Biochar Improves the Growth and Physiological Traits of Al

Amaranth and Maize Grown under Salt Stress

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Keywords: Salt stress, biochar, alfalfa, amaranth, maize, total root length, r chlorophyll content.

Abstract

Purpose:Salinity is a main factor in decreasing seed germination, plant growth and yi stress is a major problem for economic crops, as it can reduce crop yields and quality. S occurs when the soil or water in which a crop is grown has a high salt content.

Methods:We studied the impact of biochar on plant growth and the physiological prope alfa, amaranth and maize under salt stress conditions.

Results:The results showed that the maize, Alfa-alfa, and amaranth under biocha significantly enhanced the plant height androot morphological traits over the control. Th significantly increased the total root length, root diameter, and root volume. Compared tc the biochar significantly increased the chlorophyll a, b content, total chlorophyll an content under salt stress. Furthermore, the biochar significantly increased enzyme acti under salt stress in the three crops

Conclusions: Biochar treatments promote plant growth and physiological traits of alfalf and maize under salt stress condition. Overall, biochar is an effective way to mitigate s in crops. It can help to reduce the amount of salt in the soil, improve the soil structure, the availability of essential nutrients, which can all help to improve crop yields.

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Introduction

Soil degradation in the Republic of Uzbekistan is mainly caused by salinity; irrigated lands of Uzbekistan are subject to varying degrees of salinity; this salinity is es in the Republic of Karakalpakistan, Khorezm, Bukhara, Syrdarya and Jizzakh regions (l al., 2018). Among soil degradation in the world, soil salinity plays a major role; the o salinity affects the amount of carbon (C), nitrogen (N), carbon emission, bacterial gene c actinobacteria, thermophilic and betaproteobacteria in soil (Chao et al., 2021). Soil salin to soil physical properties; the effects of wind erosion on salts in soil were studied.These conducted on samples treated with salts in an arid region, and wind tunnel tests and a st 18 m/c were conducted under the influence; according to the results, Na_2SO_4, $MgSO_4$ formed high emissive surfaces, Na_2SO_4 and Na_2CO_3 crystals appear in sharp form, deh aggregates for $MgSO_4$were the primary source of dust (Jiadong et al., 2022). Soil negatively affects soil processes, including carbon-nitrogen ratio, phosphatase, cellu activity, and microbiological diversity (Shuai et al., 2021). Salinity harms the nutrition the soil; the use of rhizobacteria with compost in such soils reduces the amount of sodi the soil, and affects the activity of soil enzymes resulting in the improvement of plant nu et al., 2022).

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The drying up of the Aral Sea was caused by global climate change and the irre water resources since 1960, the poor functioning of drainage collectors and the expansion agriculture in the region, resulting in a decline in the water level and an enhance in salin 1988). Also, the transition from hydromorphic to automorphic accelerated, and de became more active. The Aral Sea's drying up, and the soil formation process began in th dunes (Assouline et al., 2015). Aral Sea, the amount of water-soluble salts in the soil inc 04-05 g/l to 71,3 g/l; according to studies, the number of microorganisms decreased with of salts in the soil (Hongchen et al., 2021). A decrease in plant life has been observed South Aral Sea. Therefore, monitoring and increasing plant life ensure ecologi (Kochkarova, 2019). The increase of plants in the dry bottom of the island leads to the i of soil properties; in this regard, the concentration of cations in the soil (Ca2+, K+, Mg cation exchange capacity, rN environment, enzyme activity (phosphatase, b-glucod acetylglucosaminidase) in the 0-10 cm layer, when planting plants decreased the conc basic cations, and electrical conductivity, the activity of enzymes and the number of mic have increased (Jiae et al., 2020), the widespread introduction of phytoremediation o

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prevents sand flying (Issanovaet al., 2015). In the dry regions of the Aral Sea, the sal soils is chloride-sulfate; the amount of salts is from 2,09 to 4,21%, the amount of chlo 0,59 to 0,82%, sulfate is from 0,68 to 2,24%, sodium is 0,67 from 1,08%, black saxovol in the studies, its phytomass (58,7 t/ha), 669 16-year-old seedlings per 1 ha, phytomas 1682 saxovol per hectare the seedling is correct (Shakhmatov et al., 2016).

Aral Sea, where the study was conducted, does not have complete soil form moment because if we take into account the participation of 6 factors in the formation assume that 1 cm of soil is formed on average in 200 years if it is considered that it has b since the drying of the island until now, there is still a 1 cm layer in the dry bottom c There is no soil, and the process of soil formation has started in some areas (Jabbarov e From this point of view, it can be said that scientists and experts who plan to condu practical and innovative research in the dry bottom of the Aral Sea should take into absence of soil cover.

Biochar application to soil plays an essential role in promoting nutrient dy modifying soil pollutants and microbial functions (Muhammad et al., 2018). Biochar co used in agriculture, promoting soil properties and improving productivity (Day et al., effect of biochar is either directly by supplying nutrients to plants or indirectly by im properties, resulting in increased plant nutrient utilization efficiency (Keeney, 198 improves soil quality and crop productivity; its effect is realized through greater soil mic enzyme activity, including microbial biomass depending on soil types, urease, alkaline and dehydrogenase enzyme activity, respectively 21,7%, 23,1%, 25,4% increased to 19,8 et al., 2020), 5 years after the application of biochar, the carbon in the soil increased by the amount of oxygen increased by 2,81% (Dong et al., 2017).

Biochar affects the changes in the physical properties of soils, including improved moisture retention properties, enhanced CO_2, N_2O and CH_4 gas formation, reduced g composition when applied to heavy soils, reduced density, increased porosity, increased use (Masiello, 2015, Kinney et al, 2012, Van Gestel 1992, Zhang 2012). Several studies that salt stress decreased seed germination (Ashraf and McNeilly, 2004) and plant grow al., 2015; Menezes et al., 2017; Jabborova et al., 2020; Jabborova et al., 2021a; Kumar e Jabborova et al., 2021b).Moreover, on the root morphological traits (Wang et al., 2008; 2016; Zeeshan et al., 2020) and physiological properties (Azari et al., 2012; Jabborova e

Saddiq et al., 2021; Jabborova et al., 2021e) in plants. Biochar's beneficial impact on pl (Jabborova et al., 2021c Jabborova et al., 2022) and enzyme activities in soil (Jabborova Song et al., 2022) were investigated in various plants under normal and stress conditio Rashidabad et al. (2009) investigated that biochar improvesmungbean's physiological an traits under salt stress. The present study evaluated the beneficial impact of biocha amaranth and maize growth and physiological characteristics under salt stress conditions.

Materials and Methods

Biochar, soil, and seed

The municipal solid waste biochar was obtained from the Soil Sciences department faculty, NUU. Pyrolysis of municipal solid waste biochar was carried out at 500 ˚C for municipal solid waste biochar traits are shown in Table 1.

Sand samples were collected from the dry bottom of the southern part of th Analysis of the sand's physicochemical properties and the salinity level of the sands in th of the Aral Sea are shown in Table 2 and Table 3.

Alfa-alfa (*Medicago sativa* L.), amaranth (*Amaranthus caudatus* L.) and maize (*Zea mo* were usedfor field experiments.

Experimental design

The Experimental work was conducted on the dried bottom of the Aral Sea. The exp conducted to study the effect of biochar on the growth, root morphological and physiolog alfalfa, amaranth and maize. The experiment was carried out in randomized block desig replications experiments in the dried bottom of the Aral Sea. Experimental treatments in Alfa-alfa (Control), T2 - Alfa-alfa (Biochar), T3 - Amaranth (Control), T4 - Amaranth (- Maize-(Control), and T6 - Maize (Biochar). After forty days, plants were harveste height, shoot and root fresh weights were measured.

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Measurement of root parameters

The roots of alfalfa, amaranth, and maize were cleaned with water with extreme caution. of the root system was dissected using a scanning system, and the results were evalua help of the Win RHIZO program.

Measurement of physiological traits

Photosynthetic pigments in alfa-alfa, amaranth and maize were measured spectrophotor the method of Hiscox and Israelstam (1979). The relative water content of leaves amaranth and maize was analyzed by the method of Barrs and Weatherly (1962).

Analysis of soil nutrients

The agrochemical parameters of the soil were analyzed after cultivation. The carbon (C) humus content were analyzed using the modified method by Tyurin (Soils, 2003) The P N contents in soil were analyzed by the method (Soils, 2002; Soils, 2005).

Analysis of soil enzymes

Urease activity of soil was determined using the method by Pancu and Gautheyrou, samples (2.5 g) were added with toluene (0.5) mL for 15 min. After mixing, urea (2.5 mL buffer were addedto 5 mL.Incubator at 38°C for 24 h. The urease activity was determ spectrophotometer. The soil enzyme activities (Invertase and catalase) were assayed according to the method by Xaziev (2005).

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Statistical analyses

Experimental data were analyzed SPSS version 29 for Mac OS. Data were described mean and standard deviations. The influence of Biochar and different plants we statistically using two-and one-way analysis of variance (ANOVA) and MANOVA. comparisons between groups, Duncan’s Multiple Range Test was applied at 0.05 level. H generated using PAST statistical software.The magnitude of the F-value determined the of the effect of treatment (p< 0.05, <0.01, and <0.001).

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Results

The results in Table 4 show the effect of biochar on morphological traits of alfa-alfa, a maize under salt stress , Morphological traits of alfalfa, amaranth and maize were decreased by salt stress.

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Alfa-alfa (biochar) treatment significantly increases the plant height by 28%, weight by 50% and roots' fresh weight by 33% as compared to control under salt s conditions, amaranth (biochar) treatment significantly enhanced the plant height by 24% weight by 54% and root fresh weight by 43% than the control.The additions of biochar caused significantly enhanced the plant height by 48%, shoot fresh weight by 25% ar weight by 50% in maize under salt stress.

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Data revealed that biochar treatments significantly improved root parameters as well a control (Table 5.). Compared to the control, Alfa-alfa (biochar) treatment significantly i root projected area by 39% and the root surface area by 31% under salt stress. The total diameter and volume were sharply enhanced by Alfa-alfa (biochar) treatment, which increased by 46%, 47% and 82%, respectively, to the control. The root surface area, pr and diameter were improved with the amaranth (biochar) by 24%, 25% and 27% to the c stress. In salt stress, amaranth (biochar) treatment significantly increased the root volume the total root length by 50%. The highest values of root surface area (63%) were obs treatment of maize (biochar) than in the control. In salt stress conditions, mai: significantly increases the total root length by 24%, root projected area by 32%, root vol and root diameter by 43% more than the control.

Data revealed that biochar treatments increased photosynthetic pigments of alfal and maize as compared with the control under salt stress (Figure 1.). Alfa-alfa (biocha significantly enhanced the chlorophyll a content by 8%, chlorophyll b content by chlorophyll content by 9% and carotenoid content by 25% than the control under salt s salt stress, amaranth (biochar) treatment significantly enhanced chlorophyll b content b chlorophyll content by 21% and carotenoid content by 12% than the control. The higl chlorophyll b content was observed in maize (biochar) treatment recording a significan 64% over the control under salt stress.

Data in Figure 2 indicated that salinity decreased the relative water content of le amaranth and maize. Compared to the control, all biochar treatments improved the re content of leaf in alfalfa, amaranth and maize. However, amaranth's maximum relative v was detected in amaranth (biochar) treatment, respectively. The results in Table 6 show impact of biochar on soil nutrients under salt stress.

The soil nutrients of N, P, K and humus contents were promoted by apply treatments. The Alfa-alfa (biochar) treatment significantly increased N content by 18%, 16%, K content by 17% and humus by 55%, respectively, than the control. The P, N, K contents increased by 15%, 17%, 17% and 20% when inoculated with amaranth (biocha However, the highest P and K contents were observed with maize (biochar) treatı (biochar) treatment had a greater effect on increasing P content (24%), K content (26% content (28%).

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The impact of biochar treatments on enzyme activities in salt stress is given in T alfa (biochar) treatment significantly enhanced the catalase by 30%, invertase by 40%, a 25% in soil under saline conditions. The catalase and urease activities were improved 17%, respectively, when the soil was amended by amaranth (biochar) over the control i Under salt stress, the catalase and urease activities increased by 13% and 24% in mai treatment.

The overall impact of biochar treatments on plant growth, physiology and enzyı under salt stress is given in Table 8 in terms of multivariate analysis of variance pı impact of biochar treatment, different plants, and the interaction between plants and bi alfa (biochar). An overall highly significant effect of biochar was recognized in most o variables, including; Plant height, SFW, RFW, Total Length, Total root ProjArea, Total S Volume, Diameter, Chl-a, Chl-b, total chlorophyll, Carotenoid, Catalase, Invertase, Ure and Humus. However, biomass allocation and relative water contents showed a no impact of biochar treatment. The difference on three plant species was significant iı parameters as revealed by MANOVA. The interaction between biochar treatment and p was significant in plant height, shoot fresh weight, total root length, total root proj. area, area, root volume, total chlorophyll, carotenoids, urease activities, P, K, and humus.

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The interrelationship between study variables in terms of Pearson's correlati plotted as a heatmap presented in Figure (3) using PAST software. The blue boxes indica

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correlation between variables; the red boxes indicate a negative correlation and the grey for significant correlations. Accordingly, Biochar treatments had a positive correlation the growth parameters measured, and significantly in plant height, diameter, urease, K (%). Moreover, N and P were significantly and positively correlated to pigment concentr

Discussion

Salt stress is one of the focal contrary environmental factors that restrict plant growth in can cause a marked reduction in plant height, root length, plant fresh weight, dry we productivity of many crops (Huang et al., 2022; Ibrahim et al., 2020, 2021; Kumar et Moreover, chlorophyll a and total chlorophyll contents of tomato plants significantly de active photosynthetic process in leaves was also damaged, tochlorosis and early leaf senescence under salinity conations. Integrating biochar in study could enhance the morphological characteristics of the chosen plants under salinity finding is consistent with the report of Hussein et al. (2022), who observed biochar impro length and plant growth in spinach (*Spinacia oleracea* L.) under salt stress. The prospec of biochar on leaf area index, photosynthetic potential, transpiration rates and chlorop significantly helped the leaf photosynthesis and net assimilation rate of rice growth and (Huang et al., 2022; Piao et al., 2022). In the current study, salt stress reduced ph pigments such as the total chlorophyll content and carotenoid content in alfalfa, amaranth Applying biochar greatly improved the salt tolerance of cabbage seedlings and increased chlorophyll a, b and total chlorophyll while lowering sucrose, proline and H_2O Zahra et al. (2020) observed a reduction in chlorophyll content and carotenoid conte genotypes under salt stress. Photosynthetic pigments and plant nutrients in winter and s showed a sharp decrease under salt stress (Saddiq et al., 2021). Also, numerous resea reported that biochar increased nutrient uptake (Ndiate et al., 2021) and plant physiologic (Zhang et al., 2020; Kul et al., 2021) in various plants under salinity stress. It was reveale et al. (2021) that the addition of biochar under salinity stress had a substantial impact ability to absorb nutrients and maintain water status, and biochar could reduce osmotic st increasing soil water content and releasing mineral nutrients in the soil solution and plant transient sodium ion binding due to its high adsorption ability. Biochar could attract ad into the soil under salinity conditions, releasing nutrients and lowering osmotic stress b water holding capacity and CO_2 absorption, which ultimately led to a noticeable imp photosynthetic, stomatal conductance and transcription rates (Ibrahim et al., 2021). A biochar was able to reduce Na/K ratio and the amount of Na in many plants, which negative impact of salts on plants (Lashari et al., 2015; Ali, 2017; Huang et al., 2022).

Biochar application could directly improve the nitrogen status of salt-affected soils. Also, impacted the quantity and activity of bacteria, which could drive N transformation a nitrogen release (Yao et al., 2022). Moreover, a considerable rose in soil nitrogen was r this increase was closely correlated with the applied dose of biochar. These findings co ability of biochar to hold the nutrients. The amount of soil organic matter was dramatica due to biochar application. In severely saline-sodic soil, marked increases in soil organi nutrients after biochar addition. Numerous studies suggested that biochar could directl source and indirectly improve soil texture to boost P status in salt-aff (Saifullah et al. 2018). Similar findings were also informed by Alfadil et al. (2021); bioch nutrient contents in the soil under salt stress. Premalatha (2022) reported that biochar in organic C and available N, P and K under salt stress. Similarly, Yao et al. (2022) have biochar promoted the availability of soil total N, P and K under saline conditions. Si have been informed by Huang et al. (2022).The biochar improved soil organic matter, to contents under salt stress. Gunarathne et al. (2020) reported that biochar promoted soil's alkaline phosphatase activity in salt stress conditions.

Soil microbial activity has been exemplified by enzyme activity, which is susceptible to the soil environment (Elzobair et al., 2016; Huang et al., 2017; Khademand Raiesi, 201 2019). In addition, soil enzyme activities were critical for soil organic matter degr nutrient cycling (Song et al., 2019; Yao et al., 2022) and are considered important indic quality. However, few studies focused on biochar's effect on enzyme activities in salin results showed that adding biochar positively affected enzyme activity in saline soils. Th of soil organic nitrogen into usable inorganic nitrogen was related to urease. Invertase w increasing the amount of soluble nutrients in the soil, which gave soil organisms enc Catalase was a major factor in the oxidation of organic matter and humus production, an the level of biological redox and microbial activity in the soil. Compared to control biochar application had a significant effect on the activities of catalase, invertase, and u current investigation (Yao et al., 2022). The use of biochar could enhance enzyme enhancing SOM, microbial activity, and microbial biomass or by placing the enzymes cl and allowing them to interact with the biochar surface (He et al., 2020; Qu et al., 2020 Resi, 2021).

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Conclusion

Biochar treatments have more stimulation impact on most of the root morphological tra growth parameters of alfalfa, amaranth and maize compared to the control in salt stress. I biochar application could improve photosynthetic pigments viz: the total chloroph chlorophyll a and chlorophyll b. The application of biochar treatments positively impro of N, P, K and humus contents in the soil in salt stress. The stimulation impact of bioch on increasing soil enzyme activities such as catalase, invertase and urease and enhan availability can reduce the application of the chemical fertilizers in salt stress.

Conflicts of Interest: The authors declare no conflict of interest.

Author Contributions

Conceptualization, D.J., T.A., and Z.J.; methodology, S.M., D.J.,A.E, M.E, A.A, I.M, S. K.S.; software, D.J., Z.J., A.E, M.E, A.A, I.M, A.N., and S.M.; validation, D.J., Z.J., A.I I.M, A.N .; investigation, D.J., T.A., A.E, M.E, A.A, I.M, Z.J.; writing—original draft D.J.; writing—review and editing, D.J., T.A. A.E, M.E, A.A, I.M and Z.J. All authors h agreed to the published version of the manuscript.

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