Assiut Journal of Agricultural Sciences 55 (2) 2024 (260-275) Website: http://ajas.journals.ekb.eg/
ISSN: 1110-0486 / EISSN: 2356-9840 E-mail: ajas@aun.edu.eg

(Original Article)

Growth Improvement of Sweet Basil (*Ocimum basilicum* L.) Irrigated with Saline Water Using Biochar and *Spirulina* Algae Extract

Mai O. Fekri*; Hala H. Gomah and Mamdouh A. Eissa

Department of Soils and Water, Faculty of Agriculture, Assiut University, Assiut, Egypt.

* Correspondence: maiosman690@gmail.com
DOI: 10.21608/AJAS.2024.260394.1324

Abstract

The current study aims to use the foliar treatment with *Spirulina* algae extract (SP) at rate 2.5g/L and biochar (BC) at rate 2% as soil amendment to alleviate the negative effects of salinity on basil plants. The irrigation with 5 dS/m saline water reduced the plant height, leaf number, branch number, leaf area, total chlorophyll, fresh, and dry weight by 10, 31,31,40, 55, 46, and 33%, respectively, compared to the fresh water. The combined addition of BC and SP (SP+BC) to the saline irrigated plants significantly increased the last above-mentioned growth parameter by 6, 21, 50, 45, 170, 8, and 31% respectively compared to the saline water without addition. The increase in branch number is not significant. BC and SP significantly ($p < 0.05$) increased the soil organic matter (SOM). The content of SOM can be arranged in the descending order: BC > SP > C. The irrigation of basil plant with saline water significantly decreased the total N, P and K in basil shoots at rate 31, 61, and 24%, respectively, compared to the fresh water. The addition of BC+SP to the saline irrigated basil caused increases in N, P, and K content by 90, 116, and 60% compared to the saline water without addition. Overall, the results of this study explained that using *Spirulina* algae extract and biochar is a good solution for improving the growth of basil plant under salinity condition.

Keywords: *Biochar; Spirulina; Basil; Salinity; Clay soil.*

Introduction

Even these days, the use of medicinal plants is still popular especially in third world countries and this is evident during the COVID-19 pandemic (Benarba and Pandiella., 2020). Among the medicinal species, basil (*Ocimum basilicum* L.), named commonly as sweet basil, is an economic value plant due to its essential oil, and chemical composition (Bilal *et al*., 2012). Water resources in Egypt are limited either conventional or non-conventional water resources and low quality water such as saline water should be used for plant cultivation (Djuma *et al*., 2016). Saline environments have an adverse effect on plant nutrition and increase soil osmotic pressure, which both hinder plant growth (Huang *et al*., 2019). So, it is insistent to develop management practices for using poor-quality water for agriculture without or with minimum reduction in crop yields (Singh *et al*., 2021).

Received: 3 January 2024/ Accepted: 1 April 2024/ Published online: 27 April 2024

Organic materials addition into the soil is a good management to mitigate the negative effect of saline water on soil properties (Chahal *et al*., 2018). The thermochemical conversion of organic material to biochar for its soil application is an effective strategy for improving the quality of degraded lands (Rizwan *et al*., 2023). Biochar application has been shown to ameliorate salt stress in several ways including: (a) lowering the concentration of toxic salts in the root zone such as Na^+ through adsorption on the biochar surfaces (Singh *et al*., 2018); (b) physical entrapment of Na^+ in fine pores of biochar (Rombolà *et al*., 2022); (c) leaching of salts from soil profile (Hammer *et al*., 2015) (d) reduction in osmotic stress through improving water holding capacity (Ali *et al*., 2017); and (e) the promotion of microbial activities in the rhizosphere (Zheng *et al*., 2018).

Using natural substances as bio-fertilizer is a good solution that can reducing rely on chemical fertilizers. *Spirulina* is a photosynthetic blue-green microalga, it has a nutrition value and high protein content (Prisa, 2019). *Spirulina* products can improve plant growth by enhancing the natural defense against biotic and abiotic stresses (Arahou *et al*., 2023). *Spirulina* water extract (5 g/L) improved *Triticum aestivum L*. tolerance to salt stress and enhanced both antioxidant activity and protein content of grains (Abd El-Baky *et al*., 2010). It is also important to mention that *Spirulina* extracts may be involved in Na^+/K^+ ions balance, leading to better cell control under stress conditions (Selem, 2019).

The current study aims to evaluate the effect of biochar application to the soil, *Spirulina* algae extract as foliar application, and their combinations on the growth of sweet basil irrigated with saline water.

Materials and Methods

1-Biochar preparation and characterization

Corn cob wastes were collected, cut into small pieces, and pyrolyzed in an oven in a stainless steel container with a lid under limited available oxygen for 2 h at 300°C. The produced biochar was crushed and passed through a 2 mm sieve. Biochar sample was digested with H_2O_2, H_2SO_4, lithium sulfate, and selenium (Parkinson and Allen., 1975) and then analyzed for total N, P and K content. Nitrogen was distilled by Kjeldahel method (Burt., 2004). Phosphorus in the digested extract was measured by the stannous chloride method (Jackson., 1973). Potassium was determined by flame photometer (Jackson., 1973). Biochar pH was evaluated by a digital pH meter in 1:10 biochar to water suspension and the electric conductivity EC was determined by an EC meter in 1:10 biochar to water extract (Burt., 2004). Bulk density was measured using a graduated cylinder (Han *et al*., 2016). Total C, H, N and S in biochar samples were measured by CHNS analyzer and table 1 shows the main characterization of the investigated Biochar. Biochar sample was characterized using scanning electron microscopic (SEM) to examine the particles morphology in the average size of 10 nm (Fig.1).

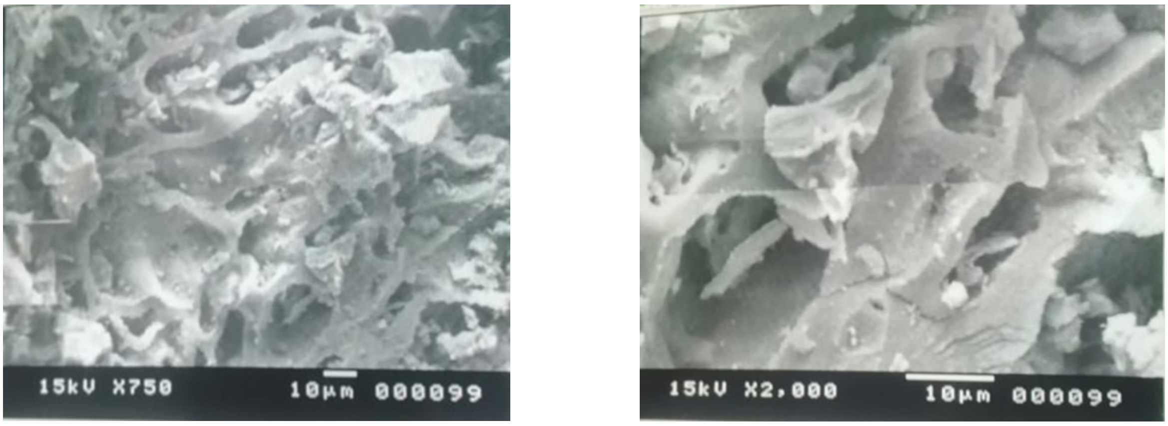

Fig. 1. Scanning electron microscopic (SEM) images of biochar

Table 1 Main characterization of the investigated biochar

pH (1:10)	EC (1:10) (dS m−1)	Bulk density (gcm−3)	Total P (g kg^{-1})	Total K (g kg^{-1})	% N	% C	% S	% H
6.81	0.42	0.3967	3.9	6.372	0.603	67.78	1.397	2.182

2-Pot experiment

A pot experiment was carried out to examine the impact of applying biochar to the soil along with foliar spraying *Spirulina* algae extract on sweet basil plants irrigated with fresh and saline water. The soil (0-20 cm) was collected from the Agriculture Faculty farm, Assiut university, Assiut, Egypt. Table 2 shows the main characterization of the studied soil. The BC treatments were prepared by mixing the soil with BC at rate 2% then filling the pots with 5 kg of the Bc treated soil (Salim., 2016; Ding *et al*., 2020), then put into plastic pots (25 cm diameter and 20 cm height), 5 kg of soil for each pot. Seeds of basil (*Ocimum basilicum L.*) were sown on at the rate of 10 seeds per pot at 6/7/2021 and were irrigated with tap water during the first 30 days. After the germination was completed, the plants were thinned to three plant per pot. The plants were fertilized with a 50 mL for each pot of half strength of Hoagland's solution (Gomah *et al*. 2020). The irrigation water salinity was increased gradually starting from 25% of final salinity with continuous weekly increase until the 100% water salinity(5dS/m) After that the basil plants were continued to be irrigated with saline water (5 dS/m) for another two months. The saline water was (5 ds/m) prepared from 2:1 of (NaCl: $CaCl_2$). The control treatments irrigated with fresh water (0.46 millmhose/cm) The plants were sprayed with *Spirulina* algae extract solution. SP was prepared by soaking 2.5 g /l water for one hour then filtrated plants were sprayed with the extract two times during the experiment, the first after two weeks of starting salinity irrigation treatment after 45 days of planting and the other two weeks later. The zero treatments were sprayed with distilled water. *Spirulina* algae extract was purchased from the National Research Center, Egypt. The moisture, protein, ash, fiber, fat and carbohydrates of *spirulina* algae extract was 5.30, 60.73, 14.32, 3.22, 5.92 and 15.81% respectively. The total N, P and K were 10, 0.1739 and 1.13%. The Fe, Mn, Zn and Cu were 747.57, 66.99, 84.73 and 72.52 mg kg^{-1} respectively. At the end of the experiment, plants and soil samples were collected and growth parameters were recoded. The experiment design was RCBD factorial experiment with 3 replicates.

Table 2 Main characterization of the investigated soil

Property	Value
Clay	47.4
Silt	30.6
Sand	22
Texture	Clay
pH (1:2.5)	7.48
EC (1:5) (dS/m)	0.22
%CaCO3	5.94
% OM	0.537
Ava N (g/Kg)	0.24
Ava P (g/Kg)	0.0223
Ava K (g/Kg)	3.9

3-Soil, plant, and *Spirulina* analysis

Soil samples were prepared for the analysis of pH, O.M and available N, P and K. The soil organic matter (SOM) was oxidized with dichromate and determined by the Walkley-black method (Nelson and Sommers.,1996). The nitrogen in soil was extracted with (1 M) KCl solution (Burt., 2004). The phosphorus in soil was extracted with 0.5 N sodium bicarbonate solution adjusted to pH 8.5 (Jackson, 1973). Potassium was extracted using 1M ammonium acetate at pH 7 (Jackson, 1973). The extracted solution for N, P and K was treated like the digested solution of biochar.

Spirulina algae extract was digested with H_2O_2, H_2SO_4, lithium sulfate and selenium (Parkinson and Allen., 1975) and then analyzed for total N, P and K concentrations as mentioned in biochar. Digestion solution at rate 3:1 HNO_3: $HClO_4$ was used for the digestion of *Spirulina* algae extract for micro nutrient determination (USEPA, 1997). The Fe, Mn, Zn and Cu in *Spirulina* algae extract were determined after digesting in ICP device. Table 3 and 4 shows the main properties of *Spirulina* algae extract compound, macro and micro nutrients concentrations in it. Table 5 shows the amino acids concentration in *Spirulina* algae extract.

Table 3 Main properties of *Spirulina* algae extract compounds

Moisture	Protein	Ash	Fiber	Fat	Carbohydrates
5.30	60.73	14.32	3.22	5.92	15.81

All the units are percentage based on dry weight. The data provided by the National Research Center, Egypt

Table 4 The micro and macro nutrients concentrations in *Spirulina* algae extract

% T.N	% T.P	% T.K	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
10	0.1739	1.130	747.57	66.99	84.73	72.52

Table 5. The amino acid concentrations (mg kg^{-1}) in *spirulina* algae extract as provided from the National Research Center, Egypt

Threonine	37.66
Valine	56.25
Methionine	71.81
Cystine	17.21
Isoleucine	60.24
Leucine	66.72
Histidine	12.34
Tyrosine	89.67
Phenylalanine	14.74
Lysine	13.59
Aspartic acid	29.88
Glutamic acid	14.85
Serine	10.93
Glycine	10.45
Arginine	7.51
Alanine	17.58
Proline	29.78

Plant samples were washed with distilled water and oven dried at 70°C and crushed in a mill. The total fresh and dry weight for each pot were recorded. Dried plant samples were digested as mentioned in biochar digestion and the total N, P and K was measured. The measurements of plants growth parameters were plant height, branch number, leaf number, plant area and total chlorophyll. Chlorophyll was measured according to Metzner *et al*. (1965). Samples of fresh leaves were randomly collected. Leaf pigments were extracted by 80% aqueous acetone and measured by spectrophotometer at 663 µm for chlorophyll a and 644 µm for chlorophyll b, then using the following equations

Chlorophyll a= 10.3 E 663 – 0.918 E 644   µg/ ml

Chlorophyll b=19.7 E 644 –3.87 E 663   µg/ ml

Values of chlorophyll a and chlorophyll b were converted to mg/ g using this equation:

$$\textbf{fresh weight (mg/g)} = \frac{\mu g/ml \times final\ volume\ (ml)}{fresh\ weight\ of\ sample\ (mg)}$$

Total chlorophyll= chlorophyll a + chlorophyll b

4-Statistical analysis

All data were performed to analysis of variance (ANOVA) using the Statistix program (version 8.1). Comparison of the means were conducted using Least Significant Difference (LSD) test at p< 0.05.

Results and Discussion

1. Effect of water salinity, biochar (BC), and *Spirulina* extract (SP) on soil pH, organic matter content and EC

The addition of biochar to soil and spraying basil plants with *Spirulina* (SP) significantly ($p < 0.05$) affected the soil pH, EC and organic matter (SOM) of the tested soil (Fig.2). The value of the soil pH ranged between 6.87 and 7.62, the highest value was found in the fresh water as a control treatment, while the lowest ones were found in biochar irrigated with saline water treatments. In general, the addition of biochar to the studied soil significantly ($p < 0.05$) reduced the soil pH compared to the control. Abo-Elyousr *et al*. (2022) found that soil pH was reduced from 8.02 to 7.48 when the soil was amended with 2.0% shrimp waste biochar. The decrease in soil pH as a results of biochar addition may be due to the low pH determined in the used biochar (6.81) The release of low-molecular weights of organic acids as results of mineralization of the added organic amendments may cause the reduction in soil pH (Ding *et al*., (2020); Abo-Elyousr *et al*. (2022).

The addition of biochar (BC) and *Spirulina* (SP) significantly ($p < 0.05$) increased the soil organic matter (SOM). The content of SOM can be arranged in the descending order: BC >BC+SP > SP > C. with both kinds of irrigation water. The studied biochar sample used in the current study was made of corn cob wastes and according to the results from the CHNS analyzer it contains 68% organic-C. Liu *et al*. (2021) found that the addition of biochar significantly increased the soil organic matter of the clay loam soils. The addition of the organic amendment that is rich in their organic carbon content increased the soil organic matter, especially biochar due to its high stability in soil (Abo-Elyousr *et al*., 2022). Biochar is characterized by its higher content of more stable organic carbon compounds and thus it slowly decomposes in the soil (Ding *et al*., 2020).

Irrigation with saline water caused noticeable increase in soil EC with all treatments compared to fresh water. The addition of BC irrigated with fresh water increased the soil EC by 22% compared to fresh water as a Control. This result is harmony with (El-sayed *et al*., 2021) and (Ding *et al*., 2020). The results from (EL-sayed *et al*., 2021) study indicated that corn cob biochar (pyrolysis at 350) increased the soil EC irrigated with fresh water at rate 7% for 2 seasons. There is also Ding et al., 2020. Ding used biochar from Banana leaves and false stems to soil irrigated with fresh water. From the results from Ding the biochar 1 and 2 increased the soil EC at rate 21 and 31%. This increase may be due to its content of nutrients releasing on the reaction of biochar with water (Joseph *et al*., 2021). The addition of biochar to soil irrigated with saline water decreased the soil EC by 19% compared to soil irrigated with saline water without any addition. Irrigation with saline water decreases the ability of plants to absorb water and nutrients. So, the nutrients will accumulate in the soil, leading to increasing soil EC. The addition of biochar can increase plant absorption. The addition of SP to fresh water treatment slightly reduced the soil EC by 9% compared to fresh water control. Crouch and Van Staden (1993) reported that SP liquid extracts boost nutrient uptake, may causing soil EC decreasing. The addition of BC, SP, SP+BC under saline condition decreased the soil EC at rate 19, 21 and 38 % compared to saline water. This may be because of their role in increasing nutrient absorption.

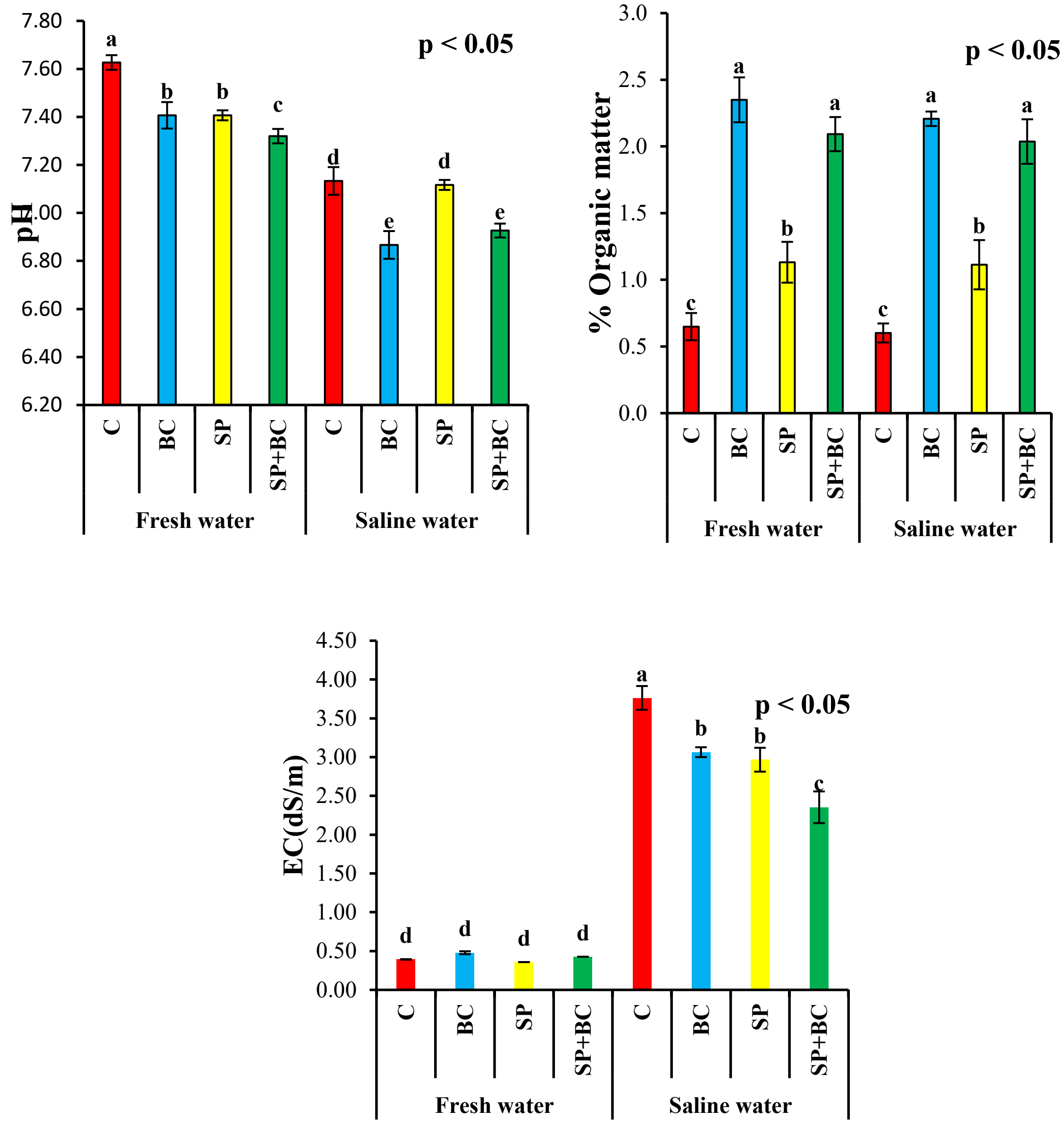

Fig.2 Effect of water salinity, biochar (BC), and *Spirulina* (SP) application on soil pH, organic matter content and EC. Means with same letters indicate no significant difference. Means with different letters differ significantly from each other at $p < 0.05$ according to LSD test. C= control.

2. Effect of water salinity, biochar (BC), and *Spirulina (*SP) on nutrient availability and uptake

Water salinity significantly ($p < 0.05$) affected nutrient availability in soil as well as the uptake in basil shoot. The soil irrigated with the saline water contained more available nitrogen (N) and phosphorus (P) compared to fresh water. Whereas it contained less content of available potassium. It seems that an antagonism occurs between the NO3 and H2PO4 from hogland solution and Cl- (the dominant anion in the saline added solution), and as a result plants absorb Cl- instead of N and P leaving N and P in the salt affected soil. This did not occur with K due to the Na+ and Ca+2 content in the saline water. This conclusion may be the reason which explain that why available N and P in the salt affected soil is higher than in the non affected ones whereas K is not. Physiological changes in the plant system that accompany salt stress have a negative impact on plant growth, and the arrival of Na+ and Cl- to the cells of leaves causes a deterioration in the nutrient uptake (Ding *et al*., 2020). The addition of BC decreased the soil available nitrogen by 35% compared to fresh water control. The addition of biochar increased the available P and K by 17 and 52% respectively compared to fresh water control. SP addition decreased the soil available N by 20% compared to fresh water control, also it increased soil available P and K by 65 and 6% compared to fresh water control. The addition of SP+BC decreased the available soil nitrogen by 34% compared to fresh water control. SP+BC addition increased soil available P and K at rate 74 and 50% compared to fresh water control. There is an increase in available nitrogen and phosphorus with an average of 21 and 13% respectively under saline control treatments only compared with fresh water control. This increase may also be due to the reduction of osmotic potential of soil solution and thus increases the difference between the water potentials of soil solution and plant root solution leading to the reduction of water and nutrient absorption which causes physiological drought. Ben-Gal *et al*. (2009) indicated that under saline conditions osmotic potential reduced, solute uptake system saturation and these systems required more energy and subsequently growth of plants decreased. This is remarkable clear with the anions because the added salts contain only one type of anions (Cl-) and may accrue antagonism with N and P.

The irrigation of basil plants with saline water control caused decreases in N, P, and K uptake of basil shoot by 31, 61, and 24%, respectively, compared to the fresh water. Control similar results were found by Ding *et al* (2020). Irrigation basil plants with saline water according to the previous study reduced N in basil plant in comparison with the control (Ding *et al*.,2020). Munns *et al*.1(986) suggested that the reduction may be because of the antagonism between Cl- and NO3- uptake by plants. This reduction in N uptake reduced plant growth as N is important for the synthesis of amino acids, the building of proteins and chlorophyll (Uchida, 2000).

There is also a reduction in potassium uptake by basil plants because Na+ ion induced Ca+2 and K+ deficiencies (Elhindi *et al*., 2017). This leads to plant growth reduction as K+ is important for many physiological processes like photosynthesis and stomatal control (Broadley *et al*., 2006). The reduction of K+ reduces photosynthetic CO2 fixation as well as the transportation of photo assimilates and damage chlorophyll (Tränkner *et al*., 2018).

There is also a reduction in total phosphorus ($p < 0.05$) because of the presence of Cl- ion (Zhukovskaya, 1973).

The addition of BC, SP and SP+BC for fresh water treatments nutrients uptake by 34, 73 and 127% for N 174, 144 and 278% for P 42, 50 and 90 for K respectively. The addition of BC, SP and SP+BC also increased the nutrients uptake of basil irrigated with saline water by 66,79, and 91% for N 78,76 and 116 for P 42, 47 and 61 for K, respectively. These increases related to the nutrients, organic matter and organic compounds as shown in the analysis content in BC+SP. Hammer *et al*. (2015) indicated that biochar addition to lettuce plants increased P and Mn in their tissues. There are similar results in other crops like increasing P, Fe, Zn, Cu, and K in maize and tomato (Kim *et al*., 2016). BC content of organic matter may encourage the useful microorganisms producing various biomolecules such as antibiotics, enzymes, antimicrobial and pathogen inhibiting volatile compounds, that help mitigate abiotic and biotic stresses (Gou *et al*., 2018). BC addition positively affects N cycling probably through modeling N mineralization and nitrification processes in a greenhouse soil (Zhang *et al*., 2021). BC acts as soil organic matter and it could improve soil P bioavailability by covering or binding P sorption sites (Morales *et al*., 2013). The application of SP increased K in basil plant under saline conditions because it leads to restoring of plasma membrane permeability (Sharma *et al.,* 1995).

Table 5. Effect of water salinity, biochar (BC), and Spirulina (SP) application on nutrient availability in soil

Treatments		N ($mg\ kg^{-1}$)	P ($mg\ kg^{-1}$)	K ($mg\ kg^{-1}$)
Fresh water	C	397.4±5.6^{b}	21.84±.3^{f}	518.22±4.1^{e}
	BC	260.2±2.7^{g}	25.55±1.1^{e}	788.92±.26^{a}
	SP	318.13±5.8^{f}	36.07±1.4^{c}	549.98±.82^{d}
	BC+SP	263.27±5.4^{g}	38.05±.5^{b}	776.9±1.98^{b}
Saline water	C	461.07±3.6^{a}	25.55±1.1^{e}	408.53±2^{g}
	BC	328.67±2^{e}	29.73±1.4^{d}	406.15±4.9^{g}
	SP	359.47±.9^{c}	39.51±.37^{b}	507.62±1.1^{f}
	BC+SP	340.83±1^{d}	44.66±1.3^{a}	701.58±9.3^{c}

Table 6. Effect of water salinity, biochar (BC), and *Spirulina* (SP) application on nutrient concentration percentage

Treatments		N (%)	P (%)	K (%)
Fresh water	C	1.62±0.02^{f}	0.27±0.01^{e}	1.2±0.02^{e}
	BC	2.16±0.18^{c}	0.74±0.05^{b}	1.7±0.02^{b}
	SP	2.81±0.11^{b}	0.66±0.03^{c}	1.80±.02^{b}
	BC+SP	3.68±0.09^{a}	1.02±0.01^{a}	2.28±0.22^{a}
Saline water	C	1.00±0.07^{g}	1.58±0.02^{f}	0.97±0.02^{f}
	BC	1.66±.0003^{ef}	2.81±0.01^{e}	1.38±0.01^{de}
	SP	1.79±0.1^{de}	2.78±0.01^{e}	1.43±0.011
	BC+SP	1.91±0.09^{d}	3.42±0.02^{d}	1.56±0.02^{c}

Means ± SD with same letters indicate no significant difference. Means ± SD with different letters differ significantly from each other at $p < 0.05$ according to LSD test. C= control.

3. Effect of water salinity, biochar (BC), and *Spirulina* (SP) on some basil growth parameters

The irrigation of basil plants with saline water caused decreases in the plant height, leaf number, branch number and leave area, chlorophyll, and fresh and dry weight by10, 31,31,40, 55, 46, and 33%, respectively, compared to the fresh water (fig.3 and table 4). The reduction in the previous plant growth parameter can be related to the adverse effect of salinity water on basil plant. Water salinity may affect plant hormones, responsible for the cellular division causing a reduction in plant height and leaves (Kozminska *et al*., 2017). Salinity stress reduces the flow of water to leaves, causing reduction in leaves number and area (Hafez *et al*., 2020). Salinity stress increased reactive oxygen species (ROS), causing chlorophyll degradation (Abo-Elyousr *et al*., 2022). The addition of BC+SP to the saline irrigated basil caused increases in the plant height, leaf number, branch number and leave area, chlorophyll, and fresh and dry weight by 6, 21, 50, 45, 170, 8, and 31%. From the last results, BC+SP could alleviate the adverse effect of salinity because their contents of minerals. BC and Spirulina are rich sources of elements like N, P and K, so it could mitigate ion imbalance causing by salinity. Potassium from BC+SP may alleviate the salinity effect through improved stomatal conductance, leading to increase total chlorophyll (Abd El-Wahed *et al*., 2023). Abo-Elyousr *et al*. (2022) indicated that BC addition reduced the ROS production through regulating the biosynthesis of antioxidative enzymes, this may be a reason for improving chlorophyll. The porous in biochar particles as shown in SEM images in (Fig. 1), may improve soil properties through facilitated the leaching of excess salts below the root zone as found by (Singh *et al*., 2021). Spirulina algae extract (SP) content of micronutrients enhance the growth of aromatic and medicine plants, as micronutrients influence the synthesis of essential oils by aromatic plants (Kumar *et al*., 2022). Proline content in SP is consider as osmoprotectants playing an essential role in osmotic modulation to increase plant tolerance it prevents protein oxidation, reduces lipid peroxidation, and preserves cell membranes (Merwad *et al*., 2018). Proline can alleviate the adverse effect of salinity through increasing antioxidant activities, leading to reducing membrane damage, improve ROS detoxification and preserved plasma membrane stability (Abo-Elyousr *et al*., 2022; Abd El-Wahed *et al*., 2023). Amino acids, e.g., arginine, have a role in improve plant growth under saline condition through reducing the accumulation of ROS and increasing the antioxidant enzyme activities (Nasr *et al*., 2022). Moreover, amino acids have a role in micronutrient chelating that facilitate the absorption and transportation of micronutrient inside plants (Marschner,1995).

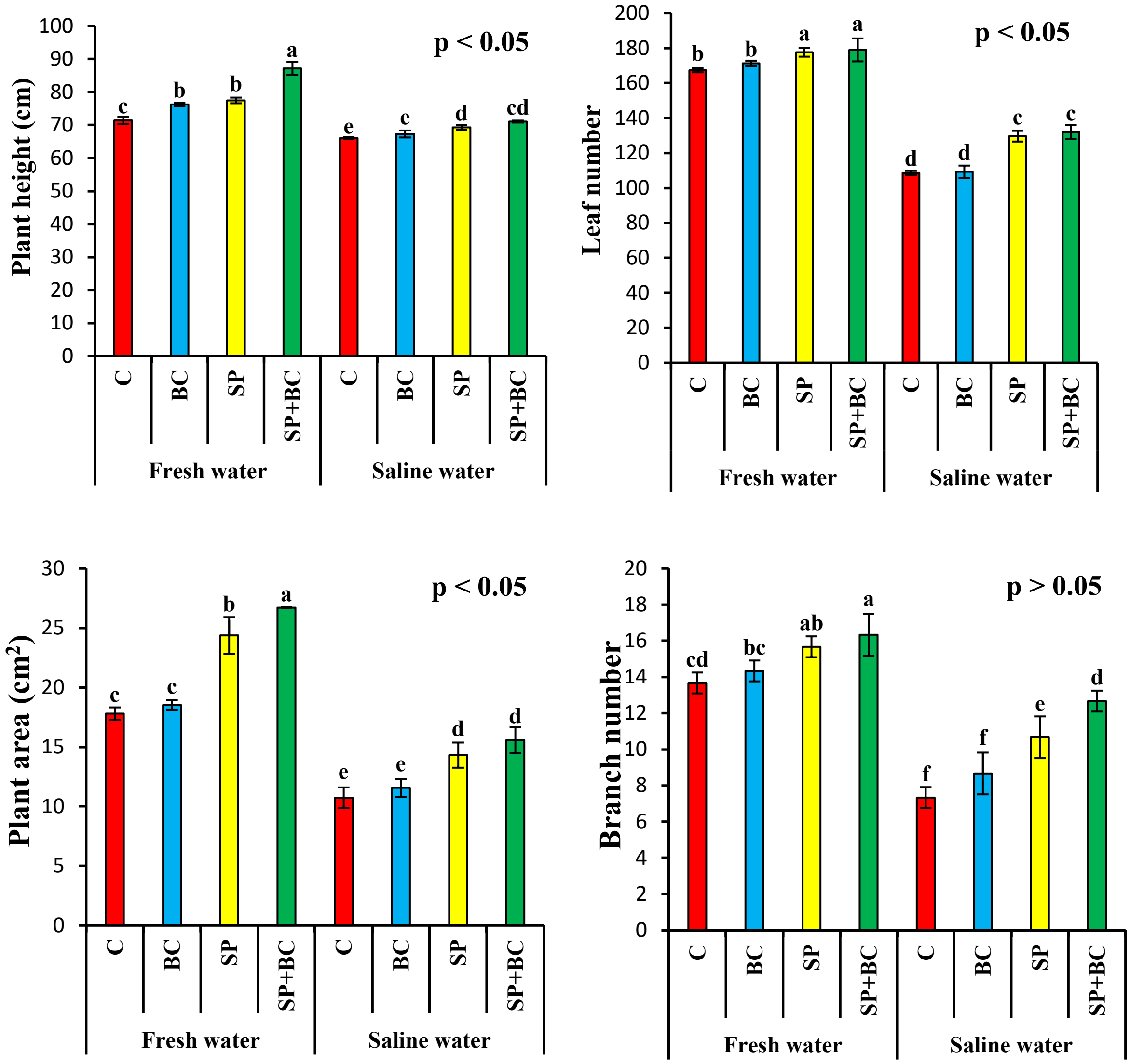

Fig. 3. Effect of water salinity, biochar (BC), and *Spirulina* (SP) application on the growth of basil plant. Means with same letters indicate no significant difference. Means with different letters differ significantly from each other at $p < 0.05$ according to LSD test. C= control.

Table 7. Effect of water salinity, biochar (BC), and *Spirulina* (SP) application on biomass accumulation and chlorophyll content in basil plant

K sources		Fresh weight (g / pot)	Dry weight (g / pot)	Total chlorophyll (mg / 100 g)
Fresh water	C	141 ± 5^{b}	21 ± 1^{b}	44 ± 3^{e}
	BC	151 ± 7^{a}	28 ± 2^{a}	68 ± 0.5^{c}
	SP	154 ± 2^{a}	29 ± 2^{a}	88 ± 3.7^{b}
	BC+SP	158 ± 1^{a}	30 ± 0.8^{a}	114 ± 2^{a}
Saline water	C	78 ± 2^{c}	16 ± 0.6^{c}	20 ± 3^{g}
	BC	82 ± 2^{c}	$18\pm.7^{c}$	33 ± 1^{f}
	SP	81 ± 4^{c}	$17\pm.1^{c}$	44 ± 2^{e}
	BC+SP	84 ± 2^{c}	21 ± 1^{b}	54 ± 3^{e}

Means ± SD with same letters indicate no significant difference. Means ± SD with different letters differ significantly from each other at $p < 0.05$ according to LSD test. C= control.

Conclusions

Ultimately, this study aimed to investigate the role of biochar (BC) and *Spirulina* (SP) algae extract on the growth of basil plant *(Ocimum basilicum* L.) irrigated with saline water. The results indicated that biochar addition as soil application and *Spirulina* algae extract as foliar application improved the adverse effect of salinity. The nutrients and amino acids in BC+SP improved plant height, leave number, branch number, plant area, total chlorophyll, fresh and dry weight. There is also increasing in the chlorophyll in the plants treated with the above-mentioned addition. Therefore, BC+ SP can be an effective solution for improving basil plant under saline condition.

References

Abd El-Baky, H.H, El-Baz, F.K, and El Baroty, G.S. (2010). Enhancing antioxidant availability in wheat grains from plants grown under seawater stress in response to microalgae extract treatments. Journal of the Science of Food and Agriculture, 90(2): 299-303.

Abd El-Wahed, M.H, Eissa, M.A, Almasoudi, N.M., and Abo-Elyousr, K.A. (2023). Macronutrient-rich biochar induces boron nanoparticles in improving the salt tolerance of pomegranate (*Punica granatum* L.) in arid degraded soils. Scientia Horticulturae, 313: 111908.

Abo-Elyousr, K. A, Mousa, M. A, Ibrahim, O. H, Alshareef, N. O, and Eissa, M. A. (2022). Calcium-rich biochar stimulates salt resistance in pearl millet (*Pennisetum glaucum* L.) plants by improving soil quality and enhancing the antioxidant defense. Plants, 11(10): 1301.

Ali, S, Rizwan, M, Qayyum, M.F, Ok, Y.S, Ibrahim, M, Riaz, M, Arif, M.S, Hafeez, F, Al-Wabel, M.I, and Shahzad, A.N. (2017). Biochar soil amendment on alleviation of drought and salt stress in plants: a critical review. Environmental Science and Pollution Research, 24: 12700-12712.

Arahou, F., Lijassi, I., Wahby, A., Rhazi, L., Arahou, M., and Wahby, I. (2023). Spirulina-based biostimulants for sustainable agriculture: Yield improvement and market trends. BioEnergy Research, 16(3): 1401-1416.

Benarba, B, and Pandiella, A. (2020). Medicinal plants as sources of active molecules against COVID-19. Frontiers in pharmacology, 11: 1189.

Ben-Gal, A., Borochov-Neori, H., Yermiyahu, U., and Shani, U.R.I. (2009). Is osmotic potential a more appropriate property than electrical conductivity for evaluating whole-plant response to salinity? Environmental and Experimental Botany, 65(2-3): 232-237.

Bilal, A., Jahan, N., Ahmed, A., Bilal, S.N, Habib, S., and Hajra, S. (2012). Phytochemical and pharmacological studies on *Ocimum basilicum* Linn-A review. International Journal of Current Research and Review, 4(23): 73-83.

Broadley, M.R, White, P.J, Bryson, R.J, Meacham, M.C, Bowen, H.C, Johnson, S.E, Hawkesford, M.J, Mc Grath, S.P., Zhao, F., Breward, N., Harriman, M., and Tucker, M. (2006). Biofortification of UK food crops with selenium. Proceedings of the nutrition society, 65(2): 169-181.

Bruun, E.W., Ambus, P., Egsgaard, H., and Hauggaard-Nielsen, H. (2012). Effects of slow and fast pyrolysis biochar on soil C and N turnover dynamics. Soil Biology and Biochemistry, 46: 73-79.

Burt, R. (2004). Soil Survey Laboratory Methods Manual. Soil Survey Investigations.

Chahal, S.S., Choudhary, O.P., and Mavi, M.S. (2018). Microbial activity is constrained by the quality of carbon and nitrogen under long-term saline water irrigation. Communications in Soil Science and Plant Analysis, 49(11): 1266-1280.

Crouch, I. J., and Van Staden, J. (1993). Commercial seaweed products as biostimulants in horticulture. Journal of Home & Consumer Horticulture, 1(1): 19-76.

Ding, Z., Zhou, Z., Lin, X., Zhao, F., Wang, B., Lin, F., Ge, Y., and Eissa, M.A. (2020). Biochar impacts on NH3-volatilization kinetics and growth of sweet basil (*Ocimum basilicum* L.) under saline conditions. Industrial Crops and Products, 157: 112903.

Djuma, H., Bruggeman, A., Eliades, M., and Lange, M.A. (2016). Non-conventional water resources research in semiarid countries of the Middle East. Desalin Water Treat 57: 2290–2303.

Elhindi, K.M., El-Din, A.S, and Elgorban, A.M. (2017). The impact of arbuscular mycorrhizal fungi in mitigating salt-induced adverse effects in sweet basil (*Ocimum basilicum* L.). Saudi journal of biological sciences, 24(1): 170-179.

El-sayed, M.E., Hazman, M., Abd El-Rady, A.G., Almas, L., McFarland, M., Shams El Din, A., and Burian, S. (2021). Biochar reduces the adverse effect of saline water on soil properties and wheat production profitability. Agriculture, 11(11): 1112.

Gomah, H.H, Ahmed, M.M, Abdalla, R.M, Farghly, K.A, and Eissa, M.A. (2020). Utilization of some organic wastes as growing media for lettuce (*Lactuca sativa L.*) plants. Journal of Plant Nutrition, 43(14): 2092-2105.

Gou, M.M., Qu, Z.Y., Wang, F., Gao, X.Y., Hu, M. (2018): Progress in research on biochar affecting soil-water environment and carbon sequestration-mitigating emissions in agricultural fields. Transactions of the Chinese Society for Agricultural Machinery, 49: 1–12.

Hafez, Y., Elkohby, W., Mazrou, Y.S., Ghazy, M., Elgamal, A., and Abdelaal, K. (2020). Alleviating the detrimental impacts of salt stress on morpho-physiological and yield characters of rice plants (*Oryza sativa* L.) using actosol, Nano-Zn and Nano-Si. Fresenius Environmental Bulletin, 29(8): 6882-6897.

Hammer, E.C., Forstreuter, M, Rillig, M.C., and Kohler, J. (2015). Biochar increases arbuscular mycorrhizal plant growth enhancement and ameliorates salinity stress. Applied soil ecology, 96: 114-121.

Han, G., Wang, D., and Xie, X. (2016). Pedotransfer functions for prediction of soil bulk density for major types of soils in China. Acta Pedologica Sinica, 53(1): 93-102.

Huang, M., Zhang, Z., Zhai, Y., Lu, P., and Zhu, C. (2019). Effect of straw biochar on soil properties and wheat production under saline water irrigation. Agronomy, 9(8): 457.

Jackson, M. L. (1973). Prentice Hall of India Ltd. New Delhi, 100.

Joseph, S., Cowie, A.L., Van Zwieten, L., Bolan, N., Budai, A., Buss, W., Cayuela, M.L., Graber, E.R., Ippolito, J.A., Kuzyakov, Y., Luo, Y., Ok, Y.S., Palansooriya, K.N., Shepherd, J., Stephens, S., Weng, Z., and Lehmann, J. (2021). How biochar works, and when it doesn't: A review of mechanisms controlling soil and plant responses to biochar. Gcb Bioenergy, 13(11): 1731-1764.

Kim, H.S., Kim, K.R., Yang, J.E., Ok, Y.S., Owens, G., Nehls, T., Wessolek, G., and Kim, K.H. (2016). Effect of biochar on reclaimed tidal land soil properties and maize (*Zea mays* L.) response. Chemosphere, 142: 153-159.

Kozminska, A., Al Hassan, M., Kumar, D., Oprica, L., Martinelli, F., Grigore, M. N, Vicente, O., and Boscaiu, M. (2017). Characterizing the effects of salt stress in *Calendula officinalis* L. Journal of Applied Botany and Food Quality, 90: 323-329.

Kumar, D., Punetha, A., Verma, P.P., and Padalia, R.C. (2022). Micronutrient based approach to increase yield and quality of essential oil in aromatic crops. Journal of Applied Research on Medicinal and Aromatic Plants, 26: 100361.

Liu, X., Wei, Z., Ma, Y., Liu, J., and Liu, F. (2021). Effects of biochar amendment and reduced irrigation on growth, physiology, water-use efficiency and nutrients uptake of tobacco (*Nicotiana tabacum* L.) on two different soil types. Science of the Total Environment, 770: 144769.

Marschner, H. (1995). Mineral nutrition of higher plants. 2nd (eds) Academic Press. New York, 15-22.

Merwad, A.R.M, Desoky, E.S.M., and Rady, M.M. (2018). Response of water deficit-stressed Vigna unguiculata performances to silicon, proline or methionine foliar application. Scientia Horticulturae, 228: 132-144.

Metzner, H., Rau, H. and Senger, H. (1965) Untersuchungen zur Synchronisierbareit einzelner Pigment mangel Mutanten von Chlorella. Planta., 65: 186-194.

Morales, M.M, Comerford, N., Guerrini, I.A., Falcão, N.P., and Reeves, J.B. (2013). Sorption and desorption of phosphate on biochar and biochar–soil mixtures. Soil Use and Management, 29(3): 306-314.

Munns, E.V. and Termaat, A. (1986) Whole-plant responses to salinity. Aust. J. Plant Physio. 13: 143-160.

Nasr, F., Razavi, F., Rabiei, V., Gohari, G., Ali, S., and Hano, C. (2022). Attenuation of chilling injury and improving antioxidant capacity of persimmon fruit by arginine application. Foods, 11(16): 2419.

Nelson, D.W. and Sommers, L.E. (1996). Methods of Soil Analysis. Part 3. Chemical Methods. Soil Science Society of America Book Series no.5, pp. 961-1010.

Parkinson, J.A., and Allen, S.E. (1975). A wet oxidation procedure suitable for the determination of nitrogen and mineral nutrients in biological material. Communications in soil science and plant analysis, 6(1): 1-11.

Prisa, D. (2019). Possible use of Spirulina and Klamath algae as biostimulants in *Portulaca grandiflora* (Moss Rose). World Journal of Advanced Research and Reviews, 3(2): 001-006.

Rizwan, M., Murtaza, G., Zulfiqar, F., Moosa, A., Iqbal, R., Ahmed, Z., and Li, H. (2023). Sustainable manufacture and application of biochar to improve soil properties and remediate soil contaminated with organic impurities: a systematic review. Frontiers in Environmental Science. 11:1277240

Rombolà, A. G., Torri, C., Vassura, I., Venturini, E., Reggiani, R., and Fabbri, D. (2022). Effect of biochar amendment on organic matter and dissolved organic matter composition of agricultural soils from a two-year field experiment. Science of The Total Environment, 812: 151422.

Salim, B.B.M. (2016). Influence of biochar and seaweed extract applications on growth, yield and mineral composition of wheat (*Triticum aestivum* L.) under sandy soil conditions. Annals of Agricultural Sciences, 61(2): 257-265.

Selem, E. (2019). Physiological effects of Spirulina platensis in salt stressed Vicia faba L. plants. Egypt J Bot 59: 185–194.

Sharma, P.N., Tripathi, A., and Bisht, S.S. (1995). Zinc requirement for stomatal opening in cauliflower. Plant Physiology, 107(3): 751-756.

Singh, G., Mavi, M.S., Choudhary, O.P., Gupta, N., and Singh, Y. (2021). Rice straw biochar application to soil irrigated with saline water in a cotton-wheat system improves crop performance and soil functionality in north-west India. Journal of Environmental Management, 295: 113277.

Singh, P., Choudhary, O.P., and Mavi, M.S. (2018). Irrigation-induced salinization effects on soil chemical and biological properties under cotton-wheat rotation on loamy sand soil in northwest India. Journal of the Indian Society of Soil Science, 66(4): 386-391.

Thomas, S.C., Frye, S., Gale, N., Garmon, M., Launchbury, R., Machado, N., Melamed, S., Murray, J., Petroff, A. and Winsborough, C. (2013). Biochar mitigates negative effects of salt additions on two herbaceous plant species. Journal of Environmental Management, 129: 62-68.

Tränkner, M., Tavakol, E. and Jákli, B. (2018). Functioning of potassium and magnesium in photosynthesis, photosynthate translocation and photoprotection. Physiologia plantarum, 163(3): 414-431.

Uchida, R. (2000). Essential nutrients for plant growth: nutrient functions and deficiency symptoms. Plant nutrient management in Hawaii's soils, 4: 31-55.

USEPA, (1997). Puget Sound Estuary Program (PSEP): Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound. USEPA Region 10, Office of Puget Sound, Seattle, Washington.

Zhang, L., Jing, Y., Chen, C., Xiang, Y., Rezaei Rashti, M., Li, Y., Deng, Qi and Zhang, R. (2021). Effects of biochar application on soil nitrogen transformation, microbial functional genes, enzyme activity, and plant nitrogen uptake: A meta-analysis of field studies. GCB Bioenergy, 13(12): 1859-1873.

Zheng, H., Wang, X., Chen, L., Wang, Z., Xia, Y., Zhang, Y., Wang, H., Luo, X. and Xing, B. (2018). Enhanced growth of halophyte plants in biochar-amended coastal soil: roles of nutrient availability and rhizosphere microbial modulation. Plant, cell & environment, 41(3): 517-532.

Zhukovskaya, N.V. (1973). Absorption and accumulation of phosphate by plants under conditions of soil salinization. Soviet Plant Physiol., 20: 55-60.

تحسين نمو نبات الريحان الحلو المروي بماء مالح عن طريق الفحم الحيوي ومستخلص طحلب الاسبيرولينا

مي عثمان فكري، هاله حسانين جمعه، ممدوح عبد الحفيظ السيد عيسى

قسم الاراضي والمياه، كلية الزراعة، جامعة اسيوط، مصر.

الملخص

تم اجراء تجربة أصص بكلية الزراعة – جامعة أسيوط – قسم الأراضي والمياه لدراسة تأثير الفحم الحيوي للتربة بمعدل (2%) ومستخلص طحلب الاسبيرولينا بمعدل (جرام للتر2.5) رشا علي الأوراق لتحسين نمو نبات الريحان المروي بماء مالح وقد اظهرت النتائج استخدام الماء المالح دون اي اضافات ادي الي انخفاض ارتفاع النبات، عدد الاوراق، عدد الافرع، مساحة الورقة، المحتوي الكلي للكلوروفيل، الوزن الرطب، الوزن الجاف بمعدل 10، 31، 31، 55،40، 46، 33% على التوالي بالمقارنة بالمعاملات الكنترول. اضافه الفحم الحيوي + مستخلص طحلب الاسبيرولينا ادي الي زيادة المعاملات السابقة بمعدل 6، 21، 50، 170، 8، 31% على التوالي بالمقارنة بالمعاملات المروية بماء مالح بدون اضافات. الزيادة في عدد الافرع كانت غير معنويه. الري بماء مالح ادي الي انخفاض التركيز الكلي للنيتروجين والفوسفور والبوتاسيوم بمعدل 31، 61، 24% على التوالي بالمقارنة بالمعاملات الكنترول المروية بماء عذب. اضافه الفحم الحيوي + مستخلص طحلب الاسبيرولينا للمعاملات المروية بماء مالح ادي الي زيادة المحتوي الكلي للنيتروجين والفوسفور والبوتاسيوم بمعدل 90، 116، 60%.

لذلك يعتبر اضافه الفحم الحيوي ومستخلص طحلب الاسبيرولينا حل جيد لتحسين نمو نبات الريحان تحت ظروف الملحية.