Atriplex (*Atriplex halimus)*: Distribution, Morphology, Physiological Tolerance to Salinity and Drought: A Review

Omar E. Gharibeh[1*], Safwan M. Shiyab[2], Hani Saoub[3]

[1,2,3]*Department of Horticulture and Crop Science, Faculty of Agriculture, University of Jordan, Jordan; E-mail: amora_gh@yahoo.com*

Abstracts: *Atriplex halimus* is a halophyte plant that is grown in semi-arid and arid regions due to its high capacity to grow in high salinity and drought conditions. The objective of this paper is to review the physiological and morphological changes of *A. halimus* under different conditions of salinity and drought conditions, as well as compare the different results that are concerned with this plant in the different areas where this plant exists. The result of this review has shown that *A. halimus* adapt to different saline conditions by creating the balance of the vegetative growth as well as changing the leaves physiology to adapt to the drought conditions by decreasing the water content which Na creates the osmotic adjustment. The *A. halimus* can reduce/or increase the photosynthesis process depending on the level of drought and salinity conditions. The accumulation of Na increased in the plant as the soil salinity increased. The review has shown that *A. halimus* increase the uptake of heavy metals if it has high concentrations in soil. The review results show that the different morphological and physiological changes of *A. halimus* differ from one area to another depending on the drought conditions and soil salinity concentrations. The results showed that *A. halimus* can be used to rehabilitate deserts that suffer high salinity and drought. Moreover, it can be used to treat the soil contaminated with heavy metals.

Keywords: *Atriplex halimus*, Drought, Salinity, Morphology.

1. INTRODUCTION

Atriplex halimus is classified as a halophytic perennial plant with the common name saltbush. Atriplex halimus has two species the diploid halimus (2n=2x=18) and the other one is the tetraploid schweinfurtbii (2n=4x=36) (Kheiria Hcini et al., 2007). This plant is known as a small shrub grown and found in arid and saline soils. The height of this plant ranges from 2-3 m and spread to 2.4 m in width. It belongs to the Chenopodiaceae family (Musallam & Abu-romman, 2023). The Atriplex halimus is distributed highly in the Mediterranean regions. It is found in Southern European countries and Middle East countries such as Jordan, Egypt, Lebanon, Saudi Arabia, Tunisia, and Algeria and other arid areas worldwide (David J. Walker & Lutts, 2014) (Mahi et al., 2015).

The interest in plants with high tolerability of salinity and arid conditions increased as the world population increased to meet the food increased requirements and finding plant species that help in alleviating desertification, especially in countries with dry climate and saline soils (Calone, Cellini, et al., 2021; Habib et al., 2016). The concern in Atriplex halimus was initiated as part of the solution of soil salinity and arid conditions in different countries. The genetic research of this plant increased to figure out the mechanisms of these plants that help in resisting salt and arid conditions (David J. Walker & Lutts, 2014).

The Atriplex halimus species grows in low annual rainfall in winter and high temperatures in summer with high potential evapotranspiration (Calone, Cellini, et al., 2021). The soils of these areas are characterized as alkaline soils with pH values ranging from 7 to 11 (David J. Walker & Lutts, 2014). Some researchers through scientific research have approved that this species can modify to meet any weather changes over time (Kheiria Hcini et al., 2007). The morphological changes used to happen to meet the different dry conditions worldwide (K Hcini et al., 2007). These characteristics of the Atriplex halimus doubled the concern of studying this species and extra characteristics related to heavy metal tolerance (Nosek et al., 2020).

The other dimension of interest with the Atriplex halimus is related to climate change (Petropoulos et al., 2018). Most of the world's efforts are concentrated on finding new resistant species that tolerate the newly initiated conditions (Calone, Bregaglio, et al., 2021). The concern was related to the study of the morphology of Atriplex halimus to figure out the mechanism this plant behaves under different conditions (Calone, Cellini, et al., 2021). This concern is also the result of the contribution of Atriplex halimus in food security that helps in fighting starvation around the world (Petropoulos et al., 2018).

This paper is a systematic review paper interested in reviewing the morphological characteristics of Atriplex halimus and its behavior under drought and saline conditions. The paper will investigate the modern literature related to these issues as well as reach conclusions about the differences between A. halimus species in different areas of the world compared to the Middle East. The systematic review included all scientific work produced in all journals including different areas that introduce or explain the variation of the morphology of these species.

2. LITERATURE REVIEW

Soil salinity and low rainfall zones accompanied by climate change conditions increased the demand to search for new salinity-resistant species to find alternative food sources and fight desertification in different areas. The saline soil affects the plant's growth in different ways (Habib et al., 2016). The general effect is related to plant growth resulting from water and nutrient uptake (Agudelo et al., 2021). The salinity conditions affect water stress which consequently decreases the soil solution's osmotic potential, dramatic effect on the nutritional imbalance, and the ionic concentration of sodium and salt cations in the soil. These factors contribute to affecting plant behavior and decrease the plant's ability to stand with these conditions (Zhao et al., 2020). Generally, these conditions encouraged the need to search for species that can stand such conditions. Atriplex halimus was one of the species that adapted in such conditions in different arid areas worldwide (Agudelo et al., 2021; Bendaly et al., 2016; Calone, Cellini, et al., 2021; Musallam & Abu-romman, 2023).

A. halimus as halophytes became a species of interest as it can be used as a source of food. Its economic potential of it and its nutritive rich value increases the concern of this species. The high mineral, lipid, protein and phenolic content of A.halimus changed the nutritive evaluation of this species (Petropoulos et al., 2018). In countries with water scarcity, this species can be used to increase the green cover and minimize soil erosion in different areas (Khan et al., 2020).

Agudelo et al. (2021) investigated the opportunities to use A. halimus as a source of food to meet climate change and to use the lands in arid zones in the Mediterranean region. The characteristics of sodium concentration under different salinity concentrations in this species were found to meet the requirements of food for human consumption (Agudelo et al., 2021). This study considered that this species can be used to meet climate change and to create food balance in dry regions. Mohammedi (2016) reported other uses of A. halimus as a medical herb. The A. halimus was reported to be used to treat diabetes mellitus. Petropoulos et al. (2018) have shown that halophytic herbs can be used widely for different medical purposes. They indicated that A. halimus can be used as an herb to replace the formulated chemical compounds to be used for different medical purposes (Petropoulos et al., 2018).

The A. halimus showed different constant behavior in different saline and drought conditions compared to other halophytes (Calone, Cellini, et al., 2021). Calone et al. (2021) have shown that A. halimus did not show any leaves reduction under different salinity concentrations compared to A. hortensis which is one of the same family. Moreover, the A. halimus genotypes showed no effect on negative values of isotope carbons compared to A. hortensis. The longtime of saline effect reached 27 days showing that the different morphology of the A. halimus did not change (Calone, Cellini, et al., 2021).

The A. halimus was found to adapt physiologically and morphologically to any new conditions of water and salinity conditions (Alam et al., 2022; Kheiria Hcini et al., 2007). Different studies have shown that A. halimus modify its mechanism physiologically and biochemically side by side by modifying the morphological and anatomical features to meet extreme temperatures, salinity, drought and trace elements in soil (Al-Muwayhi, 2020; Alam et al., 2022; Sidhoum et al., 2020; David J. Walker & Lutts, 2014). Mahi et al. (2015) have shown that halophytes react with higher soil salinity concentrations by modifying some morphological features.

3. METHODOLOGY

This study applied the systematic review. The systematic review is a known procedure that facilitates the deep analysis of literature and answers specific questions in some scientific areas (Nunn & Chang, 2020).

The questions of the current study were formulated based on the primary findings of the literature related. The review techniques can be used to draw concept maps related to a research area through the collected relative resources. Most of the scientific reviewing methods apply those suggested by Askey and O'Malley (2005). The steps suggested by Askey and O'Malley to execute reviewing include the following:

1. The first step is to recognize the study questions through research in electronic databases related to the subject.

2. Searching for relevant studies using electronic sources that meet the research questions.

3. Classify the collected studies according to the study questions that can be used to answer these questions.

4. Draw charts for the collected data and the information collected from studies in step 3.

5. Summarize the results of the different studies according to each question.

6. Contact the relevant consultants' groups to find more sources to support the results of their review subjects.

As the objective of this reviewing paper is dependent on the international findings in the area of the study, the searched electronic sites should provide the ability to search for the studies related globally. So, electronic searching was carried out in two popular search engines Google Webpage and Google Scholar. Searching through the previously mentioned sources was made with the use of the following keywords and combinations of them: *Atriplex halimus*, drought, salinity, morphology, and physiology.

The eligibility criteria were set up after reading the titles and abstracts of the available and related literature. Thus, the studies included in the systematic review only after fulfilling the following inclusion criteria:

1. Studies dealing with the *Atriplex halimus* related to morphology and physiological features of *A. halimus* and drought and salinity tolerability.

3. Studies published from January 2010 to December 2022.

4. Only English language studies will be used.

5. Full-text access.

The exclusion criteria will be:

1. Papers published before 2010

2. The published papers investigated *Atriplex halimus* in areas out of the scope of this paper.

3. Any type of published or unpublished work including dissertation, letters to editors, commentaries, and similar ones.

4. Review articles.

The included studies were read in detail and attention was made to the study aims. For the preparation of this systematic review, as it has no specific guidelines to implement, the author followed the PRISMA guidelines 2020.

The research questions:

1. What are the different morphological features of *Atriplex halimus* in the Middle East area compared to other regions?

2. What are the psychological criteria of *Atriplex halimus* that contributed to salinity and drought tolerance?

3. What is the effect of different geographical areas on the behavior of *Atriplex halimus*?

The paper will apply the systematic PRISMA procedure to accomplish the objectives: the tolerance of *Atriplex halimus* to drought, and the tolerance of *Atriplex halimus* to salinity.

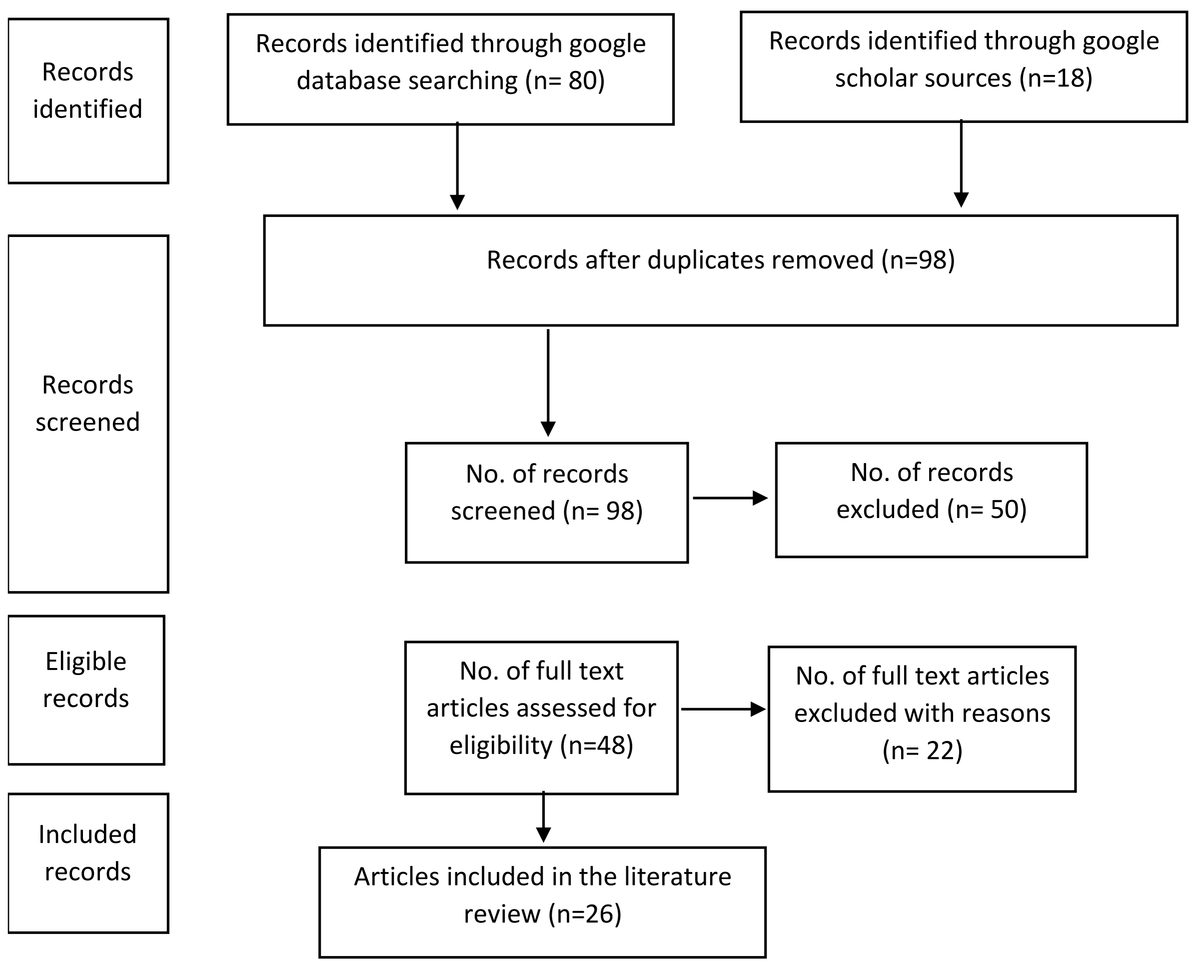

Figure 1.1: PRISMA Flowchart

4. DISCUSSION

4.1 What are the different morphological features of *Atriplex halimus* in the Middle East area compared to other regions?

Salinity stress is a common phenomenon in arid regions associated with complicated consequences on plants (Petropoulos et al., 2018). Functional, morphological changes and other anatomical modifications are expected in plants. Walker and Lutts (2014) have shown that *A. halimus* as one of the halophytes is capable of making morphological and physiological changes that help in standing the arid conditions, the high salinity and the heavy metals of soil. This capability of *A. halimus* and other halophytes makes this plant the first position of interest in arid regions (Agudelo et al., 2021; Petropoulos et al., 2018). The new uses of this plant as food or medical purposes increased its importance and the interest to study the morphological features to develop and distribute it (Petropoulos et al., 2018).

The *A. halimus* belongs to the Chenopodiaceae species (Kheiria Hcini et al., 2007). The *A. halimus* is a halophytic perennial shrub. It grows in arid and semi-arid conditions. This plant resists high salinity and drought conditions. The *A. halimus* is considered a typical landscape in arid and semi-arid areas (Agudelo et al., 2021; Mohammedi, 2016; Pérez-Romero et al., 2020; Petropoulos et al., 2018). Also, it is considered important forage for animals. The *A. halimus* is known to grow to a height 1-2 m and distribute to 2.4 m width. It is known to have deep roots ((D. J. Walker et al., 2014). The leaves of *A. halimus* are silver white. The stems of the *A. halimus* have alternate leaves with different shapes and dimensions with lengths reaching 4 cm. The inflorescence of the *A. halimus* is born on leafless twigs. It has yellow or green flowers. The fruits are very rich and spread horizontally. The fruits look like the kidney with dimensions 3.5-4 by 5-6 mm (D. J. Walker et al., 2014).

Kheiria et al. (2007) studied the morphological changes of *A. halimus* concerning the fruits in different areas in Tunisia. The study was concerned with the size and shape of the fruit. The results of the study showed that the large size of *A. halimus* was found in the northern parts of Tunisia, while the small size fruits were found in the southern parts. The northern parts are characterized by higher rainfall amounts compared to the southern parts of the country. The fruits ranged from smooth to whole margin in the northern parts while it was toothed margins in the southern parts of Tunisia (Kheiria Hcini et al., 2007). The *A. halimus* was characterized by whole-wing margins bracteoles. The results showed that the *A. halimus* dry fruit weight was higher in the northern parts compared to the southern parts. Also, the results revealed that the populations of *A. halimus* were different through different geographical distributions (Kheiria Hcini et al., 2007).

4.2 What are the physiological criteria of *Atriplex halimus* that contributed to salinity and drought tolerance?

A. halimus is found to modify physiologically to meet different drought and salinity soil conditions. Agudelo et al. (2021) have reported that the high salinity increased the protein and phenolic content of *A. halimus*. Under saline conditions, the concentration of Na^+ in *A. halimus* leaves was less than the other halophytes species. Nemat Alla et al. (2011) studied the different physiological aspects of *A. halimus* in different saline and drought conditions. The results showed that 300 to 550 mM NaCl did not affect the weight, height, fresh and dry weight. The *A. halimus* did not show any changes and 3 or 6 days after the treatment and was not affected by the saline conditions. After 10 days of the experiment, the stomatal conductance, the transpiration rate and photosynthetic rates were increased when the NaCl concentration was 50 mM but it decreased when the NaCl increased to 300 and 550 mM. The K was decreased with the increase of NaCl. The drop of fresh weight was justified due to the low water content of the plant in dry conditions. The photosynthesis was decreased in *A. halimus* due to the decrease in stomatal conductance which is adaptive mechanism practiced by the plant to increase water use efficiency. The results showed that *A. halimus* can tolerate NaCl and drought conditions through decreasing the growth, minimize gas exchange which helps improving water use efficiency. These results were approved by Ishtiyaq et al. (2023).

Other experiments tended to study the effect of water stress and salinity on *A. halimus* behavior through simulation conditions (Agudelo et al., 2021; Bendaly et al., 2016). These experiments applied different salinity levels to *A. halimus* to measure the behavioral response in different salinity conditions (Agudelo et al., 2021; Bendaly et al., 2016). Perez-Romero et al. (2020) studied the physiological change of *A. halimus* in different saline conditions. The results of the experiment showed that the increase in salinity reduce the vegetative growth of *A. halimus*. Also, the plant growth underground was reduced in high salinity conditions. The results showed that photosynthetic limitations were dominated in plants and the limitations of stem conductivity. These results were similar to the results found by Nemat Alla et al. (2011). More results were found to indicate that turgor loss was similar in all the salinity treatments.

Bendaly et al. (2016) studied the effect of salinity on the physiological changes in *A. halimus* especially the physiological changes of the leaves. The *A. halimus* plants were harvested and analyzed after 60 days of planting. The biomass of *A. halimus* was increased under moderate salinity conditions and decreased in highly salinity conditions. These results match the findings of Perez-Romero et al. (2020) and Nemat Alla (2011). The concentration of Na increased continuously as well as the water content of the plant reached some salinity concentration where the water content was decreased this was justified by Na's contribution to creating the osmotic adjustment in leaves (Bendaly et al., 2016). The carbohydrates and the amino acids were accumulated in the leaves of the plant. The leaves of *A. halimus* were noticed to store α alanine, proline, and sucrose. Also, the increase of NaCl increased the accumulation of the malate in the leaves (Bendaly et al., 2016). The results showed that these solutions did not contribute to the osmotic adjustment of the leaves of the plant. The photosynthesis was decreased for the *A. halimus*. This result was reported also by Perez-Romero et al. (2020) and Nemat Alla (2011). The proline and sucrose accumulation in the leaves of *A. halimus* helps in protecting the leaves from oxidative damage.

The leaves of the Atriplex species are characterized by the presence of salt bladders, the leaf epidermis is characterized by upper and lower vesicles. These features play a very important role in *A. halimus*'s ecological significance (Agudelo et al., 2021). The anatomic structure of *A. halimus* is different which facilitates the different responses to different sodium chloride salinity levels (Al-Muwayhi, 2020). Mahi et al. (2015) have discussed the anatomical features of *A. halimus*. The results showed that *A. halimus* showed many modifications depending on the external conditions.

Mouna et al. (2020) studied the effect of salinity on different leaf criteria including transpiration, the leaf area and the turgor. The results of *A. halimus* showed that under low saline conditions, the biomass of the leaves increased, and the transpiration was high. The continuous exposure of *A. halimus* to high salinity conditions minimizes the transpiration, turgor, and leaf area and under extreme salinity conditions it became harmful to the plant. The decrease of water content available for the plant growth decrease the water loss through transpiration of the plant. The results of this experiment reflect the leaf modification to meet the different salinity of drought of *A. halimus* (Mouna et al., 2020).

A. halimus is characterized by having high phytostabilization and/or limited phytoextraction capacities (Ishtiyaq et al., 2023). This feature of *A. halimus* increased its use to treat soils with high heavy metal concentrations (Acuña et al., 2021). Ishtiyaq et al. (2023) studied the behavior of *A. halimus* under different saline and water stress conditions with the presence of different concentrations of Ni and Cd. The study was concerned with the phytoremediation, phytoextraction, and osmoprotectants of *A. halimus*. In the low salinity concentrations, *A. halimus* was found to have a higher accumulation of Cd and Ni in the shoots and roots. The increase of salt concentration by 5% for the treatments decreased the Ni and Cd concentration of both shoots and roots (Ishtiyaq et al., 2023). The results showed that the roots are capable to accumulate Ni and Cd more than shoots. Similar results were found by Bankaji et al. (2019). This leads to the conclusion of the phytostabilization of *A. halimus* which is similar to Acuna et al. (2021) results. On the other hand, the results showed that *A. halimus* was able to uptake most of the NaCl from the soil through the time of the experiment. These results have shown that the soil's low salinity was converted to non-saline soils through the experiment and the salinity was reduced with time justified for the *A. halimus* uptake of Na from the soil. This approves the views that encourage the use of *A. halimus* as a reclamation plant for saline soils (Acuña et al., 2021).

Gomez-Bellot et al. (2021) studied the effect of two types of irrigation water sources (reclaimed wastewater and reverse osmosis brine) on the behavior of *A. halimus* compared to other halophyte plants. Under high water potential the *A. halimus* decrease the leaves' water potential and improve leave turgor as a response (Gómez-Bellot et al., 2021). Higher intrinsic water efficiency was found in *A. halimus* compared to other plant species (Gómez-Bellot et al., 2021). The analysis of leaves showed that the concentration of K, Mg, Na and Zn was higher than *A. halimus* compared to a higher concentration of Ca and B in other plant leaves (Gómez-Bellot et al., 2021). These results showed that *A. halimus* modification under different water quality conditions is higher compared to other plants (Gómez-Bellot et al., 2021).

4.3 What is the effect of different geographical areas on the behavior of *Atriplex halimus*?

A. halimus was found to behave differently in different geographical areas based on the characteristics of the area related to amounts of rainfall and soil salinity. Kheiria et al. (2007) found that *A. halimus* change its morphology according to the characteristics of the different areas. The behavior of *A. halimus* in areas with semi-arid zones is different compared to the arid zones.

Hcini et al. (2007) studied the effect of the geographical area inside Tunisia on the fruits and chromosome numbers of *A. halimus*. The results of the study revealed that the distribution and density of *A. halimus* were different from one area to another depending on the level of drought as well as the level of soil salinity. The results showed that the density of *A. halimus* was higher in the areas with higher rainfall amounts and with lower soil salinity. The northern parts of Tunisia were characterized by a high density of *A. halimus*, while the southern parts were characterized by lower densities (Kheiria Hcini et al., 2007). The results showed that the vegetarian characteristics were different from one area to another. The areas characterized by higher rainfall amounts and lower salinity conditions were characterized by higher biomass of *A. halimus*. With the movement toward the southern parts, the biomass of *A. halimus* decreased and the fruit characteristics changed side by side with the decrease in the dry weight of the fruits (Kheiria Hcini et al., 2007).

Haddioui et al. (2008) studied the distribution of *A. halimus* in different populations and their characteristics and modification as a result of response to salinity and drought conditions. The results showed that the salinity tolerance varied from one population to another. The results showed that higher salinity tolerability was found among the *A. halimus* brought through the Atlantic Ocean the tolerability to salinity was moderate compared to the species that was brought through continental sites. This indicates that the different area species have different features to respond to salinity and doughtiness (Haddioui et al., 2008). The different areas of the population showed different biomass and different fruit weights according to their capacity to tolerate saline and drought conditions (Calone, Cellini, et al., 2021; Habib et al., 2016). The areas characterized by low rainfall and high salinity have *A. halimus* species that have more tolerability to bother salinity and drought (Musallam & Abu-romman, 2023).

Elframawy et al. (2016) studied the genetic variations of *A. halimus* in different areas in Morocco. The study included two types of *A. halimus* the first type is erect habit while the others are bushy plants. The study revealed that there were wide genetic variations among the two species in different areas. The different species have different RNA sequences which determine the difference between the different species for the different salinity and drought conditions. The genetic structure was the constraint that affect the *A. halimus* response to different conditions (Elframawy et al., 2016).

CONCLUSIONS AND RECOMMENDATIONS

The *A. halimus* is considered one of the halophytes and belongs to the Chenopdiaceae species. This plant was known for its ability to tolerate high salinity and drought conditions. The features of this plant call for its use to preserve arid and semi-arid from desertification. Also, the large areas of semi-arid and arid regions' distribution call to increase this plant be used as a source of food for animals to increase it to be used for medical treatment purposes. The objective of this study was to investigate the morphological and physiological variations that accompany the ability of this plant to tolerate different saline and drought conditions. The understanding of the morphological and physiological change of this plant will help in increasing it in different semi-arid and arid areas. The results revealed that *A. halimus* has a high capacity to tolerate high salinity and drought conditions. The *A. halimus* under high salinity and drought conditions pass in different morphological and physiological changes that helps stand these conditions. One of the morphological changes is that *A. halimus* can decrease the biomass related to the vegetative growth over the ground and under the ground to meet drought conditions. The leaves of *A. halimus* decrease the transpiration and photosynthesis activities to meet high salinity and drought conditions. The areas with more rainfall and less saline conditions have species of *A. halimus* that produce higher fresh and dry fruit weights. In wet conditions, the nutritive contents of *A. halimus* is richer and can be used for more than one purpose. The results revealed that the continuous increase of salinity in soil affects the growth of *A. halimus* negatively.

Moreover, the results showed that *A. halimus* can help in the uptake of heavy metal from soil. This will help in the reclamation of soils with high heavy metals concentrations. The geographical distribution of *A. halimus* varied according to the extent of drought and salinity in different areas. One more feature of *A. halimus* was found it more capacity to tolerate salinity and drought conditions compared to the other species of halophytes in different areas. The study recommended the increase of this plant in semi-arid and arid areas as a source of land protection and as a source of food in these areas.

REFERENCES

[1] Acuña, E., Castillo, B., Queupuan, M., Casanova, M., & Tapia, Y. (2021). Assisted phytoremediation of lead contaminated soil using Atriplex halimus and its effect on some soil physical properties. International Journal of Environmental Science and Technology, 18(7), 1925–1938. https://doi.org/10.1007/s13762-020-02978-5

[2] Agudelo, A., Carvajal, M., & Martinez-Bellesta, M. del C. (2021). Halophytes of the Mediterranean Basin — Underutilized Species Climate Change. Foods, 10(119).

[3] Al-Muwayhi, M. (2020). Anatomical Response of Atriplex Leaves under Different Levels of Sodium Chloride Salinity. Journal of Plant Production Sciences, 9(1), 33–37. https://doi.org/10.21608/jpps.2020.130641

[4] Alam, H., Zamin, M., Adnan, M., Ahmad, N., Nawaz, T., Saud, S., Basir, A., Liu, K., Harrison, M. T., Hassan, S., Alharby, H. F., Alzahrani, Y. M., Alghamdi, S. A., Majrashi, A., Alharbi, B. M., Alabdallah, N. M., & Fahad, S. (2022). Evaluating the resistance mechanism of Atriplex leucoclada (Orache) to salt and water stress; A potential crop for biosaline agriculture. Frontiers in Plant Science, 13(August), 1–12. https://doi.org/10.3389/fpls.2022.948736

[5] Askey, H. O'Malley, L. (2005). Scoping studies: towards a methodological framework. International Journal of Social Research Methodology, 8(1), 19–32.

[6] Bankaji, I., Pérez-Clemente, R. M., Caçador, I., & Sleimi, N. (2019). Accumulation potential of Atriplex halimus to zinc and lead combined with NaCl: Effects on physiological parameters and antioxidant enzymes activities. South African Journal of Botany, 123, 51–61. https://doi.org/10.1016/j.sajb.2019.02.011

[7] Bendaly, A., Messedi, D., Smaoui, A., Ksouri, R., Bouchereau, A., & Abdelly, C. (2016). Physiological and leaf metabolome changes in the xerohalophyte species Atriplex halimus induced by salinity. Plant Physiology and Biochemistry, 103, 208–218. https://doi.org/10.1016/j.plaphy.2016.02.037

[8] Calone, R., Bregaglio, S., Sanoubar, R., Noli, E., Lambertini, C., & Barbanti, L. (2021). Physiological adaptation to water salinity in six wild halophytes suitable for mediterranean agriculture. Plants, 10(2), 1–17. https://doi.org/10.3390/plants10020309

[9] Calone, R., Cellini, A., Manfrini, L., Lambertini, C., Gioacchini, P., Simoni, A., & Barbanti, L. (2021). The c4 atriplex halimus vs. The c3 atriplex hortensis: Similarities and differences in the salinity stress response. Agronomy, 11(10). https://doi.org/10.3390/agronomy11101967

[10] Elframawy, A., Deif, H., & El-Bakatoushi, R. (2016). Genetic Variation among Fragmented Populations of <i>Atriplex halimus</i> L. Using Start Codon Targeted (SCoT) and ITS1-5.8S-ITS2 Region Markers. American Journal of Molecular Biology, 06(02), 101–115. https://doi.org/10.4236/ajmb.2016.62011

[11] Gómez-Bellot, M. J., Lorente, B., Ortuño, M. F., Medina, S., Gil-Izquierdo, Á., Bañón, S., & Sánchez-Blanco, M. J. (2021). Recycled wastewater and reverse osmosis brine use for halophytes irrigation: Differences in physiological, nutritional and hormonal responses of crithmum maritimum and atriplex halimus plants. Agronomy, 11(4). https://doi.org/10.3390/agronomy11040627

[12] Habib, S. H., Kausar, H., & Saud, H. M. (2016). Plant Growth-Promoting Rhizobacteria Enhance Salinity Stress Tolerance in Okra through ROS-Scavenging Enzymes. BioMed Research International, 2016. https://doi.org/10.1155/2016/6284547

[13] Haddioui, A., Bouda, S., Lemine, M. M. O. M., Hammada, S., & El Hansali, M. (2008). Effect of salinity on growth of five natural populations of Atriplex halimus L. in Morocco. Journal of Agronomy, 7(2), 197–201. https://doi.org/10.3923/ja.2008.197.201

[14] Hcini, K, Farhat, M. Ben, Harzallaho, H., & Bouzid, S. (2007). Diversity in natural populations of Atriplex halimus L. in Tunisia. Noticiario de Recursos Fitogeneticos (IPGRI/FAO).

[15] Hcini, Kheiria, Ferchichi Ouerda, H., & Bouzid, S. (2007). Morphological variability of fruit and chromosome numbers in tunisian populations of atriplex halimus L. (Chenopodiaceae). Caryologia, 60(3), 203–211. https://doi.org/10.1080/00087114.2007.10797938

[16] Ishtiyaq, S., Kumar, H., Souza, R., Varun, M., & Favas, P. (2023). Physiological Responses and Adaptations of the Halophyte Atriplex halimus to Soil Contaminated with Cd, Ni, and NaCl. Soil Syst., 7(46), 2–16.

[17] Khan, W.-D., Tanveer, M., Shaukat, R., Ali, M., & Pirdad, F. (2020). Salt and Drought Stress Tolerance in Plants: Signaling and Communication in Plants. 403. http://link.springer.com/10.1007/978-3-030-40277-8

[18] Mahi, Z., Belkhodja, M., & Lemoine, R. (2015). Anatomical features of Atriplex halimus L. to Saline Environments 1, 2. 1(6), 69–76.

[19] Mohammedi, Z. (2016). Resistance, pharmacology properties and nutritional value of a shrub from arid environments Atriplex halimus. Research Journal of Medicinal Plant, 10(1), 10–18. https://doi.org/10.3923/rjmp.2016.10.18

[20] Mouna, M., Insaf, M., & Samia, B. (2020). Effect of salt stress on some physiological parameters of young plants of atriplex halimus and atriplex canescens. Plant Cell Biotechnology and Molecular Biology, 21(47–48), 17–28.

[21] Musallam, A., & Abu-romman, S. (2023). Molecular Characterization of Dehydrin in Azraq Saltbush among Related Atriplex Species. 1–12.

[22] Nemat Alla, M. M., Khedr, A. H. A., Serag, M. M., Abu-Alnaga, A. Z., & Nada, R. M. (2011). Physiological aspects of tolerance in Atriplex

halimus L. to NaCl and drought. Acta Physiologiae Plantarum, 33(2), 547–557. https://doi.org/10.1007/s11738-010-0578-7

[23] Nosek, M., Kaczmarczyk, A., Jędrzejczyk, R. J., Supel, P., Kaszycki, P., & Miszalski, Z. (2020). Expression of genes involved in heavy metal trafficking in plants exposed to salinity stress and elevated Cd con centrations. Plants, 9(4). https://doi.org/10.3390/plants9040475

[24] Nunn, J., & Chang, S. (2020). What are systematic reviews? WikiJournal of Medicine, 7(1), 1–11. https://doi.org/10.15347/wjm/2020.005

[25] Pérez-Romero, J. A., Mateos-Naranjo, E., López-Jurado, J., Redondo-Gómez, S., & Torres-Ruiz, J. M. (2020). Importance of physiological traits vulnerability in determine halophytes tolerance to salinity excess: A comparative assessment in atriplex halimus. Plants, 9(6). https://doi.org/10.3390/plants9060690

[26] Petropoulos, S. A., Karkanis, A., Martins, N., & Ferreira, I. C. F. R. (2018). Halophytic herbs of the Mediterranean basin: An alternative approach to health. Food and Chemical Toxicology, 114(January), 155–169. https://doi.org/10.1016/j.fct.2018.02.031

[27] Sidhoum, W., Bahi, K., & Fortas, Z. (2020). The effect of salinity gradient and heavy metal pollution on arbuscular mycorrhizal fungal community structure in some Algerian wetlands. Acta Botanica Croatica, 79(1), 3–14. https://doi.org/10.37427/botcro-2020-001

[28] Walker, D. J., Lutts, S., Sánchez-García, M., & Correal, E. (2014). Atriplex halimus L.: Its biology and uses. Journal of Arid Environments, 100–101, 111–121. https://doi.org/10.1016/j.jaridenv.2013.09.004

[29] Walker, David J., & Lutts, S. (2014). The tolerance of Atriplex halimus L. to environmental stresses. Emirates Journal of Food and Agriculture, 26(12), 1081–1090. https://doi.org/10.9755/ejfa.v26i12.19116

[30] Zhao, C., Zhang, H., Song, C., Zhu, J. K., & Shabala, S. (2020). Mechanisms of Plant Responses and Adaptation to Soil Salinity. Innovation, 1(1), 100017. https://doi.org/10.1016/j.xinn.2020.100017

[31] Khan, T. I., Jam, F. A., Akbar, A., Khan, M. B., & Hijazi, S. T. (2011). Job involvement as predictor of employee commitment: Evidence from Pakistan. International Journal of Business and Management, 6(4), 252.

[32] HAMID, M., Jam, F.A., Mehmood, S. (2019). Psychological Empowerment and Employee Attitudes: Mediating Role of Intrinsic Motivation. International Journal of Business and Economic Affairs, 4(6), 300-314.

[33] Shahbaz, M., Jam, F. A., Bibi, S., & Loganathan, N. (2016). Multivariate Granger causality between CO2 emissions, energy intensity and economic growth in Portugal: evidence from cointegration and causality analysis. Technological and Economic Development of Economy, 22(1), 47-74.

DOI: https://doi.org/10.15379/ijmst.v10i3.1606