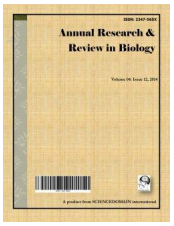

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Effects of Biochar Amended Saline Soil on Growth and Some Metabolic Activities of Two Soybean Cultivars in Saudi Arabia

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AAK, AAI, YMAS and EFA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AAI, YMAS and EFA managed the analyses and literature searches of the study. All authors read and approved the final manuscript.

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ABSTRACT

Application of biochar to soil additionally restores soil Carbon and nutrients lost from bioenergy cropping systems as a result of biomass harvesting. This study was carried out to investigate the effect of biochar amended saline soil on plant growth, leaf chlorophyll, soil mineral contents and some physiological parameters of two Soybean cultivars in Saudi Arabia. The obtained results showed that plant height, fresh and dry weight, chlorophyll a and b content of both varieties (Giza-111 and Clark) were inhibited in saline soil while enhanced in biochar one which derived from Pomegranate trees or biochar two which obtained from acacia trees. The highest value of

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carbohydrate and protein contents observed in Giza-111 with the compare to Clark cultivars under salinity conditions. It was concluded that soybean is a sensitive plant to salinity stress, but the extent of this sensitivity varies among cultivars. As a result, Giza-111 cultivar showed more capability to survive under salinity condition compared with another variety regarding of almost all plant parameter examined. Considering, biochar one was found more appropriate under salinity condition.

Keywords: Soybean; saline soil; biochar; growth.

1. INTRODUCTION

Biochar (derived from natural organic materials (woody debris, corn stalks, macadamia shell, etc.) is a stable form of charcoal produced in a high temperature (350ºC or above) low oxygen processes, such as controlled pyrolysis or even natural forest fire. Due to its molecular structure, biochar is chemically and biologically more stable than the original carbon form it comes from, making it more difficult to be converted back to CO_2, meaning it can store carbon for a long time (carbon sequestration). On the other hand, the surface of biochar can contain many chemically reactive groups, such as COOH, OH, ketone, that give biochar a high potential to absorb toxic substances. Those are Aluminum (AL), manganese (Mn) in acid soils and arsenic (As), cadmium (Cd) in heavy metal contaminated soils. Thus, biochar could be used to rehabilitate environments that may be hostile to plant growth or harmful to human health (heavy metal contaminated soils). The addition of biochar to agricultural lands has recently received much attention due to the apparent benefits to soil quality and enhanced crop yields, as well as the potential of gaining carbon credits by carbon sequestration [1].

Salinity is significant abiotic stress that reduces crop productivity, with the extent of agricultural land salinization increasing due to climate change and poor land management [2]. Worldwide, more than 40% of irrigated agricultural land has been predicted to be soon affected by salinity [3]. To ensure food security into the future, crops with improved tolerance to salt stress were required. Plants vary tremendously in their ability to tolerate salinity. Salt tolerance of plants may be dependent on growth stage, varieties, nutrition and environment [4]. Netondo et al. [5] reported that photosynthetic activity decreases when plants are grown under saline conditions leading to reduced growth and productivity. The reduction in photosynthesis under salinity attributed to a decrease in chlorophyll content [6] and activity of photosystem II [7]. Salinity can affect chlorophyll content through inhibition of chlorophyll synthesis or acceleration of its degradation [8]. Knowledge about causes and consequences of the water stress in plants still has many dark areas. Therefore, the objective of this work was to influence the effect of biochar and saline applications on growth, photosynthetic pigments, protein and carbohydrate contents of soybean cultivars.

Soybean seeds are a major source of high-quality protein and oil for human consumption [9]. The unique chemical composition of soybean has made it one of the most valuable agronomic crops worldwide [10]. Its contain protein that has excellent potential as a major source of dietary protein. The oil produced from soybean is highly digestible with no cholesterol [11]. Growth, development, and yield of soybean are the result of genetic potential interacting with the environment. Soybean seed production may be limited by environmental stresses such as soil salinity [12]. Minimizing ecological importance will optimize seed yield [13]. It severely limits growth and development of plants by affecting different metabolic processes such as CO_2 assimilation, oil and protein synthesis [14]. Soybean is classified as salt-sensitive instead of moderately salt tolerant [15].

2. MATERIALS AND METHODS

2.1 Plant Material

An experiment was conducted in greenhouse Biology Department, Faculty of Science, Taif University, Saudi Arabia, for 8 weeks to the end of the Vegetation Growth Stag (VGS) beginning Oct. 2017, to examine the impact of two types of biochar (biochar 1 which derived from Pomegranate trees and biochar 2 which derived from Acacia trees after pyrolysed at 350ºC) on growth and photosynthetic pigments, as well as some metabolic activities of two soybean cultivars grown in control and saline conditions. Seeds of tow soybean cultivars were obtained from Agricultural Research Center, Giza, Egypt (Table 1) [16,17].

2.2 Experimental Design, Treatments and Soil Analysis

The experimental design which was conducted is Randomized Complete Blok Design (RCBD), The treatments were included two Cultivars (Giza111 and Clark) X 10 treatments by three replications with a total 60 pots (Table 2). Five seeds were sown 3 cm deep in each pot, filled with 1500 g soil, using 30 pots in each cultivar. Pots then placed in the greenhouse until the end of (VGS). The temperature variation in the greenhouse was 17-21ºC. Tap water was added to the containers by the treatments to achieve 100% FC. After emergence, seedlings were thinned to keep three plants in each pot.

Biochar applications amended to the soil with or without Hoagland solution. The chemical composition of biochar 1 & 2 and soil extracts (1:5) pH, TDS, EC and mineral elements (Na, Ca, K, Cl, Mg, N, P) before planting and at the end of (VGS) were estimated according the methods adopted by APHA [18].

Table 1. Soybean cultivars and its maturity group, pedigree and days to maturity used in this investigation

Cultivars	Maturity group	Pedigree	Day to maturity
Giza 111	IV	Crawford X	120-125
Clark	IV	Celest	days
		Lincoin X	120-125
		Rishland	days

2.3 Growth Characters and Some Metabolic Activates

The growth curves (The variation in plant height/week in Cm) of two soybean cultivars under a non-saline (control) and saline (6 DS^{M-1}NaCl) conditions with or without biochar for eight weeks were followed. Shoot length (cm), fresh and dry weight of shoots (g/plant), fresh and dry weight of roots (g/plant), and shoot/root ratio was determined. The dry weights were measured after drying the samples at 70ºC for 48 h in an oven [19]. Chlorophyll, a, b and total in leaves of soybean were estimated at the end of (VGS) using the method described by Henry et al. [20]. Plants were air dried at room temperature for three weeks to get consistent weight. The dried plants were later ground to powder. Two grams of ground plant material was shaken separately in methanol for 48 h on a shaker at room temperature. Extracts were filtered using a Buckner funnel and Whatman No1 filter paper. Each filtrate was concentrated to dryness under reduced pressure at 40ºC using a rotary evaporator [21]. For the determination of carbohydrate (soluble, insoluble and totals) the anthrone-sulfuric acid method was used [22,23,24]. Protein contents (soluble, insoluble and totals) were estimated in dry weight according to the method adopted by Lowry et al. [25].

Means, standard deviations (SD) and one-way analysis of Variance (ANOVA) were calculated for the means of growth characters, metabolic activities and soil samples with treatments to assess the heterogeneity of samples around their means. These techniques were according to SPSS software [26].

3. RESULTS AND DISCUSSION

Application of biochar to soil additionally restores soil Carbon and nutrients lost from bioenergy cropping systems as a result of biomass harvesting [27,28]. The impact of biochar on alkaline soils in

Table 2. A different treatments distributed under randomized complete Blok design (RCBD) on the two soybean cultivars (giza111and Clark)

No.	Treatments
1	Soil + water (as a control)
2	Soil + Hoagland Solution
3	Soil + Saline (6dS m^{-1} NaCl) conditions
4	Soil + Biochar (1) derived from Pomegranate 1 g Kg^{-1} (w/w)
5	Soil + Biochar (2) derived from acacia 1 g Kg^{-1} (w/w)
6	Soil + Hoagland Solution + Saline conditions
7	Soil + Hoagland Solution + Biochar (1)
8	Soil + Hoagland Solution + Biochar (2)
9	Soil + Saline conditions + Biochar (1)
10	Soil + Saline conditions + Biochar (2)

agricultural fields remain poorly understood. The chemical composition of biochar 1 derived from Pomegranate and biochar 2 derived from acacia after pyrolyzed at 350 are listed in Table 3. Biochar 1 contains the highest concentration of phosphate and micronutrient cations in comparison to biochar two that contains nitrate and magnesium.The percentage of seed germination of two soybean cultivars (Giza 111 and Clark) seeds under various treatments are listed in Table 4. In general, biochar 1and two enhanced germination of seeds of both varieties, whatever the time elapsed. In the case of saline soil (6 ds/m NaCl) the percentage of seed germination was decreased in comparison to the control. Biochar represents precious bio-resources, which have been utilized mainly as a bio-fertilizer in agriculture due to their well-established role as diazotrophs, establishing proficiency in diverse soil ecologies, and ability to compete with native flora and fauna [29].

The imposed treatments variably altered plant height (Fig. 1) saline soil (6dsm^{-1} NaCl) noticeably induced of both cultivars to the height of the control sprayed with 100% tap water. However, saline soil amended Hoagland solutions overcome the inhibitory effect of salinity, i.e., enhanced plant height to increase up to values surpassing the control plants. The magnitude of enhancement was more pronounced in Soybean Giza 111 than in Clark. Also, biochar 1 was more stimulatory than biochar 2 with or without Hoagland solutions. The adsorption capacity of biochar is mainly because of the presence of functional groups generated during the pyrolysis process that in turn depends on raw material (feedstock) and the pyrolysis temperature [30,31].

Similarly, the growth curves (calculated as plant height) of Soybean Giza 111and Clark under various treatments were followed for eight weeks (Fig. 2). Soil salinity was reduced the plant heights after five weeks. However, biochar 1 or 2 amended saline soil with Hoagland solutions have enhanced the growth of two cultivars. Recently, Bhaduri et al. [32] illustrated that saline soil mitigation by biochar depends upon the amount of biochar, incubation time, biochar material, and type of soil enzymes. However, an organic amendment also improves the physicochemical properties of saline soil [33,34].

Table 4 displays the values of fresh and dry weight of shoot or roots under various soil treatments; it shows that saline soil (6 dSm^{-1} NaCl) inhibited fresh and dry weight of both Giza and Clark plants, relative to the control values (100% tap water). In this respect, the Person's correlation (r) between soil and growth variables of Giza 111 cultivar (Table 5) indicated that the TDS had significant negative correlation with root fresh and dry weight, shoot dry weight; EC with root fresh and dry weight, shoot dry weight and chlorides with dry shoot/root ratio ($P< 0.05$). Biochar 1 or 2 amended alone or with Hoagland solution relatively enhanced root and shot fresh and dry weight of both plants. This emphasized that the calcium had a significant positive correlation with new shoot/root ratio and sodium with dry shoot/root ratio in Giza 111 cultivar, while sodium with shoot fresh weight and potassium with dry shoot/root ratio in Clark cultivar ($P< 0.05$). The sweet/dry rate of root or shoot were somewhat similar in response to the applied treatments compared with that of the fresh weight. Root length was apparently different in response to the used treatments compared with that of the clean and dry weight. Generally, soil salinity slightly reduces root length of the two soybean cultivars in comparison to control. The soybean fresh and dry weight significantly decreased with NaCl application but enhanced with Biochar treatment (Table 4). Thomas et al. [35] reported that biochar (pyrolyzed at 378ºC and applied at the rate of 50 t ha^{-1}) enhances the growth of two herbaceous plants (*Abutilon theophrasti* and *Prunella vulgaris*) under salt stress. Nutman [36] showed that the biochar materials had been reported to stimulate the root growth. The different properties of biochar in comparison to the soil cause the improved root growth; however, roots may grow into the biochar pores [37,38]. After a forest fire, a layer of char enhances the root biomass (47%) and root tip number (64%) [39] the root length of rice was increased with biochar additions [40]. Germination and rooting of fir embryos (*Abies numidica*) increased dramatically from 10% to 20% without additions to 32-80% of embryos when activated carbon was added to various growth media [41]. Therefore, not only abundance but also growth behavior of roots may change in response to the presence of biochar.

The chlorophyll content is much sensitive to salt exposure, and a reduction in chlorophyll levels was obtained (Table 6). Chlorophyll a and chlorophyll b contents of both Giza 111 and Clark plants exhibited obvious enhancement by

Table 3. Chemical composition of soil before planting and after harvested of the two soybean cultivars (Giza 111 and Clark cultivars) under different treatments

Treat	TDS	EC	pH	Cl	PO_4	NO_3	Ca	Mg	Na	K
	mg/g	µmohs/cm					mg/100 g			
Soil Ref.	156.1	191.0	10.6	7.8	137.7	72.1	12.2	15.8	8.6	3.3
Biochar1	159.7	264.0	10.0	11.3	236.0	89.0	14.6	9.7	17.8	4.0
Biochar2	130.5	217.0	10.0	4.3	67.8	144.6	12.7	13.1	13.6	4.0
Giza111										
1	65.3	133.6	8.4	16.3	83.2	75.2	9.7	8.5	7.8	3.7
2	189.6	364.0	8.4	9.2	206.3	309.4	14.6	9.7	39.4	4.4
3	321.0	550.0	8.6	10.6	133.0	51.9	12.2	24.3	10.0	3.5
4	324.0	490.0	8.7	9.2	55.5	44.0	12.2	12.4	6.6	3.6
5	96.4	185.0	8.9	9.9	120.3	10.7	9.7	8.5	22.8	3.6
6	424.0	704.0	8.6	7.8	67.7	252.6	21.9	1.2	30.6	4.0
7	247.0	378.0	8.7	7.1	221.1	311.0	12.2	14.6	39.0	4.4
8	256.0	470.0	8.7	6.4	181.0	309.4	12.7	13.1	38.4	4.5
9	421.0	762.0	8.9	11.3	258.4	50.5	17.0	9.7	10.0	3.8
10	511.0	755.0	8.9	12.1	150.1	36.7	13.1	10.5	6.0	3.8
T. mean	285.5±144.1	479.2±221.4	8.7±0.2	10.0±2.9	147.7±68.5	145.1±131.5	13.5±3.6	11.3±5.9	21.1±14.6	3.9±0.4
Clark										
1	60.9	136.0	9.2	6.4	136.2	51.6	10.2	10.7	8.0	3.5
2	185.6	378.0	9.1	7.8	193.1	306.8	13.1	17.7	38.8	4.2
3	384.0	610.0	8.8	10.6	57.6	69.5	14.1	7.5	7.8	3.6
4	90.9	129.3	9.2	6.4	65.5	56.5	11.2	9.7	11.4	3.6
5	82.8	181.5	9.2	4.3	38.2	39.1	12.2	13.4	4.8	3.7
6	429.0	755.0	9.2	11.3	260.5	310.6	9.7	17.0	28.8	3.7
7	304.0	501.0	8.9	7.8	107.0	311.7	14.6	13.9	38.4	4.8
8	324.0	591.0	8.9	12.1	90.1	311.5	13.6	10.5	38.4	4.9
9	572.0	1008.0	9.0	11.3	208.7	63.4	7.3	16.0	13.2	3.8
10	572.0	822.0	9.2	8.5	44.5	112.3	8.3	29.9	21.0	3.8
T. mean	300.5±192.5	511.2±304.1	9.1±0.2	8.7±2.6	120.1±77.1	163.3±127.8	11.4±2.5	14.6±6.3	21.1±13.9	4.0±0.5

Table 4.Growth parameters of soybean Giza 111 and Clark cultivars under different treatments

Treat	Germination	Root length(cm)	Fresh wt. (g/plant)			Dry wt. (g/plant)		
			Root	Shoot	Shoot/Root	Root	Shoot	Shoot/Root
Giza11								
1	40.00±20.00	36.20±10.18	1.63±0.95	4.24±0.73	3.06±1.22	0.82±0.32	1.07±0.14	1.43±0.52
2	60.00±20.00	30.38±6.37	0.93±0.06	3.98±0.83	4.35±1.13	0.39±0.07	1.01±0.22	2.72±1.00
3	26.67±11.55	30.00±7.53	1.16±0.32	4.04±0.44	3.63±0.88	0.36±0.19	0.65±0.03	1.80±0.52
4	60.00±20.00	30.71±8.08	1.15±0.38	3.87±0.80	3.55±1.19	0.52±0.15	1.12±0.23	2.23±0.71
5	40.00±20.00	30.33±6.09	1.10±0.20	4.41±0.64	4.01±0.22	0.46±0.06	1.13±0.08	2.48±0.24
6	33.33±11.55	26.25±6.08	0.93±0.11	4.93±1.36	5.32±1.30	0.32±0.01	0.86±0.20	2.70±0.73
7	60.00±20.00	27.80±3.49	1.13±0.20	4.32±1.24	3.78±0.52	0.43±0.08	1.05±0.23	2.42±0.17
8	60.00±20.00	29.83±9.39	0.91±0.50	3.37±2.04	3.64±1.34	0.39±0.27	1.36±0.39	5.44±5.10
9	60.00±0.00	23.88±4.05	0.81±0.20	3.09±1.01	3.81±0.72	0.43±0.11	0.90±0.26	2.09±0.19
10	46.67±11.55	32.50±6.35	0.70±0.07	3.42±0.45	4.90±0.23	0.38±0.04	0.95±0.10	2.50±0.07
Total	48.67±18.71	29.66±7.16	1.05±0.41	3.97±1.03	4.01±1.03	0.45±0.20	0.96±0.29	2.50±1.78
F-Value	1.804 ^{ns}	1.404 ^{ns}	1.310 ^{ns}	0.824 ^{ns}	1.470 ^{ns}	2.843*	3.804***	1.345 ^{ns}
Clark								
1	53.33±23.09	30.00±5.44	0.84±0.24	3.33±0.91	4.04±1.04	0.59±0.29	0.82±0.08	1.59±0.62
2	33.33±11.55	25.80±6.61	1.05±0.20	3.52±1.89	3.23±1.17	0.57±0.13	0.82±0.35	1.48±0.57
3	33.33±11.55	30.20±6.98	0.99±0.55	2.33±0.80	2.53±0.53	0.37±0.28	0.52±0.12	1.82±0.86
4	46.67±30.55	31.50±4.42	1.05±0.28	2.56±0.59	2.47±0.17	0.46±0.14	0.65±0.16	1.48±0.28
5	40.00±20.00	32.17±7.57	0.83±0.45	2.44±0.89	3.13±0.50	0.33±0.18	0.57±0.09	1.98±0.72
6	26.67±11.55	26.25±5.19	0.80±0.10	2.98±0.49	3.70±0.24	0.29±0.04	0.63±0.08	2.18±0.24
7	40.00±34.64	23.80±6.42	0.70±0.14	3.03±0.88	4.45±1.67	0.22±0.09	0.75±0.17	4.16±3.05
8	30.00±14.14	35.00±5.66	0.88	3.50	3.97	0.37	0.79	2.15
9	60.00±0.00	28.00±5.55	0.93±0.23	2.66±0.62	2.87±0.35	0.40±0.10	0.53±0.11	1.32±0.17
10	40.00±28.28	24.80±2.17	0.69±0.02	2.33±0.08	3.41±0.22	0.34±0.09	0.45±0.12	1.35±0.01
Total	40.71±19.99	28.54±6.10	0.88±0.27	2.84±0.88	3.34±0.94	0.40±0.18	0.65±0.18	1.96±1.26
F-Value	0.719 ^{ns}	1.599 ^{ns}	0.520 ^{ns}	0.595 ^{ns}	1.745 ^{ns}	1.296 ^{ns}	1.691 ^{ns}	1.534 ^{ns}

*Ns: means non-significant, *: P< 0.05, ***: P<0.001*

Table 5. Correlation between chemical composition of soil, growth parameters and some metabolic activates of soybean Giza 111 and Clark cultivars under different treatments

	TDS	EC	pH	Cl	PO4	NO3	Ca	Mg	Na	K
Germ	0.018	0.029	0.139	-0.343	0.553	0.376	-0.049	-0.069	0.321	0.559
Giza 111										
Ro.fr	-0.733*	-0.761*	-0.563	0.489	-0.461	-0.168	-0.536	0.140	-0.202	-0.281
sh.fr	-0.350	-0.394	-0.402	-0.105	-0.560	0.204	0.143	-0.309	0.291	-0.038
sh/ro	0.594	0.570	0.206	-0.312	-0.061	0.207	0.709*	-0.519	0.228	0.157
Ro. dry	-0.691*	-0.710*	-0.553	0.603	-0.439	-0.281	-0.602	0.235	-0.342	-0.359
Sh. dry	-0.679*	-0.693*	-0.315	-0.360	-0.227	0.415	-0.436	-0.042	0.509	0.405
Sh/Ro	-0.013	0.021	0.048	-0.667*	0.165	0.607	0.075	-0.111	0.642*	0.674*
Chl a	0.375	0.347	0.315	0.325	-0.330	-0.583	0.068	-0.079	-0.501	-0.552
Chl b	0.210	0.104	0.458	-0.394	0.213	0.130	-0.089	0.219	0.251	0.136
Total chl	0.354	0.243	0.560	-0.231	0.060	-0.123	-0.054	0.171	0.024	-0.105
Chl a/b	0.019	0.081	-0.289	0.670*	-0.319	-0.462	0.085	-0.190	-0.561	-0.453
S. carb	-0.679*	-0.693*	-0.315	-0.360	-0.227	0.415	-0.436	-0.042	0.509	0.405
T. Carb	-0.013	0.021	0.048	-0.667*	0.165	0.607	0.075	-0.111	0.642*	0.674*
Ins. carb	0.147	0.189	0.129	-0.668*	0.241	0.587	0.188	-0.115	0.604	0.665*
S. prot	0.210	0.104	0.457	-0.394	0.213	0.130	-0.089	0.219	0.251	0.136
T. prot	0.354	0.243	0.559	-0.231	0.060	-0.123	-0.054	0.171	0.024	-0.105
Ins. prot	0.375	0.347	0.315	0.326	-0.330	-0.583	0.068	-0.080	-0.501	-0.552
Clark										
Germ	-0.050	-0.050	0.193	-0.281	-0.003	-0.662*	-0.544	-0.034	-0.535	-0.335
Ro.fr	-0.326	-0.265	-0.098	0.043	0.123	-0.179	0.174	-0.514	-0.177	-0.238
sh.fr	-0.304	-0.196	-0.007	0.156	0.483	0.671*	0.299	-0.184	0.665*	0.555
Sh/Ro	-0.034	-0.007	-0.016	0.044	0.193	0.599	0.190	0.131	0.582	0.605
Ro. dry	-0.476	-0.443	0.361	-0.256	0.165	-0.266	-0.140	-0.168	-0.203	-0.339
Sh. dry	-0.595	-0.514	0.048	-0.128	0.277	0.535	0.475	-0.388	0.524	0.490

Sh/ro	-0.050	-0.043	-0.397	-0.016	-0.037	0.535	0.578	-0.188	0.482	0.639*
Chl a	0.687*	0.644*	0.260	0.236	0.120	0.069	-0.662*	0.907**	0.159	0.016
Chl b	0.626	0.588	0.278	0.201	0.126	0.206	-0.552	0.929**	0.290	0.118
Total chl	0.648*	0.608	0.273	0.213	0.125	0.164	-0.589	0.926**	0.250	0.086
Chl a/b	-0.215	-0.249	-0.116	-0.066	-0.221	-0.697*	-0.075	-0.608	-0.717*	-0.565
S. carb	-0.595	-0.514	0.048	-0.128	0.277	0.535	0.475	-0.388	0.524	0.490
T.Carb	-0.050	-0.043	-0.397	-0.016	-0.037	0.535	0.578	-0.188	0.482	0.639*
Ins. carb	0.048	0.042	-0.421	0.005	-0.085	0.467	0.521	-0.131	0.414	0.582
S. prot	0.626	0.588	0.278	0.201	0.126	0.206	-0.552	0.929**	0.290	0.118
T. prot	0.648*	0.608	0.273	0.213	0.125	0.164	-0.589	0.926**	0.250	0.086
Ins. prot	0.687*	0.644*	0.260	0.236	0.120	0.069	-0.662*	0.907**	0.159	0.016

Table 6. Chlorophyll, Carbohydrates and protein contents of soybean Giza 111 and Clark cultivars under different treatments

Treat	Chlorophyll (mg/g fresh weight)				Carbohydrate (g/ g dry weight)			Protein (g/ g dry weight)		
	Chll. a	Chll. b	Chl a/b	Total	Soluble	Insoluble	Total	Soluble	Insoluble	Total
Giza 111										
1	2.24±0.51	3.61±0.74	0.62±0.04	5.86±1.24	6.53	5.15	11.68	1.00	3.33	4.34
2	2.32±0.79	4.20±1.62	0.56±0.07	6.51±2.37	7.56	5.70	13.26	0.66	3.54	4.20
3	1.74±1.40	3.17±3.14	0.55±0.05	7.91±4.54	7.01	3.44	10.44	1.11	3.31	4.42
4	2.28±0.25	4.33±0.84	0.53±0.05	6.61±1.08	8.38	4.95	13.33	1.37	3.12	4.49
5	2.79±0.57	5.55±1.20	0.50±0.01	8.34±1.77	11.75	2.68	14.43	1.52	2.78	4.31
6	2.59±1.03	4.94±2.28	0.53±0.04	7.53±3.32	9.27	2.61	11.89	1.62	2.27	3.89
7	1.51±0.95	7.08±5.08	0.34±0.27	8.59±4.14	9.96	3.57	13.53	1.68	2.52	4.20
8	2.21±0.49	4.37±0.99	0.51±0.01	6.58±1.48	12.23	1.92	14.15	1.65	1.53	3.17
9	2.31±0.80	4.19±1.86	0.57±0.06	6.50±2.65	5.84	4.67	10.51	1.49	2.36	3.85
10	3.26±0.83	5.90±1.40	0.55±0.03	9.16±2.22	6.66	5.15	11.82	1.80	2.41	4.21
Total	2.43±0.82	4.94±2.15	0.53±0.11	7.36±2.50	8.52±2.23	3.98±1.31	12.50±1.43	1.39±0.36	2.72±0.62	4.11±0.39
F-value	0.952 ^{ns}	0.603 ^{ns}	1.816 ^{ns}	0.490 ^{ns}	--	--	--	--	--	--
Clark										
1	2.01±0.34	3.54±0.99	0.58±0.10	5.54±1.30	8.31	4.88	13.19	0.79	3.80	4.58
2	2.03±0.21	4.10±0.46	0.49±0.01	6.13±0.67	9.34	5.56	14.91	1.28	3.21	4.49
3	1.60±0.27	2.65±0.56	0.61±0.03	4.25±0.83	12.30	3.71	16.01	0.69	3.90	4.59
4	1.54±0.58	2.62±1.22	0.61±0.06	4.16±1.80	10.72	8.18	18.89	0.79	3.56	4.34
5	2.11±0.37	4.03±0.69	0.52±0.01	6.14±1.06	9.34	10.92	20.27	0.89	3.55	4.44
6	2.46±0.43	4.80±0.98	0.51±0.02	7.25±1.40	7.35	8.52	15.87	1.12	3.42	4.54
7	2.00±0.18	3.87±0.21	0.52±0.02	5.87±0.40	8.59	6.87	15.46	1.16	3.43	4.58
8	2.19	4.27	0.51	6.46	9.00	9.07	18.07	1.09	3.30	4.39
9	2.57±0.88	4.55±1.57	0.57±0.01	7.12±2.44	10.10	7.35	17.45	1.06	3.24	4.30
10	3.43±0.07	6.76±0.15	0.51±0.00	10.18±0.22	10.37	8.24	18.62	0.89	3.43	4.33
Total	2.15±0.61	4.01±1.30	0.55±0.06	6.16±1.90	9.54±1.40	7.33±2.14	16.87±2.15	0.98±0.19	3.48±0.23	4.46±0.11
F-value	3.505**	4.081***	2.654*	3.898***	--	--		--	--	--

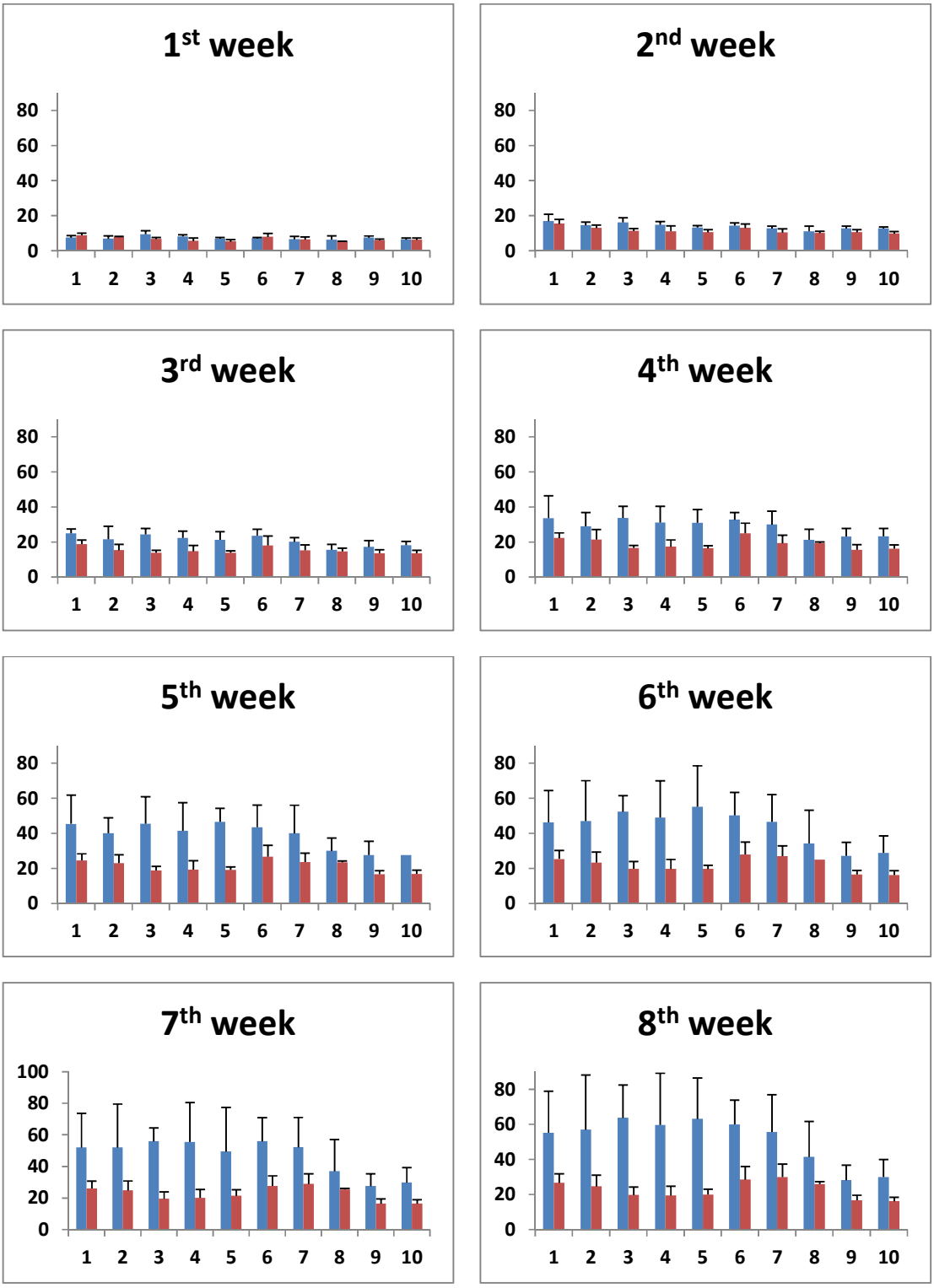

Fig. 1. The plant heights of soybean Giza 111 and Clark cultivars under different treatments
Giza 111 ■ Clark ■

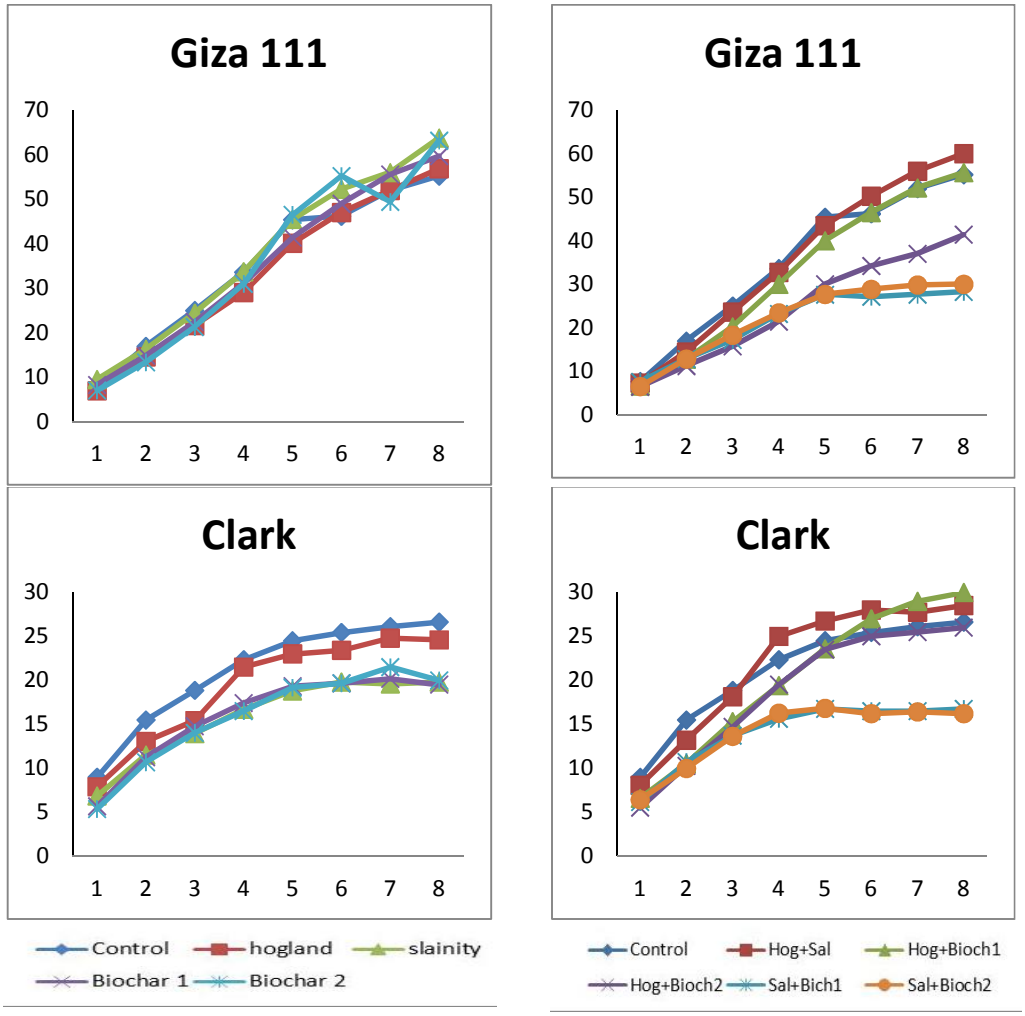

Fig. 2. Growth curve of soybean Giza 111 and Clark cultivars under different treatments

biochar-amended soil compared with saline soil. Improvement in the growth of salt-stressed plants under the influence of biochar may be due to the improved photosynthesis, chlorophyll content, and enhanced ribulose biphosphate carboxylase activity. The correlation between soil and growth variables indicated that there is a significant positive correlation between chlorides with the a/b ratio in Giza 111 cultivar; and TDS with the a and total child; and EC with chl a in Clark cultivar. Alleviates salinity induced stress on growth of soybean by improving photosynthesis and transpiration rates, as salt stress caused the drastic decline in photosynthesis and transpiration in cowpea, kidney bean [42] and bush bean [43]. The reduction in photosynthesis under salinity attributed to a decrease in chlorophyll content [6] and activity of photosystem II [7]. Salinity can affect chlorophyll content through inhibition of chlorophyll synthesis or acceleration of its degradation [8].

Salt stress affects many physiological and biochemical processes in plants, resulting in the alteration of some metabolic pathways. Amongst the significant effects are those involving carbohydrate metabolisms, with the accumulation of sugars and some other organic solutes (Table 5) rivaled that, soluble carbohydrates contents of two soybean cultivars were higher in all saline-treated soil. However, biochar 1 or 2 amended saline soil reduced it. This may be attributed to biochar was improves the physicochemical properties of soil especially, sodium removal as sodium leaching and EC (Table 6). Carbohydrates are frequently associated with active osmotic adjustment and have long been known to increase in a wide

range of plants grown under salinity. Carbohydrate diversion plays a vital role in the adaptive processes linked with NaCl tolerance, such as Na^+ and Cl^- translocation and compartmentation, solute synthesis for interdependent mechanisms of growth and osmotic adjustment, and protein turnover [44].

Data in (Table 6) indicated that salinity stress leads to a significant reduction in soluble protein contents and the Clark cultivar more badly affected than Giza111. However, biochar 1 or 2 overcome in the protein contents. The decrease in protein content under salinity stress may be due to the disturbance in nitrogen metabolism or inhibition of nitrate absorption as reported by El-Zeiny et al. [44]. Also, Xu et al. [45] reported that salinity stress induces changes in the ion content of plant cell which intern cause changes in the activity of individual metabolic systems that might have severe consequences for protein.

4. CONCLUSIONS

These studies illustrated that biochar might be very useful in mitigating salinity stress from the soil and also inhibits Na+ uptake by plants grown in saline soils which in turn enhanced the mineral nutrients in plants. Moreover, biochar and Hoagland solutions application promotes the P and N content in soybean plants. Giza-111 cultivar showed more capability to survive under salinity condition compared with Clark cultivar regarding of almost all plant examined. Considering, Giza-111 was found more appropriate under salinity condition and recommended to use in a breeding program for enhancing soybean production in newly reclaimed soils of Saudi Arabia. However, further research is needed to establish the mechanisms of biochar-mediated mineral uptake by plants under saline conditions both at the soil and plant levels.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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