OPEN ACCESS

Haya: The Saudi Journal of Life Sciences
Abbreviated Key Title: Haya Saudi J Life Sci
ISSN 2415-623X (Print) | ISSN 2415-6221 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Unraveling the Mitigating Capability of Foliar Application of Potassium Nitrate too Salt Toxicity in Sunflower

Sahar Saleem[1], Muhammad Umair[2]*, Chandni Zafar[3], Sara Aimen[3], Nida Afaqi[4], Mohammad Llyas[5], Muhammad Aaqib Siddique[6], Nida Altaf[7], Aiman Zahid[8]

[1]Department of Botany, Government College University Faisalabad (Layyah Campus), Pakistan
[2]Department of Botany Division of Science and Technology, University of Education Lahore, Pakistan
[3]Department of Botany, The Women University Multan, Pakistan
[4]Department of Plant Sciences, Quaid-e-Azam University, Islamabad, Pakistan
[5]Department of Botany, Abdul Wali Khan University, Pakistan
[6]Department of Biological Sciences University, Thal University Bhakkar, Pakistan
[7]Department of Agronomy University of Agriculture Faisalabad, Pakistan
[8]Department of Botany University of Agriculture Faisalabad, Pakistan

DOI: https://doi.org/10.36348/sjls.2024.v09i08.001 | **Received:** 19.06.2024 | **Accepted:** 22.07.2024 | **Published:** 05.08.2024

***Corresponding author:** Muhammad Umair
Department of Botany Division of Science and Technology, University of Education Lahore, Pakistan

Abstract

Agricultural crops face a major issue in the form of salinity. It causes injuries to plants by causing accumulation of Na+ and Cl- ions, which leads to nutrient imbalance and ultimately low yield. It also causes fluctuations in physiological processes, which destabilize the uptake and distribution of nutrients in crops. Sunflower (Helianthus annuus L.) is the 2nd ranked oilseed crop after soybean. Sunflower possesses high oil content (42-50%) and protein content (15-20%), which makes it one of the most valuable oil crops. Exogenously applied K+ significantly enhance all morphological and physiological parameters. K+ is also member of triad group of nutrients for plants including N and P. In current study effect of foliar application of K at 500 ppm were examined on growth, biochemical and physiological attributes of sunflower hybrid L-16003 grown under saline conditions. Data was recorded for various growth, biochemical and physiological parameters of plants. Analysis of data revealed that salinity adversely affected gas exchange parameters which resulted in reduced growth and yield of sunflower. Exogenous foliar application of K significantly improved gas exchange attributes such as stomatal conductance, CO2 assimilation, transpiration rate and water use efficiency. It also enhanced chlorophyll pigments which resulted in increase of photosynthetic rate ultimately leading to healthy growth of plants grown under saline conditions. Root length, shoot length, plant fresh weight, dry weight and achenes weight were also increased by foliar application of K. Overall, foliar application of K significantly improved all attributes of sunflower and helped to alleviate harmful effects of salinity.

Keywords: Sunflower, Foliar application, Potassium, Salinity.

1. INTRODUCTION

In arid and semi-arid regions, growth and yield of plants are restricted due to poor quality of water and soil salinity. Salinity is one of major abiotic stressors [1]. Salinity has very harmful effects on many metabolic and physiological processes. These harmful effects depend on duration and intensity of salinity [2]. Plants growth and yield are adversely affected by salt toxicity, because salt toxicity causes reduction in osmotic water availability, nutritional imbalance, ion toxicity and reduction in photosynthetic rate by reducing enzymes activity. Salt toxicity generates ROS, which damage components of membranes and cell organelles by producing oxidative stress [3]. These oxidative stresses cause many physiological changes such as reduction in DNA, proteins, photosynthetic activities and nutritional imbalances [4, 5]. Chloroplast structure and photosynthetic pigments are also affected by salt toxicity, which cause reduction in yield, in severe cases it may lead to death of plants [6].

Agricultural crops face a major issue in the form of salinity. It causes injuries to plants by causing accumulation of Na+ and Cl- ions, which leads to nutrient imbalance and ultimately low yield [7, 8]. Salt toxicity causes fluctuations in physiological processes, which destabilize the uptake and distribution of nutrients in crops [9]. An opposite association is found between K+ and Na+ in soil. Salinity causes accumulation of more Na+ ions which leads to reduction in K+ concentration in roots and shoots [10]. Salinity also affects growth parameters like number of leaves, stem diameter, shoot length and its fresh and dry weight [11].

Potassium is one of the most important macronutrients, it enhances plant growth in both normal and stress conditions. Application of K+ reduces the transpiration rate and enhance water uptake by roots, which causes turgidity of stomata and photosynthetic rate is increased which results in higher growth and yield [12]. Exogenously applied K+ at 1% significantly enhance all morphological and physiological parameters [13]. K+ is also member of triad group of nutrients for plants including N and P. Application of K+ enhances catalytic activity of enzymes and speed up all metabolism processes involving enzymes [14]. Previous studies elaborated that exogenously applied K+ improve physiological and antioxidant mechanisms of sunflower and also has positive effects on overall productivity of sunflower [15]. Exogenous application of chitosan and K+ maintains turgor pressure which helps plants to regulate antioxidant mechanisms to reduce toxic effects of salinity which results in improved growth and yield of sunflower [16]. Exogenous application of any macronutrient helps plants to improve carotenoids, chlorophylls, height and leaves depending on biochemical properties of that nutrient [17]. It is reported that K+ alleviates salinity harmful effects in sunflower by increasing the production of proteins which regulate a lot of functions of plants under stress. Foliar application of K+ at 1% increases oil production of sunflower and it also enhances proportion of unsaturated fatty acids in sunflower oil [13]. Additionally, 1% application of K+ also enhances proline production which helps plants in osmotic adjustment under stress [18].

Sunflower (Helianthus annuus L.) is the 2nd ranked oilseed crop after soybean [19]. Sunflower possesses high oil content (42-50%) and protein content (15-20%), which makes it one of the most valuable oil crops. Unsaturated fatty acids such as oleic and linoleic acids are more than 90% in sunflower oil. These unsaturated fatty acids provide a lot of benefits to human beings [20]. Sunflower plays critical role to fulfill the oil needs of Pakistan. Sunflower genotypes can be substituted to response abiotic stresses [21]. Abiotic stresses cause nutrient imbalances in sunflower. In response sunflower uses various mechanisms to mitigate these nutritional imbalances such as reduction in leaf area to reduce water loss and osmotic adjustments by the application of minerals and organic compounds [22]. Exogenously applied foliar spray is considered as more practical approach to enhance growth and yield of crops cultivated under stress conditions [23]. A greater and advanced knowledge of the physiological basis of stress tolerance is required to develop stress tolerance crop genotypes [24]. For this purpose, this experiment was designed to observe growth and physiological parameters of sunflower hybrid L-16003 and to analyze the mitigating efficacy of foliar application of KNO3 in sunflower as a protectant against salt toxicity.

2. MATERIALS AND METHODS

2.1. Experimental Details

Foliar application of K+ was assessed to cope salinity stress in sunflower. A pot experiment was conducted according to CRD factorial with three replicates. Plastic pots and seeds of sunflower hybrid L-16003 were purchased from market. These pots were filled with 5 kg growth media consisting of clay, sand, silt and compost in equal proportion. 15 days of emergence plants were thinned to one plant in each pot. Then pots were divided into groups according to their respective treatments. 140 mM NaCl treatment was at three leaf stage, after application of salinity treatments pots were irrigated with fresh water. While first replication of foliar application of potassium was done after seven days of salinity treatment application. In this experiment three replications of KNO3 were used at an interval of seven days after first replication. Pots were irrigated throughout the experiment.

2.2. Biochemical, Mineral, and Antioxidant Enzyme Activity Measurement

After five days of third replication of KNO3, data of antioxidant and biochemical traits were recorded. According to Arnon method [25], chl a, b and carotenoids were measured by extraction of leaves in 80% acetone solution by using the following formula with spectrophotometer:

$$\text{Chlorophyll a} = [12.7\ (\text{OD } 663) - 2.69\ (\text{OD } 645) \times V/1000 \times W$$

$$\text{Chlorophyll b} = [12.7\ (\text{OD } 645) - 4.68\ (\text{OD } 663) \times V/1000 \times W$$

$$\text{Carotenoids} = [\text{OD } 470 + 0.114\ (\text{OD } 663) - 0.638\ (\text{OD } 645)/2500] \times 1000$$

Where, W is the fresh leaf weight and V is the extract volume. Standard procedure of USDA Laboratory Staff [26] was used to measure the concentrations of Na+ and K+ with the help of flame photometer. While Chance and Maehly [27] method was used to note the readings of peroxidase (POD) and catalase (CAT) activities on a spectrophotometer. While gas exchange parameters like transpiration rate (E), CO2 assimilation rate (A) as well as stomatal conductance (gs) were recorded according to Long procedure [28] with the help of an infrared gas analyzer. Water use effieciency (WUE) was measured by dividing CO2 assimilation rate with transpiration rate (A/E).

2.3. Growth Attributes

Growth parameters like number of leaves were counted manually. Measuring tape was used to measure root length and shoot length. From the level of soil to the top of plant was considered as shoot length, while from soil to the tip of root was considered as root length. Fresh weight of plants of plants was measured after harvesting plants with the help of weight balance. Then plants were dried in sunlight for three days and then oven dried at 65 ◦C. Achenes of each plant were collected in separate bags, then achenes weight was also measured with the help of weight balance.

2.4. Statistical Analysis

This experiment to assess the effects of foliar application of KNO3 was performed according to CRD. Three replications of each treatment were applied on their respective pots and each pot represents one replicate. Statistix 8.1 software was used for ANOVA of recorded data. To check the significant differences among mean values of each treatment Tuckey's HSD test was used. While R-studio was utilized to measure correlation between all traits.

3. RESULTS AND DISCUSSION

3.1. Growth Attributes

Foliar application of K significantly affected growth parameters of sunflower hybrid grown under both normal and stress conditions as shown in Table-1. L-16003 hybrid produced highest number of leaves (21.63) under foliar application of K under normal conditions. But under saline conditions number of leaves were significantly reduced (7.87). when K was applied under saline conditions it significantly increased number of leaves (13.47). Same trend was also observed for other growth parameters such as shoot length and root length, their highest values were also observed under foliar application of K. Plant fresh weight was also significantly affected by salinity, it causes 29% reduction in fresh weight as compared to controlled plants. When K was applied exogenously it caused 21% under normal conditions increase as compared to controlled and 9% increase in fresh weight as compared to plants affected by salinity. Similar trends were also observed for plant dry weight. Achenes weight was also adversely affected by salinity. Salinity caused 47% reduction in achenes weight as compared to controlled plants. Foliar application of K also helped plants to recover their achenes weight.

These results of our study were in accordance Latef and Chaoxing]29] and Mostofa *et al.*, [30]. They also found similar results on growth parameters of pepper and rice respectively. They concluded that reduction in growth attributes were result of Na+ and Cl- toxicity caused by their accumulation in root systems. Accumulation of these ions increase osmotic pressure, which reduces water uptake and water use efficiency of plants [31]. Plants had developed various mechanisms to mitigate the toxic effects of salinity such as osmotic adjustment, by reducing photosynthesis rate. Exogenous application of minerals or growth promoters enhance growth performance of crops [32, 33]. Foliar application of K provides turgidity to guard cells, which result in enhanced photosynthetic rate and growth [34].

Table-1: Mean Values ± SE of Growth Attributes of Sunflower at Various Levels of Salinity and Foliar Application of Potassium

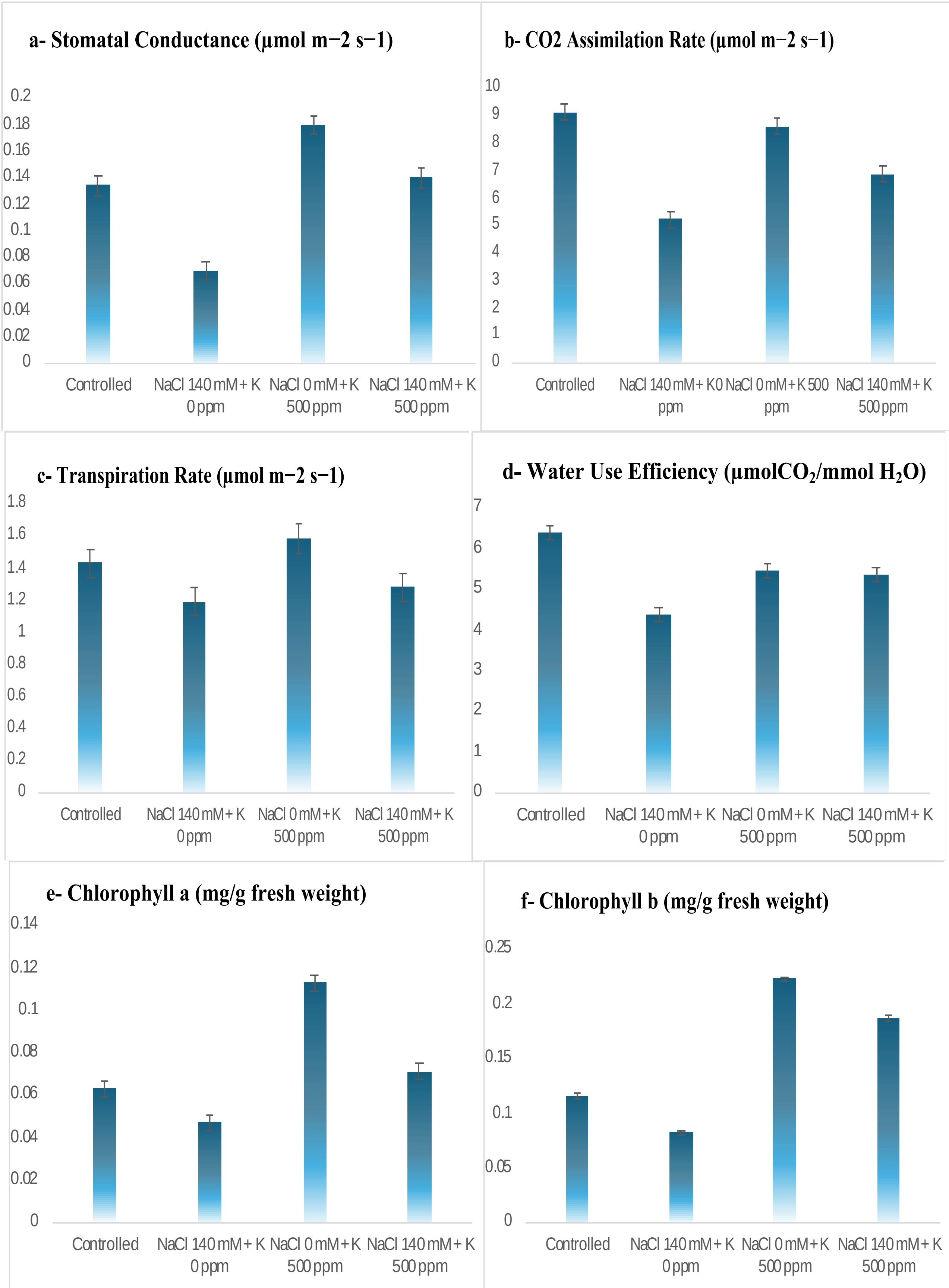
Treatments	Controlled	NaCl 140 mM + K 0 ppm	NaCl 0 mM + K 500 ppm	NaCl 140 mM + K 500 ppm
No. of Leaves	17.22 ± 0.47	7.87 ± 0.12	21.63 ± 0.63	13.47 ± 0.67
Shoot Length	23.87 ± 1.31	17.19 ± 1.03	26.47 ± 1.12	18.73 ± 0.83
Root Length	4.87 ± 0.23	3.91 ± 0.14	6.23 ± 0.43	4.92 ± 0.17
Plant Fresh Weight	60.13 ± 1.21	42.64 ± 0.65	72.44 ± 2.11	47.67 ± 1.72
Plant Dry Weight	6.32 ± 0.23	4.23 ± 0.14	7.47 ± 0.31	4.63 ± 0.19
Achenes Weight	3.37 ± 0.08	1.77 ± 0.03	4.98 ± 0.12	2.08 ± 0.09

3.2. Biochemical and Physiological Attributes

Physiological and biochemical parameters such as CO2 assimilation, transpiration rate, water use efficiency, stomatal conductance, chl a, b and carotenoids were significantly affected by salinity as shown in Figure-1. Figure-1a shows the values of stomatal conductance of sunflower hybrid under both normal and drought conditions influenced by foliar application of K. Salinity caused significant reduction in stomatal conductance. When K was not applied exogenously, salinity caused maximum reduction in gas exchange parameters. But when K was applied exogenously it significantly helped plants to enhance their gas exchange attributes. Salinity also reduced CO2 assimilation by plants as shown in Figure-2b. Salinity caused 42% reduction in CO2 assimilation which resulted in reduction of photosynthetic rate. When foliar application of K was done, it caused 31% increase in CO2 assimilation in plants as compared to plants without exogenous K under saline conditions. Like all other gas exchange attributes transpiration rate was also adversely affected by salinity. Salinity caused 17% reduction in transpiration rate of plants as compared to controlled plants. Foliar application of K caused 11% increase in transpiration rate as compared to controlled plants and 8% increase as compared to plants under salinity without exogenous application of K (Figure-1c). Salinity also reduced water use efficiency of plants (Figure-1d).

Salinity also caused significant reduction in photosynthetic pigments of plants such as chl a, b and carotenoids. Salinity caused 25%, 29% and 51%

reduction in chl a, b and carotenoids respectively. This reduction in photosynthetic pigments result in reduced photosynthesis which ultimately lead to reduction in growth and yield of plants. Foliar application of K helped plants to restore their photosynthetic pigments, it caused 51%, 128% and 51% increase in chl a, b and carotenoids of plants as compared to plants without exogenously applied K under saline conditions as shown in Figure-1e, f, g.


a- Stomatal Conductance (µmol m−2 s−1)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Controlled
NaCl 140 mM+ K 0 ppm
NaCl 0 mM+K 500 ppm
NaCl 140 mM+ K 500 ppm
b- CO2 Assimilation Rate (µmol m−2 s−1)
10
9
8
7
6
5
4
3
2
1
0
Controlled
NaCl 140 mM+ K0 ppm
NaCl 0 mM+K 500 ppm
NaCl 140 mM+ K 500 ppm
c- Transpiration Rate (µmol m−2 s−1)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Controlled
NaCl 140 mM+ K 0 ppm
NaCl 0 mM+K 500 ppm
NaCl 140 mM+ K 500 ppm
d- Water Use Efficiency (µmolCO$_2$/mmol H$_2$O)
7
6
5
4
3
2
1
0
Controlled
NaCl 140 mM+ K 0 ppm
NaCl 0 mM+K 500 ppm
NaCl 140 mM+ K 500 ppm
e- Chlorophyll a (mg/g fresh weight)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Controlled
NaCl 140 mM+ K 0 ppm
NaCl 0 mM+K 500 ppm
NaCl 140 mM+ K 500 ppm
f- Chlorophyll b (mg/g fresh weight)
0.25
0.2
0.15
0.1
0.05
0
Controlled
NaCl 140 mM+ K 0 ppm
NaCl 0 mM+K 500 ppm
NaCl 140 mM+ K 500 ppm

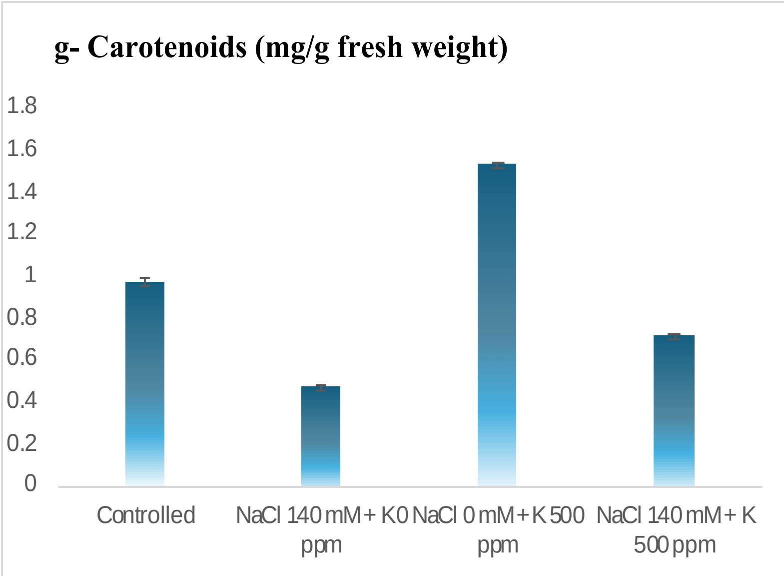


Figure-1: Graphical Representation of Mean Values of Stomatal Conductance, CO2 Assimilation, Transpiration Rate, WUE, Chl a, Chl b and Carotenoids at Various Levels of Salinity and Foliar Application of Potassium

3.3. Enzymatic Activities

The activity of catalase was significantly impacted by the application of K on the leaves, both in normal and saline conditions as shown in Figure-2a. On the other hand, peroxidase activity was only influenced by the saline environment. Notably, the sunflower hybrid exhibited the highest increase in catalase activity under saline stress when K was not applied. The impact of the foliar application of K was evident in the sunflower hybrid, yielding noteworthy results. Figure-2b illustrates the peroxidase data under various conditions with foliar applied K. The results indicated a substantial increase in peroxidase activity under salt stress. These findings of enzymatic activities under salt stress and affected by foliar application of K were in correspondence with Akram *et al.*, [35] findings. He found that 150 mM salt stress enhanced catalase and peroxidase activities in sunflower crop.

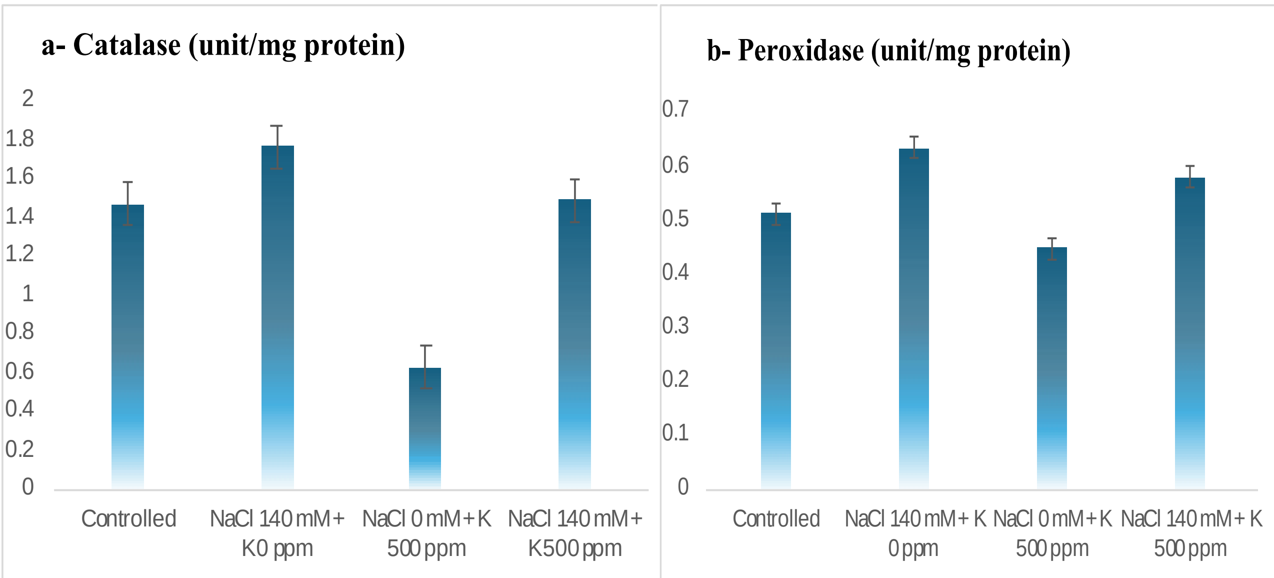


Figure-2: Graphical Representation of Mean Values of Catalase and Peroxidase Activity at Various Levels of Salinity and Foliar Application of Potassium

3.4. Mineral Homeostasis

Salinity adversely affects on K+ accumulation in roots and shoots. As salinity cause higher accumulation of Na+ ions which cause reduction of K+ and disturbs sodium potassium ratio. Salinity caused 42% and 43% reduction in K+ accumulation in roots and shoots of sunflower plants respectively as compared to controlled plants. But when K was applied exogenously, it significantly helped plants to restore their levels of K+ accumulation in roots and shoots. Foliar application of K enhanced 30% and 62% K+ accumulation in roots and shoots respectively as compared to plants without exogenous application of K under saline conditions as shown in Figure-3a, 3b.

The presence of sodium in the roots was not noticeably impacted by the foliar treatment. While sodium content in shoot was significantly affected by both salinity and foliar application of K. Salinity caused significant increase in Na+ accumulation in both roots and shoots of sunflower plants as shown in Figure-3c, d. Salinity caused 31% increase in Na+ accumulation in both roots and shoots of sunflower plants. Effect of foliar application of K was not prominent in roots but it helped plants to recover Na+ level in shoots (Figure-3c, 3d).

Zaman *et al.*, [14] found that Na+ and K+ travels parallel to each other. K+ transporters are unable to differentiate between these two cations. Salt stress increases the accumulation of Na+. These increased level of Na+ occupy K+ transporters which results in reduction of K+. So foliar application of K increases K+ level which provides turgidity to guard cells and stability to membranes. Raza *et al.*, [13] found that exogenous application of K at 1% increases all attributes of plants such as growth, biochemical and physiological.

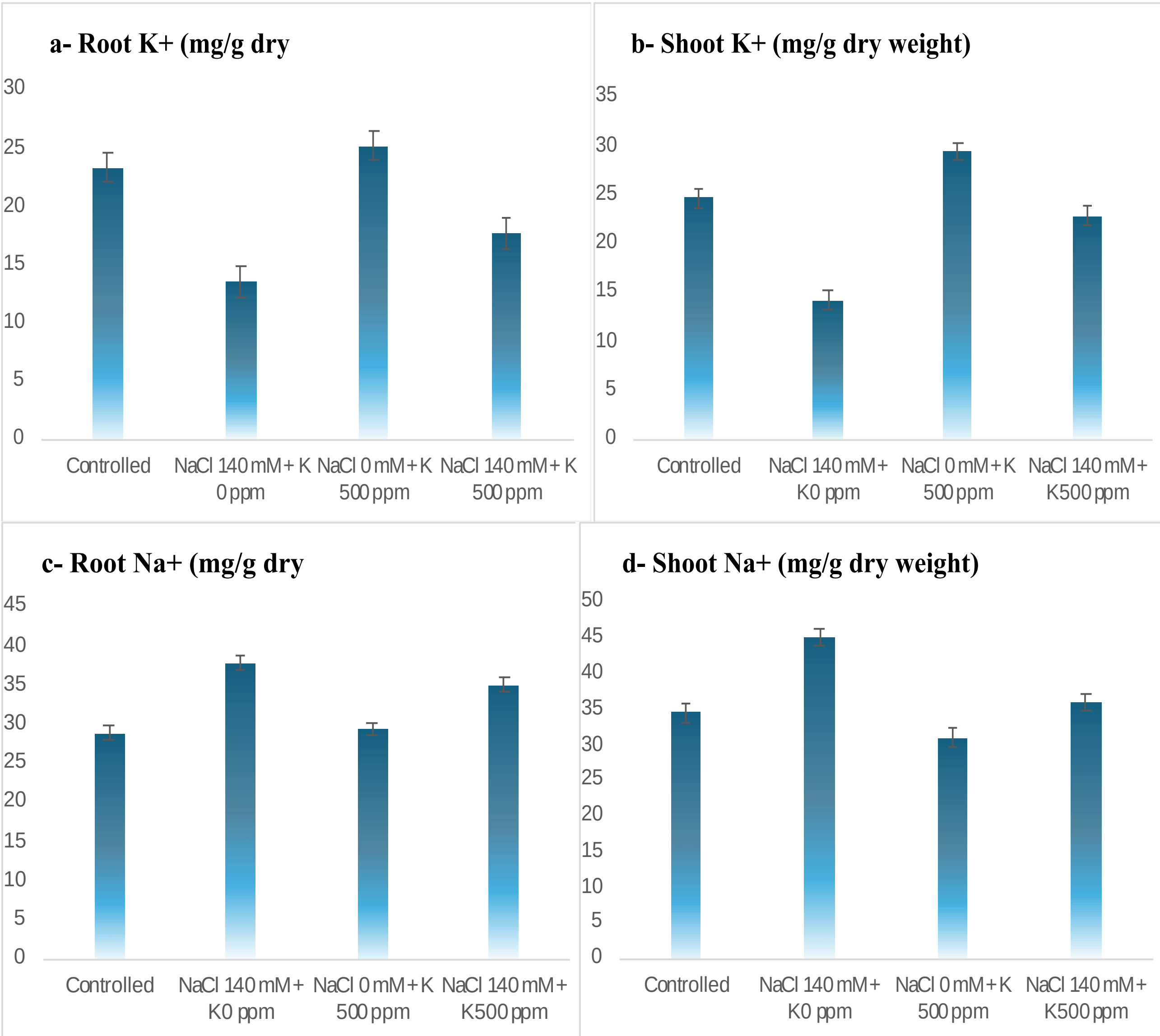


Figure-3: Graphical Representation of Mean Values of Accumulation of Na+ and K+ at Various Levels of Salinity and Foliar Application of Potassium

3.5. Correlation Analysis

Among various growth, biochemical and physiological attributes strong positive and negative correlations were found as shown in Figure-4. Correlation matrix showed that attributes such as number of leaves, root length, shoot length, plant fresh weight, plant dry weight, achenes weight, chl a, chl b, carotenoids, CO_2 assimilation, transpiration rate, stomatal conductance, water use efficiency and K+ accumulation in roots and shoots were positively correlated with each other's. While all these attributes were negatively correlated with catalase activity, peroxidase activity and Na+ accumulation in roots and shoots.

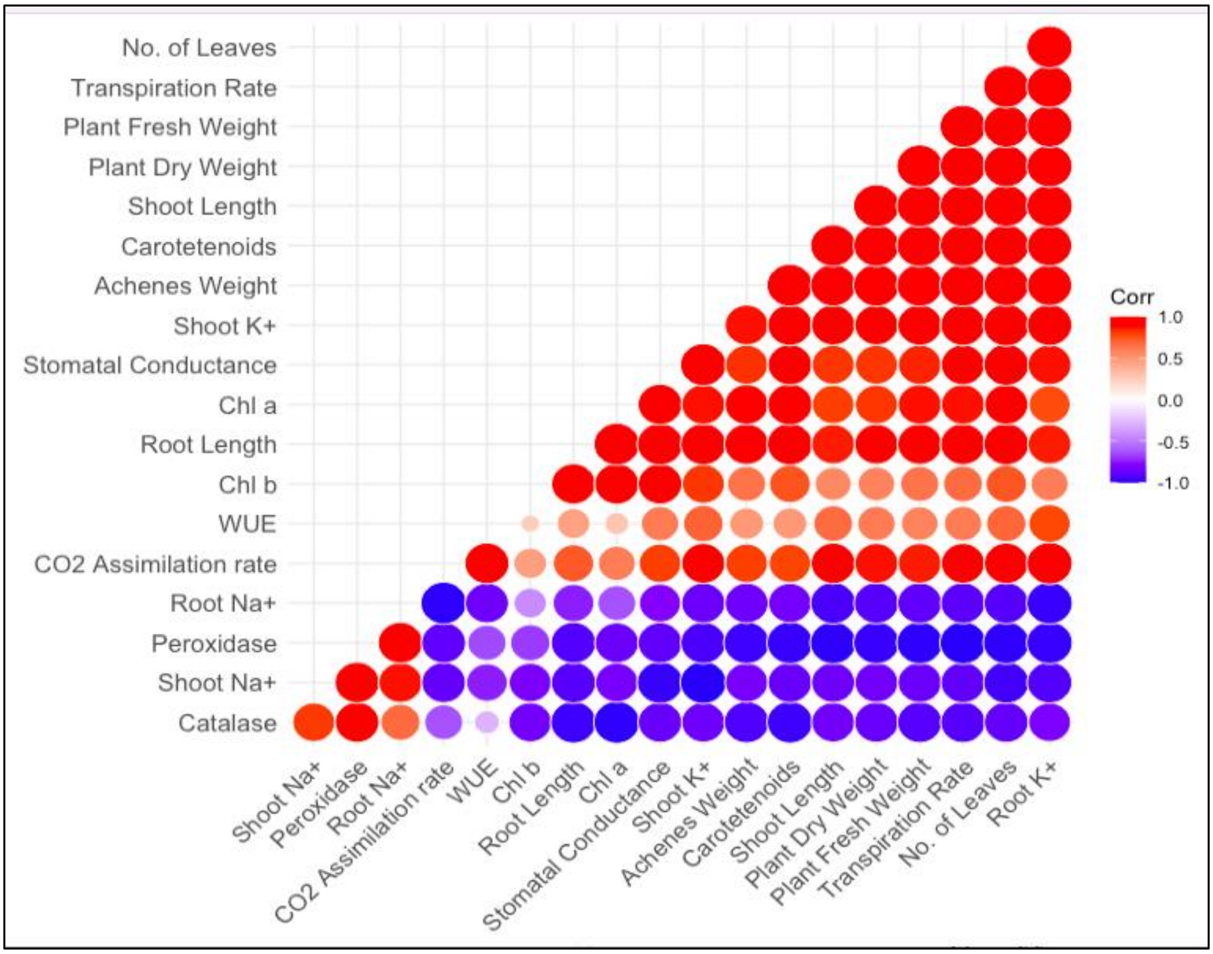


Figure-4: Correlation Matrix between Growth, Biochemical and Physiological Parameters of Sunflower

4. CONCLUSIONS

From results of this study it can be concluded that the foliar application of potassium at a concentration of 500 ppm significantly improved the growth, physiological parameters, gas exchange characteristics, antioxidant levels, and the balance of sodium and potassium in sunflower plants under saline conditions. It also increases K+ level which provides turgidity to guard cells and stability to membranes. This treatment promoted healthy growth in sunflowers. Additional studies are required to understand the molecular mechanisms by which potassium exerts these beneficial effects in sunflowers and other crops.

REFERENCES

1. GGupta, B., & Huang, B. (2014). Mechanism of salinity tolerance in plants: physiological, biochemical, and molecular characterization. *International journal of genomics*, *2014*(1), 701596.
2. Rozema, J., & Flowers, T. (2008). Crops for a salinized world. *Science*, *322*(5907), 1478-1480.
3. Hasanuzzaman, M., Raihan, M. R. H., Masud, A. A. C., Rahman, K., Nowroz, F., Rahman, M., ... & Fujita, M. (2021). Regulation of reactive oxygen species and antioxidant defense in plants under salinity. *International Journal of Molecular Sciences*, *22*(17), 9326.
4. Sarker, U., & Oba, S. (2018). Drought stress enhances nutritional and bioactive compounds, phenolic acids and antioxidant capacity of Amaranthus leafy vegetable. *BMC Plant biology*, 18, 1-15.
5. Sarker, U., Islam, M. T., & Oba, S. (2018). Salinity stress accelerates nutrients, dietary fiber, minerals, phytochemicals and antioxidant activity in Amaranthus tricolor leaves. *PLoS One*, *13*(11), e0206388.
6. Hurtado, A. C., Chiconato, D. A., de Mello Prado, R., Junior, G. D. S. S., & Felisberto, G. (2019). Silicon attenuates sodium toxicity by improving nutritional efficiency in sorghum and sunflower plants. *Plant Physiology and Biochemistry*, 142, 224-233.
7. Paul, P. L. C., Bell, R. W., Barrett-Lennard, E. G., & Kabir, E. (2020). Variation in the yield of sunflower (Helianthus annuus L.) due to differing tillage systems is associated with variation in

solute potential of the soil solution in a salt-affected coastal region of the Ganges Delta. *Soil and Tillage Research*, 197, 104489.

8. Hafeez, M. B., Raza, A., Zahra, N., Shaukat, K., Akram, M. Z., Iqbal, S., & Basra, S. M. A. (2021). Gene regulation in halophytes in conferring salt tolerance. *In Handbook of bioremediation, Academic Press*, 341-370.
9. Taher, M., Beyaz, R., Javani, M., Gürsoy, M., & Yildiz, M. (2018). Morphological and biochemical changes in response to salinity in sunflower (Helianthus annus L.) cultivars. *Italian Journal of Agronomy*, *13*(2), 141-147.
10. Alsaeedi, A., El-Ramady, H., Alshaal, T., El-Garawany, M., Elhawat, N., & Al-Otaibi, A. (2019). Silica nanoparticles boost growth and productivity of cucumber under water deficit and salinity stresses by balancing nutrients uptake. *Plant Physiology and Biochemistry*, 139, 1-10.
11. Ramadan, A. A., Abd Elhamid, E. M., & Sadak, M. S. (2019). Comparative study for the effect of arginine and sodium nitroprusside on sunflower plants grown under salinity stress conditions. *Bulletin of the National Research Centre*, *43*(1), 1-12.
12. Jan, A. U., Hadi, F., Akbar, F., & Shah, A. (2019). Role of potassium, zinc and gibberellic acid in increasing drought stress tolerance in sunflower (Helianthus annuus L.). *Pak J Bot*, *51*(3), 809-815.
13. Raza, M. A. S., Saleem, M. F., Khan, I. H., Hussain, M. B., & Shah, G. M. (2018). Amelioration in growth and physiological efficiency of sunflower (Helianthus annuus L.) under drought by potassium application. *Communications in soil science and plant analysis*, *49*(18), 2291-2300.

    Zaman, B. U., Ali, A., Arshadullah, M., Din, J. U., Suhaib, M., Yousra, M., & Ahmed, S. (2018). Growth response of sunflower to potassium sulphate application in saline-sodic soil. *Asian Journal of Research in Agriculture and Forestry*, *1*(3), 1-7.
14. Wada, S., Takagi, D., Miyake, C., Makino, A., & Suzuki, Y. (2019). Responses of the photosynthetic electron transport reactions stimulate the oxidation of the reaction center chlorophyll of photosystem I, P700, under drought and high temperatures in rice. *International Journal of Molecular Sciences*, *20*(9), 2068.
15. Shehzad, M. A., Nawaz, F., Ahmad, F., Ahmad, N., & Masood, S. (2020). Protective effect of potassium and chitosan supply on growth, physiological processes and antioxidative machinery in sunflower (Helianthus annuus L.) under drought stress. *Ecotoxicology and environmental safety*, 187, 109841.
16. Cui, Y. N., Xia, Z. R., Ma, Q., Wang, W. Y., Chai, W. W., & Wang, S. M. (2019). The synergistic effects of sodium and potassium on the xerophyte Apocynum venetum in response to drought stress. *Plant Physiology and Biochemistry*, 135, 489-498.
17. Zamani, S., Naderi, M. R., Soleymani, A., & Nasiri, B. M. (2020). Sunflower (Helianthus annuus L.) biochemical properties and seed components affected by potassium fertilization under drought conditions. *Ecotoxicology and environmental safety*, 190, 110017.
18. F.A.O. *Statistical Year Book*; Food and Agriculture Organization of United Nations: Rome, Italy, 2013.
19. Aishwarya, S., & Anisha, V. (2014). Nutritional composition of sunflower seeds flour and nutritive value of products prepared by incorporating sunflower seeds flour. *International Journal of Pharmaceutical Research & Allied Sciences*, *3*(3), 45-49.
20. Wu, H., Zhang, X., Giraldo, J. P., & Shabala, S. (2018). It is not all about sodium: revealing tissue specificity and signalling roles of potassium in plant responses to salt stress. *Plant and soil*, 431, 1-17.
21. Farrukh Saleem, M., Bilal Hafeez, M., Ramzan, Y., & Nadeem, M. (2022). Impact of soil applied humic acid, zinc and boron supplementation on the growth, yield and zinc translocation in wheat. *Asian Journal of Agriculture and Biology*, (Online).
22. Anwar, Z., Basharat, Z., Bilal Hafeez, M., Zahra, N., Rafique, Z., & Maqsood, M. (2021). Biofortification of maize with zinc and iron not only enhances crop growth but also improves grain quality. *Asian Journal of Agriculture and Biology*, (Online).
23. Temme, A. A., Kerr, K. L., & Donovan, L. A. (2019). Vigour/tolerance trade-off in cultivated sunflower (Helianthus annuus) response to salinity stress is linked to leaf elemental composition. *Journal of Agronomy and Crop Science*, *205*(5), 508-518.
24. Arnon, D. I. (1949). Copper enzymes in isolated chloroplasts. Polyphenoloxidase in Beta vulgaris. *Plant physiology*, *24*(1), 1.
25. Richards, L. A. (Ed.). (1954). Diagnosis and improvement of saline and alkali soils (No. 60). US Government Printing Office.
26. Chance, B., & Maehly, A. C. (1955). Assay of catalaseand peroxidase. *Methods Enzymol*, *2*, 764–775.
27. Long, S.P., Farage, P. K., & Garcia, R. L. (1996). Measurement of leaf and canopy photosynthetic CO_2 exchange in the field. *J Exp Bot*, *47*, 1629–1642.
28. Abdel Latef, A. A. H., & Chaoxing, H. (2014). Does inoculation with Glomus mosseae improve salt tolerance in pepper plants?. *Journal of Plant Growth Regulation*, 33, 644-653.
29. Mostofa, M. G., Fujita, M., & Tran, L. S. P.

(2015). Nitric oxide mediates hydrogen peroxide- and salicylic acid-induced salt tolerance in rice (Oryza sativa L.) seedlings. *Plant growth regulation*, 77, 265-277.

30. Kosová, K., Vítámvás, P., Prášil, I. T., & Renaut, J. (2011). Plant proteome changes under abiotic stress—contribution of proteomics studies to understanding plant stress response. *Journal of proteomics, 74*(8), 1301-1322.
31. Rehman, A., Hassan, F., & Qamar, R. (2021). Application of plant growth promoters on sugarcane (Saccharum officinarum L.) budchip under subtropical conditions. *Asian Journal of Agriculture and Biology*, 2.
32. Farooq, O., Ali, M., Sarwar, N., Mazhar Iqbal, M., Naz, T., Asghar, M., & Ehsan, F. (2021). Foliar applied brassica water extract improves the seedling development of wheat and chickpea. *Asian Journal of Agriculture and Biology*, 1.
33. Waraich, E. A., Ahmad, R., Ashraf, M. Y., Saifullah, & Ahmad, M. (2011). Improving agricultural water use efficiency by nutrient management in crop plants. *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science, 61*(4), 291-304.
34. Akram, N. A., Ashraf, M., & Al-Qurainy, F. (2012). Aminolevulinic acid-induced changes in some key physiological attributes and activities of antioxidant enzymes in sunflower (Helianthus annuus L.) plants under saline regimes. *Scientia Horticulturae*, 142, 143-148.