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Impact of Biochar on Vegetative Parameters, Leaf Mineral Content, Yield and Fruit Quality of Grande Naine Banana in Saline-sodic Soil

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DUE to the changes in climatic condition and increasing salt affected soils, it was necessary to develop new agriculture practices to cope with these problems. The aim of the present study was to investigate the effect of wood sawdust biochar (WB) on Grande Naine banana plant performance. The study was conducted during 2013 and 2014 seasons with addition rates of 0, 5, 10, 20 Mg ha^{-1} of WB to saline-sodic soil in a private farm in Kafr Yaaqob village, Kafr El-Zayat, El- Gharbyia Governorate, Egypt. The obtained results showed better growth, productivity and fruit quality by increasing addition rates of biochar. Length and girth of pseudostem, leaf area, also bunch, cluster and finger weights were greatly increased with 20 Mg ha^{-1} rate of WB. All fruit quality parameters, i.e. number of fingers per cluster, finger length and diameter, pulp weight, peel weight, total soluble solids (T.S.S), total sugars and starch were positively enhanced by increasing biochar application. In addition, leaf mineral revealed higher contents by increasing the application of BW. The study recommends adding biochar to the orchards of Grande Naine banana grown in saline-sodic soils at 20 Mg ha^{-1} rate of BW.

Keywords: Banana, Salt stress, Biochar, Yield, Growth, Mineral content.

Introduction

Salinity affected soils is worldwide problem. The quest new agriculture practices to cope with salinity problems always are of interest. Biochar products recently occupied the attention of many researchers for its role in alleviation problems associated with salinity stress. Banana (*Musa spp.*) is one of the important tropical and subtropical crops worldwide. The species of banana was found to be sensitive to salinity (Silva et al. 2009). Salinity is the main problems facing banana cultivation in arid and semi-arid regions, which reflect sever reduction in growth and yield production (Willadino et al., 2011 and Junior et al. 2012). Biochar is defined as a pyrolysis of biomass derived from organic waste, manure and crop residues which exposed to oxygen-limited conditions (Lehmann and Joseph, 2009). Many studies introduced biocahr as a new clue for plant adaptation in saline soils. Adding 4.5 Mg ha^{-1} of BioRichar (as second product of biochar) at vegetative stages of banana during acclimatization stage, significantly increased plant height, pseudo-stem diameter, total leaf number and leaf area as compared to control (Din et al., 2018). Biochar application significantly increased plant growth potential and yield of physic nut plants (Suppadit et al. 2015). Baronti et al. (2014) found that biochar application at rates of 22 and 44 Mg ha^{-1} enhanced growth parameters and yield of grape, (*Vitis vinifera* L.). Biochar increases vineyard productivity based on regulating plant water availability (Genesio et al., 2015). Biochar application reduced the detrimental effects of replant disease on peach tree with improving the vegetative growth and production yield (Atucha and Litus, 2015). Thomas *et al*. (2013) has been found that biochar reduced salt stress leading to productivity increase of *Prunella vulgaris* and *Abutilon theophrasti*. Fruit of watermelon 'Sweet 16' (*Citrullus lanatus*) showed higher content of T.S.S and sugars by biochar application (Villocino and Quevedo, 2013). Biochar-induced changes in soil physico-chemical properties, susequently improve soil fertility and crop nutrition (Gul and Whalen, 2016). In addition the availability of nitrogen and phosphorous were clearly increased after application of biochar to different type of soils (Atkinson et al., 2010, Joseph et al., 2010, Barrow, 2012). Adding the rice paddy husk biochar at 10 Mg ha^{-1} in banana plantation soils were led to significant increase in soil content of N, P, K, Mg, Na and C (Mankasingh et al., 2011). For advance, it was necessary to see the role of biochar on banana plants grown in saline

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condition. Therefore, the present study aimed to find out the biochar mechanisms that alleviate salt stress on banana plants.

Material and Methods

The study was carried out during 2013 and 2014 seasons on Grande Naine banana plants grown in saline-sodic soil in a private farm in Kafr Yaaqob village, Kafr El-Zayat, El- Gharbyia Governorate, Egypt. The experiment was laid out in a randomized complete block design using four application rates of biochar 0, 5, 10, 20 Mg ha^{-1} with three replications (The plot area was 108 m^2 including three plants in three rows). Biochar at different rates were added to the surface soil of the plot area and mixed together. Mother plants were planted at 4.0 X 3.0 m and the start of the experiment was in March 2013. Three suckers were left around each hole with removing the others ones. The Physical and chemical properties of the plantation soil are shown in Table 1.

TABLE 1. Soil characteristics of banana orchard at the start of the treatments .

Prosperities	Value	Prosperities	Value
pH (saturated soil paste)	8.26	NPK available (mg kg^{-1})	
EC (soil past extracts %)	12.68	N	40.91
Soluble ions (meq L^{-1})		P	4.92
Ca^{2+}	30.8	K	195.8
Mg^{2+}	25	NPK total (g kg^{-1})	
Na^+	70.55	N	0. 75
K^+	1.17	P	0. 86
Cl^-	88.6	K	3.51
$HCO3^-$	20.98	C%	0.91
SO_4^{2-}	16.85	O.M%	1.55
Exchangeable cations (c mol kg^{-1})		C:N ratio	12.3
Ca^{2+}	12.5	$CaCO_3$%	1.58
Mg^{2+}	7.3	Particle size distribution (%)	
Na^+	17.36	Clay	45.72
K^+	1.55	Silt	22.17
CEC	47.88	Sand	32.15
ESP %	36.38	Texture	Clay

Soil was classified as saline-sodic soil according to Bresler et al. (1982).

Preparation of biochar

Wood sawdust (WB) was used as a feed stock to separately produce biochar through slow pyrolysis in a kiln with a retention time of 2 h. Biochar was cooled overnight, then gently crushed and grind to pass through a 0.5 mm sieve before use. Table 2 shows some characteristics of biochar type used.

The recommended agricultural practices were applied on the experimental plants. According to Ibrahim (2003) compost at the rate of 60 Mg/feddan/year was added in the first week of December, then NPK at the rates of 800, 100, 1000 N, P_2O_5, K_2O actual g/plant, respectively were applied in the forms of 33.5% ammonium nitrate N, 80% phosphoric acid P_2O_5 and 48% potassium sulphate K_2O, respectively.

TABLE 2. Characteristics of biochar used in this study

C:N ratio	C (%)	Total K(%)	Total P (%)	Total N (%)	BD (g cm^{-3})	CEC (c mol kg^{-1})	EC (1:10)	pH (1:10)	Prosperities
31.03	65.2	0.952	0.122	1.96	0.30	31.6	2.15	8.64	**After pyrolysis**

CEC (Cation Exchange Capacity), BD (Bulk Density) .

Growth parameters

Length and girth of pseudostem were recorded. Leaf area (m^2) of the third full sized leaf (from the top) was measured according to Murry (1960). Leaf length was measured along the midrib and width at the widest part of the leaf.

Yield determination

Bunch weight was estimated for the production yield calculation at harvest time. Subsequently, yield was calculated where yield = bunch weight (kg) X number of bunches (2593 plants /hectare).

Parameters of fruit quality

Cluster and finger weights, number of fingers/ cluster, finger length and diameter (cm), pulp weight (g), peel weight (g), total soluble solids (T.S.S Brix), total sugars (%) and starch (%) were estimated according to A.O.A.C (1995) as a reflection of fruit quality. Ripened fingers were taken from the middle portion of the cluster for the previous analysis.

Chemical analysis

According to Hewitt (1955), the third upper leaf in the descending foliar succession of the plant at bunch shooting was used as leaf sample for leaf mineral measurements. Micro-kjeldehl method was used for total nitrogen determination as described by Page, (1982). The method described by Cottenie et al. (1982) was used for phosphorus determination. Potassium (K) and sodium (Na) were determined by flame photometer according to the method of Jackson (1958). Electrolyte conductivity (EC) was determined as indicator to ion leakage according to Tripathy et al. (2000).

Statistical analysis

The obtained data were performed by Statistical Graphics Corporation, STATGRAPHICS Plus (St. Louis, MO, USA) for one way analysis of variance and employing Duncan's multiple range tests at the 0.05 confidence level.

Results

Effect of biochar on vegetative growth and yield

Results in Table 3 showed general positive measurements of vegetative growth and yield by biochar applications comparing to the control treatment. It is clear that the best measurements were correlated to the higher application rate of 20 Mg ha-1 of WB in both seasons of (2012 and 2013) compared to the other application rates of WB. Pseudostem length and girth, leaf area and yield recorded 283.50 cm, 91.77 cm, 2.15 m2 and 82.51 ton ha-1, respectively with 20 Mg ha-1 of WB in the second season of 2013. Pseudostem length revealed a significant increase by increasing WB applications. However, pseudostem girth showed no significant differences between 5 Mg ha-1 of WB and control, it showed significances with the other treatments compared to 5 Mg ha-1 of WB and control treatments. Leaf area showed a significant increment with 20 Mg ha-1 of WB in both seasons of (2012 and 2013) compared to the other application rates of BW and the control. The production yield showed no significant difference between 10 and 20 Mg ha-1 of WB but showed significant differences with the other treatments.

Effect of biochar on fruit quality

Results in Tables 4 and 5 exhibited the fruit quality characteristics at the studied levels of WB. All parameters of fruit quality were enhanced by increasing the rates of WB. There were no significant differences concerning cluster weight between the rates of 10 and 20 Mg ha^{-1} of WB but the significances were clear with 5 Mg ha^{-1} and the control (Table 4). Weight of finger revealed no significant differences between 5 and 10 Mg ha^{-1} of WB levels but both rates showed significant differences compared to the control treatment (Table 4).

TABLE 3. The effect of biochar on pseudostem length and girth, leaf area and yield of Grande Naine banana plants grown in saline-sodic soil during 2012 and 2013 seasons.

Parameters	Pseudostem length(cm)		Pseudostem girth (cm)		Leaf area (m^2)		Yield (ton ha^{-1})	
Treatments	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**
Control	269.30 d	269.80 d	80.20 cd	82.00 cd	1.96 cd	2.00 cd	71.57 d	72.44 d
5 Mg ha^{-1}	273.10 c	274.70 c	82.60 c	83.10 c	1.98 bc	2.01 bc	74.73 c	75.54 c
10 Mg ha^{-1}	277.50 b	280.30 b	88.60 ab	89.10 ab	2.00 b	2.02 b	80.49 ab	80.51 ab
20 Mg ha^{-1}	281.10 a	283.50 a	90.30 a	91.77 a	2.12 a	2.15 a	82.39 a	82.51 a

Means followed by the same letters are not statistically different by LSD at 0.05 levels. Mg (mega gram), ha (hectare)

TABLE 4. The effect of biochar on cluster and finger weight, No. of fingers/cluster, finger length and diameter of Grande Naine banana plants grown in saline-sodic soil during 2012 and 2013 seasons.

Parameters	Cluster weight (Kg)		Finger weight (g)		No. of fingers/cluster		Finger length (cm)		Finger diameter (cm)	
Treatments	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Control	1.69 d	1.71 d	96.2 d	96.07 d	14.08 d	14.01 d	14.67 d	14.93 d	3.17cd	3.19cd
5 Mg ha^{-1}	1.84 c	1.85 c	100.1 bc	99.99bc	16.22 bc	16.66 bc	15.85bc	15.94bc	3.27bc	3.29bc
10 Mg ha^{-1}	1.89 ab	1. 91 ab	101.8 b	102.5b	17.11ab	17.15ab	16.83 b	16.91 b	3.34 b	3.35 b
20 Mg ha^{-1}	1.93 a	1.95 a	106.6 a	106.6 a	18.19 a	18.17 a	18.23 a	18.55 a	3.52 a	3.55 a

Means followed by the same letters are not statistically different by LSD at 0.05 levels. Mg (mega gram), ha (hectare)

Finger weight with WB rate of 20 Mg ha^{-1} showed significantly best results compared to the other rates and the control (Table 4). Similar results to finger weight were shown by number of fingers per cluster without significant differences between the rates of 10 and 20 Mg ha^{-1} of WB (Table 4). Results of finger length were exactly similar to that shown by finger weight concerning the significant differences between the levels of WB and the control (Table 4). Finger diameter results showed no significant differences between application rate of 5 Mg ha^{-1} and the control and between the rates of 5 and 10 Mg ha^{-1} (Table 4). In addition, finger diameter with the application rate of 20 Mg ha^{-1} of WB showed significant differences compared to the other rates and the control (Table 4). The increase in pulp weight reflected a decrease in peel weight along with increasing WB application rates as shown in Table 5. Pulp and peel weight revealed no significant differences between 5 and 10 Mg ha^{-1} of WB levels but both rates showed significant differences compared to the control treatment (Table 5). Pulp and peel weight with WB rate of 20 Mg ha^{-1} showed significantly best results compared with the other rates and the control (Table 5). Total soluble solids (T.S.S) results exhibited no significant differences between WB rate of 5 Mg ha^{-1} and the control (Table 5). As well as, application of WB rates at 5 and 10 Mg ha^{-1} figured out no significant differences concerning T.S.S results (Table 5). In addition, results of T.S.S at application rate of 20 Mg ha^{-1} of WB showed no significant differences compared to the rate of 10 Mg ha^{-1} but significantly differed than the rate of 5 Mg ha^{-1} and the control (Table 5). Total sugars results at the rate of 5 Mg ha^{-1} revealed no significant differences than the control (Table 5). Moreover, total sugars results at rate of 20 Mg ha^{-1} of WB significantly differed compared to the other rates and the control (Table 5). Results of starch were exactly similar to that shown by T.S.S concerning the significant differences between the levels of WB and the control (Table 5).

TABLE 5. The effect of biochar on pulp and peel weight, T.S.S, total sugars and starch of Grande Naine banana plants grown in saline-sodic soil during 2012 and 2013 seasons

Parameters	Pulp weight (g)		Peel weight (g)		T.S.S %		Total sugars %		Starch %	
Treatments	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Control	56.95 d	57.01 d	41.06 d	40.31 d	18.17 cd	18.72 cd	15.98cd	15.99cd	2.01cd	2.03cd
5 Mg ha^{-1}	62.58 bc	63.56bc	37.49bc	36.40bc	19.17 bc	19.22 bc	16.01c	16.02 c	1.96bc	1.99bc
10 Mg ha^{-1}	64.11 b	64.75b	36.81 b	35.74 b	20.76 ab	20.75 ab	16.85 b	16.89 b	1.80ab	1.81ab
20 Mg ha^{-1}	70.44 a	71.56 a	37.98 a	38.08 a	21.58 a	21.64 a	17.53 a	17.59 a	1.79 a	1.81 a

Means followed by the same letters are not statistically different by LSD at 0.05 levels. Mg (mega gram), ha (hectare)

Effect of biochar on leaf mineral content

Results in Table 6 exhibited that the increase in leaf content of NPK and the decrease of Na and electrolyte conductivity (EC) were due to the increase of WB applications. At the first level of WB application (5 Mg ha^{-1}), results presented no significant differences on NPK content compared to the control (Table 6). However, the increase of NPK with the rate of 10 Mg ha^{-1} showed no significant differences compared to the rate of 5 Mg ha^{-1} but it significantly differed than the control (Table 6). The leaf content of NK showed significant increase with the application rate of 20 Mg ha^{-1} compared to the other rates and the control (Table 6). From the other side, the leaf content of P showed no significant differences between the application rate of 20 Mg ha^{-1} and the other treatments (Table 6).

TABLE 6. The effect of biochar on leaf mineral content of Grande Naine banana plants grown in saline-sodic soil during 2012 and 2013 seasons.

Parameters	N%		P%		K%		Na%		EC%	
Treatments	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Control	2.99 cd	3.01 cd	0.22 cd	0.23 cd	2.85 cd	2.85 cd	0.85 a	0.85 a	85.5 a	87.4 a
5 Mg ha^{-1}	3.03 bc	3.04 bc	0.23 bc	0.23 bc	3.05 c	3.06 c	0.69 b	0.66 b	84.6 b	84.5 b
10 Mg ha^{-1}	3.10 b	3.11 b	0.27 ab	0.26 ab	3.38b	3.38 b	0.53 c	0.52 c	81.3 c	81.5 c
20 Mg ha^{-1}	3.28 a	3.30 a	0.29 a	0.28 a	3.80 a	3.81 a	0.47 d	0.45 d	78.5 d	77.5 d

Means followed by the same letters are not statistically different by LSD at 0.05 levels. Mg (mega gram), ha (hectare)

The leaf contents of Na were significantly decreased at all levels of BW compared to the control (Table 6). Electrolyte conductivity (EC) results showed similar results to that stated with Na percentage in the leaves (Table 6).

Discussion

The aim of this study was to quest new strategies that enable plants to cope with saline-sodic soils. Generally soil salinity commonly causes inhibition in plant growth which usually correlated to osmotic stress (Munns and Tester, 2008). Many studies reported that salt stress resulted in reduction in plant performance and yield (Ali et al., 2017). Specific studies on banana plants grown in salt affected soil carried by Junior et al. (2012) and Willadino et al. (2011) comes in harmony with the present results where the control treatment (salinity affected) showed negative growth parameters and yield compared to biochar treatments (Table 3). Biochar addition to saline soil ameliorated plant growth and yield (Table 3, Drake et al., 2016). Leaf area is an indicator of plant performance, photosynthesis, use efficiency of water or nutrient and yield potential (Smart, 1974, Williams, 1987). In addition, leaf area considered as a parameter of light interception and plant productivity (Gifford et al. 1984 and Koester et al. 2014). According to Wardlaw (1972), banana leaf area strongly correlated to the size, quality and rate of fruit development which in agreements with results shown in Tables (4 and 5). In the same direction, biochar application led to the increase of T.S.S and sugars in fruits (Table 5, Villocino and Quevedo 2013). Furthermore, results in Table 5 comes in the same line with many studies which reported that biochar addition to the soils improved soil fertility and NPK uptake (Atkinson et al., 2010, Joseph et al., 2010, Barrow, 2012 and Gul & Whalen 2016). Improving the availability of nutrients after biochar addition was thought to high surface area per unit mass which subsequently increment wide range of ions and cations exchangeable capacity, CEC (Atkinson et al., 2010 and Laird et al., 2010). Ion homeostasis was found to be affected by Na^+ uptake which compete the uptake of other cations (Zhu 2003, Munns and Tester 2008, Shabala and Cuin 2008). Therefore, lower content of Na^+ in leaves (Table 6) interpret increasing leaves content of NPK under all biochar treatments. This suggests a role of biochar in adsorbing Na^+ on its surface, subsequently decreasing Na^+ uptake by the plants. Furthermore, electrolyte conductivity (EC) defined as an indicator of membrane stability in salt stress conditions (Stevens et al., 2006, Lopez-Perez et al., 2009 and Lashari et al., 2015). The measurement of EC therefore suggests uncontrolled ion uptake due to the damage of root membrane under stress condition. This hypothesis comes in agreements with results shown in Table 6 where biochar application reduced EC measurements at all rates compared to the control, suggesting a role of biochar against membrane damage.

Conclusion

Biochar application as amendment in saline-sodic soil leads to amelioration negative effects of stresses which may happen to the plant performance and yield. Adding biochar at rate of 20 Mg ha^{-1} introduced the best data for all parameters under investigation compared to the control. Therefore, the study suggests this application rate of WB or higher rates need to be under investigation.

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Conflicts of interest

The author declares that there are no conflicts of interest related to the publication of this work.

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تأثير البيوشار على القياسات الخضرية والمحتوى المعدنى للأوراق والمحصول وجودة ثمار الموز صنف جراندنان تحت ظروف الأرض الملحية الصودية

عاطف مصطفى محمد النشرتى أبو عجيلة
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أجريت التجربة خلال موسمى ٢٠١٣- ٢٠١٤ لمعرفة تأثير إضافة بيوشار نشارة الخشب للأرض الملحية الصودية على أداء الموز صنف جراندنان المنزرع فى مزرعة خاصة بقرية كفر يعقوب- مركز كفر الزيات- محافظة الغربية- مصر. تم إضافة البيوشار باربع تركيزات هى ٠ ، ٥ ، ١٠ ، ٢٠ طن للهكتار. أظهرت النتائج تحسن النمو الخضرى والإنتاجية وصفات الثمار بزيادة معدلات إضافة البيوشار للتربة. بصفة خاصة كانت لمعاملة البيوشار بمعدل ٢٠ طن للهكتار تاثير معنوى على زيادة طول وسمك السيقان ، مساحة الأوراق ، أوزان الأسباط والكفوف والأصابع. كما أن صفات جودة الثمار المتمثله فى عدد الأصابع فى الكف ، طول وسمك الإصبع ، وزن لحم وقشرة الإصبع ، نسبة المواد الذائبة الكلية والسكر والنشا كلها أظهرت تحسن معنوى بزيادة معدلات إضافة البيوشار. بالإضافة إلى ذلك فإن إضافة البيوشار أظهر زيادة محتوى الأوراق من عناصر النتروجين والفوسفور والبوتاسيوم وإنخفاض محتواها من الصوديوم. كما كان للبيوشار تأثير معنوى على خفض التوصيل الهيدروليكى لمستخلص خلايا الأوراق والذى يعكس ثبات الأغشية البلازمية لجدر خلايا نباتات الاشجار المعاملة به. وفى النهاية توصى الدراسة بإضافة البيوشار بمعدل ٢٠ طن للهكتار ودراسة تأثير إضافة تركيزات أعلى للحد من تأثير الآثار السلبية لمشكلة الأراضى الملحية الصودية على نمو وإنتاج وجودة ثمار الموز صنف جراندنان.