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Research Article

Potassium induced metabolic changes with or without NaCl salinity in maize plants growing in aridlands

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ABSTRACT

This study aimed to determine whether the application of different potassium salts (KCl, K2SO4, KNO3, KH2PO4) can alleviate the NaCl induced salinity in maize plants. NaCl stress decreased maize morphological parameters versus the control. NaCl combined with different type of potassium supplements were not significantly increased the root and stem length versus treatments with NaCl. However, a decrease in chlorophyll 'a', 'b', and total chlorophyll concentrations have been noted in the NaCl stressed plants when compared to control. The chlorophyll content rose with age in the leaves of control and treated plants. When compared to NaCl stressed plants, the chlorophyll content was higher in the NaCl with different types of potassium. Proline content increase in Maize plants under treatment with NaCl when compared to the control. To provide stress protection, several types of potassium are added along with NaCl to further reduce the proline concentration. Compared to the control, the phenol content of Maize plants treated with NaCl marginally increased. The phenol concentration was further raised by the addition of various potassium types along with NaCl, providing additional stress protection. The present study; therefore, suggests that exogenous potassium salts confers tolerance to salt stress to maize plants and have a significant role in partial alleviation of salinity stress especially in arid and semi-arid regions. Keywords: salinity, potassium salt, alleviation, biochemical, pigments.

INTRODUCTION

Soil salinity is an abiotic stress that reduces growth and development in plants. It represents an increasing threat to agricultural production throughout the world mainly in the arid regions [1]. Huge rise in world population and increasing rate of urbanization have forced farmers in searching of more and more productive lands that in turn utilizing marginal lands with saline water, and it forced to study the effects of salinity on crops [2]. Worldwide, there is large agricultural areas being irrigated and, although drainage is an important component of irrigation, only limited areas are drained and which creates salinity problems [3].

In arid and humid regions of the globe, farmer's practice of using poor irrigation water is also increasingly threatening agriculture [4]. Salinity is a serious problem for commercial agriculture, particularly in arid and semi-arid regions because most of the agricultural plants are salt sensitive. Higher plants are poisoned by soil with high sodium (Na^+) concentrations [5]. Osmotic stress due to drought and salinity is also a serious problem in agriculture as it reduces the crop productivity [6]. Excessive NaCl causes diverse reactions in plants, including morphological, physiological, and metabolic alterations. Many of the plant developmental processes are affected by salt stress in all growth stages [7].

Uncertain mechanisms of salt tolerance can be partially explained by effectors of stress adaptation that control ion homeostasis, osmolyte production, toxic radical scavenging, water transport, and coordination of long-distance responses [8]. Osmotic adjustment is often all plants' first response to salt stress. It is thought that the buildup of compatible solutes in the cytoplasm contributes to salt tolerance. Plants produce and accumulate suitable osmolytes like proline (PRO), which is involved in the osmotic adjustment, to counteract salt stress and increase their cells' osmotic potential [9].

Usually, farmers do leaching techniques and other agronomical crop managements for reducing salinity effects in agricultural lands, but these practices always not turn into success [10]. Additionally, water shortages due to economic factors may push farmers to use more water of lower quality in terms of salt content. Although it is not a permanent fix, increasing plant resilience to soil salinity may offer an option. Treatments using growth regulators have been reported to lessen the negative effects of salt [11]. Many crops grow and yield significantly more when plant growth regulators are used in stressful environments, but adding potassium supplements to stressed plants has received less attention. The addition of potassium supplements (by foliar application) to irrigation water is one potential strategy for minimizing the impact of salinity on plant productivity [12]. Winter wheat grain yield was shown to increase and leaf senescence to be delayed by foliar application of K^+ [13].

This study aimed to determine whether foliar spray of potassium salts can alleviate the salt stress in maize (*Zea mays*) plants in terms of morphological parameters, photosynthetic pigments contents and biochemical constituents.

MATERIALS AND METHODS

Horticulturally important vegetable plant species, Maize (*Zea mays*) (Family: Poaceae) was selected for the present investigation. The seeds were locally purchased. The NaCl was obtained from the Horticulture Lab of Faculty of Food and Agriculture, UAEU.

The research's experimental component was conducted at the UAEU Faculty of Food and Agriculture's Al-Foah Experimental Station. The methods used are explained in the paragraphs that follow.

The plants were grown in Al-Foah Experimental Station, part of UAEU's Faculty of Food and Agriculture. To ensure good germination, the seeds were spread separately in raised seedbeds and covered with fine soil.

The treatments were divided into 6 sections. They were, Control, NaCl, NaCl +Foliar spray of potassium salts (KCl, K_2SO_4, KNO_3, KH_2PO_4). 50 pots were selected for each treatment. Before transplating, the pots were irrigated with the respective treatment solutions. Control plants were irrigated with well water.

Every effort was made to prevent leaching as three plants were planted in each pot, which was then irrigated to the field's capacity with deionized water up to 45 days after planting (DAP). To reduce spatial effects in the greenhouse, the placement of each pot was planned out at intervals of eight sections. On 90 DAS, plants were randomly removed in order to study growth, pigment content, and biochemical components.

Growth parameters

The height of the plant, stated in centimeters, was calculated from the soil line to the end of the shoot. The length of the plant's roots, stated in centimeters, was calculated from the first cotyledonary node's point to the tip of the longest root.

Fresh weight was calculated using an electronic balance and figures were quoted in grams after the plants were washed in tap water. The plants were dried for 24 hours at 60°C in a hot air oven after being given a fresh weight. The weight was measured after drying, and the values were given in grams.

Estimation of photosynthetic pigments

Chlorophyll was extracted from the leaves and estimated by the method of Arnon [14] and expressed in milligram per gram fresh weight.

Biochemical analysis

Proline content was estimated following the method of Bates et al. [15] and the results were expressed in mg per g dry weight.

Total phenol was estimated by the method of Malick and Singh [16] and were expressed in milligrams per gram fresh weight.

Statistical analysis

Statistical analysis was performed by following standard procedures.

RESULTS AND DISCUSSION

Economically important vegetable plant species Maize was selected for the present investigation. Pot culture experiments were conducted to identify the stress mitigation action of different type of potassium supplement (foliar) on NaCl stressed plants. In this experiment variation in growth, photosynthetic pigments and biochemical constituents were studied.

Morphological parameters (Fig. 1-3)

Compared to the control, maize plants under NaCl stress had shorter roots and stems. In comparison to treatments using NaCl, the addition of several types of potassium supplements did not appreciably lengthen the roots and stems. Salt stress reduced the shoot and root fresh weight. The application of K salts to the stressed plants have no significant effects.

Compared to the control, NaCl shocks reduced the root and stem length and DW of Maize plants. Compared to treatments with NaCl alone, potassium compounds enhanced the length of the roots and stems. By changing the external water potential, raising ion toxicity, or generating an ion imbalance, salinity can hinder root growth [17], and can impose biochemical restraints on cell wall expansion, which in turn can inhibit root growth [18].

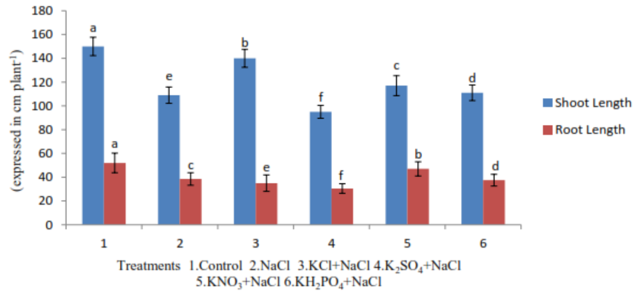

Fig. 1. Effect of foliar spray of potassium salts on shoot and root length of salt stressed maize (*Zea mays*).

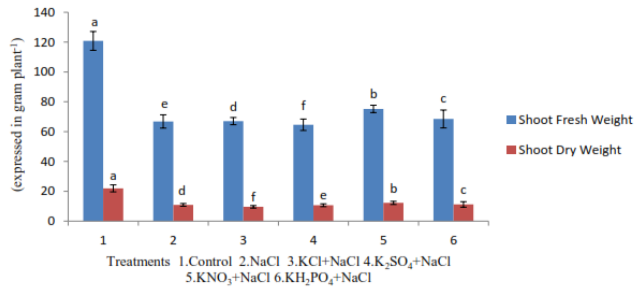

Fig. 2. Effect of foliar spray of potassium salts on shoot fresh and dry weight of salt stressed maize (*Zea mays*).

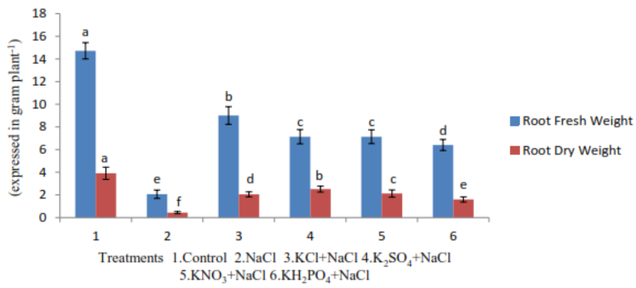

Fig. 3. Effect of foliar spray of potassium salts on root fresh and dry weight of salt stressed maize (*Zea mays*).

Biochemical contents

The amount of chlorophyll in leaves of control and treated plants rose with age, while a decrease in chlorophyll 'a', 'b', and total chlorophyll contents was seen in the NaCl stressed plants when compared to the control (Fig. 4). The NaCl with different type of potassium increased the chlorophyll content when compared to NaCl stressed plants.

Proline content decrease in Maize plants under treatment with NaCl when compared to the control (Fig. 5). Addition of different type of potassium together with NaCl decrease the proline content further, to confer stress protection.

Compared to the control, the phenol content of Maize plants treated with NaCl marginally increased (Fig. 6). The phenol concentration was further raised by the addition of various potassium types along with NaCl, providing additional stress protection.

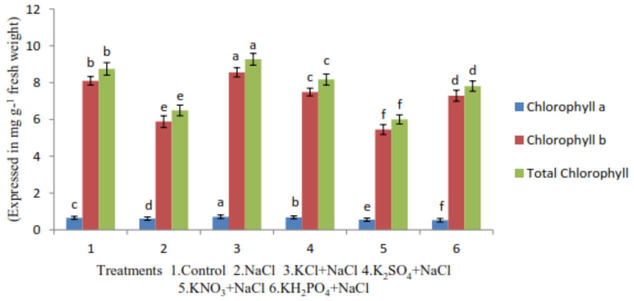

Fig. 4. Effect of foliar spray of potassium salts on photosynthetic pigment contents in maize (*Zea mays*) under salt stress.

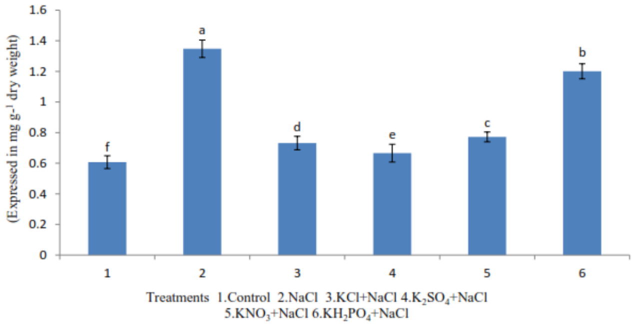

Fig. 5. Effect of foliar spray of potassium salts on proline contents in maize (*Zea mays*) under salt stress.

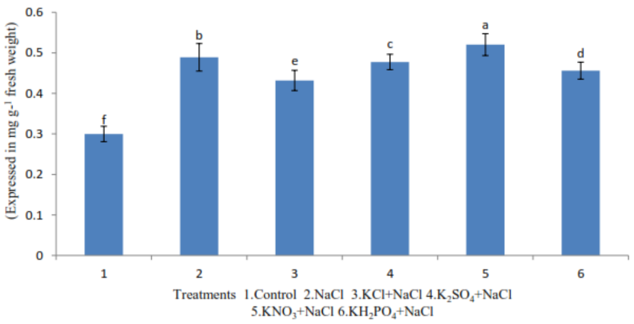

Fig. 6. Effect of foliar spray of potassium salts on phenol contents in maize (*Zea mays*) under salt stress.

The breakdown of the chlorophyll pigments and the instability of the pigment protein complex have both been suggested as causes for the decrease in leaf chlorophyll under salinity. In addition, rather than the degradation of chlorophyll, it is thought that salt ions are interfering with the *de novo* synthesis of proteins, the structural component of chloroplast [19].

Salt stress alters gene expression in the majority of plants, increasing the production of osmoregulators and osmoprotectors [20]. The primary physiological mechanism by which plants respond to soil-salt stress is osmotic adjustment [21]. The buildup of free proline and soluble sugar in the leaves during stressful conditions is crucial for plant adaptability [23]. Most plants respond to salt stress by accumulating more amino acids and amines in their tissues. The manner in which these compounds are accumulated varies between species and can include the accumulation of a single component or a number of them. When grown in moist, non-saline soils, plant species that collect proline typically have modest levels of this amino acid; nevertheless, when drought or salt conditions are applied, their contents rise [24].

Salinity treatment increased the proline contents of all parts of the plants to a larger extent. Similar observations were made in NaCl-treated soybean [25], barley [26] and sorghum plants [27]. Potassium salt spray reduced this proline accumulation to only a limited extent. However, plants under NaCl stress contained more proline than the control group did. These outcomes support the findings of Yazici et al. [28], who discovered that salt-stressed *Portulaca oleracea* seedlings treated with stress mitigators had an increase in the concentration of osmolytes. But when compared to the control, potassium spray on maize plants enhanced the proline content. A recent study showed that application of potassium fertilizers would minimize the adverse effects of salinity stress.

CONCLUSION

Based on the results obtained, it can be concluded that potassium salts application can reduce the deleterious effects of NaCl stress in maize plants. So, the cultivation of maize in saline dry areas can be possible with the foliar supplementation of potassium salts, but, this idea should be tested in field conditions also. Field experiments with more number and varieties of maize plants with different doses of potassium salts are needed to further support this conclusion.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS CONTRIBUTIONS

C. A. J. planned the study, participated in lab works and interpretation of data. S. A. S. A. S. and S. S. S. A. S are students and they worked on this study as part of their senior project research, they participated in sample collection, lab works, G. A. R. assisted in lab works and analysis of data and K. S. S. participated in interpretation of data helped in manuscript preparation.

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