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An Extensive Analysis of Salinity Tolerance of *Portulaca oleracea L.* for Sustainable Agriculture

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Abstract Nowadays, crop insufficiency and decrease in productivity resulting from soil salinization is threatening the world. Thus, it is extremely important to improve crop yield and prevent land degradation process. This study investigated the response of a halophyte, Dandur (*Portulaca oleracea L.*) genotype, to salt stress in different soil mediums. *P. oleracea* plants were grown in the salinized soil of two different texture (clay and clay loam) under different salinity levels: non-saline, slightly saline, moderately saline, highly saline and extremely saline, where salinity is calculated, as the electrical conductivity of a saturated soil paste extract (EC_e, dS m^{-1}). Physiological, morphological and biochemical analyses collectively affirm the plant's capacity to withstand salinity stress. Various parameters, including stem diameter, shoot length, fresh (FW) and dry weight (DW), chlorophyll content index (CCI), transpiration rate (E), photosynthetic rate (Pn), water usage efficiency (WUE), uptake nutrient content, K^+/Na^+ ratio, and TDS exhibited varying responses to increased salinity in clay and clay loam soils. According to the obtained result plants growing in clay soils demonstrated greater tolerance as compared to plants growing in clay loam soils.

Keywords: soil salinization, salt stress, halophyte, Dandur (*P. oleracea*), electrical conductivity

1. Introduction

The availability of land for farming has decreased due to climate change, resulting in the salinization of one-third of global agricultural land. Approximately 6% of arable land becomes unproductive because of salinization related to climate change (Kumar and Sharma, 2020a). Half of the irrigated areas are affected by salinity, with over 20% experiencing higher salinity concentrations.

Halophytes, accounting for roughly 1% of all plant species on Earth, are adapted to survive in environments with high salinity due to their unique biological mechanisms. In the face of climate change, these plants could play a key role in meeting the basic needs of an expanding population in both developing and developed countries.

Purslane (*P. oleracea*), a member of the Portulacaceae family (Ocampo and Columbus, 2012), is indigenous to tropical and subtropical climates. This succulent species functions as a C4 halophyte, demonstrating the remarkable ability to switch from the C4 photosynthetic pathway to the CAM pathway under conditions of environmental stress, such as drought or salinity, thereby enhancing its water use efficiency (He et al., 2021).

In light of the need to better understand the morphological, physiological, and biochemical responses of the local Armenian genotype of *P. oleracea* to salinity stress, the present study seeks to investigate the effects of various clay and clay loam soil types and salinity gradients on this genotype. The salinity levels span from 0-2 dS m^{-1} (non-saline) to 2-4 dS m^{-1} (slightly saline), 4-8 dS m^{-1} (moderately saline), 8-16 dS m^{-1} (strongly saline), and greater than 16 dS m^{-1} (extremely saline).

2. Materials and methods

2.1. Growth conditions

A 20 kg soil sample was evenly distributed into sterile PVC pots, with one seed planted in each pot. Once the seedlings showed signs of rapid growth, salt treatments were introduced. To avoid osmotic shock, the salt concentrations were gradually elevated over a 15-day period.

2.2 Morphological, physiological, and biochemical parameters

The morphological evaluation of *P. oleracea* focused on two fundamental traits—shoot length and stem diameter—measured under both standard (control) conditions and varying levels of salinity stress.

To assess some physiological parameters were measured fresh weight of root (RFW) and shoot (SFW), dry weight of root (RDW) and shoot (SDW), chlorophyll content index (CCI), gas exchange parameters—including transpiration rate (E), photosynthetic rate (Pn), water use efficiency (WUE), at the same time sodium (Na^+), potassium (K^+) levels and TDS were quantified as biochemical parameters (Karen A. Ghazaryan et al., 2024).

3. Result

Exposure to extreme salinity levels led to a substantial suppression of shoot length in *P. oleracea*, with reductions of 1.56 times in clay and 1.35 times in clay loam soils, relative to controls. Additionally, exposure to NaCl significantly affected stem morphology, resulting in a pronounced decline in stem diameter by 2.99 times and 3.42 times, respectively.

Under extreme salinity conditions in clay soils, *P. oleracea* exhibited marked reductions in both biomass parameters, with root and shoot fresh and dry weights decreasing by 3.37 and 6.59 times, and by 1.93 and 4.94 times, respectively. The similar pattern also is observed in clay loam soil, resulting in fresh and dry weight reductions by 2.61 and 4.46 times and by 1.83 and 5.25 times, relative to control treatments.

With increasing salinity, reduction of CCI was greater. A decline of 5.83 and 5.37 times was observed in clay and clay loam soil as salinity increased from non-saline to extreme. Pn and E values were reduced in both soil types. In clay soil these indices decreased by 3.51 and 2.60 times and in clay loam soil by 4.60 and 4.91 times. In contrast to this, WUE value leading to a 1.06 time rise in clay loam soil. However, plants in clay soils showed a 1.36 time lower WUE value.

According to the Fig. 1 under salt stress, the K^+/Na^+ ratio in *P. oleracea* decreased significantly in both clay and clay loam soils, with a larger reduction in shoots (93.55% and 95.16%) and roots (94.00% and 95.17%). Additionally, TDS levels in the shoots increased as soil salinity rose, while the roots exhibited the opposite pattern.

Conclusion

Biochemical, physiological, and morphological analyses confirmed the plant's stress tolerance, with better adaptation in clay soil compared to clay loam. However, stress symptoms appeared in all growth parameters at extreme salinity levels. *Dandur's* distinctive ability to withstand dehydration and sustain growth, especially in favorable conditions, offers valuable opportunities for further research in agriculture. This trait is particularly relevant for addressing food security concerns arising from climate change in saline regions of Armenia and other European nations.

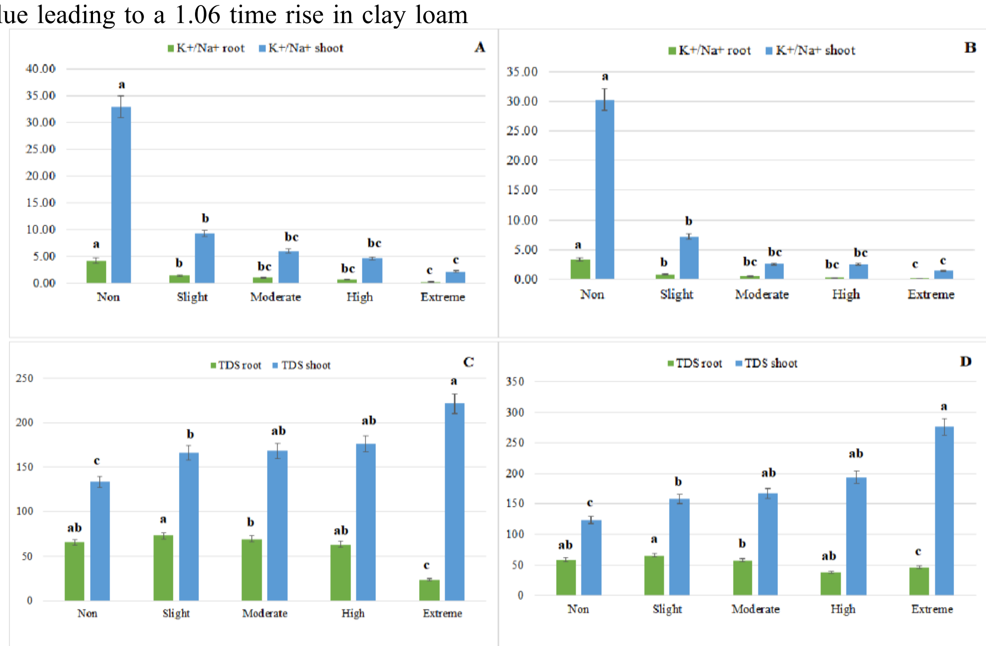

Fig. 1. Effect of salinity on biochemical parameters of *P. oleracea* during salt treatment (A-K^+/Na^+ of root and shoot of plants in clay soil, n = 5, $P < 0.05$, B- K^+/Na^+ of root and shoot of plants in clay loam soil, n = 5, $P < 0.05$, C-TDS of root and shoot of plants in clay soil, n = 5, $P < 0.05$, D-TDS of root and shoot of plants in clay loam soil, n = 5, $P < 0.05$)

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