Effect of Biochar on Some Soil Properties and Tomato Growth under Saline Water Conditions

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Abstract— Pots experiment was conducted At the Key Laboratory of Efficient Irrigation-Drainage and Agricultural Soil-Water Environment-Hohai University. The aim of this research was to study the effect of biochar on some soil properties and tomato yield under saline water conditions. For this purpose biochar 0.0 (T1), 0.05 % (T2), 2% (T3) and 4% (T4) with two levels of salts in irrigation water (SL1 (1) and SL2 (3 dS/m^{-1})) were used. The results of soil bulk density were 1.04, 1.09 and 1.20 g/cm^3 for T2, T3 and T4 respectively, compared to control (1.016 g/cm^3). The application of biochar showed a significant ($P < 0.05$) change in soil bulk density, total porosity among the different rates of treatments application. The results of soil particle density showed non-significant difference between biochar treatments and control, also the clay, sand and silt fraction of the soils were not significantly affected by biochar applications. The statistical results indicated that there was no significant difference in physical soil properties before and after using the two treatments of saline water. Soil pH was decreased about (27%) by all biochar treatments. The soil EC results were 1.22, 0.59 and 0.40 dS/m^{-1} for T2, T3 and T4 respectively, compared to control 1.32 dS/m^{-1}. Organic carbon was increased with biochar treatments, T2 recorded 1.2%, T3 was 1.47% and T4 was 1.66% compared to control (0.98%). The results of soil pH were not significantly different ($p<0.05$) with that for saline water treatments. The average of soil EC was decreased about 8% by T2 and 55% by T3 and 70 % by T4. The application of biochar significantly ($P < 0.05$) increases tomato height, leaf number and yield relative to control. Also, the higher quantity of biochar applied the higher tomato height, leaf number and yield observed. Using of saline Water represents lower values for tomato height, leaf number and yield, but application of biochar with saline water showed a highest results in tomato height, leaf number, yield, physical and chemical soil properties. Generally, biochar reduced the effect of saline water and the degree of reducing depends on the concentration of salts and the rate of biochar.

Index Terms— Biochar, Electrical conductivity, Soil organic matter, Porosity, Bulk density, Organic carbon, Tomato.

1 Introduction

The decreasing of soil fertility in many developing countries has brought forward the importance of technologies that are locally available, economically possible and environment friendly [1]. improving environmental quality by reducing soil nutrient leaching losses, reducing bioavailability of environmental contaminants, sequestering C, reducing greenhouse gas emissions, and enhancing crop productivity in highly weathered or degraded soils, has been the goal of agro ecosystem researchers for years. Biochar may help achieve these goals [2]. The term biochar refers to all residual products of biomass pyrolysis excluding those that are condensates from the vapor phase. Sometimes as a co-product of pyrolysis and thus usually happens as a component of soil organic matter (SOM) where slash-and-burn agriculture is widely practiced, and in soils of the fire-prone Eco regions [3, 4, 5].

In addition to acting as a carbon sequester, biochar has several positive effects on soil properties, such as increasing water holding capacity, enhancing CEC, as well as add nutrients and improve nutrients uptake by plant and biological properties. [6, 7].

Biochar properties vary significantly on the basis of their respective feedstock and production process which can in turn affect their performance in field-scale, agricultural applications, and their ability to sequester carbon. Moreover, soil properties and climatic conditions are also considered as serious factors which control the consequences of biochar amendment [8]. Certain biochars may increase crop yield, while others may decrease yield for reasons that are readily explainable using known responses of crops to for example altered pH or salt contents [9]. The effects of biochar on soil physical properties depend on several factors, such as biomass or feedstock type, pyrolytic condition, application rate, and environmental condition. One of the ways to improve soil physical properties that recently has received increased attention is biochar, biochar amendments have been reported to improve soil bulk density, porosity, water retention, and hydraulic conductivity [10]. Recently, researchers have found that biochar has the potential to increase soil water holding capacities of sandy soils. But, studies of biochars impact on improving a soils saturated hydraulic conductivity have reported mixed results [11].

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International Journal of Scientific & Engineering Research Volume 8, Issue 4, April-2017
ISSN 2229-5518

Biochar has the capacity to exchange cations (such as nitrogen in the form of ammonium, $NH4^+$) with soil solution, and thus store crop nutrients. The extent of this capacity (cation exchange capa city, CEC) is effectively absent at very low pH and increases at higher pH [12]. The effect of biochar on native soil organic carbon (SOC) mineralization is controversial. Numerous studies have reported that the application of biochar stimulated SOC mineralization. The anomalous behavior of biochar towards SOC mineralization primarily depends on characteristics of the biochar and soil properties [13]. Biochar is commonly alkaline، The pH values of biochar at different pyrolysis temperature ranged from slightly acidic (≈6.5) to highly alkaline (≈11.5) across a wide variety of feedstock and residence time intervals. In some studies, the biochar was produced near neutral pH [14]. The most striking effects of biochar have been found in highly weathered acidic soils ،The number of studies on biochar in alkaline soils is low often showing little or no effect. One of the reasons is that biochar increases soil pH, especially in case of high-temperature biochar. Therefore, biochar may also be beneficial in alkaline soils as well if a suitable type of biochar is applied [15]. Tomato is one of the most important vegetable crops, is moderately tolerant to salinity, and is commonly cultivated in saline areas However, the high salt concentrations are seriously disrupted tomato crop growth at all stages of growth, and significantly reduced crop yield. The aim of this study is to study the effect of biochar on some soil properties and tomato yield under saline water conditions.

MATERIALS AND METHODS

This experiment was carried out in a greenhouse at the Water-Saving Park of Hohai University, Jiangning Campus located on latitude 31°57′N and longitude 118°50′E, 144 m above sea level, Nanjing, Jiangsu Province, China, during the period between April 19 and August 18, 2015, To evaluate the effect of biochar on some soil properties, tomato yield under saline water conditions. This area is characterized by a humid subtropical climate and it is under the influence of the East Asia Monsoon. The annual mean temperature inside the greenhouse is 15.5°C, with monthly mean ranging from 6.4 to 27.8°C, while the highest temperature was 44.0°C and the lowest was 1.5°C. The mean pan evaporation is 900 mm and annual mean precipitation of 1072.9 mm. The soil at the experimental site is classified as loam texture.

The experiment was set up with a completely randomized design with three replications. The treatments as: biochar 0.0(T1), 0.05 % (T2), 2% (T3) and 4% (T4) with two levels of salts in irrigation water (SL1 (1) and SL2 (3ds/m)). 20 kg of air-dried soil was placed in plastic pots with 35.6 dm3 in volume. Soil physical and chemical analysis were done according to the method that described by [16].

Tomato (*Solanum lycopersicon* L. var. *Yazhoufenwang*) seeds were sown in a nursery on 6th and 10th March of 2015, after 5 weeks of sowing the seedlings were transplanted on 14th April of 2015 at the four-leaf stage. The biochar of this study was produced from wheat straw. Wheat straw biochars (WB) were prepared from wheat straws through low-temperature pyrolysis at approximately 450°C. The WB samples were milled and screened, and biochars that were less than 1 mm in size were selected for use.

Tomato fruits of each treatment were harvested and weighted at the end of the treatments period (fruit maturation and harvesting stage), all plant materials were harvested on August 18, 2015.

Statistical analysis

Means and variations acquired by one-way analysis of variance (ANOVA) to compare the means of different soil chemical, physical and mechanical properties under study area, differences between individual means were tested using the Duncan multiples range test (DMRT) (p = 0.05 significance level) according to[17].

RESULTS AND DISCUSSION:

Table 1 and Table 2 show the effect of biochar on physical and chemical soil properties under saline water treatments. Table 3 shows Effect of biochar on tomato height, leaf number and yield under saline water treatments.

Table 1. Effect of biochar on physical soil properties under saline water treatments

Treaments	BD g/cm3	PD g/cm 3	Porosity %	Sand %	Silt %	Clay %
T1	1.016^{a}	2.5^{a}	59.6^{a}	41^{a}	17^{b}	42^{a}
T1SL1	1.012^{a}	2.5^{a}	59.6^{a}	38^{a}	21^{a}	41^{a}
T1SL2	1.002*	2.5^{a}	60^{a}	40^{a}	18^{b}	42^{a}
T2	1.04^{b}	2.5^{a}	58^{a}	33^{b}	24^{a}	43^{a}
T2SL1	1.053^{b}	2.5^{a}	58^{a}	37^{a}	21^{a}	42^{a}
T2SL2	1.015^{b}	2.5^{a}	59.6^{a}	38^{a}	22^{a}	40^{a}
T3	1.09^{c}	2.5^{a}	56^{b}	39^{a}	21^{a}	40^{a}
T3SL1	1.08^{c}	2.5^{a}	56^{b}	41^{a}	17^{a}	42^{a}
T3SL2	1.063^{c}	2.5^{a}	57^{ab}	43^{a}	14^{c}	43^{a}
T4	1.20^{d}	2.5^{a}	52^{c}	35^{a}	23^{a}	42^{a}
T4SL1	1.19^{d}	2.5^{a}	52^{c}	38^{a}	20^{a}	42^{a}
T4SL2	1.19^{d}	2.5^{a}	52^{c}	39^{a}	21^{a}	40^{a}

Mean values with different superscript letters in the same column differ significantly ($p < 0.05$).

Table 2. Effect of biochar on chemical soil properties under saline water treatments

Treatments	EC dS/m	pH	$Ca^{++}+Mg^{++}$ Meq/L	Cl Meq/L	HCO_3 Meq/L	OC %
T1	1.32^{a}	6.2^{b}	3.5^{d}	4.4^{b}	0.8^{bc}	1.013^{a}
T1SL1	1.72^{a}	4.3^{c}	12.7^{b}	9.6^{bc}	2.07^{a}	1.13^{a}
T1SL2	2.24^{a}	4.5^{c}	16.2^{a}	7.73^{a}	1.2^{b}	1.14^{a}
T2	1.22^{b}	4.6^{c}	7.7^{c}	9.73^{bc}	2.07^{a}	1.2^{b}

International Journal of Scientific & Engineering Research Volume 8, Issue 4, April-2017
ISSN 2229-5518

T2SL1	1.57^{b}	4.3^{c}	10.0^{b}	7.93^{a}	1.34^{b}	1.29^{b}
T2SL2	1.95^{b}	4.8^{c}	13.8^{b}	11.33^{c}	0.8^{bc}	1.27^{b}
T3	0.59^{c}	4.2^{c}	3.47^{b}	11.2^{c}	1.2^{b}	1.47^{c}
T3SL1	1.49^{d}	4.3^{c}	9.8^{b}	7.87^{a}	1.07^{b}	1.42^{c}
T3SL2	1.75^{d}	4.5^{c}	8.6^{bc}	16.8^{e}	1.27^{b}	1.41^{c}
T4	0.40^{d}	4.5^{c}	2.7^{d}	4.03^{b}	0.94^{bc}	1.66^{d}
T4SL1	1.02^{b}	5.3^{bc}	3.36^{d}	5.9^{b}	1.07^{b}	1.59^{d}
T4SL2	1.30^{b}	4.7^{c}	9.4^{b}	7.47^{a}	0.6^{c}	1.61^{d}

Mean values with different superscript letters in the same column differ significantly ($p < 0.05$).

Table 3. Effect of biochar on tomato height, leaf number and yield under saline water treatments

Treatments	Plant Height (cm)	Number of Plant Leaves	Yield (g/plant)
T1	105.33^{bc}	24.33^{a}	787.43^{c}
T1SL1	91.67^{b}	19^{b}	781.1167^{c}
T1SL2	88^{d}	18^{b}	657.45^{d}
T2	107^{bc}	24.0^{a}	882.57^{b}
T2SL1	93.95^{c}	20.67^{b}	861.34^{b}
T2SL2	92.7^{c}	18.67a	753.85^{c}
T3	116.67^{b}	26^{a}	1015.33^{a}
T3SL1	97.15^{c}	20.67^{b}	1003.72^{a}
T3SL2	93.33^{c}	19.0^{b}	830.75^{b}
T4	127.33^{a}	26.67^{a}	1086.51^{a}
T4SL1	98.98^{b}	19.67^{b}	1037.44^{a}
T4SL2	101.67^{bc}	19.67^{b}	958.17^{a}

Mean values with different superscript letters in the same column differ significantly ($p < 0.05$).

Effect of Biochar on Soil Physical Properties:

The effect of biochar on soil particle size distribution, soil bulk density, particle density and total porosity is presented in Table 1. The clay, sand and silt fraction of the soils were not significantly affected by biochar applications (Table 1).

The application of biochar showed a significant ($P < 0.05$) change in soil bulk density, total porosity among the different rates of treatments application. The results of soil bulk density were 1.04, 1.09 and 1.20 g/cm^3 for T2, T3 and T4 respectively, compared to control (1.012). The results of soil particle density showed non-significant difference between biochar treatments and control (Table 1). Generally biochar decreased Soil Porosity but the obvious effect of biochar was recorded by T3a and T4. This agrees with findings of [11].

Effect of Biochar on Soil Physical Properties under saline water conditions

The results of physical soil properties recorded non- significant differences before and after using the two treatments of saline water (SL1&SL2). This result indicated that the biochar application minimized the effect of salts concentrations of irrigation water. This shows a high degree of agreement with the results of [18].

Effect of Biochar on Soil Chemical Properties:

Effect of Biochar on Soil pH and Electrical Conductivity:

The effect of biochar on Soil pH and Electrical Conductivity is presented in Table 2. Biochar applications significantly ($P < 0.05$) reduced soil pH and EC. Soil pH was decreased about (27%) by all biochar treatments Table 2 and Figure 1. The soil EC results were 1.22, 0.59 and 0.40 for T2, T3 and T4 respectively, compared to control 1.32 dS/m^{-1} (Figure 2). This results indicated that increasing of biochar application rates led to more decrease in soil EC [15].

Effect of Biochar on Organic Carbon

The results of soil organic carbon obtained by biochar treatments were significantly difference ($P<0.05$) than that for control (Table 2 and Figure 3). Organic carbon was increased with biochar treatments, T2 recorded 1.2%, T3 was 1.47% and T4 was 1.66% compared to control (0.98). This agrees with results of [13].

Effect of Biochar on Soil pH, Electrical Conductivity and Organic carbon under saline water conditions

The statistical Results showed that the pH values obtained by using of biochar with SL1 and SL2 were not significantly different ($p<0.05$) with the results of biochar untreated by saline water (Table). The average of soil EC before biochar treatments was 1.32, 1.72 and 2.24 for T1, T1SL1 and T1SL2 compared to 1.22, 1.57 and 1.95 for T2, T2SL1 and T2SL2 respectively, and the results of T3, T3SL1 and T3SL2 were 0.59, 1.49 and 1.95 respectively, the results indicated that the biochar reduced the effect of saline water and the degree of reducing depends on the concentration of salts and the rate of bichar [18] from this the biochar treatment T4 represents a best values in reducing soil EC the results were 0.4, 1.02 and 1.30 for T4, T4SL1 and T4SL2 respectively, (Table 2). Generally, the results showed there was no significant difference happen in soil organic carbon when using biochar with saline irrigation water (Table 2).

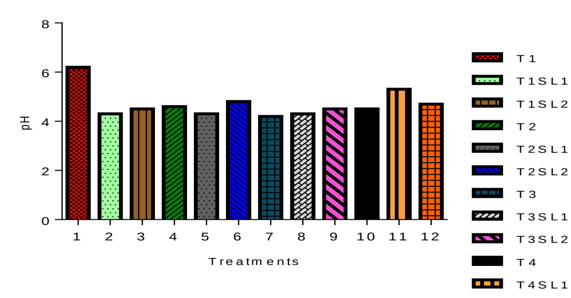

Figure 1 Effect of biochar on soil pH under saline water treatments

International Journal of Scientific & Engineering Research Volume 8, Issue 4, April-2017
ISSN 2229-5518

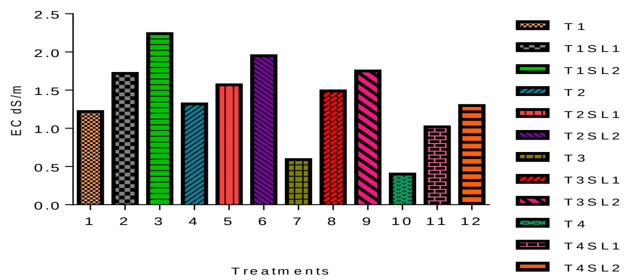

Figure 2 Effect of biochar on soil EC under saline water treatments

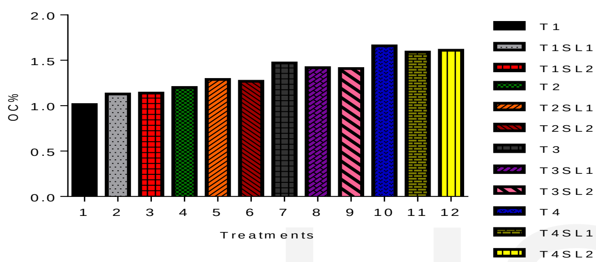

Figure 3 Effect of biochar on soil OC under saline water treatments

Effect of biochar on tomato height, leaf number and yield

Table 3 shows the effect of biochar on tomato height, leaf number and yield. The application of biochar significantly (P < 0.05) increases tomato height, leaf number and yield relative to control. Also, the higher the quantity of biochar applied, the higher the tomato height, leaf number and yield observed. The lowest tomato height of 88cm was observed in control with SL2 and the highest values recorded by T4 (127.33cm) without saline water treatment. The results showed that the maximum number of tomato leafs acquired by T4 (26.67) and lower value of 18 was observed in control with SL2. The observed tomato yield in control with SL2 (657.45) was lower than tomato yield in T2 (882.57), T3 (1015.33) and T4 (1086.51) Table 2 and Figure 4. Generally, using of saline Water represents lower values for tomato height, leaf number and yield but application of biochar with saline water showed good results in tomato height, leaf number and yield than that for control (Table 3). [6, 7].

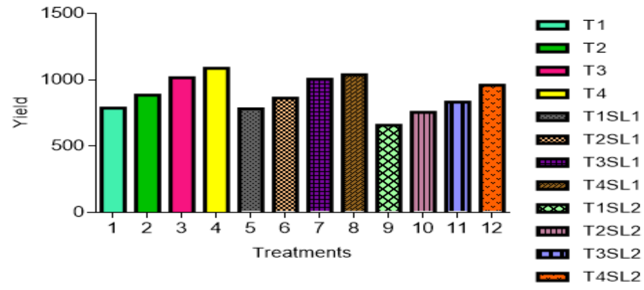

Figure 4 Effect of biochar on tomato yield under saline water treatments

CONCLUSION

The selected soil properties were significantly affected by biochar applications. The application of biochar showed a significant (P < 0.05) change in soil bulk density, total porosity among the different rates of treatments application. The results of soil particle density showed non-significant difference between biochar treatments and control, meanwhile, the clay, sand and silt fraction of the soils were not significantly affected by biochar applications. The statistical results indicated that there was no significant difference in physical soil properties before and after using the two treatments of saline water. Soil pH and EC were decreased by all biochar treatments. Organic carbon was increased significantly with biochar treatments. The results of soil pH were not significantly different (p<0.05) with that for saline water treatments. Biochar significantly (P < 0.05) increase tomato height, leaf number and yield relative to control. Also, the higher the quantity of biochar applied, the higher the tomato height, leaf number and yield observed. Using of saline Water represents a lower values for tomato height, leaf number and yield but application of biochar with saline water showed a good results in tomato height, leaf number, yield and physical and chemical soil properties. Generally, biochar reduced the effect of saline water and the degree of reducing depends on the concentration of salts and the rate of biochar.

ACKNOWLEDGEMENTS

The authors would like to greatly express their deepest and warm gratefulness to the staff at the Key Laboratory of Efficient Irrigation-Drainage and Agricultural Soil-Water Environment in Southern China, Nanjing, Jiangsu Province, China for their remarkable role.

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