International Journal of Engineering& Scientific Research
Vol.5 Issue 4, April 2017,
ISSN: 2347-6532 Impact Factor: 6.660
JournalHomepage:http://www.ijmra.us,Email:editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

BIOCHAR AMENDMENTS IMPROVES TOMATO GROWTH, YIELD AND IRRIGATION WATER USE EFFICIENCY UNDER POOR SILT LOAM SOIL

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Abstract: Biochar has been reported to improve soil physical, chemical and crop yield. This study presents a novel attempt to analysing the influence of biochar application eg. 0%, 2% and 4% w/w on the soil properties, growth, yield and water productivity of tomato plant under poor silt loam soil. To study influence of three different biochar application on the tomato performance, comprehensive experimental works was carried out using pots inside the greenhouse. The results showed soil bulk density, water content and soil organic matter were improved significantly as biochar application rate increased. Biochar application also enhanced plant height, stem diameter, plant fresh and dry weights and yield components of tomato plant. It was found that biochar application at 4% treatment in the whole growing period was best to improve tomato plant growth and yield, providing abiochar amendment recommendation for tomato production in field. Moreover, biochar application improved the irrigation water use efficiency. Therefore, biochar amendment could be an effective option to improvepoor soil which affected croplands.

Keywords: Biochar, Bulk density Growth; Yield

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1. Introduction

Recently, Biocharhas several sustainability achievementsincluding improvements of soil and plant growth, energy production, and C sequestration. Furthermore, it can produced asprocess heat, bio-oil, co-products like hydrogen, syngas, and liquid smoke via thepyrolysis process.in developing countries its used as the implication of small stoves using forfood processing could help to decrease the pressure on forests and reducerespiratory diseases (Barrow 2011, Hardy S, et al.2013, Mankasingh et al. 2011).The annual soil application of agriculture residues is one of the management tools available for increasing soil organic matter content (Reeves, 1997). However, at the same time the demand for biomass for bioenergy production is growing, putting even more pressure on plant production and the utilization of agriculture and forestry residues (Powlson et al., 2011).

The biocharinclusion in recent agricultural strategy israre, this due to the unknown behavior ofbiochar in the long term, which considered as negative influences on soil quality and thebiochar cannot convincingly be removed from soil after been adding. Because it may prevent the action of pre-emergent herbicides or introduce xenobiotics into the soil and stimulate the loss of native soil organicmatter, all of thesecould be perceived as negative outcomes. Furthermore, biochar production can be polluting to the wider environment andto human health (Barbosa et al.,2006) or may induce the stripping of forest areas for charproduction leaving them exposed to soil degradation and erosion (Wardle et al., 2008Ayoub, 1998, Jones et al., 2011b; Lehmann et al., 2011).Due to its high specific surface area, Biochar has a significant adsorbing ability. Furthermore, may contribute to increasing the water holding capacity and plant-available water capacity of soil (AWC) due to its internal porosity (V. Hansen et al. 2016,Bruun et al., 2014, Uzoma et al., 2011, Abel et al., 2013).

An improvement in soil structure may be especially beneficial in coarse sandy soils showing high mechanical resistance to root growth due to low compressibility and high friction(Madsen, 1985). Consequently, the yield potentials of crops can generally not be fully exploited in coarse sandy soils.There are several researches conducted on the Biochar effects on plant growth (Waterset al. 2011, Sohi et al. 2010). Study carried out by Jeffery et al. (2011) which comprising of 177individual studies revealed that positive effects of biocharincorporation into soils outbalance negative and neutral effects.According to the literatures, many researchers stated that the biochar addition positively reduces N2O emissions from soil and nutrient leaching losses, suppress plant disease, improve plantgrowth, ameliorate soil acidity and stimulate soil microbial activity (Smith et al., 2010; Jones et al.,2011b; Lehmann et al., 2011, Taghizadeh-Toosi, 2011, Graber et al., 2010, Lehmann et al., 2003, Yuan and Xu, 2011, Elad et al., 2010)

The aim of this study was to evaluate the effect of biochar oncrop performance and soil quality. Keyelements of the crop and soil during theexperiment were measured as defined in tables and figures below. The measurements included thosemade directly in the field alongside those measured in the laboratoryusing soil and biochar collected from the experiments.

2. Materials and methods

2.1 Experimental setup

The experiment was conducted in a greenhouse from April to August 2014 at the Water Saving Park Agricultural Experimental Farm at Soil and Water Engineering Department at Hohai University in Nanjing, China. The farm is located at 31°95′N, 118°83′E, in a suburb of Nanjing at an area downstream of the Yangtze River drainage basin with an average elevation of 15 m above the sea level. This area is characterized by a humid subtropical climate and is under the influence of the East Asia Monsoon. The mean annual temperature is 15.5 °C, with monthly mean ranging from 2.4 to 27.8 °C; the highest temperature in this area is 43.0 °C while the lowest is −2.9 °C. The average annual rainfall is 1062 mm. The average temperature and humidity during the growing season inside the greenhouse are 30◦C and 79.75%, respectively. The soil at the experimental site is silt loam, Table1 shows the physical and chemical properties of the soil used.

Table 1: Soil properties of the 0 - 0.2 m layer in the experiment site and biochar used

properties	Bulk density (g/cm3)	pH	EC (dS m^{-1})	OM (mg kg^{-1})	Total N (g kg^{-1})	Texture
Soil	1.35	8.6	0.87	0.12	0.1	Silt loam
Biochar	0.43	9.9	1.0	803.58	0.65	-

2.2 Experimental Design

A randomized complete block design with three treatments [CK (no biochar, control), T1 (2% w/w biochar) and T2 (4% w/w biochar)],under three replications for each treatment was used. The biochar used was a commercial product produced from wheat straw, and pyrolyzed at 350–550°C in a vertical kiln, manufactured by Sanli New Energy Company, Henan Province, China. Tomato(*CV. Lycopersiconesculentum Mill, Yazhoufenwang*) plant was used as the crop material which was transplanted on 14April 2014 and harvested on 10 August 2014. The tomato seedlings were transplanted in the pots which were 42 cm in height with upper diameter of 30cm and lower diameter of 25 cm. 21 kg of dry soil was put in each pot.Nine pots were used and each pot was filledwith biochar and soil mixture. The experiment was designed with fully irrigation schedule 100% of the reference evapotranspiration (ET_0) for four stages of plant growth: seedling and establishment, flowering, fruit setting and fruit ripening stage. The irrigation water applied for each pot was 128 mm during the cropping season.

2.3 Measurements

Soil properties were measured at the end of the season, bulk density (BD) was calculated as g/cm^3 on dry weight basis, from the surface (0–20 cm) soil depth with three replicates from each pots. Soil electrical conductivity (EC) and pH were measured by using standard methods described by (Tan 2005). Soil organic matter (OM) was measured by the oil bath-K_2CrO_7 titration method (Nelson et al. 1996). Soil water content was measured gravimetric every seven days interval by auger.

Plant growth was measured as plant height, stem diameter and dry matter. Data on plant height andstem diameter was collected every week. Plant fresh and dry weights were measured at the end of the season. Yield components were measured as, total number of fruitsper plant, single fruit weight, fruit diameter, fruitwater content, fruit color index (CI), and total yield per plant. CI was measured following (López Camelo & Gómez 2004). Most of the yield components data were collected at the final harvest.

2.4 Statistical analysis

The experiment had a randomized completely block design with one factor and three treatments, each treatment had three replicates for destructive sampling during the experiment. Data set of each variable was subjected to analysis using the statistical package of MSTATC (Fischer 1990).When F values were significant, means were compared using one-way analyses of variance (ANOVA) followed by LSD test, at $P \leq 0.05$.

3. Results and discussion

The results obtained from the experimental works were discussed in the following sections.

3.1 Effect on soil properties

Table 2 shows that soil bulk density (BD) decreased significantly as the biochar quantity went up in each during the growing period. The biggest reduction was presented in treatment 2, with the most reduction of 1.12 g cm^3 in the BD, followed by treatments 1, compared to the least in control treatment (CK). These results showed that biochar application indeed made lower soil BDduring the growing period.This due to porosity of biochar is very high and when it used in soil it significantly decrease bulk density by increasing the pore volume (Lehmann et al., 2011).Moreover, decrease in soil bulk density following the application of biochar can positively influence root development and growth (Atkinson et al., 2010; Laird et al., 2010).

The change of soil water content in the pots during the experiment under biochar and without biochar treatments are shown in Table 2. It was found that biochar treatments had comparatively higher soil water content with respect to non-biochar treatment. Biochar treatment T2 showed the highest value of water content followed by T1 and CK, respectively. This due to application of biochar increase the proportion of the soil pore size, and thus enhance soil moisture content and other soil hydrological properties. Our result also agrees with Novak et al., (2009), who stated that additions of biochar to soils can improve soil water storage capability.

The application of biochar did not have any effect on electrical conductivity (EC) and pH of the soil. Meanwhile, the addition of biochar increased soil organic matter, the highest values (0.61 and 0.33 mg kg^{-1}) observed at T2 and T1 treatment, respectively (Table 2).

Table 2: Soil properties under different biochar amendments

Parameters	CK	T1	T2
Bulk density (g cm^3)	01.35 a	01.24 b	01.12 c
Water content (%)	23.45 c	25.23 b	27.52 a
Electrical conductivity (dS m^{-1})	0.87 a	0.88 a	0.90 a
pH	08.6 a	08.6 a	08.70 a
Organic matter (m kg^{-1})	0.12 c	0.33 b	0.61 a

Means within rows of each parameter followed by different letters are statistically different at $p<0.05$ (LSD test)

3.2 Effect on growth parameters

Table 3 shows the effect of biochar on tomato growth parameters. The statistical analysis showed that biochar additions significantly improved growth parameters. Plant height is an important index to reflect tomato yield. During the whole growth stage, plant height per plant displayed obvious differences in all biochar treatments (Table 3). Plant height in treatments 1 and 2 were largest at 23.78 and 20.13 cm, which significant higherthan that in control treatmentCK, at establishment and growth stage. In flowering growing period, plant height in treatment 2 was biggest at 40.10 cm, followed by treatments 1 and CK. When it come into fruit setting stage, treatment 2 also received the highest value at 70.21 cm, which was significantly higherthan the control treatment. At the last growing stage, the treatment 2 and 1still sustained had the highest plant height.

Stem diameter increased quickly as the biochar quantity went up in each growing period. The biggest increments in each stagewas presented in treatment 2, with the most increments of 11.23mm instem diameter, followed by treatments 1, compared to theleast in control treatment CK at 6.98 mm. These result showed that biochar indeed made higher growth of tomato plant in all growing stages.

Table 3 shows the effects of different biochar application rates on plant fresh and dry weights, at the end of maturity stage. Biochar significantly improved the plant fresh and dry weights. Fresh and dry weights of the whole tomatoplantwere highest for treatment 2 (101.19 and 46.21 g per plant, respectively) and 89.65 and 39.88 g, respectively of treatment 1 took the second place. Control treatment ranked last at 74.82 and 34.18 g, respectively. The improvements of tomato growth parameters under biochar application could attributed to the improvements in BD, soil water content and soil organic matter. Our results were in agreement with the result obtained by Hansen et al., 2016, who stated that biochar addition enhanced plant growth.

Table 3: Growth parameters of tomato in the four growth stages under different biochar amendments

Parameters	Treatments	Tomato Growth Stages			
		Establishment and growth	Flowering	Fruit setting	Fruit Ripening
	CK	6.22 c	8.14 c	9.65 b	10.47 b
Stem diameter (mm)	T1	6.63 b	8.79 b	10.12 a	11.16 a
	T2	6.98 a	9.23 a	10.20 a	11.23 a
	CK	18.40 c	30.15 c	52.43 c	65.77 c
Plant height (cm)	T1	20.13 b	39.66 b	63.18 b	78.30 b
	T2	23.78 a	40.10 b	70.21 a	84.71 a
	CK				74.82 c
Fresh plant weight(g)	T1				89.65 b
	T2				101.19 a
	CK				34.18 c
Dry plant weight(g)	T1				39.88 b
	T2				46.21 a

Means within columns of each parameter followed by different letters are statistically different at $p<0.05$ (LSD test)

3.3 Effect on Yield components

Effects of different biochar application rates on tomato yield components during the growing period are shown in Table 4. Biochar amendments significantly increased all yield components, except fruit diameter and color index were not affected by biochar addition. T2 and T1 treatments recorded highest fruit number per plant, fruit weigh, fruit water content and total yield per plant compare to those under no biochar- control treatments. This attributed to the improvement of soil properties and plant growth parameters under biochar additions. Our result in line with Hammer et al. (2015), who reported that biochar enhanced growth and yield of plant.

Table 4: Yield components of tomato plant under different biochar amendments

Parameters	CK	T1	T2
Fruit No. per plant	7 c	9 b	11 a
Fruit diameter	50.9 a	51.2 a	51.2 a
Weight of single fruit (g)	35.48 c	40.23 b	55.39 a
Yield per plant (g)	250.36 c	370.07 b	609.40 a
Fruit water content (%)	89.85 c	91.14 b	92.35 a
Fruit color index (CI)	1.30 a	1.30 a	1.31 a

Means within rows of each parameter followed by different letters are statistically different at $p<0.05$ (LSD test)

Similarly, the irrigation water use efficiency(IWUE) was also significantly affected by biochar treatments (Figure 2).Tomato IWUE increased as the amount of BA rate increased. The highest value obtained at T2 followed by T1 and CK treatment.

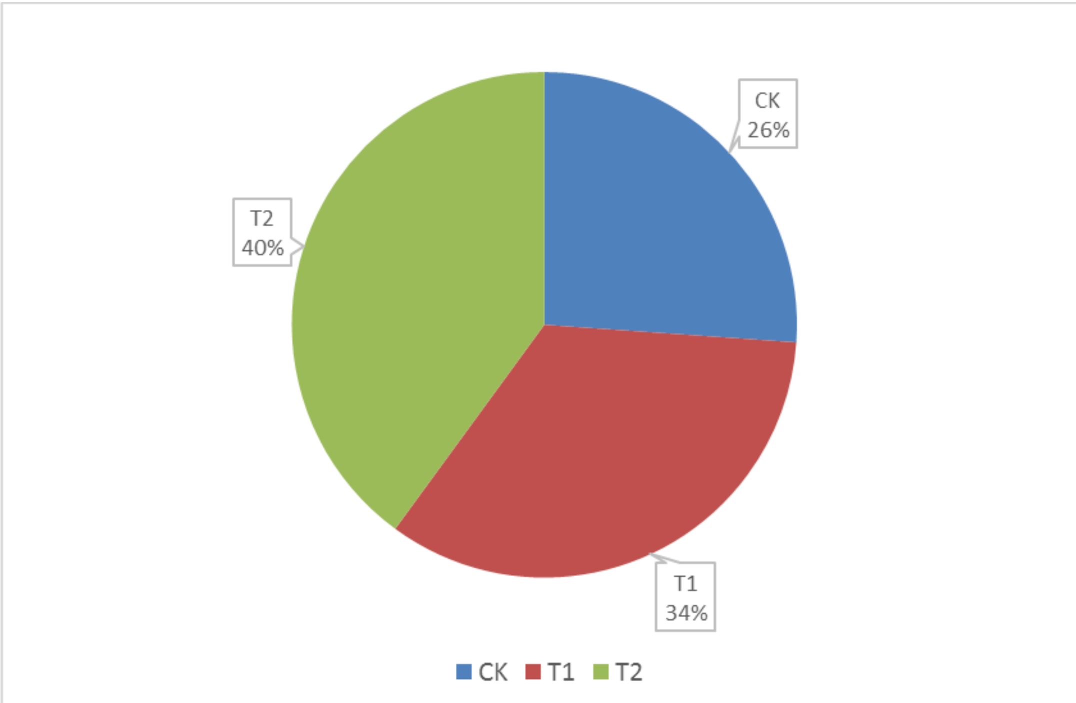

Figure 2: Effect of biochar amendments on Irrigation Water Use Efficiency (IWUE, kg m^3) during tomato growing season.

4. Conclusion

This study evaluated and analyzed the effect of different biochar additions on soil properties, plant growth and yield components of tomato plant under silt loam poor soil during 2014 growing season in pot experiment. Soil bulk density, water content and organic matter were significantly increased with increasing application rates of biochar, especially at high application rate. Applying biochar to poor silt loam soil had the potential for increasing plant growth, yield components and irrigation water use efficiency of tomato plants. Consequently, under poor soil, biochar might be a promising amendment for improving soil properties and subsequently enhancing plant productivity.

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