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Effect of biochar application on barley plants grown on calcareous sandy soils irrigated by saline water

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ABSTRACT

In sustainable agriculture, protect the ecosystem by reducing chemical fertilizers are the main goal. Applying biochar to soils is a method to increase the available nutrients, improve soil physio-chemical characteristics and enhance plant growth. The current experiment assess, the influences of biochar (BC) on barely growth under saline conditions. Barely plants grown on a calcareous sandy soil were amended with BC at a rate of 0 (CK), 1 (BC_1) and 3% (BC_3) of soil weight and irrigated by saline water (EC=13.8 dS m^{-1}). The results showed that BC treatments realized significant effects on soil salinity, pH, soil organic matter (SOM), and plant nutrients. The diverse dosages of biochar of BC_1 and BC_3 could enhance SOM by 42.4 and 55.2% and the dry biomass was ameliorate by 4.7 and 15.4 %, respectively compared to the control. The biochar additions to soil increase the agronomic parameters preformance of nutrients utilization by barley plants. The results confirmed that the added biochar could augment the barley production, and improve the soil characteristics under saline conditions as well as its contribution for agriculture sustainability.

KEYWORDS: Barley, Salinity, Biochar, Calcareous sandy soils.

1. NTRODUCTION

Barley (*Hordeum vulgare*) is an important crop to feed animals, malt, and humanbeing that ranks the 5th among all crops over the world. Its importance derives from its wide adaptability to different soils and its ability to grow under marginal environments such as drought, low and high temperature and salinity conditions (Baum et al., 2003). The total cultivated area of barley in the world is 47 million hectares with an annual production of 147.4 million tones and average productivity of 3136 kg ha^{-1} (FAOSTAT, 2018). In Egypt, barley is considered the fourth most important food crop, with a cultivated area of about 31612 hectares in 2017 which produced 115478 tones with an average of 3653 kg ha^{-1} (FAOSTAT, 2018). In addition, barley plants are common grown in the newly reclaimed soils (calcareous soils) which generally characterized by low fertility, high content of calcium carbonate and alkaline pH (Shata et al., 2007).

Many factors such as soil organic matter content can play an important role to facilitate the availability of some nutrients to crops grown in calcareous soils (Awad, 2001; Awad., 2016). Among organic amendments, biochar which is considerd a material with high carbon content that produced from the biomass pyrolysis (Woolf et al., 2010). The advantages of biochar addition for soil quality, plant growth & yield, and agronomical diseasewere demonstrated by many authors (Lehmann et al., 2003; Vaccari et al., 2011; Suppadit et al., 2012; Inal et al., 2015). Moreover, adding the biochar to soils led to an increase in their cation exchange capacity (Liang et al., 2006), available nutrients and growth conditions (Lehmann et al., 2003) which resulting in improved lettuce yield (Gunes et al., 2014), soybean (Suppadit et al., 2012), wheat (Vaccari et al., 2011) and corn (Uzoma et al., 2011; Inal et al., 2015) in different soils. In addition, various soil physio-chemical properties would be improved after biochar application due to its high specific surface area, direct nutrient additions via ash or organic fertilizer amendments as well as its ability to retention more water and nutrients availability (Glaser et al., 2015).

Globally, soil and water salinity are serious problems for growers due to its negatively effects on water and ion transport throughout the soil–plant–atmosphere continuum (Kafi and Rahimi, 2011). The world’s population is estimated to increase from 6 to about 10 billion by 2050. To meet the food demand of the growing world population, a large increase in food production is a must (United Nations, 2012). The scarcity of fresh water in arid and semi-arid countries (such Egypt) poses an additional challenge to irrigated the agriculture area. So, it is necessary to use the available water regardeless its quality to irrigated the agriculture area to meet the increases of food demand.

Both biotic and abiotic stress (salinity and drought stress) are one of the major problems encountered in agricultural environments. Biochar application could mitigate salt stress on plants in agriculture soils (Thomas et al., 2013). The positive effects of biochar application on wheat **crop and their traits were reported under both non** and salt stress conditions (Akhtar et al., 2014). To some extent, there is a lack of the knowledge on the effect of biochar on increasing the resistance of barley plant to different stress especially under saline conditions and its effect on barley growth and yield. The main objective of this study is to test the ability of barley plants grown in new reclaimed soil for tolerate salinity conditions and ameliorate soil physio-chemical characteristics induced by biochar application.

2.Materials and Methods

2.1.Pot experiment

A pot experiment was conducted to investigate the effects of maize cobs biochar on some soil properties and barley plants grown in a calcareous sandy soil. A surface soil sample (0–30 cm) was collected from the experimental farm, Arab El-Awammer research station, agriculture research center, Assuit, Egypt. Some physical and chemical properties of the tested soil were analyzed according to Klute (1986) and Page et al. (1982) and they are shown in Table 1.

Table (1): Phsio-chemical properties of tested soil.

Properties	Value
Sand (g kg^{-1})	901
Silt (g kg^{-1})	70
Clay (g kg^{-1})	29
Texture class	Sandy
$CaCO_3$ (g kg^{-1})	259
pH (1:2.5 suspension)	7.78
EC(1:2.5 suspension, dS m^{-1})	0.56
Organic matter (g kg^{-1})	1.9
Available nitrogen (mg kg^{-1})	26.88
Available Olsen P (mg kg^{-1})	5.41
Available-K (mg kg^{-1})	52.1

Table 2. The main properties of used biochar in the experiment.

Property	pH (1:5)	EC(1:5)	O. M	C/N	Total (g kg^{-1})		
	----	(dS m^{-1})	(g kg^{-1})	Ratio	N	P	K
Value	**11.38**	**5.515**	**933.4**	**26.33**	**18.04**	**3.18**	**28.6**

Four kg soil was mixed by biochar (BC) material amounted 0, 1 and 3% (CK, BC1 and BC3) then the mixture were packed in plastic pots (20 cm in width* 40 cm in length). In all pots, barley seeds (8 seeds) were sown on 1st of November 2018, with tap water then thinned to 5 plants after germination and continued to irrigate with tap water near field capacity for 30 day. After that, the Barley plants were irrigated for other 50 days with artificially saline water prepared by a mixture of NaCl and CaCl2 salts of a 2:1 molecular weight ratio so the final concentration was 120 mol m-3(EC=13.8 dS m-1). Nitrogen was added with the irrigation water at a level of 0.75 g N pot-1 as urea (46 % N) after 15 and 30 days from sowing. Barley plants were harvested after 80 days from sowing and the total fresh shoot weight and plant height per pot were recorded.

2.2. Plant and soil analysis

The photosynthetic pigments; chlorophyll a (Chl-A), chlorophyll b (Chl-B), total chlorophyll (Chl A+B), and carotenoid contents were assessed using the following equations according to the modified protocol of Lichtenthaler (1987). Briefly, 100 mg of fully expanded fresh leaf was extracted with 10 ml ethyl alcohol (95%) in a test tube and kept in darkness until the samples color was completely turned into white. Chl-a , Chl-b and carotenoid concentrations were measured spectrophotometery at 663, 644 and 452 nm, respectively.

Chl. a = (13.36*A663) – (5.19*A644)

Chl. b = (27.49* A 644) – (8.12*A 663)

Carotene = {(1000*A452) – (2.13* Chl. a) – (9.76* Chl. b)} /209.

The harvested plants were washed with distilled water and oven-dried at 70°C then the total dry matter weight per pot was recorded. For total N, P, K and Na determination, the plants samples were digested with a mixture of 350 ml H_2O_2, 0.42 g selenium powder, 14 g $LiSO_4{\cdot}H_2O$ and 420 ml concentrated H_2SO_4 (Parkinson and Allen, 1975). The N, P and K elements were analyzed according to the standard methods described by Page et al. (1982). In shoot, the ratio of Na/k was caculated.

Available nitrogen was extracted by 2M potassium chloride, and it determined using micro-kjeldahl method Burt (2004). Available phosphorus was extracted by (0.5 M Na HCO3 at pH 8.5), the extracted P was measured calorimetrically using stannous chloride phosphomolybdic sulfuric acid system as describe by (Jackson,1973). Available potassium was extracted by ammonium acetate method and measured by flame photometry (Jackson, 1973). The soil organic matter (SOM) was determined using the Walkley Black method (Jackson, 1973) while the organic matter in the biochar was determined using the loss-on-ignition method (Matthiesen et al., 2005).

Agronomic efficiency of applied nitrogen (AEN) and phosphorus (AEP) were calculated using the following equation:

AE_N(g/mgN) or AE_p(g/mg p) =

{(fresh shoot weight at applied N or P (g/pot) – fresh shoot weight of N or P at control (g/pot)} / amount of N or P applied (g/pot)

2.3. Data analysis

The experimental design was complete block design (CBD) with three replicates. The Analysis of Variance (ANOVA) and Duncan multiple range tests at 5% level of probability were used to test the significant of differences between the treatments. Data statistical analyses were performed using Costat software (Steel and Torrie, 1982).

3.Results and discussion

3.1. Soil chemical characteristics

The added biochar (BC) to the tested soil had significant effects on soil chemical properties (pH, EC and SOM) as shown in table (3). The magnitude of this increase depends upon the biochar level. The application of BC_1 and BC_3 increased soil pH by 1.4and 1.6%, respectively, compared to the control. The increase in soil pH may be due to the higher pH value of the biochar (Table 2). These results agreed with other studies which confirmed that the BC may led to increase the soil pH (Eissa, 2019).

The EC of the tested soil increased by increasing the application level of BC. In addition, soil salinity significantly increased by 10.8 and 14.6% as a result BC_1 and BC_3 application, respectively, compared to the control.

Soil organic matter (SOM) is one of several key indicators of soil quality (Andrews et al., 2004). The application of the BC_1 and BC_3 increased SOM by 44.4 and 55.2 % respectively, compared to the untreated soil. The increase in SOM due to the application of the BC refers to its high organic matter content (Table 2) . This result was confirmed Previously in several studies (Lehmann, 2007; Usman and Gameh, 2008; Hamed et al., 2011).

Table 3. Effect of biochar application rat on pH, EC and OM soil after harvest barely

Trreatment	pH (1:2.5)	EC(1:2.5,dS m^{-1})	O.M (g Kg^{-1})
CK	7.58 ±0.02b	2.28±0.03 b	8.26± 0.21b
BC_1	7.68 ±0.02a	2.52± 0.02a	11.76±0.60 a
BC_3	7.70 ±0.03a	2.61±0.09a	12.83± 0.92a

CK= control, BC1= 1 % biochar, BC3=3 % biochar. Note: Means denoted by the same letter indicate no significant difference according to Duncan's test at p <0 .05.

3.2. Soil nitrogen, phosphorus and potassium availability

The nutrients availability of nutrients was affected by the saline conditions and shortage of some nutrients availability may occur due to these condiation (Syeed et al., 2011). In the current study, the available soil nitrogen (N), and potassium (K), significantly improved with the BC application (Table 4). The availability of soil N significantly affected by the addition of BC_1 and BC_3 which it increased by 60.0 and 9.5 %, respectively, above the control. Also, the application of BC increased the available soil K which BC_1 and BC_3 increased it by 11.6 and 85.9 %, respectively, in comparison to the control. However BC applcation at the investigated levels decreased the soil available P that couled be due to the P retention by the function groups of biochar and/or high calcium carbonate content and calcium chloride in saline water irrigation. Other studies shows that the addition biochar may an increase in the soil cation exchange capacity (CEC) (Liang et al., 2006) and improves the soil available nutrients (Lehmann et al., 2003).

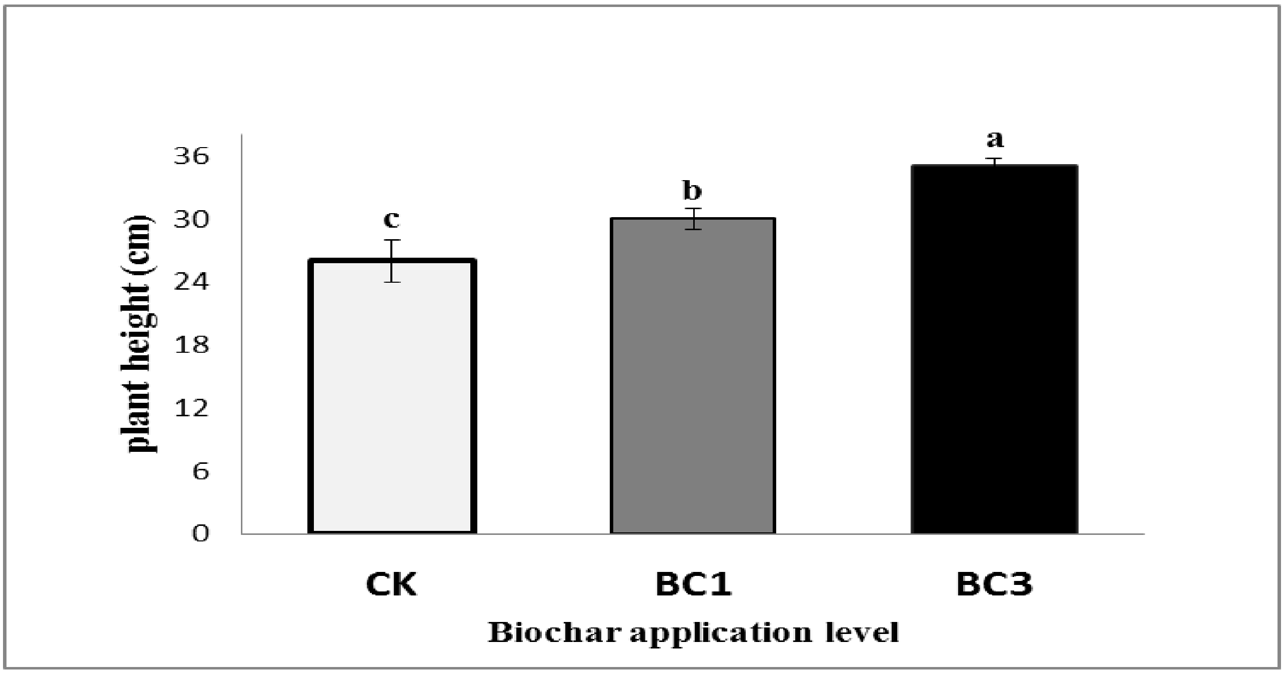
Table (4): Effect of biochar application on available nutrient after barely harvesting

Treatment	Availble nutrient(mg kg-1)		
	N	P	K
CK	9.44 ± 0.25b	8.56 ± 0.53a	31.0 ±4.00 b
BC1	15.11 ± 1.07a	5.64 ± 0.23b	34 ± 7.00 b
BC3	10.34 ± 0.06b	4.21 ± 0.39c	57 ± 4.00 a

CK=control, BC1= 1%biochar, BC3=3%biochar. Note: Means denoted by the same letter indicate no significant difference according to Duncan's test at p < .05.

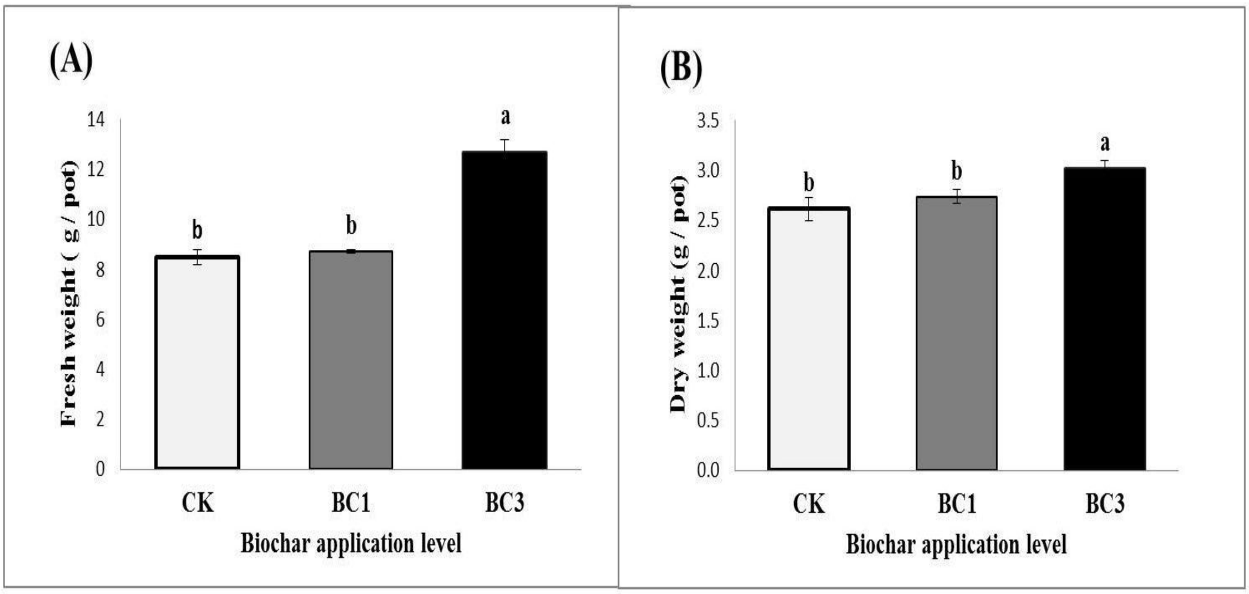
3.3. Pant growth parameters

In the current study, the plant height, dry, and fresh weight were significantly ($p < 0.05$) increased by BC application (Figure 1and 2). The application of BC_1 and BC_3 significantly increased the plant height of barely plants by 2.4 and 49.6 % respectively, compared to the control. Biochar application in sandy soil (Uzoma et al. 2011) and calcareous soil (Inal et al., 2015), increased the growth, yield, and nutrients uptake of corn plants. Biochar application increased tomato growth and its biomass inspite of using saline irrigation water (3.6 dS m^{-1}) compared to the non-saline (0.9 dS m^{-1}), irrigation water (Usman et al. 2016). Fresh and dry weight of barely plants were significantly affected by application of BC_1 and BC_3 since the fresh weight increased by 15.4 and 34.6 % and dry weight by 4.7 and 15.4 % respectively, compared to the control. Increasing fresh and dry weights of shoot caused by biochar application can be attributed to increased soil nutrients availability and improved growth conditions, which resulting in improved yield. Previous studies reported an increase in plant growth performance with biochar application (Naeem et al., 2017).These positive effects can result from both direct and indirect effects of using biochar (nutrients in the biomass and soil physical, chemical and biological properties improvement) as confirmed by Major et al. (2010) and Abdipour et al.(2019).



CK=control, BC1= 1%biochar, BC3=3%biochar. Note: Means denoted by the same letter indicate no significant difference according to Duncan's test at p < .05.

Fig 1. Effect of biochar application on plant height (cm) of shoot barely.



C= control, BC1= 1% biochar, BC3=3% biochar. Note: Means denoted by the same letter indicate no significant difference according to Duncan's test at p < .05

Fig 2. Effect of biochar application on fresh and dry weight (g pot^{-1}) of shoot barely plants

3.4.Nitrogen (N) phosphorus (P) and potassium (K) uptake and Na/K ratio by barely plants.

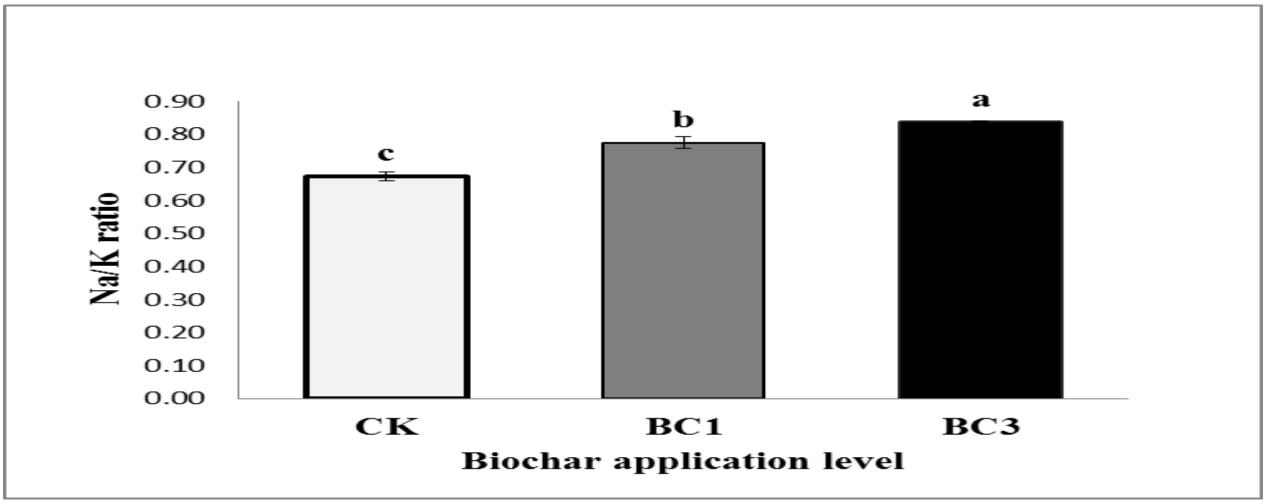
Nitrogen, P and K uptake were significantly ($p < 0.05$) affected by the BC application (Table 5 and figure 3). The nitrogen uptake significantly increased by 71.5 and 20.6% induced by BC_1 and BC_3 , respectively, compared to the control. The biochar addition led to an increase in phosphorus taken by growing plants, since the BC_1 and BC_3 treatments increased p uptake by 7.1 and 8.0%, respectively, compared to the control. The application of BC increased the K uptake significantly compared to control, since the BC_1 and BC_3 treatments increased K uptake by 1.3 and 42.6%, respectively, compared to the control. The increase in K uptake in biochar amended soils might be attributed to rich amount of K in the biochar ash. Biochar plays a critical role in soil ecosystem because it provides substrates for decomposing microbes, improves soil structure and water holding capacity (Abiven et al.,2009). Also, biochar application in the culture medium improves soil physical chemical properties, preserves soil organic matter, increases nutrient availability, and eventually improves crop yield (Vaccari et al., 2011; Abdipour et al., 2019).

Table 5. Effect of biochar application on N, P and K uptake by barely

Treatment	Uptake (mg pot^{-1})		
	N	P	K
CK	89.39 ±9.73c	2.40±0.20 b	67.58±5.27b
BC1	153.35 ±2.32a	2.69± 0.24ab	68.48±1.60b
BC3	107.77± 3.23b	2.98±0.08 a	96.35±2.01a

CK= control, BC1= 1% biochar, BC3=3% biochar. Note: Means denoted by the same letter indicate no significant difference according to Duncan's test at p <0.05.

Ratio of Na/K in barely shoot was significantly affected by BC application since the BC_1 and BC_3 treatments increased it by 15.0 and 24.5 % respectively, compared to the control. In agreement with these results, the biochar application improve K/Na ratio and reduced Na uptake in salinity stressed plants, which finally alleviated growth of Lactuca sativa (Hammer et al. 2015) and wheat (Akhtar et al. 2015) due to its effects on mitigating salinity stress.

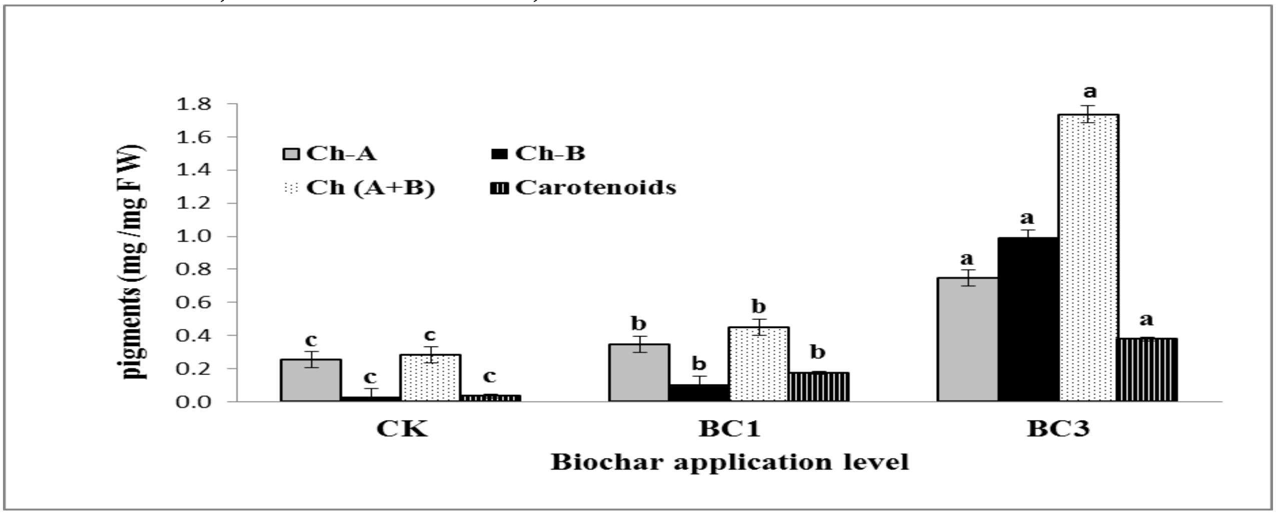


C= control, BC1= 1% biochar, BC3=3% biochar. Note: Means denoted by the same letter indicate no significant difference according to Duncan's test at p < .05

Fig 3. Effect of biochar application on Na/k ratio in the shoot tissues of barely plants.

3.5. Some photosynthetic pigments

Chlorophyll contents are effective indicator of plant health and growth condition (Lichtenthaler, 1987). The chlorophyll a, b, total (a+b) and carotene of barely leaves were significantly increased in the biochar amended soil (Figure 4). Chlorophyll a, b and total (a+b) contents of leaves were significantly ($p < 0.05$) increased from 0.2537 to 0.3457, from 0.0288 to 0.1053, and from 0.2825 to 0.4509 mg/g, respectively, at the 1.0% of biochar level compared to the control. The corresponding values of 3.0% biochar level, were increased from 0.2537 to 0.7469, from 0.0288 to 0.9893, and from 0.2825 to 1.7362 mg/g, respectively, compared to the control. Carotene in the shoot tissues of barely plants was significantly affected by biochar application. Carotene increased in treatments BC_1 and BC_3 by 399 and 981 % respectively, compared to the control. Salinity in treated plants degrades the content of photosynthetic pigments (Taffouo et al. 2010). These findings are in agreement with those of Manuchehri and Salehi (2014). The decrease in chlorophyll content in the plants grown under saline conditions resulted from increasing degradation and inhibition synthesis of that pigment (Garcí aSánchez et al. 2002).

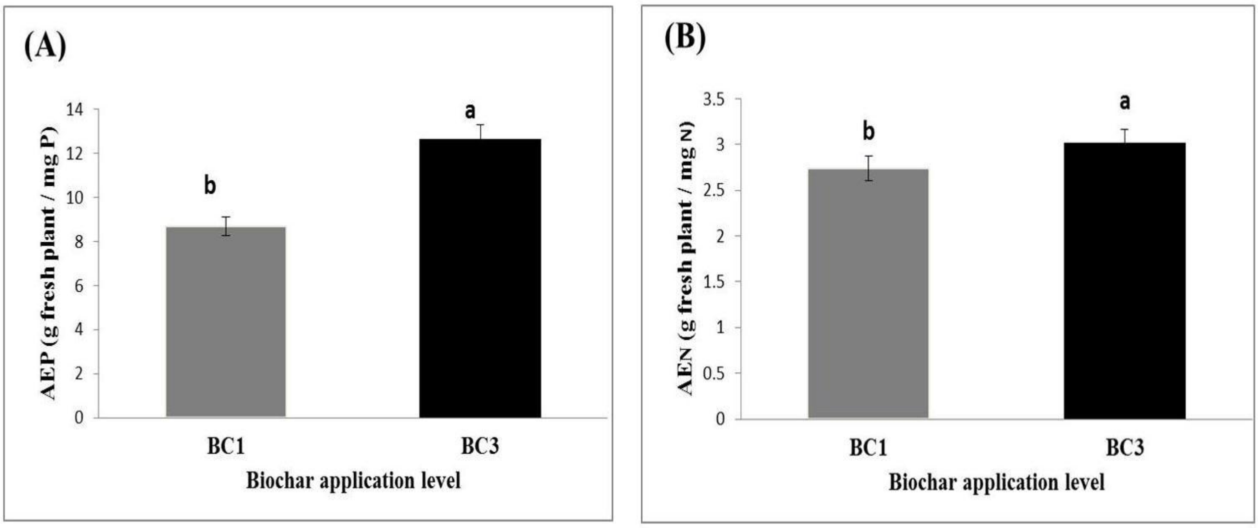


Chl A= chlorophyll A, Chl B= chlorophyll B, Chl A+B= chlorophyll A and B. The data were collected at the full blooming stage. CK= control, BC1= 1% biochar, BC3=3% biochar Note: Means denoted by the same letter indicate no significant difference according to Duncan's test at p < .05.

Fig 4. Effect of biochar application on some photosynthetic pigments (mg/g) of the shoot tissues of parly plants.

3.6.Agronomic efficiencies of applied phosphorus (AE_p) and nitrogen (AE_N).

The agronomic efficiencies of applied phosphorus (AE_p) and nitrogen (AE_N) ware significantly improved by biochar application (figure 5). The AEp was significantly ($P<0.05$) increased by 8.69 and 12.65 mg P/g fresh shoot as a result of BC_1 and BC_3 treatments, respectively, compared to control one. The corresponding values of the agronomic efficiency of AE_N were 2.74 and 3.01 mg N/g fresh shoot compared to control treatment respectively. Agronomic efficiency of both AE_p and AE_N are function of the soil capacity to supply sufficient amount of nutrients and the ability of plants to uptake them (Baligar et al., 2001). These results demonstrated that the biochar additions to the calcareous sandy soil increased the agronomic efficiencies of the applied N and P by barley plants. It is attributed to the fact that the biochar has the ability to retain the nutrient from leaching in this soil and being a source of nutrient supply which it in improves the nutrient use efficiency.



BC1= 1%biochar, BC3=3%biochar. Note: Means denoted by the same letter indicate no significant difference according to Duncan's test at p < .05.

Fig 5. Effect of biochar application rat on agronomic efficiency of applied phosphorus (AEp) and nitrogen (AE_N) of barely plant

4. Conclusions

Improving soil properties due to the addition of biochar resulted in an increase of the available amounts of nitrogen, phosphorus and potassium of the soil and therefore, in the plants. Applying the biochar to the calcareous sandy soil encouraged of barley growth and porduced a marked increase in biomass under saline water irrigation conditions. This study indicated that the soil application of the organic amendments helps the ability of the barley to tolerate salinity. The addition of biochar increased the agronomic efficiencies of applied nitrogen and phosphorus as well as photosynthistic pigments. According to this study, marginal water can be used to irrigate barley plants grown on sandy soils treated with biochars. So, this study confirms the contribution of biochars to the sustainability of agriculture and water conservation . Thus, the increase in food demand can be countered by increasing the agricultural land.

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تاثير البيوشار علي الشعير النامي في الأراضي الرملية الجيرية والمروي بمياه مالحة

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الملخص العربي

حماية النظام البيئي وتقليل إستخدام الاسمدة الكيمائية من الاهداف الرئيسية للزارعة المستدامة. إضافة البيوشار للتربة هو طريقة لزيادة محتوها من العناصر الغذائية الميسرة ، وتحسين الخصائص الكيميائية للتربة وزيادة نمو النبات . نفذت تجربة أصص تم فيها دراسة تاثير البيوشار **(BC)** علي نمو الشعير النامي في الظروف الملحية . تم زراعة الشعير في الاراضي الرملية الجيرية وتم إضافة البيوشار بمعدلات **[** صفر% **(CK)** و ١% **(BC_1)** و٣%**(BC_3)]** من وزن التربة وتم ريها بمياه مالحة تركيزها **($EC= 13.8$ dS m^{-1})**. وأظهرت النتائج ان اضافة البيوشار له تاثير معنوي وكبيرعلي ملوحة التربة ودرجة الحموضة والمادة العضوية والعناصر الغذائية . المعاملة بالبيوشاربمعدل **(BC_1)** و**(BC_3)** أدت الي زيارة المادة العضوية بنسبة ٤٢.٤ و٥٥.٢ % وكانت الزيادة في الكلتة الحيوية الجافة بنسبة ٤.٧ و١٥.٤ % علي التوالي مقارنة بالكنترول. بشكل عام ، أكدت نتائج الدراسة الحالية ان اضافة البيوشار يمكن ان يزيد من انتاج الشعير ويحسن من خصائص التربة تحت الري بمياه مالحة. أدت إضافة الفحم الحيوي إلى زيادة الكفاءة الزراعية للنيتروجين والفوسفور المضاف وصبغات التمثيل الضوئي .تؤكد هذه الدراسة على مساهمة الفحم الحيوي في استدامة الزراعة والحفاظ على المياه وبالتالي يمكن مواجهة الزيادة في الطلب على الأغذية بزيادة الأراضي الزراعية باستخدام المياه العادمة فى الزراعة.

الكلمات المفتاحة : الشعير ، الملوحة ، البيوشار ، الاراضي الرملية الجيرية.