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Role of Biochar in Mitigating Salinity Stress in Tomato

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Abstract— The problem of soil salinization is a scourge of global agricultural productivity. Biochar as an organic amendment has the potential to remediate salt affected soils, thereby alleviating salt stress on plants. This research was set to access the effect of 5% and 10% urban waste biochar in easing the harmful effects of salt stress on growth and physiological parameters of the tomato crop. The results of the study showed that both rates of biochar were efficient in improving overall plant performance. However, the 10% biochar level was more effective than 5% level for most of the parameters. Under saline water irrigation biochar amendment at 5% and 10% level increased the plant growth parameters by 43.1%-35.8% in plant height, 91.0%-113.7% in shoot fresh weight, 65.4%-74.8% in shoot dry weight, 23.4%-24.9% in no of leaves, 45.3%-39.1% in leaf area, 86.2%-115.5% in root fresh weight and 56.25%-62.5% in root dry weight, respectively. İn case of physiological parameters, this increase was 45.2%- 39.1% in leaf relative water content and 21.9%-22.25% in total chlorophyll level, respectively. In the light of results, it is concluded that incorporation of urban waste biochar could be a sensible approach for improving crop yield in salt stressed soils. Keywords: salinity stress, biochar, tomato, growth and physiological features

Index Terms— biochar, growth and physiological traits, salinity stress, tomato

1 Introduction

Among all the abiotic stresses limiting crop plant production worldwide, salinity stress is considered as the most brutal environmental factor. Salt toxicity can cause severe damages in various plant parts including tissue burning, root and shoot death, leaf abscission, reduction of stomata conductance, disrupted cellular metabolism and decreased photosynthetic activity. Salinity, besides decreasing the agricultural production of most crops, also disturbs soil physico-chemical properties and the ecological balance of the region.

There are studies conducted on several practices to lessen the damaging effects of salt stress on plants, such as, scraping, flushing, and leaching to drain the extra salt from the plants root zone [1], utilization of various irrigation techniques [2] and improvement of salt tolerance of plants [3]. However, these approaches because of high costs and labor-consuming requirements can be inefficient in overcoming salinization problem. In recent years, the use of organic soil regulators has received much attention as more promising and sustainable approach for enhancing fertility of salt-affected soils, ultimately improving crop yield.

Biochar, a byproduct of the process of pyrolysis, is a carbon-rich material which has gained much attention as a soil conditioner and is considered as an organic amendment [5]. When applied to salt-affected soils, biochar results in improved physical, chemical and biological soil properties [6], [7]. Biochar amendments benefit the salt-affected soils via elevating the soil organic carbon and nutrients status [7], improving cation exchange capacity (CEC) which improves water and nutrient retention [8], soil porosity and hydraulic conductivity [9], [6].

Since Na^+ accumulation and K nutrition impairment are a significant feature of salt-stressed plants [10], improving K availability is considered an effective approach to optimize K: Na ratio to enhance plant development and yield under salt-stressed soils [11], [12]. Biochar amendment increases K concentration in salt-affected soils, which counter the adversative effects of Na+, thus limiting the Na+ absorption of crops and reducing the salinity stress [13], [16].

The present study was set to access the effect of urban wastes biochar in alleviating the damaging effects of the salt stress on growth and physiology of tomato crop.

2 MATERIALS AND METHODS

The research was established as a pot experiment in a greenhouse at Horticulture Department of Atatürk University, Turkey. To evaluate the effect of biochar in alleviating the deleterious effect of salinity on tomato growth, a randomized complete block design experiment was conducted with three replications. Tomato variety "H2274" (*Lycopersicon esculentum Mill*. Cv. H2274) was used as the plant material.

2.1 Treatments Plan

Two sources of irrigation water were used in the study i.e. (saline and non-saline water). Sodium chloride (NaCl) was used to prepare 100mM saline irrigation water. The urban wastes biochar was used in the study, which was produced by SYNPET company using the Thermal Conversion Process (TCP™). The experiment comprised of six treatments, including the combination of two types of irrigation water (S0 and S1) and different proportions of biochar i.e. 0% (B0), 5% (B1) and 10% (B2).

2.2 Trial Arrangement

Biochar at desired rates were mixed thoroughly with the sandy loam soil before filling the pots. Treated soil was then filled in the pots having 3 kg capacity and placed in the greenhouse randomly on the benches.
and physiological traits of the

2.3 Sowing

Tomato seedlings were grown in multi-cell seedling trays (radius and height as 5 cm) and were transferred to the pots when reaching at three-leaf period. After the seedlings were transferred to the pots, already prepared 100Mm saline-water irrigation was applied twice a week to create salt stress for the plants. Salt control plants were sprinkled with normal water to maintain 60% soil moisture. After 60 days from transplantation, the plant samples were collected to measure the growth

2.4 Growth Parameters

After sixty days of sowing, fifteen plants were harvested from each replication, and were examined for the plant growth variables including root and shoot fresh weight, root and shoot dry weight, root and shoot length and no of leaves per plant was determined. Dr weights of the plants was determined by oven drying the samples at 70°C for 48 hours. Leaf area was quantified with a leaf area meter (LI-3100, LICOR).

2.5 Chlorophyll readings

The amount of chlorophyll was assessed by the method defined by Lichtenthaler and Buschmann [15]. Calculations for spectrophotometric readings were made by using the formula given below and the amount of chlorophyll in fresh weight was expressed as "mg/g".
Chlorophyll a (mg/g) = (12,7 * 663 nm) – (2.69 * 645 nm) * V / W*10000
Chlorophyll b (mg/g) = (22.91 * 645 nm) - (4.68 * 663 nm) * V / W*10000
Total chlorophyll = chlorophyll a + chlorophyll b

2.6 Statistical Analysis

The data obtained was analyzed using the SPSS 25 package program. Different letters indicate significant differences tested by Duncan's multiple comparison ($P < 0.05$).

3 RESULTS

3.1 Morphological Parameters of Tomato

Plant Growth characteristics of the tomato showed significant differences regarding salinity stress and biochar amendments. Saline water irrigation without biochar addition (BC0-S1), significantly ($P \leq 0.05$) reduced the plant height by 25.8% when compared to the control (BC0-S0). Conversely, biochar amendments at both rates, with and without salt stress, resulted in improved plant height. When comparing the treatments, 5% biochar (BC-1) increased the plant height by 43.1%/38.6%, whereas 10% biochar (BC-2) resulted in 35.8%/31.9% increase under saline/non-saline water irrigation, respectively, compared to the plants grown in biochar control pots. No significant differences were recorded among the biochar application rates (Fig.1).

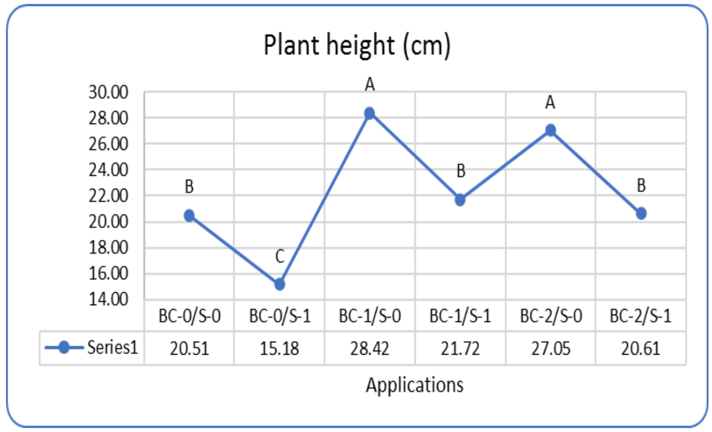

Fig. 1. Effect of biochar on plant height in grown tomato under salt stress

Plants irrigated with saline water (BC0-S1) showed a significant reduction of 16.6% and 19.6% in terms of shoot fresh and dry weights, respectively Biochar application at both levels predominantly increased the shoot fresh and dry weights when used under normal or salt stress conditions. Shoot fresh weight under saline water irrigation was increased by 91% by BC-1 and 113.7% with BC-2 as compared to the treatment where application of saline water was made. Whereas, increase in shoot dry weight under the same conditions was 65.4% and 74.8%, respectively (Fig. 2, 3).

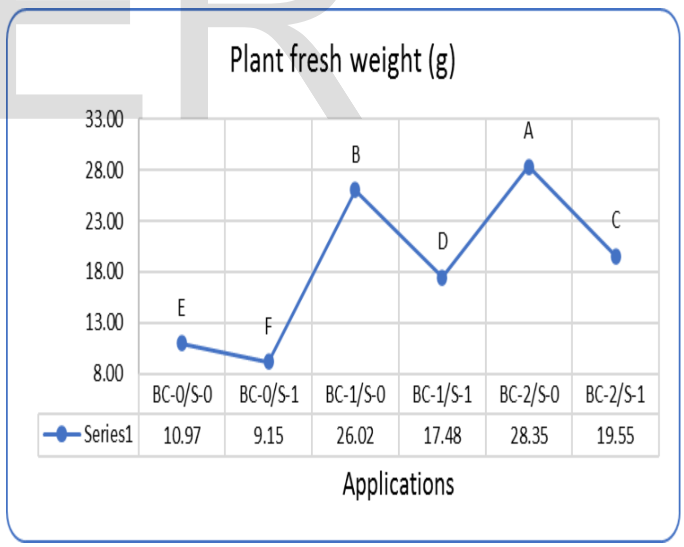

Fig. 2. Effect of biochar on leaf area in grown tomato under salt stress

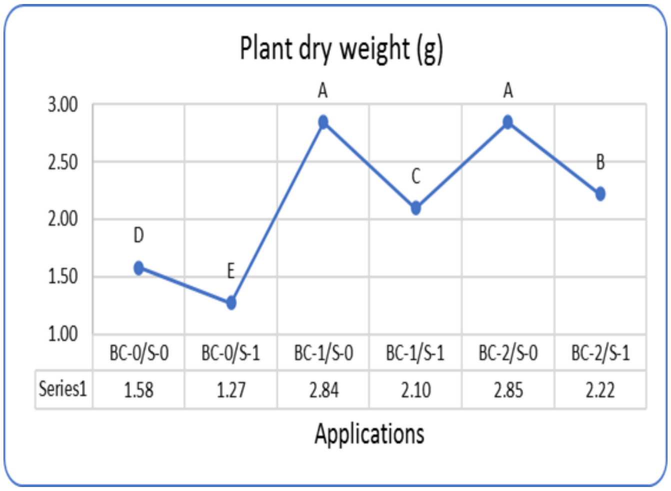

Fig. 3. Effect of biochar on plant fresh weight in grown tomato under salt stress

Salinity stress triggered a significant reduction in no of leaves per plant. The reduction was 13.0% in comparison with the unamended control. Biochar under controlled settings at both rates efficiently increased the no of leaves with 13.6% at 5% biochar (BC-1) level and 23.7% at 10% biochar (BC-2) level. When comparing the biochar application rates, the results were more pronounced at the 10% level. Biochar was equally effective in ameliorating the effect of saline water irrigation on no of tomato leaves. Under stress environment, BC-1 and BC-2 showed 23.4% and 24.9% increase in no of leaves, respectively. No significant variations amid biochar levels were observed (Fig. 4).

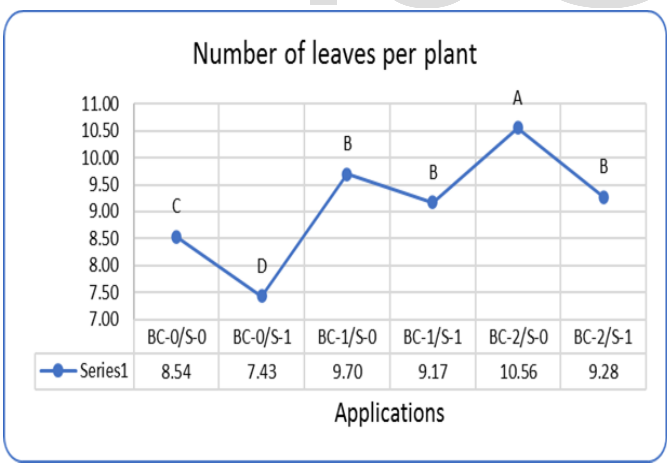

Fig. 4. Effect of biochar on number of leaves per plant in grown tomato under salt stress

Salt stress caused by saline irrigation water significantly reduced the leaf area. A clear reduction of 13.3% was noted under stress condition compared to unamended control. Leaf area was increased by 84.2% and 82.4% when alone application of biochar was made at 5 and 10% levels, respectively. A biochar application under stress at the 5% level showed a 45.3% increase in leaf area, while an increase of 39.1% was recorded with 10% biochar. The difference between the application levels was not statistically significant in both controlled and stressed conditions (Fig. 5).

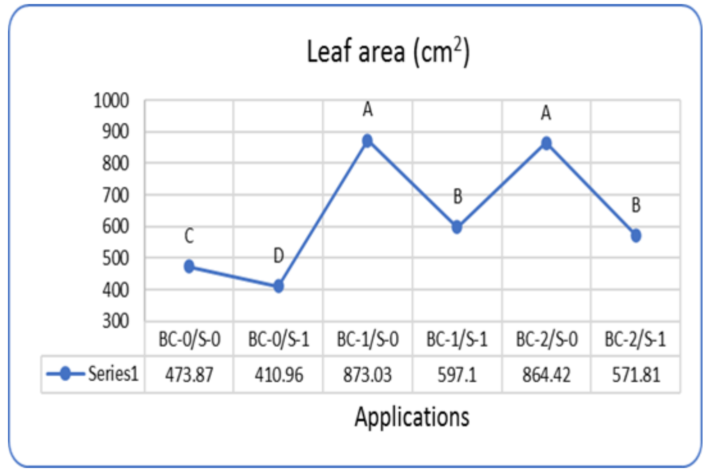

Fig. 5. Effect of biochar on leaf area in grown tomato under salt stress.

Plants established in the stressed condition exhibited a considerable reduction in root fresh and dry weights. Saline water irrigation caused a 22.0% decrease in root fresh weight and a 36.0% decrease in root dry weight, without biochar application. Biochar addition at 5% and 10% level increased root fresh weight by 151.3% and 112.9%, respectively, under controlled conditions. Whereas an increase in root dry weight under the same conditions at 5% and 10% biochar was 88.0% and 60.0%, respectively. Biochar amendment was also proved effective in the salt stress environment. A significant increase of 86.2% and 115.5% was observed in root fresh weight at 5 and 10% biochar level, respectively under salt stress. While in case of root dry weight, 56.25 and 62.5% increase were noted at 5 and 10% biochar level, respectively. Biochar at its highest rate (10%) resulted in the highest root fresh weight, however, results were opposite in case of root dry weight, where lowest rate (5%) had the highest values (Fig. 6, 7).

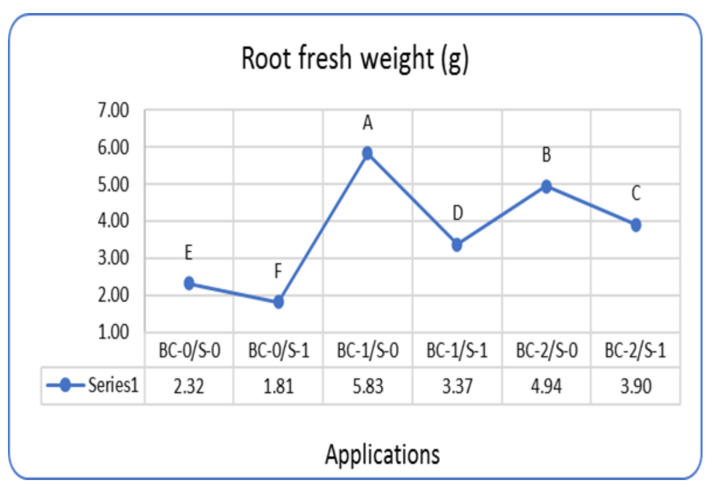

Fig. 6. Effect of biochar on root fresh weight in grown tomato under salt stress

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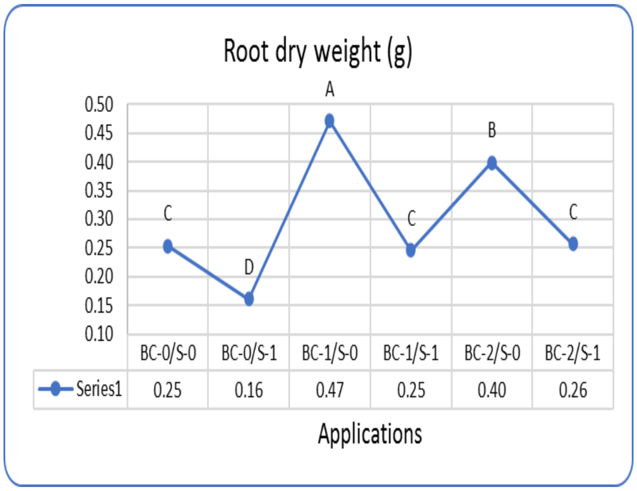

Fig. 7. Effect of biochar on root dry weight in grown tomato under salt stress

3.2 Physiological Parameters of Tomato Crop

Results showed that the relative water content of the leaf (LRWC) was significantly affected under saline water irrigation. Salt stress caused a reduction of 30.9% in LRWC compared to the normal conditions. Biochar amendment effectively ameliorated this effect and increased the LRWC in both salt free and stressed settings. However, in salt free conditions 5% biochar showed no significant effect on LRWC when compared to the control. While 10% biochar resulted in a 11.6% increase in LRWC in the plants irrigated with non-saline water. Biochar addition, under salt stress at both levels (5 and 10%) efficiently increased the LRWC by 45.2% and 39.1%, respectively, relative to the salt stressed plants with no application of biochar (Fig. 8).

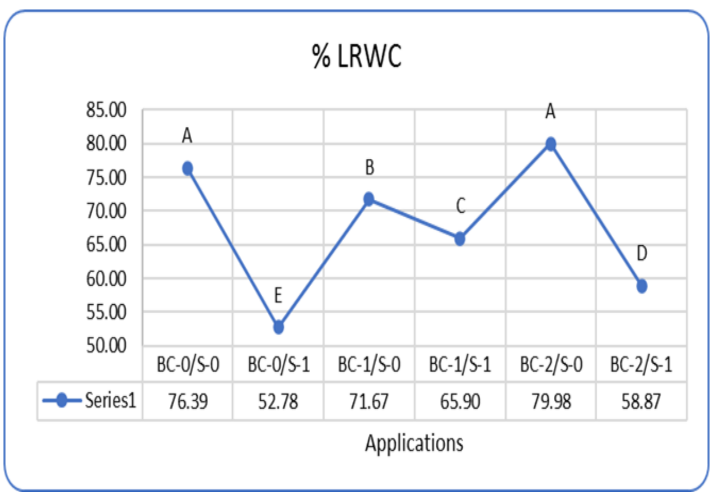

Fig. 8. Effect of biochar on %LRWC in grown tomato under salt stress

In the present study, saline water irrigation resulted in reduced chlorophyll a, b and total chlorophyll content. Biochar amendment minimized this negative effect on both rates under normal and saline water irrigation. However, in terms of chlorophyll a, no significant effect of biochar application rates was observed under non- saline water irrigation. Salt stress caused a 12.9% reduction in chlorophyll a content relative to the control. Incorporation of 5% biochar under saline-water irrigation, significantly increased the chlorophyll a content by 19.6%, while the effect of 10% biochar did not differ significantly when compared with their respective control (Fig. 9).

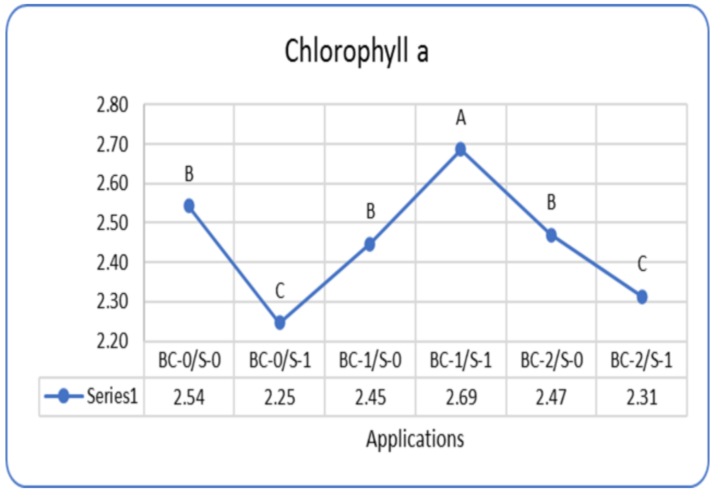

Fig. 9. Effect of biochar on chlorophyll a in grown tomato under salt stress

A reduction of 4.8% was noted in the chlorophyll b content under salt stress, but this effect was not significant compared to the control. Biochar amendment in salt free condition increased the chlorophyll b content by 57.6% and 97% at 5% and 10% biochar level, respectively. Under saline-water irrigation, the increase in chlorophyll b content was 26.9% at 5% biochar level and 67.3% at 10% biochar level (Fig. 10).

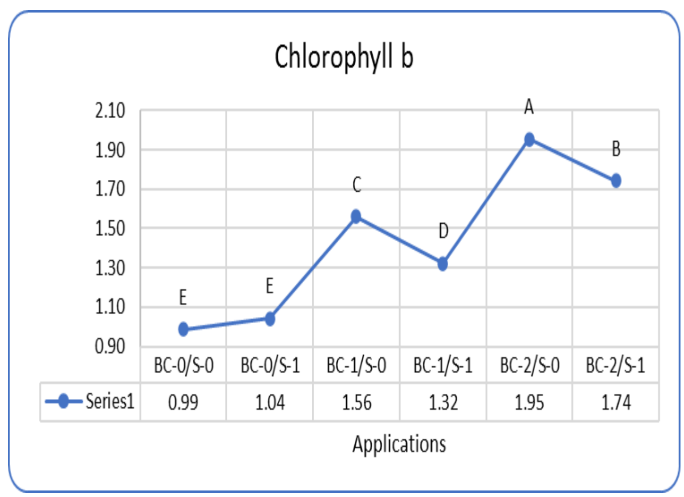

Fig. 10. Effect of biochar on chlorophyll b in grown tomato under salt stress

Salt stress triggered a 6.8% decrease in total chlorophyll content when compared to the control. Biochar application at 5 and 10% levels under normal conditions resulted in 13.6% and 25.2% increase in total chlorophyll content, respectively. Whereas, increase in total chlorophyll content under salt stress at 5 and 10% biochar was 21.9% and 22.25%, respectively (Fig. 11).

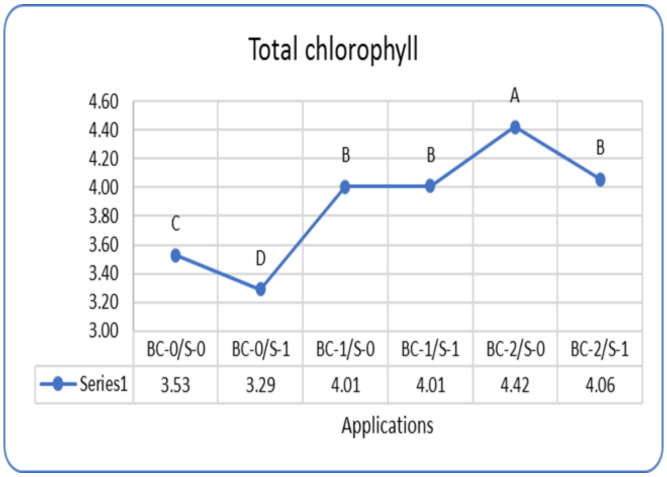

Fig. 11. Effect of biochar on total chlorophyll in grown tomato under salt stress

4 DISCUSSION

Salt stress is believed as one of the main brutal environmental factors restraining plant production worldwide. The findings of the present research undoubtedly confirm this by indicating a significant negative effect of salt stress on growth and physiological parameters of the tomato crops.

Morphological Parameters

A successive decrease in the growth features of tomato plant was observed when irrigated with saline water. Under salt stress seedling height, shoot fresh and dry weights, no of leaves, leaf area and root fresh and dry weights were reduced by 25.8%, 16.6%, 19.6%, 13.0%, 13.3%, 22.0% and 36.0%, respectively. These results are in line with the conclusions of Akhtar et al. Usman et al. Mostafizur Rahman et al. Andersen and Liu and Tanveer et al. [6], [16], [17], [18], [19]. Salt stress interrupts plant development primarily because of osmotic stress and specific ion toxicity [20], as well as by causing a nutritional imbalance, thereby resulting in reduced plant growth [21], [20]. However, application of biochar at both levels resulted in improved vegetative growth either under saline or normal water irrigation. Corroborating the results in this study, Usman et al. observed a noteworthy increase in the vegetative parameters of tomato crop under saline irrigation water regimes with the application of biochar amendments [16]. Similarly, the results of the trial conducted by Hansen et al. also confirm enhanced plant growth with biochar addition [22]. Improvement in plant performance due to the biochar application could be elucidated by the fact that biochar increases soil porosity and reduces the bulk density, thus making the conditions favorable for improved growth and root proliferation in saline environments. Under saline irrigation, biochar amendment, because of its Na^+ adsorbing potential, mitigates the suppressive effect of salinity on the plant growth parameters [23], [6], [18], [24]. Melas et al. reported that the addition of biochar to salt stressed soil, due to its high adsorption capacity resulted in reduced plant sodium uptake by transient Na+ binding and by supplying mineral nutrients i.e. K+, Ca^{2+}, $Mg^{2+)}$ into the soil solution, hence speeding up crops growth and development [25].

Physiological Parameters

The results of the present study illustrated a significant reduction in the physiological processes of the tomato plant under salt stress. Similar results have also been recorded earlier by Munns and Tester, Thomas et al, Akhtar et al. and Kanwal et al [26], [9], [18], [27]. Salinity has the potential to reduce leaf relative water content (LRWC). A significant decrease in LRWC under saline-water irrigation recorded in this study is in conformity with the findings of other researchers [28], 32]. Plant deal with salt stress by decreasing tissue water content which may be achieved by low leaf water potential [32]. The low LRWC of leaves is an indication of less capacity to uptake water. Biochar usage in our study efficiently increased the LRWC under saline-water irrigation. These findings correlate with those of Akhtar et al. where biochar application under drought stress resulted in increased LRWC and water use efficiency in tomato plants [33]. Increase in water status of maize tissue in sandy soil with the biochar application has been reported by Uzoma et al. [34]. Biochar has the potential to improve the water holding capacity of soil, thus increasing plant relative water content [35].

Salinity decreased the chlorophyll content and this could be related to the increased activity of chlorophyllase enzyme caused by salt stress [36] and limited N uptake [37]. Another possible cause of decrease in chlorophyll level could the osmotic stress, causing major harm to chloroplast layers and builds the membrane penetrability or loss of membrane uprightness [38]. According to the results of our study, biochar significantly increased the chlorophyll content in salt stressed conditions. These findings correlate with the study of Kanwal et al. where biochar addition resulted in increased chlorophyll content under salt stress [27]. Akhtar et al. also stated that the biochar amendment resulted in a significant increase in chlorophyll content at different salt concentrations [39]. Increase in chlorophyll level might be due to the enhanced level of N in leaves [39]. Andersen, and Liu reported that the elevated photosynthesis rate with biochar application is an indication of increased chlorophyll level [18]. The biochar is acknowledged for its ability to modify soil physico-chemical properties [40], modify the rhizosphere zone for improved morphological and physiological characteristics of a root, thus increasing the overall plant performance [41], [42].

4 CONCLUSION

In consideration of results, it is concluded that the use of urban waste biochar positively affected growth and physiological parameters, thereby alleviating the toxic effect of salt stress on tomato crop. Biochar application at both levels was proved efficient in improving overall plant performance under normal and saline-water irrigation.

REFERENCES

[1] M. Inoue, "Salinization status and salt removal techniques," *geotechnical engineering Management*, vol. 60, pp. 12–15, 2012.

[2] O. Belkheiri and M. Mulas, "The effects of salt stress on growth, water relations and ion accumulation in two halophyte Atriplex species," ***Environmental** and Experimental Botany*, vol. 86, pp. 17–28, 2013.

[3] I. Hichri *et al.*, "The Solanum lycopersicum WRKY3 transcription factor SlWRKY3 is involved in salt stress tolerance in tomato," *Frontiers in Plant Science*, vol. 8, p. 1343, 2017.

[4] D. Egamberdieva, S. Wirth, S.D. Bellingrath-Kimura, J. Mishra, and N.K. Arora, "Salt-tolerant plant growth promoting rhizobacteria for enhancing crop productivity of saline soils," *Frontiers in Microbiology*, vol. 10, 2019.

[5] F. Qi *et al.*, "Thermal stability of biochar and its effects on cadmium sorption capacity," ***Bioresource Technology***, vol. 246, pp. 48–56, 2017.

[6] S.S. Akhtar, M.N. Andersen, and F. Liu, "Biochar Mitigates Salinity Stress in Potato," *Journal of Agronomy and Crop Science,* vol. 201, pp. 368–378, 2015.

[7] W. Lu, W. Ding, J. Zhang, H. Zhang, J. Luo, and N. Bolan, "Nitrogen Amendment Stimulated Decomposition of Maize Straw-Derived Biochar in a Sandy Loam Soil: A Short-Term Study," *Plos One*, pp. 1–16, 2015.

[8] D. Laird, P. Fleming, B. Wang, R. Horton, and D. Karlen, "Biochar impact on nutrient leaching from a Midwestern agricultural soil," *Geoderma*, vol. 158, no. 3–4, pp. 436–442, 2010.

[9] T.E. Schumacher, "Effect of Biochar on Chemical Properties of Acidic Soil," no. May, 2013.

[10] J. Liu and J.-K. Zhu, "An Arabidopsis mutant that requires increased calcium for potassium nutrition and salt tolerance," *Proceedings of the National Academy of Sciences,* vol. 94, no. 26, pp. 14960–14964, 1997.

[11] I. Cakmak, "The role of potassium in alleviating detrimental effects of abiotic stresses in plants," *Journal of Plant Nutrition*, vol. 168, no. 4, pp. 521–530, 2005.

[12] K. Chakraborty, R. K. Sairam, and D. Bhaduri, "Effects of different levels of soil salinity on yield attributes, accumulation of nitrogen, and micronutrients in Brassica spp.," *Journal of Plant Nutrition,* vol. 39, no. 7, pp. 1026–1037, 2016.

[13] J.A. Drake, T. R. Cavagnaro, S.C. Cunningham, W.R. Jackson, and A.F. Patti, "Does biochar improve establishment of tree seedlings in saline sodic soils," *Land Degradation & Development*, vol. 27, no. 1, pp. 52–59, 2016.

[14] S. Ali *et al.*, "Biochar soil amendment on alleviation of drought and salt stress in plants: a critical review," pp. 12700–12712, 2017.

[15] H.K. Lichtenthaler and C. Buschmann, "Chlorophylls and carotenoids: Measurement and characterization by UV-VIS spectroscopy," *Current Protocols in Food Analytical Chemistry*, vol. 1, no. 1, pp. F4–3, 2001.

[16] A.R.A. Usman, M.I. Al-wabel, Y.S. Ok, A. Al-harbi, A. Al-faraj, and A. Al-omran, "Conocarpus Biochar Induces Changes in Soil Nutrient Availability," *Pedosphere,* vol. 26, no. 1, pp. 27–38, 2016.

[17] M.M. Rahman *et al.*, "Effects of NaCl-Salinity on Tomato (Lycopersicon esculentum Mill.) Plants in a Pot Experiment," *Open Agriculture,* vol. 3, no. 1, pp. 578–585, 2018.

[18] S.S. Akhtar, M.N. Andersen, M. Naveed, Z.A. Zahir, and F. Liu, "Interactive effect of biochar and plant growth-promoting bacterial endophytes on ameliorating salinity stress in maize," *Functional Plant Biology.*, vol. 42, no. 8, pp. 770–781, 2015.

[19] M. Tanveer, B. Shahzad, A. Sharma, and E.A. Khan, "24-Epibrassinolide application in plants: An implication for improving drought stress tolerance in plants," ***Plant Physiology** and **Biochemistry***, vol. 135, pp. 295–303, 2019.

[20] R. Munns and M. Tester, "Mechanisms of salinity tolerance.," *Annu. Rev. Plant Biol.*, vol. 59, pp. 651–681, 2008.

[21] V. Chinnusamy, A. Jagendorf, and J.-K. Zhu, "Understanding and improving salt tolerance in plants," *Crop Science*, vol. 45, no. 2, pp. 437–448, 2005.

[22] V. Hansen, D. Müller-Stöver, L. J. Munkholm, C. Peltre, H. Hauggaard-Nielsen, and L. S. Jensen, "The effect of straw and wood gasification biochar on carbon sequestration, selected soil fertility indicators and functional groups in soil: an incubation study," *Geoderma*, vol. 269, pp. 99–107, 2016.

[23] J. Novak, I. Lima, and B. Xing, "Characterization of designer biochar produced at different temperatures and their effects on a loamy sand," *Annals of Environmental Science,* vol. 3, no. 843, pp. 195–206, 2009.

[24] V.N. Chaganti, D.M. Crohn, and J. Sim, "Leaching and reclamation of a biochar and compost amended saline – sodic soil with moderate SAR reclaimed water ˇ unek," vol. 158, pp. 255–265, 2015.

[25] B. Giovanna, O. Ortiz, and J.M. Alacaniz, "Can biochar protect labile organic matter against mineralization in soil," *Pedosphere*, vol. 27, no. 5, pp. 822–831, 2017.

[26] R. Munns and M. Tester, "Mechanisms of salinity tolerance.," *Annual Review of Plant Biology*, vol. 59, pp. 651–681, 2008.

[27] S. Kanwal *et al.*, "Application of biochar in mitigation of negative effects of salinity stress in wheat (Triticum aestivum L.)," *Journal of Plant Nutrition,* vol. 41, no. 4, pp. 526–538, 2018.

[28] J. Qin *et al.*, "NaCl salinity-induced changes in water status, ion contents and photosynthetic properties of Shepherdia argentea (Pursh) Nutt. seedlings," *Plant, Soil and Environment*, vol. 56, no. 7, pp. 325–332, 2010.

[29] K.T. Win, Z.O. Aung, T. Hirasawa, T. Ookawa, and H. Yutaka, "Genetic analysis of Myanmar Vigna species in responses to salt stress at the seedling stage," ***African Journal** of **Biotechnology***, vol. 10, no. 9, pp. 1615–1624, 2011.

[30] N. Kapoor and V. Pande, "Effect of salt stress on growth parameters, moisture content, relative water content and photosynthetic pigments of fenugreek variety RMt-1," *Journal of Plant Sciences*, vol. 10, no. 6, pp. 210–221, 2015.

[31] F. Jahan, D. Bhusan, M. Jahiruddin, Y. Murata, and M. A. Hoque, "Improvement of salinity tolerance in rice during boro season by proline application," *Progressive agriculture*, vol. 29, no. 4, pp. 295–303, 2018.

[32] M.A.S. Polash, M. A. Sakil, M. Tahjib-Ul-Arif, and M. A. Hossain, "Effect of salinity on osmolytes and relative water content of selected rice genotypes," ***Tropical Plant Research***, vol. 5, no. 2, pp. 227–232, 2018.

[33] S.S. Akhtar, G. Li, M.N. Andersen, and F. Liu, "Biochar enhances yield and quality of tomato under reduced irrigation," *Agricultural Water Management*, vol. 138, pp. 37–44, 2014.

[34] K.C. Uzoma, M. Inoue, H. Andry, H. Fujimaki, A. Zahoor, and E. Nishihara, "Effect of cow manure biochar on maize productivity under sandy soil condition," ***Soil Use** and **Management**,* vol. 27, no. 2, pp. 205–212, 2011.

[35] M.A. Shashi, M.A. Mannan, M.M. Islam, and M.M. Rahman, "Impact of rice husk biochar on growth, water relations and yield of maize (Zea mays L.) under drought condition," *Agriculture.*, vol. 16, no. 02, pp. 93–101, 2018.

[36] M.P. Reddy and A.B. Vora, "Salinity induced changes in pigment composition and chlorophyllase activity of wheat," ***Indian Journal of Plant Physiology***, vol. 29, no. 4, pp. 331–334, 1986.

[37] J.W. Van Hoorn, N. Katerji, A. Hamdy, and M. Mastrorilli, "Effect of salinity on yield and nitrogen uptake of four grain legumes and on biological nitrogen contribution from the soil," *Agricultural Water Management*, vol. 51, no. 2, pp. 87–98, 2001.

[38] X. Tang, X. Mu, H. Shao, H. Wang, and M. Brestic, "Global plant-responding mechanisms to salt stress: physiological and molecular levels and implications in biotechnology," *Critical Reviews in Biotechnology*, vol. 35, no. 4, pp. 425–437, 2015.

[39] S.S. Akhtar, M.N. Andersen, and F. Liu, "Residual effects of biochar on improving growth, physiology and yield of wheat under salt stress," *Agricultural Water Management,* vol. 158, pp. 61–68, 2015.

[40] J. Lehmann, M. C. Rillig, J. Thies, C. a. Masiello, W. C. Hockaday, and D. Crowley, "Biochar effects on soil biota - A review," *Soil Biology and Biochemistry.*, vol. 43, no. 9, pp. 1812–1836, 2011.

[41] X. Zhang, H. Wang, and L. He, "Using biochar for remediation of soils contaminated with heavy metals and organic pollutants," pp. 8472–8483, 2013.

[42] S. Abrishamkesh, M. Gorji, H. Asadi, G.H. Bagheri-Marandi, and A.A. Pourbabaee, "Effects of rice husk biochar application on the properties of alkaline soil and lentil growth," ***Plant*, *Soil and Environment***, vol. 61, no. 11, pp. 475–482, 2015.

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