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Salinity-Induced Alterations in Cations Uptake And Their Mitigation By Exogenous Treatments In Wheat Seedlings

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Abstract: Salinity poses a danger to the production of wheat (Triticum aestivum L.), by impacting plant growth and productivity. Deficits in vital minerals like potassium (K^+) and calcium (Ca^{2+}) result from the buildup of sodium (Na^+) and chloride (Cl^-) ions in salty soils, which impairs nutrient absorption. To mitigate salinity-induced decrease in mineral content in wheat seedlings, this study examines the ameliorative effects of growth regulators, specifically gibberellins (GA) and cytokinins, in combination with potassium (K^+) and calcium (Ca^{2+}) supplementation. It was discovered that cytokinins and gibberellins improved mineral uptake under salt stress by promoting stress tolerance, nutrient translocation, and root development. Furthermore, the application of exogenous potassium and calcium led to the restoration of ionic balance, a decrease in Na^+ toxicity, and an overall increase in seedling vigor. Seed priming with plant growth regulators and minerals helped to improve the level of nutrients in wheat seedlings under saline conditions.

Keywords: Wheat, seedling, salinity, minerals, plant growth regulators

I. INTRODUCTION

One of the main abiotic stressors that negatively impacts plant growth and yield, especially in the young seedling stage, is salinity. Excessive levels of salinity in the substrate can cause toxicity, osmotic stress, and ionic imbalance, all of which have an adverse effect on the mineral nutrition content of seedlings. An accumulation of sodium (Na^+) and chloride (Cl^-) ions occurs frequently in plants exposed to salinity; these ions compete with vital nutrients including potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}) for absorption, leading to nutritional shortages and altered ion ratios (Munns and Tester, 2016). The perturbation of nutritional equilibrium is of utmost importance as it has a direct impact on crucial physiological mechanisms, including membrane stability, enzyme activities, and general metabolic processes that are required for the growth of seedlings (Gupta and Huang, 2017). Furthermore, because of alterations in soil chemistry and the dynamics of competitive uptake at the root-soil interface, salt stress can hinder the absorption of essential macro-elements like Potassium (K^+), Calcium (Ca^{2+}) and micronutrients such as iron (Fe), manganese (Mn), and zinc (Zn) (Acosta-Motos *et al*., 2017, Landi *et al*., 2021, Nounjan *et al*., 2021). Because of this, seedlings cultivated in salinity frequently show decreased growth, chlorosis, and a decreased total mineral content, which impairs the growth of plants (Arif *et al*., 2020). Because certain varieties have evolved ways to handle greater salinity levels by either rejecting harmful ions or compartmentalizing them within vacuoles, the magnitude of these effects can vary depending on the species and genotype of the plant (Razzaghi *et al*., 2020). Since potassium is necessary for synthesis of proteins, enzyme activation, and systemic cellular homeostasis, the competitive absorption of Na^+ at the expense of K^+ is a major cause of cellular dysfunction in salty conditions (Shabala *et al*., 2021). Furthermore, excessive salinity-induced osmotic stress hinders nutrient translocation within the plant and reduces water intake, which exacerbates mineral deficits (Parihar *et al*., 2022). To counteract the detrimental effects of salinity on mineral content, salt-tolerant genotypes frequently use processes such as ion compartmentalization, selective ion absorption, and increased antioxidant activity (Amini *et al*., 2021, Roy *et al*. 2022). To generate crops that can flourish in saline soils, which are becoming more and more common because of irrigation practices and climate change, the breeding and biotechnological approaches must comprehend these mechanisms (Yuan *et al*., 2021). Due to its heightened sensitivity to elevated salt concentrations during the seedling stage, wheat (*Triticum aestivum* L.) is especially vulnerable to salinity stress, which is a significant factor affecting agricultural production. Wheat seedlings grown in salinity frequently display stunted growth, chlorosis, and dramatic reductions in the absorption of vital minerals like potassium (K^+), calcium (Ca^{2+}), and micronutrients (Yadu *et al.,* 2023). The application of growth regulators and vital nutrients, which can improve the plant's physiological and biochemical resilience in salt environments, has been the main strategy to lessen these negative consequences.

Gibberellins (GA) and cytokinins, two growth regulators, have demonstrated great potential in reducing stress brought on by salinity. Gibberellins have the ability to increase cell division and elongation, which enhances root growth and makes it easier for plants to absorb nutrients even in saline environments (Tiwari *et al.*, 2023). On the other side, cytokinins aid in the preservation of chlorophyll content, postpone senescence, and enhance nutrient translocation, all of which enable stressed seedlings retain their ideal mineral content (Kaur and Singh, 2023). The adverse effects of salinity can be lessened by the exogenous administration of these hormones, which can also strengthen the antioxidant defense system, lower ion toxicity, and improve nutritional balance.

Furthermore, it has been discovered that nutrient imbalances caused by salinity can be counteracted by feeding wheat seedlings with potassium (K^+) and calcium (Ca^{2+}). According to Ashraf *et al.* (2023), potassium is vital for osmotic adjustment, enzyme activity, and turgor pressure maintenance, all of which are necessary for plant life under salt stress. In signaling pathways that control stress responses and stabilize cell membranes, calcium acts as a secondary messenger and lessens the harmful effects of Na^+ and Cl^- ions (Shahbaz *et al.*, 2023). In addition to improving general seedling vigor in saline settings, the addition of these vital nutrients can help restore ionic equilibrium, boost nutrient uptake, and improve overall development when combined with growth regulators.

II. MATERIAL AND METHODS

Mineral Estimations: The mineral estimations of seedlings were done after 96 hours of sowing. Radicle, coleoptile and endosperms were dried in oven before digestion. 70 mg of dried and well ground material was acid digested in 5ml of 9:1 H_2SO_4 and $HClO_4$ mixture and diluted with 25 ml distilled water. Sodium and Potassium: Sodium and potassium were estimated in the above acid digest with a flame photometer using standard KCl for potassium and NaCl for Sodium. For standard, 1000 ppm solution was prepared by dissolving 2.542g NaCl + 1.909g KCl in 1000 ml of distilled water and further working dilutions were made from it. The values were calculated and expressed as mg/g tissue dry wt. Calcium and Magnesium: Calcium and Magnesium were estimated by EDTA titration (USDA Handbook No. 60, 1954).

III. RESULTS AND DISCUSSION

A. *Sodium Content*

Sodium content in radicle, coleoptile and endosperm of 96h old seedlings showed a sharp increase with increment in salinity regimes (Fig. 1). All the seed priming treatments proved beneficial in reducing the Na^+ content, but it was observed that under unstressed conditions Ca^{2+}+ GA_3 was best, while maximum reduction in sodium content under salt stress conditions was found with K^++GA_3+CK.

B. *Potassium Content*

Potassium content of radicle, coleoptile and endosperm declined with increasing salinity regimes (Fig.2). The decline was drastic in endosperm and radicle. However, coleoptiles possessed the highest K^+ content of all organs studied. Seed soaking treatments with nutrients and growth regulators greatly boosted the contents of K^+ in all organs. However, K^+ treatment had the highest efficacy although K^++GA_3 nearly attained the same content as with K+ alone. All the interactions were insignificant.

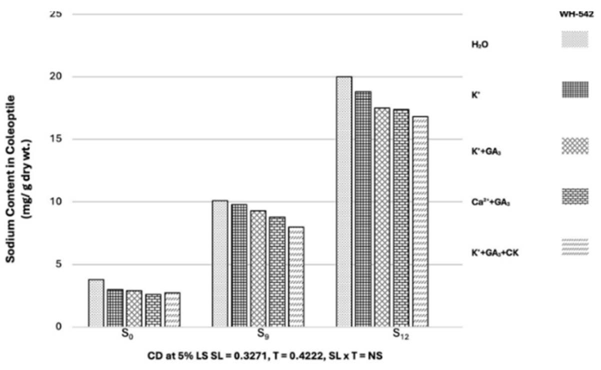

Fig 1(a) Sodium Content in Coleoptile

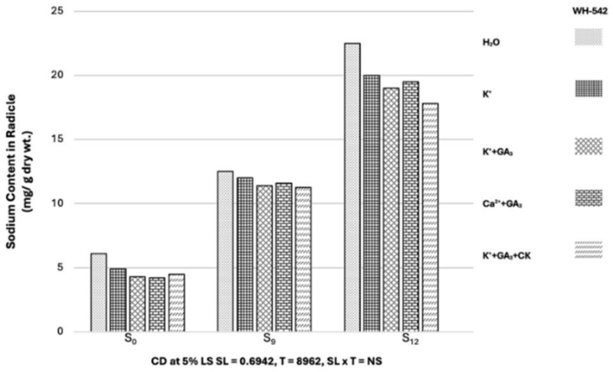

Fig 1(b) Sodium Content in Radicle

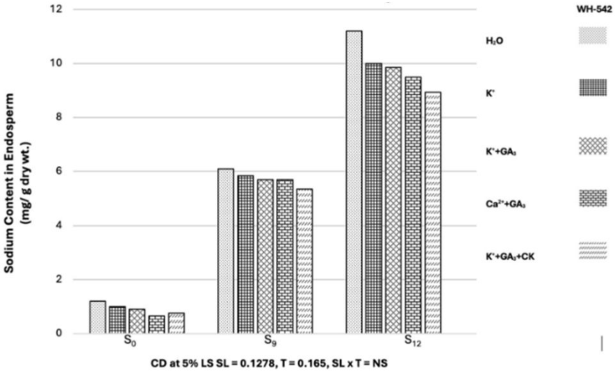

Fig 1(c) Sodium Content in Endosperm

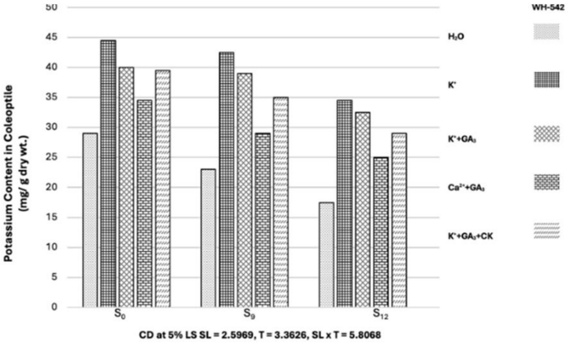

Fig 2(a) Potassium Content in Coleoptile

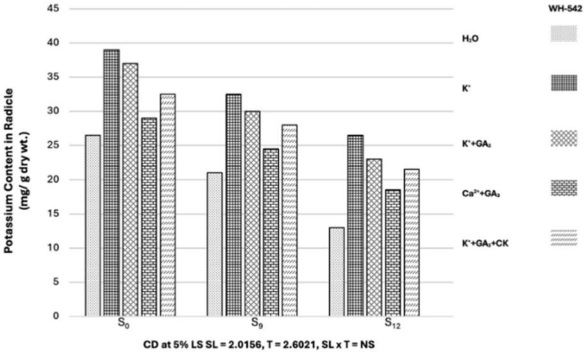

Fig 2(b) Potassium Content in Radicle

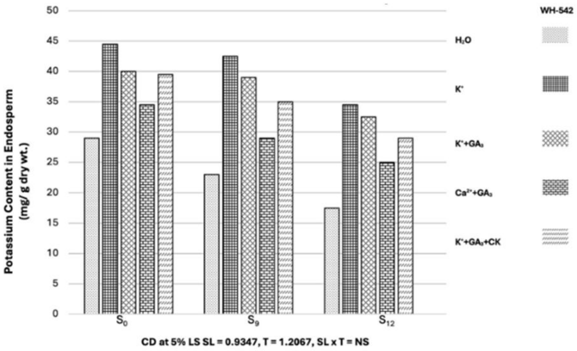

Fig 2(c) Potassium Content in Endosperm

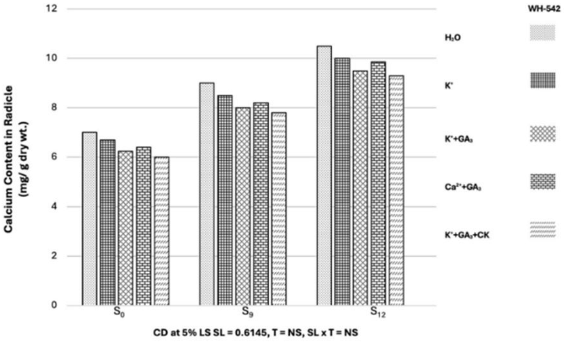

Fig 3(a) Calcium Content in Coleoptile

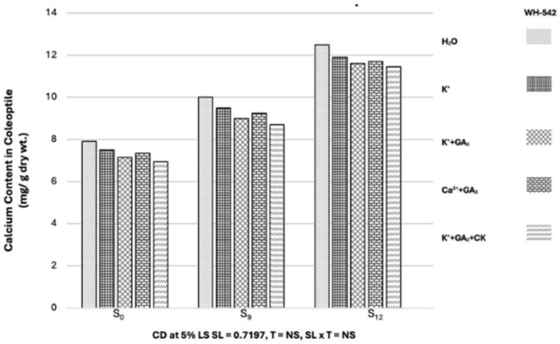

Fig 3(b) Calcium Content in Radicle

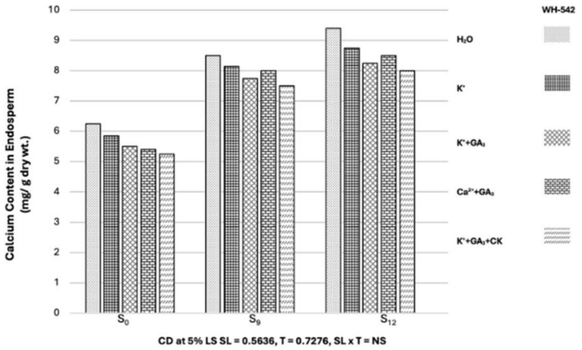

Fig 3(c) Calcium Content in Endosperm

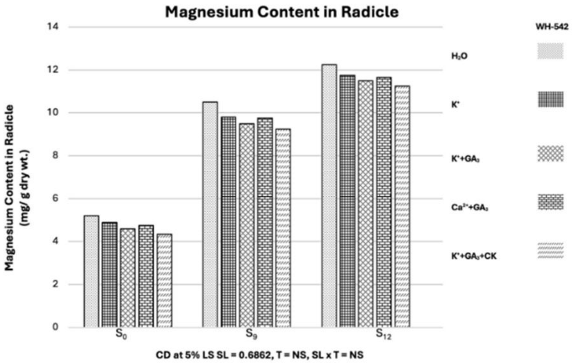

Fig 4(a) Magnesium Content in Coleoptile

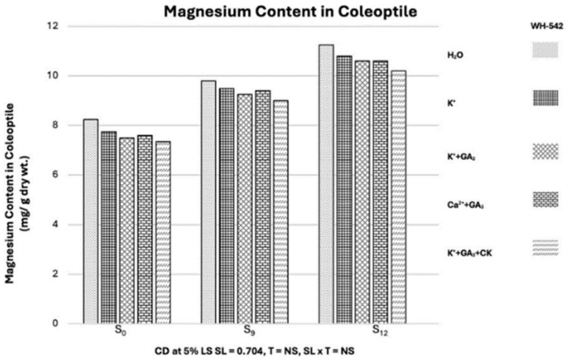

Fig4(b) Magnesium Content in Radicle

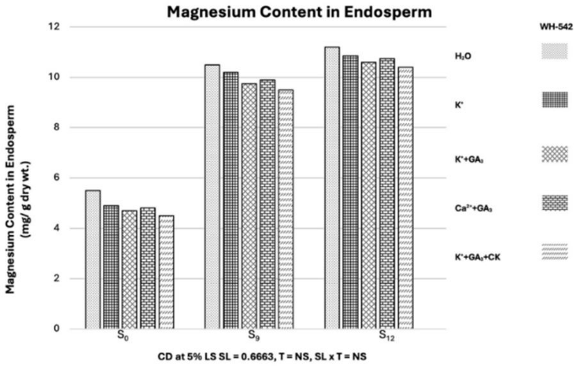

Fig 4(c) Magnesium Content in Endosperm

Salinity enhanced sodium rather sharply in all the organs studied, however the increase was more in radicle than coleoptile (Fig.1). Contrary K content was reduced in the seedling (Fig.2). This antagonism between Na and K accumulation was well documented sharma et al 1996 in wheat. Under salt stress, the increased Na+ content disturbs the nutrient balance and osmotic regulation and causes specific ion toxicity under saline conditions Joshi, 1984. The low K^+/Na^+ ratio did indicate the preferential uptake of Na^+ over K^+ under saline conditions.

Different seed priming treatments reduced the accumulation of Na^+ (Fig.1) and improved the K^+ content (Fig.2) in seedling under non saline and saline conditions, this may be due to the fact that with seed soaking treatments, selectivity for Na^+ over K^+ decreased as compared to untreated seedlings. Ashraf *et al*., 2023 represented that high concentration of K^+ in the growth medium enhanced the uptake and transport of K^+ i.e. enhanced the concentration of K^+ and concomitantly reduced Na^+ concentration leading to higher K^+/Na^+ ratio.

C. Calcium Content

Reduction in Ca content in radicle, coleoptile and endosperm with increasing Cl^- dominated salinity levels were observed (Fig 3). Coleoptile registered the highest Ca content. Similarly, nutrients and hormones treatments enhanced the Ca content. The treatment of Ca^{2+}+GA_3 registered the highest Ca content amongst the treatments. It may be noted that the interaction amongst treatments and salinity levels were significant.

Results shown in Fig. 3 clearly depict that calcium content decreased with increase in salinity level. Further, calcium content was found more in coleoptile than radicle and endosperm. Salinity reduced calcium content less in coleoptile than in endosperm and radicle. Shahbaz et al, 2023 also explained the beneficial role of Calcium in nutrients homeostasis under salt stress in wheat

D. Magnesium Content

The magnesium content of radicle, coleoptile and endosperm was enhanced with increase in salinity levels in all the above organs (Fig 4). However, pre-sowing seed soaking with nutrients and hormones registered a decline and the depletion was emphatically more with K^++GA_3+CK treatment in all the organs studied. It may be noted here that coleoptile, in general denoted comparatively high Mg level. More Mg content with increasing salinity could accrue from reduced lengths of radicle and coleoptile and with treatments the decline in Mg could be the resultant of its high utilization with nutrients and hormones.

Various seed priming treatments of growth regulators (GA_3 and CK) and minerals (K^+, Ca^{2+}) were found beneficial in mitigating the salt induced adverse effects on the content of various cations. These results were in accordance with many research workers. Kaur and Singh (2023) reported that in wheat seedlings, kinetin treatment reduced transport of salt ions from root to shoot. Tiwari et al, 2023 also observed increase in nutrient uptake with increase in salinity in wheat seedlings. The beneficial effects of growth regulators might at least partly be due to changes in the membrane permeability and selectivity in favour of nutritional ions rather than toxic ions.

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