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The Effect of Biochar Applications at Different Doses on Soybean Seedlings Grown in Salty Conditions

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This study was carried out in greenhouse of Ataturk University Plant Production Implementation and Research Center to investigate the effects of biochar application at different doses on the mineral element content of soybean seedlings under salt stress in Erzurum Province, Turkey. In the study, some mineral contents in the leaves and roots of soybean seedlings were investigated. The experiment, which was established in a completely randomized design with three replications in each of five pots, was factorial. According to the data obtained from the study, it was stated that while the leaf and root plant nutrient content of soybean seedlings decreased in salty conditions in general, the applied biochar increased the leaf and root plant nutrient content. This positive effect of biochar treatments on enhancing mineral element content was dose dependent. In conclude, biochar can be used as an amendment for increasing plant nutrient use efficiency of plants under saline conditions.

1. Introduction

Soybean (*Glycine max* L.), which offers more than 25 percent of protein in the world requirements in terms of feed and minerals, is one of the most significant oil plants and improves soil fertility via nitrogen fixation through nodosities on its roots (Alekel et al., 1998). Soybeans have been shown to stop the progression of cancer and osteoporosis and to improve coronary heart disease (Alekel et al., 1998). They are additionally utilized in the confectionery industry, infant food production, animal feed manufacturing, and energy generation from plants (Lucas et al., 2001). Owing to these significant characteristics, soybean production is consistently increasing, although it has not yet exceeded the noteworthy levels achieved by corn, wheat, and rice. The abiotic element known as salt stress, which has a negative impact on plant development and growth, is particularly dangerous to the soybean (*Glycine max* L.) and other species of legume (Ashraf and Wu, 1994; Kul et al., 2021).

Salinity, one of the greatest challenges to global food security (Abd El-Mageed et al., 2020), considerably influences the fresh and dry weight of the cultivated crops (Demir and Mazi, 2008; Galvan-Ampudia and Testerink, 2011). Most of biological processes in plants, such as development, growth, germination, and photosynthesis are severely impacted depending on the density and duration of salt stress (Mugdal et al., 2010), which dramatically influences water and osmotic pressure in plants (Bressan et al., 2008). In

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addition, high salt concentrations considerably altered the ion uptake in plants, increasing Cl^- and Na^+ uptake while decreasing the uptake of K^+, Ca^{+2}, Mg^{+2} and other cations (Parida et al., 2005; Kusvuran et al., 2008; Guo et al., 2015). Even though expensive and momentary methods such as enhancing salt irrigation water, employing species and varieties with high salt tolerance, or fertilization are used to reduce the effect of salt stress on plants, biochar implementations to improve physicochemical properties such as cation exchange capacity and Na^+ absorption have surfaced as a common method in recent years in terms of sustainable technology (Drake et al., 2016).

Biochar, which is rich in humic compounds (Lorenz and Lal, 2014), has gained significance as a green manure crop, a means of carbon sequestration in the soil, and an enhancer of soil productivity through agrochemical immobilization. In fact, studies indicate that biochar treatments have a considerable impact on a variety of soil parameters under biotic and abiotic stress conditions (Wu et al., 2014; Rizwan et al., 2016).

In this research, the impact of varying salt concentrations on the leaf and root mineral element content of soybean (*Glycine max* L.) was tested utilizing the biochar form of hazelnut shell, which is designated a fuel following hazelnut harvest.

2. Materials and Methods

The study was conducted in the greenhouses of the Atatürk University Plant Production Application and Research Center and the labs of the Field Crops Department of the Faculty of Agriculture. Containers containing soil, sand, and peat (3:1:1/v:v:v) were adjusted with biochar at three different concentrations: 0% (control), 2.5%, and 5% of soil weight. In the study, the biochar form of hazelnut shell, which was supplied by a private company, was used. In the research, salt was applied with irrigation water at 0, 50, and 100 mM NaCl. By sowing soybean seeds in pots, saline water applications were initiated. In order to avoid the seeds from being harmed by abrupt exposure to salt stress, the salt stress was first raised gradually by 25 mm, and the final dosages were set. The application dosages were adjusted by monitoring the EC values of the soil. In the study, 3 biochar (B0: without biochar (Control), B1: 2.5% biochar and B2: 5% biochar) and 3 salinity doses (0 (S0), 50 (S1) and 100 (S2) mM NaCl) in 9 different combinations (T0: S0B0, T1: S0B1, T2: S0B2, T3: S1B0, T4: S1B1, T5: S1B2, T6: S2B0, T7: S2B1, T8: S2B2) in a 3x9 factorial design with 3 replications. While SPSS (SPSS, 2010) was utilized for statistical analysis of the data, Duncan's multiple range tests were employed to assess the variations between the means.

3. Results and Discussion

Plant nutrient element contents except for of soybean leaves were dramatically and significantly reduced in line with the increase in salt, as shown in Tables 1 and 2.

When the S0B0 was compared with S1B0 and S2B0 applications, the N, P, K, Mg, Ca, B, Fe, Mn, Zn and S elements in the leaves decreased by 10-17%, 11-29%, 13-26%, 25-40%, 10-29%, 22-47%, 53-58%, 12-39%, 8-31% and 15-35% respectively, while the Na and Cl ratio increased by 33%-44% and 28%-49% respectively. In the study, the B2 application gave the highest concentrations of N (35%), P (18%), K (30%), Ca (77%), Mg (15%), Mn (10%), and B (23%), while the B1 application gave the highest concentrations of S (4%), Fe (8%), and Zn (5%). In the study, B2 application yielded the highest levels of N (39%), P (20%), K (52%), Ca (92%), and B (8.6%), while B1 application produced the highest levels of Mg (420%), S (5%), Mn (14%), Fe (103%), and Zn (36%) (Table 1 and Table 2). The highest content of N (27%), P (40%), K (81%), Ca (135%), and B (21%) in 100 salt application was recorded in B2 application, while the highest content of S (29%), Mn (29%), Fe (118%) and Zn (63%) was observed in B1 application.

In the study, mineral contents of roots except for Na and Cl showed a significant decrease as a result of the general increase in salt concentration (Table 3 and Table 4). When the S0B0 was compared with S1B0 and S2B0 applications in the experiment. the N, P, K, B, Mn, Ca, Zn, Fe and S elements present in the leaves decreased by 9-37%, 14-21%, 29-52%, 17-24%, 16-38%,14-28%, 19-41%, 19-30% and 27-49% respectively, while the Na and Cl ratio increased by 28-46% and 20-67% respectively. While the highest N (4%), P (12%), K (10%), Mg (15%), Mn (108%), Fe (11%) and Zn (7%) content was recorded within the B2 application with different biochar applications without using salt. the highest Ca (10%) and B (6%) content was obtained from the B1 application (Table 3 and Table 4).

Table 1. Leaf mineral content of soybean seedlings under salinity with biochar treatment[1]

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)
T0	1.82 D	0.28 B	1.72 B	0.52 D	0.20 B	0.26 A
T1	1.95 C	0.29 B	1.80 B	0.65 C	0.19 B	0.27 A
T2	2.44 A	0.33 A	2.23 A	0.92 A	0.23 A	0.22 B
T3	1.63 E	0.25 C	1.49 CD	0.47 E	0.15 D	0.22 B
T4	1.90 CD	0.25 C	1.56 C	0.54 D	0.78 BC	0.23 B
T5	2.26 B	0.30 B	2.26 A	0.90 AB	0.19 B	0.18 C
T6	1.51 F	0.20 D	1.28 E	0.37 F	0.12 E	0.17 C
T7	1.88 CD	0.23 C	1.43 D	0.53D	0.16 CD	0.22 B
T8	1.91 C	0.28 B	1.80 B	0.87 B	0.16 CD	0.17 C

[1]Values followed by different small and capital letters in same column shows significant differences at P< 0.01 levels. respectively. using t-test. *Statistical difference at P< 0.01.

Table 2. Leaf mineral content of soybean seedlings under salinity with biochar treatment[1]

Treatments	Mn (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	B (mg/kg)	Cl (mg/kg)	Na (mg/kg)
T0	82.48 C	299.63 B	15.67 CD	9.12 B	1.27 E	498.28 CD
T1	89.09 AB	324.01 A	16.43 C	8.68 BC	1.32 E	468.49 EF
T2	90.43 A	305.17 B	16.37 C	11.21 A	1.27 E	512.02 C
T3	73.02 D	143.59 E	14.50 D	7.09 DE	1.63 B	664.79 B
T4	83.52 BC	291.46 B	19.70 A	7.27 CDE	1.37 E	453.04 F
T5	78.24 CD	167.43 D	14.97 D	7.70 BCD	1.27 E	468.06 EF
T6	50.56 F	125.16 F	10.87 F	4.85 F	1.89 A	715.15 A
T7	65.06 E	273.13 C	17.73 B	5.34 F	1.53 C	466.57 EF
T8	65.01 E	147.37 E	12.99 E	5.87 EF	1.46 D	482.36 DE

[1]Values followed by small and capital in a column shows significant differences at P< 0.01 levels. respectively. using t-test. ** Statistical difference at P< 0.01.

Table 3. Root mineral content of soybean seedlings under salinity with biochar treatment[1]

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)
T0	0.94 A	1.47 C	0.60 B	0.29 C	0.067 AB	0.073 A
T1	0.95 A	1.56 B	0.61 B	0.35 A	0.050 CD	0.073 A
T2	0.98 A	1.64 A	0.66 A	0.32 B	0.077 A	0.073 A
T3	0.86 B	1.26 E	0.47 D	0.25 D	0.053 CD	0.053 B
T4	0.63 D	1.35 D	0.47 D	0.28 C	0.043 DE	0.047 BC
T5	0.95 A	1.44 C	0.52 C	0.29 C	0.067 AB	0.050 BC
T6	0.59 D	1.16 F	0.32 E	0.21 E	0.073 A	0.037 C
T7	0.99 A	1.26 E	0.66 A	0.23 D	0.037 E	0.037 C
T8	0.79 C	1.28 E	0.45 D	0.28 C	0.057 BC	0.043 BC

[1]Values followed by small and capital in a column shows significant differences at P< 0.01 levels. respectively. using t-test. *Statistical difference at P< 0.01.

Table 4. Root mineral content of soybean seedlings under salinity with biochar treatment[1]

Treatments	Mn (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	B (mg/kg)	Cl (mg/kg)	Na (mg/kg)
T0	6.40 D	32.33 AB	4.45 AB	2.64	2.60	462.21 EF
T1	6.42D	29.79 BC	4.72 A	2.80	3.14	488.81 DE
T2	13.34 A	35.84 A	4.75 A	2.65	3.81	493.41 DE
T3	5.39 E	26.27 CD	3.62 C	2.20	3.11	589.71 C
T4	5.31 E	25.26 CD	4.14 B	2.67	1.35	447.77 F
T5	10.44 B	35.52 A	4.14 B	2.45	4.76	558.52 C
T6	3.97 F	22.70 D	2.61 D	2.00	4.34	672.44 A
T7	5.17 E	28.59 BC	3.39 C	1.62	3.71	510.40 D
T8	9.47 C	29.35 BC	3.57 C	3.90	3.45	634.85 B

[1]Values followed by small and capital in a column shows significant differences at P< 0.01 levels. respectively. using t-test. *Statistical difference at P< 0.01.

Study results also show that B2 has the highest amount of N (11%), P (14%), K (11%), Ca (16%), Mg (26%), Mn (94%), Fe (33%) and Cl (53%) while B1 has the highest amount of B (22%) in 50 mM salt application. The highest P (10%), Ca (33%), S (16%), Mn (139%), Fe (30%), Zn (37%) and B (95%) were seen in the B2 application while the highest N (68%) and K (107%) content was determined in the B1 application for 100 salt applications.

Soluble salts, which are easily absorbed by plants, prevent the plant from uptaking water, disrupt the soil structure and adversely affect plant growth (Kanber et al., 1992; Gungor and Erozel, 1994). Furthermore, because salt stress in plants increases the quantity of Cl and Na ions in the environment, it contributes to nutritional deficiency in plants by decreasing the concentrations of essential nutrients such as K^{+}, NO^{-3} and Ca^{+2}. In the research, it was stated that although the Cl and Na content of the plant's leaf and root samples increased owing to rising salt levels, the overall mineral content decreased significantly. In this situation, which occurs in the nutrient content of the plant, it is possible that the excess Na^{+} ion taken by the plants will adversely affect the ion balance in consequence of the increase in the salinity level. Because the ion imbalance caused by increased salt stress both limits the uptake of essential elements that are important for plant nutrition and causes various physiological problems in the plant (Gorham et al., 1985). In numerous research (Yildirim et al., 2008; Zhu et al., 2008; Rouphael et al., 2012), it was discovered that salt stress considerably reduced the mineral element content of plant leaves and roots. As a matter of fact, in a study, it was determined that the negative effects of salt stress were reduced by biochar applications; oxidative stress level and membrane damage decreased, root, stem growth, flower formation and fruit set increased (Karabay, 2017). It has been found that varying amounts of biochar applications, notably B2 application relative to other applications, give a greater favorable influence on the mineral content in the leaves and roots, preventing the detrimental effect of salt stress on the mineral content of the soybean plant. Our findings are also supported by comparable investigations (Xue et al., 2012; Chaganti and Crohn, 2015; Ekinci et al., 2022).

4. Conclusion

In the study, it can be concluded that salinity stress conditions could adversely affect mineral nutrient content of the leaves and roots of the soybean plant, resulting in nutritional deficiency. Yet, the study also revealed that the biochar's improved the mineral content of the plant, so mitigating this detrimental impact of salinity stress. Based on the study results, it can be inferred that the application of biochar derived from hazelnut waste contributed to the enhanced growth of soybean seedlings subjected to salinity stress. Moreover, incorporating biochar as an amendment has the potential to alleviate moisture stress in agricultural areas. The utilization of hazelnut shells as a raw material for biochar production offers a promising avenue in this regard.

Conflict of Interest

There is no conflict of interest among the authors.

Credit authorship contribution statement

All authors equally contributed to the manuscript.

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