



Mitigation of salinity stress in *Plantago ovata* L. through optimal zinc concentrations

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Results and discussion

Root dry weight was significantly affected by the concentrations of both Na and Zn in the nutrient solution and by their interaction. Under the 7.70 μM Zn treatment, the dry weights of roots and leaves increased by 31.69% and 31.43%, respectively, compared to the control. In our experiment, the dry weight of *P. ovata* was consistently negatively affected by salinity, although the extent of this effect varied with different concentrations of Na and Zn in the nutrient solution. The root is the first organ exposed to salinity stress, and its efficiency can be rapidly impaired due to the reduced water potential caused by high salt levels (Zhou *et al.*, 2023).

Root Na concentrations gradually increased with higher Na concentration treatments, reaching an average of 3.6 times greater at 100 mM Na compared to 0 mM Na. In *P. ovata*, Na concentrations in roots and leaves increased gradually with treatment levels up to 100 mM, then plateaued.

Root Zn concentrations were unaffected by Na and Zn treatments and their interaction. But, leaf Zn concentrations were significantly affected by Zn treatments and by the Na and Zn interaction.

The concentrations of K in the roots were unaffected by Na and Zn treatments, as well as by their interaction. External Na clearly decreased leaf K concentrations and increased the root Na-to-K ratio, even at the lowest Na treatment. In our experiment, Na treatments did not significantly affect root K concentration or uptake. Our results showed that with increasing external Zn, the ratio of Na to K in roots and the root Na concentrations decreased, while root K concentrations remained roughly constant.

Our study demonstrates that *Plantago ovata* exhibits considerable salt tolerance. Also, salinity decreases root dry weight and increases Na concentrations in both roots and leaves, while optimal zinc treatment (7.70 μM) significantly increases leaf dry weight.

References

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Abstract

Understanding the role of zinc (Zn) in alleviating salinity stress in plants is a complex and intriguing area of study. This research examines the effects of different Zn application levels on *Plantago ovata* under salinity stress. Plants were exposed to a range of sodium chloride (NaCl) concentrations (0–200 mM) and zinc sulfate (ZnSO_4) concentrations (3.85–11.55 μM), and changes in dry weight as well as sodium (Na), Zn, and potassium (K) levels were analyzed. Salinity decreased root dry weight and increased Na concentration in both roots and leaves, as well as the Na-to-K ratio in roots. Zn and K uptake were not affected under any NaCl treatments.

Introduction

Salinity is a major challenge for agriculture, especially in arid and semi-arid regions, mainly due to excessive sodium chloride (NaCl) in the soil (Singh *et al.*, 2023). Salinity not only affects plant growth but also impacts yield by causing ionic, osmotic, and oxidative stresses. Micronutrients like zinc (Zn) enhance plant stress resistance by mitigating toxic ion damage. Research has shown that appropriate Zn application to soil or foliage under salt stress reduces Na accumulation in leaves and increases biomass in many plant species (Tolay, 2021).

Plantago ovata Forssk. (Isabgol), an annual medicinal herb native to arid and semi-arid regions such as the Islamic Republic of Iran. Our objectives were: (i) to assess the magnitude of the negative effects of different NaCl concentrations in artificial saline soil on *P. ovata* growth and nutrient accumulation, and (ii) to evaluate the potential mitigating effects of Zn supplementation across various soil concentrations.

Materials and methods

A pot experiment was conducted in the greenhouse of the Faculty of Agriculture at Yasouj University, Iran. Approximately 15 *P. ovata* seeds were sown in polyethylene cuboid pots filled with washed soft sand. After germination, pots were supplied once with 150 mL of modified quarter-strength Hoagland's nutrient solution. Experimental treatments consisted of 5 salinity concentrations (0, 50, 100, 150 and 200 mM NaCl) and 3 Zn concentrations (3.85, 7.70 and 11.55 μM ZnSO_4). Two weeks after salt stress application, the plants were harvested and concentrations of Na, K and Zn were determined.