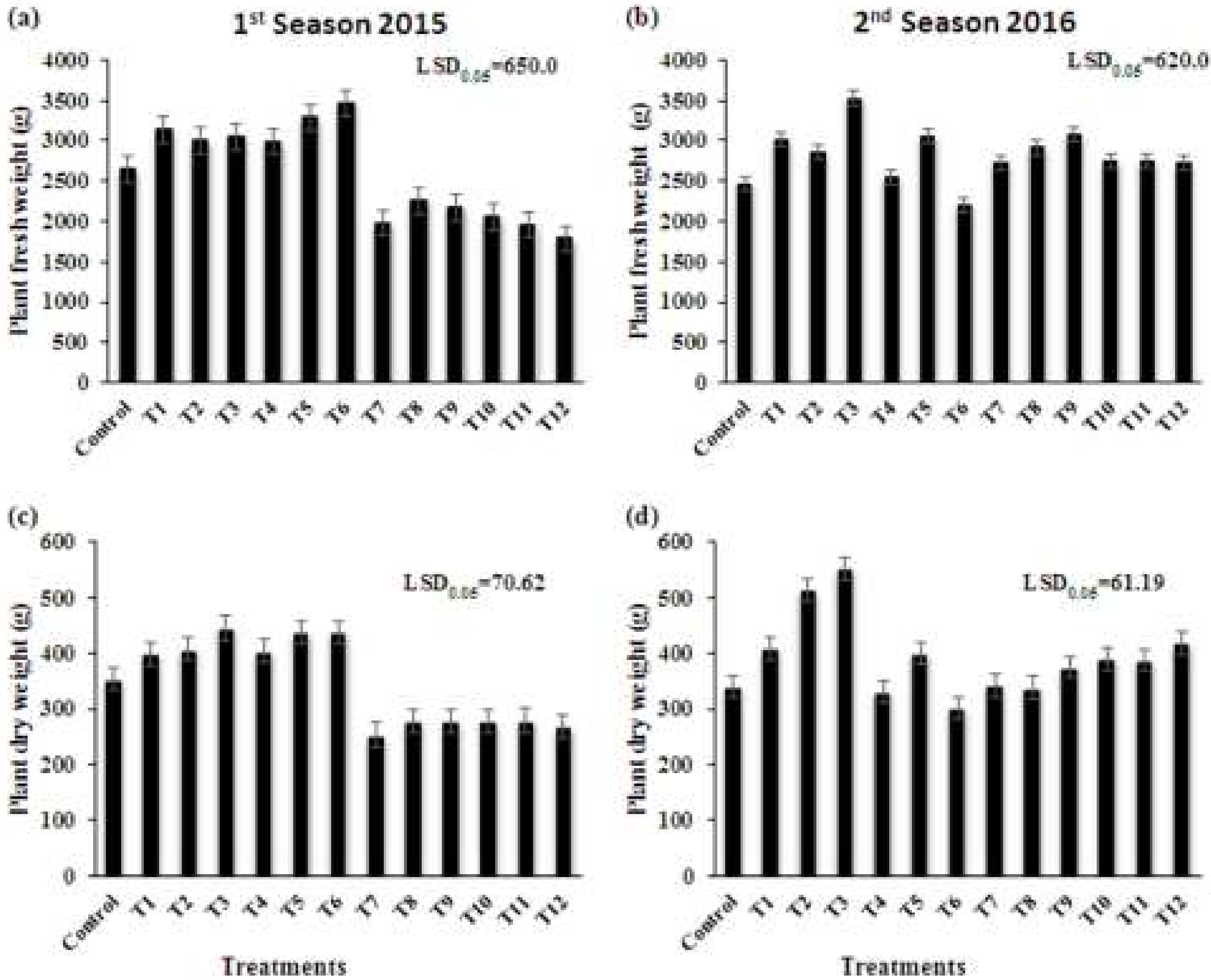

Figure 2. Plant fresh weight (A and B) and plant dry weight (C and D) of tomato cv. Indian during two seasons of 2015 and 2016

The positive tomato growth responses from biochar application were due to not only biochar characteristics (Table 1) but the indirect improving soil properties such as porosity, WHC, SOC and CEC (Table 3, 4). The raising in soil cation exchange capacity as result of biochar addition should improve soil nutrients (Glaser *et al*., 2002; Abrishamkesh *et al*., 2015; Vaccari *et al*., 2015; Li *et al*., 2018).

CONCLUSION

Under this greenhouse experiment, application of biochar at three different rates by mixing thoroughly with the top-twenty-centimeters of alkaline soil caused significant improvements in some soil physical and chemical properties after two successive seasons. On the other hand, sugarcane bagasse made slight improvements in soil physical properties and SOC. Only biochar promoted plant growth and yield of tomato at both seasons. The superior biochar application rate was 20 ton ha^{-1} which recorded the higher growth parameters compared to the rest of treatments.

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سلوك الفحم الحيوي في الأراضى القاعدية وتأثيره على نمو وإنتاج الطماطم

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البيوتشار (الفحم الحيوي) يدرس كمحسن للخواص الطبيعية والكيميائية للتربة. ومع ذلك ، فإن سلوك الفحم الحيوي القلوي في الأراضى القاعدية تحت ظروف جافة وشبه جافة في مصر لم يتم دراسته بشكل كافى. في هذه الدراسة ، أجريت تجارب حقلية تحت ظروف الصوبة الزراعية لاستكشاف تأثير استخدام كلا من الفحم الحيوى و مصاصة قصب السكر بطريقتي اضافة مختلفتين وبثلاثة معدلات مختلفة (10، 20، 30 طن هكتار) على بعض خواص تربة طميية طينية قاعدية وكذلك على نمو ومحصول الطماطم. أجريت التجارب لموسمين متتاليين في 2015، 2016م. كنتيجة لاضافة الفحم الحيوى خلطا مع الطبقة السطحية من التربة بمعدلات 20، 30 طن للهكتار انخفض كلا من الكثافة الحقيقية والظاهرية للتربة وارتفعت المسامية الكلية وسعة الاحتفاظ بالماء. النتائج اوضحت ان اضافة الفحم الحيوى لم تؤثر على رقم التفاعل (pH) بينما انخفض التوصيل الكهربى وارتفع محتوى التربة من الكربون العضوى وكذلك الكاتيونات المتبادلة وبالتالى السعة التبادلية الكاتيونية. اضافة الفحم خلطا مع 20 سنتيمتر من الطبقة السطحية من التربة كان افضل تأثيرا من وضع الفحم اسفل تلك الطبقة على نمو الطماطم. اضافة مخلفات عضوية مثل مصاص قصب السكر احدث تأثيرات ايجابية محدودة فى خواص التربة الطبيعية والكيميائية. فى المقابل هذا يظهر التأثير المفيد من اجراء عملية حرق المخلفات النباتية فى غياب جزئى أو كلى للاكسجين على خواص التربة. نمو الطماطم ومحصوله فقط تاثر معنويا بمعدل اضافة 20 طن للهكتار من الفحم الحيوي.