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FOLIAR SPRAY OF MINERAL ELEMENTS ANTAGONISTIC TO SODIUM — A TECHNIQUE TO INDUCE SALT TOLERANCE IN PLANTS GROWING UNDER SALINE CONDITIONS

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Abstract

Plants growing in saline substrates show deficiencies in absorption of some essential mineral elements through roots due to presence of excessive sodium in the rhizosphere. Sodium being antagonistic to other cations does not let them enter in roots and hence apart from its own toxicity in metabolism**,** the plants suffer with deficiencies of some mineral elements necessary for growth. Potassium an essential mineral element is much affected due to this antagonistic behavior of sodium ion. *Lagenaria siceraria* being a broad leaf vegetable was selected for these experiments. Plants growing at saline substrate was sprayed with specially prepared spray material containing different dilutions of potassium nitrate. The anatomy of leaf with special reference to that of stomata was also studied to ensure absorption of required minerals. Plants were grown in Lysimeters filled with sandy loam and irrigated with 0.2% (EC iw 3.4 dSm^{-1}) and 0.4% (EC iw 6.1 dSm^{-1}) dilutions of sea salt. They were further subjected to four treatments viz., i) non - spray, ii) foliar spray with water, iii) foliar spray with 250 ppm KNO_3, iv) foliar spray with 500 ppm KNO_3 respectively. Those sprayed by 250 ppm KNO_3 under saline conditions not only inhibited toxic effects of salt on fruit formation, but also increased their production 76.91 % by weight per plant, Spray with higher concentrations of KNO_3 did not show much benefit.

Introduction

Salinity is an environmental stress that limits growth and development of plants. Excessive sodium present in the rhizosphere, apart from it's own toxic behavior in plant metabolism, causes physiological droughts. Being antagonistic to other cations, sodium inhibits their entry in root system; hence plants suffer deficiency of other mineral elements, which are essential for growth. An immediate response of salinity induced water potential imbalance is closure of stomata, which on one hand effects on the carbon fixation in leaves and on the other causes deficiency of same essential minerals with specific reference to monovalent potassium cation required for enzyme activation and membrane transport.

The above-mentioned problem created by presence of excessive sodium in root zone could be avoided if potassium is provided through foliar spray to the plants. Supply of essential trace elements through foliar spray is well documented in literature (Banger *et al*., 1991). Hence including potassium in foliar spray medium for the plants raised under saline condition would be of great interest. Presence of broad leaves with hairs (trichomes) are expected to provide better opportunity for retaining film of water spray and make minerals available for stomatal absorption. *Lagenaria siceraria* of the family Cucurbitaceae was selected in the present study. Further more, being a vegetable plant of about 4 month growing period, the results will be available within short time.

Material and Method

Study of salt tolerance during germination stages is the first step to look into growth of any plant under saline environment. The effect of various levels of salinity levels given through dilutions of the sea salt was studied at germination stage in Petri plates. Since establishment of seedlings was found very poor in saline soil at 0.5% sea – salt level (E.C iw 7.3 dSm^{-1}), further experiment were conducted at the levels of 0.2% (E.C iw 3.4 dSm^{-1}), and 0.4% (E.C iw.6.1 dSm^{-1}) only.

Experiment on growth was conducted in lysimeters (drum pot culture) which was designed by Boyko (1966) and further modified by Ahmad & Abdullah (1982). Sets of 48 plastic drums were installed at cemented platform in a slightly slanting position, baring a basal outlet for draining excess amount of water. They were filled with 300 kg of costal sand each, capable of retaining 45 L of water at saturation. Any additional amount of water easily leaches out from the drainage outlet. The practice of over irrigation avoids salt accumulation in the rhizosphere.

Experiments were divided into four sets, viz.,

i. Non-spray
ii. Foliar spray with water
iii. Foliar spray with 250 - ppm KNO_3
iv. Foliar spray with 500 - ppm KNO_3

Out of a total of 36 drums, 9 drums were used in each set, comprising of three different irrigation regimes given to three drums under each treatment viz., i) Non-saline water ((E.C 0.5 dS, m^{-1}), ii) 0.2%: sea-salt solution (E.C 3.4 dS, m^{-1}), iii) 0.4%: sea-salt solution (E.C 6.1dS, m^{-1}). Five seeds of *Lagenaria siceraria* were sown in each drum pot irrigated with non- saline water. Irrigation with gradually increasing concentrations of sea- salt in irrigation water was started in plants at five leaf stages (including cotyledonary leaves) and continued till it reached to the salinity levels of 0.2% and 0.4%. Three plants were kept in each drum. N.P.K (1: 2: 1) was given in three split dozes. Insecticide and fungicide was used whenever needed.

Observations on the following parameters were recorded

1. Total area of all leaves of a plant undergoing different treatment was measured at grand period of growth using graph paper.
2. Length and breadth of stomatal pore were seen under microscope
3. Fresh weight of fruits of each plant was taken at final harvest.

Results and Discussion

The extent of salt tolerance differs in plants at different stages of vegetative and reproductive growth. Germination is most crucial stage for glycophytes in this regard. About 60% seeds of *Lagenaria siceraria* germinated in 0.4% sea-salt dilution (EC = 6.1 dSm^{-1}) in Petri plates experiment whereas it was very poor beyond this concentration (Fig. 1). Seedling establishment was reduced to about 30% only in soil made saline by 50% sea-salt concentration (EC = 7.3 dSm^{-1}). Growth and development was noted in irrigation water in the levels of 0.2% (EC = 3.4 dSm^{-1}) and 0.4% (EC = 6.1 dSm^{-1}) sea

salt salinity. The mean values of replicates with reference to effects of foliar spray of KNO_3 on total leaf area and fruit weight per plant of *Lagenaria siceraria* (vern. Lauki) grown through saline water irrigation is given in Fig. 3 and 4. Details on the percent increase / decrease under different treatments is presented in Table 1a, b, c. Application of foliar spray of potassium given through potassium sulphate has been reported in rice to increase tillers per plant, grain straw ratio and yield significantly at saline soils EC = 6.0 and 12 .0 dSm^{-1} (Din. *et al*., 2001).

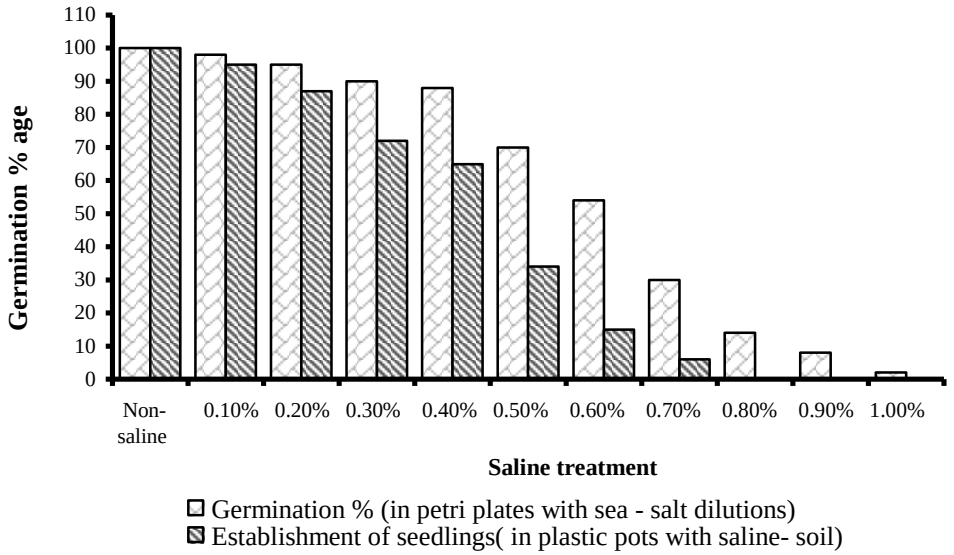

Fig. 1. Germination % and seedling establishment of *Lagrnaria siceraria* under saline condition.

It may be noted that plants of family Cucurbitaceae are considered moderately salt tolerant. The threshold values of *Cucurbita pepo* var. Squash, Scallop EC iw = 3.2 dSm^{-1}, (Mass, 1986). Minhas & Gupta, (1993) found reduction of 10% yield at EC iw =2.0 dSm^{-1}, 75% at EC iw =4.7 dSm^{-1} in Bottle gourd (c. *Lagenaria*). In our studies it was observed that fruit weight per plant was reduced by 22.15% at 0.2% and by 54.78 % at 0.4% dilutions of salt irrigation (Table 1-a, b, c), where as foliar spray of 250 ppm KNO_3 not only suppressed the inhibitory effect at 0.2% sea salt irrigation level but increased the fruit weight by 76.91 % per plant. Increasing concentration of KNO_3 in foliar spray by 500 ppm was not of much benefit under saline water irrigation. Hence foliar spray of KNO_3 @ 250 ppm could be profitable for offsetting toxic effects of excessive sodium of rhizosphere up to a level of 3.4 dSm^{-1} salinity.

Chemical fertilizers particularly nitrogen is reported to play a crucial role in the construction of amino acid compounds and proteins (Miller & Donahue, 1990; Salisbury & Ross, 1992), whilst potassium has its role in the photosynthetic e^{*1} transport chain (Overnell, 1975; Suksri, 1998). The effect of high salinity and supplementary phosphorus and potassium on physiology and nutrition development of spinach was studied by Cengiz Kaya *et al*., (2001) also found that foliar spray of 5 mM of KH_2PO_4 alleviated the adverse effects of high salinity on plants. Anwarul Islam *et al*., (2003) used 0.1% KNO_3 as foliar spray on jute plant leaves and obtained good results whereas 250 ppm KNO_3 was good enough in the present studies.

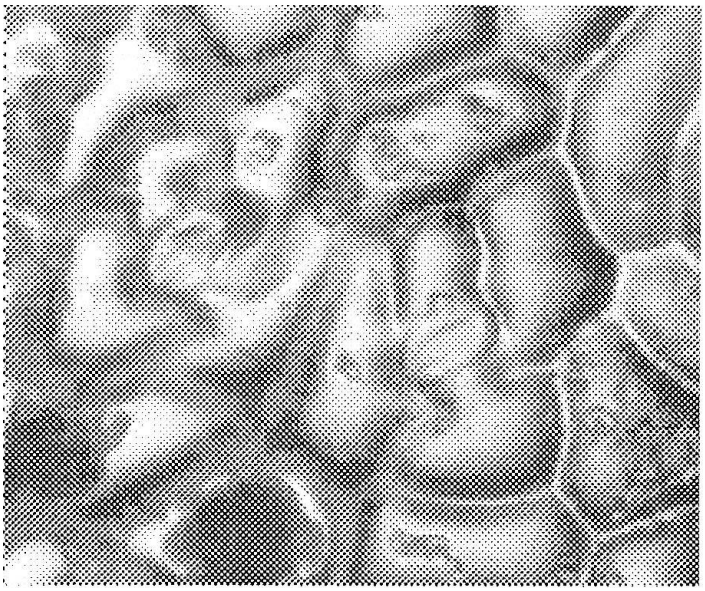

Fig. 2. Area of stomata aperture of *Lagenaria siceraria* 93,437, 500nm (length 16250nm *breadth 5750nm).

Potassium supplied through spray medium in present investigation is a monovalent cation with hydrated ionic radius of 0.331 nm; where as the area of stomatal aperture of *Lagenaria siceraria* was found 93,437,500 nm (length 16250nm and breadth 5750 nm). (Fig. 2). Hence there should not be any difficulty in its absorption through stomatal aperture and should be readily available to palisade cells for entering in metabolic pool. This will facilitate photosynthesis and provide nitrogen for amino acids and protein metabolism.

Foliar spray of nutrient did not only increase the crop yields but also reduce the quantities of fertilizer applied through soil. Foliar application can also reduce the lag time between application and uptake by the plant. Being given through spray medium of single salt composition, there is an advantage of not facing the problems of ion antagonism, which is encountered in mineral uptake through roots under saline environment. The role of potassium in ionic balance is reflected in nitrate metabolism. (Jeschke *et al*., 1985). Nitrogen being an active participant of chlorophyll and proteins is an essential element for plant growth.

Recipe of spray medium is also important in which surfactant/ adjuvant are mixed to spread the liquid on the surface of leaf and let it stay there for some time for stomatal absorption (Mengel & Kirkby, 1987). Taking two essential minerals e.g., potassium salt with nitrogen (as potassium nitrate) is of added advantage for growth. The role of potassium in ionic balance is reflected in nitrate metabolism (Jeschke *et al*., 1985). Nitrogen being is an active participant of chlorophyll and proteins is an essential element for plant growth. Hence there was considerable improvement in growth even under saline strata in present investigation.

Table 1a. Effect of Foliar spray of KNO_3 on total area of leaves and fruit weight per plant of *Lagenaria siceraria* growing under various levels of saline water irrigation.

Treatment	%Promotion & Reduction	Conclusion
	Non-saline treatment	
Non-spray	Percentages of promotion and reduction have been calculated on the basis of values given for Non-saline, Non-spray control (Fig No.3 and 4)	
Foliar spray with water only	i) Leaf area = - 0.53 %	i) Plants show insignificant reduction in total leave area. Being irrigated regularly there should not be any shortage of water in uptake through roots.
	ii) Fruit wt. = + 8.85%	ii) There is a little improvement in fruit weight per plant.
Foliar spray with 250 ppm KNO_3	i) Leaf area = + 15.99 %	i) Total leaf area has been increased upto greater extent probably due to availability of Potassium and Nitrogen increase.
	ii) Fruit wt. = + 86.91%	ii) Increase in weight of fruit per plant is maximum under above-mentioned conditions.
Foliar spray with 500 ppm KNO_3	i) Leaf area = +7.79 %	i) Increase in total leave area per plant is less than 50% in comparison with that of 250 ppm of KNO_3 spray.
	ii) Fruit wt. = + 25.18%	ii) Though fruit weight per plant has been considerably increased but it is less than the increase shown under 250 ppm KNO_3 spray.

Table 1b.

Irrigation with 0.2 % sea - salt Dilution (EC iw = 3.4 dSm^{-1})		
Non-spray	i) Leaf area = - 0.90 %	i) Plants show slight reduction in total leaves area at above mentioned salinity level.
	ii) Fruit wt. = -22.15%	ii) Weight of fruits per plant is considerably reduced at this salinity level.
Foliar spray with water only	i) Leaf area = - 0.81 %	i) Plants show slight reduction in total leaf area. Being regularly irrigated should not have any shortage of water uptake through roots.
	ii) Fruit wt. = - 15.9 %	ii) Though fruit weight per plant is considerably reduced under salinity above-mentioned level but this reduction is improved by 6.25 % in comparison with Non-spray treatment.
Foliar spray with 250 ppm KNO_3	i) Leaf area = +11.99%	i) Increase in total leaves area is evident under 250 ppm KNO_3 foliar spray in comparison with Non-spray or only water spray treatment under prevailing salinity.
	ii) Fruit wt. = +76.91%	ii) Increase in weight of fruits per plant is maximum under 250 ppm KNO_3 foliar spray in comparison with that of Non-spray or only water spray treatment under prevailing salinity.
Foliar spray with 500 ppm KNO_3	i) Leaf area = +4.46 %	i) Increase in total leaves area is nearly three times less than that of 250 ppm KNO_3 spray but it is still more than that of Non- spray or water spray treatments under prevailing salinity.
	i) Fruit w.t = + 17.95%	ii) Increase in fruit weight per plant is about four times less than that of 250 ppm KNO_3 spray but still more than that of Non spray or only water spray treatment under prevailing salinity.

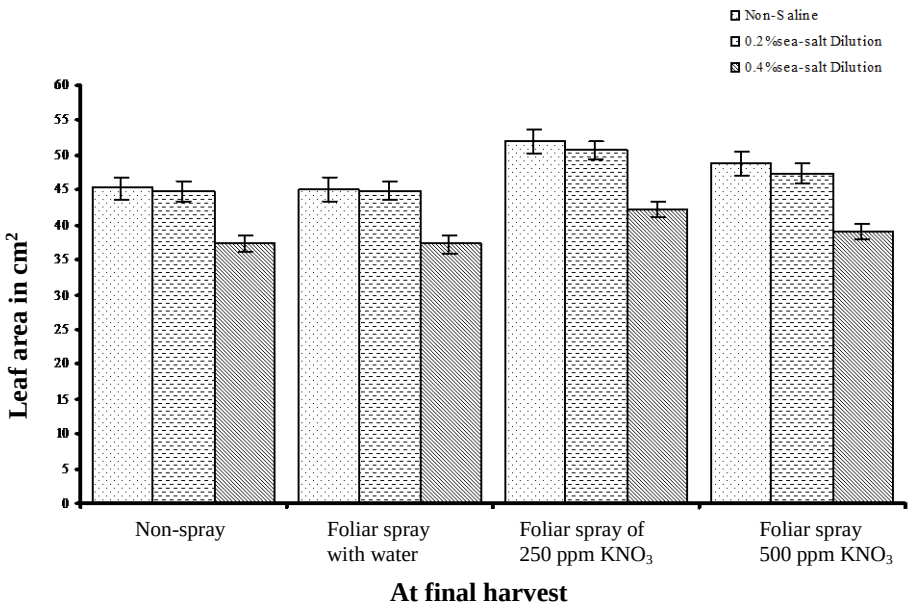

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Fig. 3. Effect of foliar spray of KNO_3 on total leaf area of *Lagenaria siceraria* (varn. lauki) grown through saline water irrigation

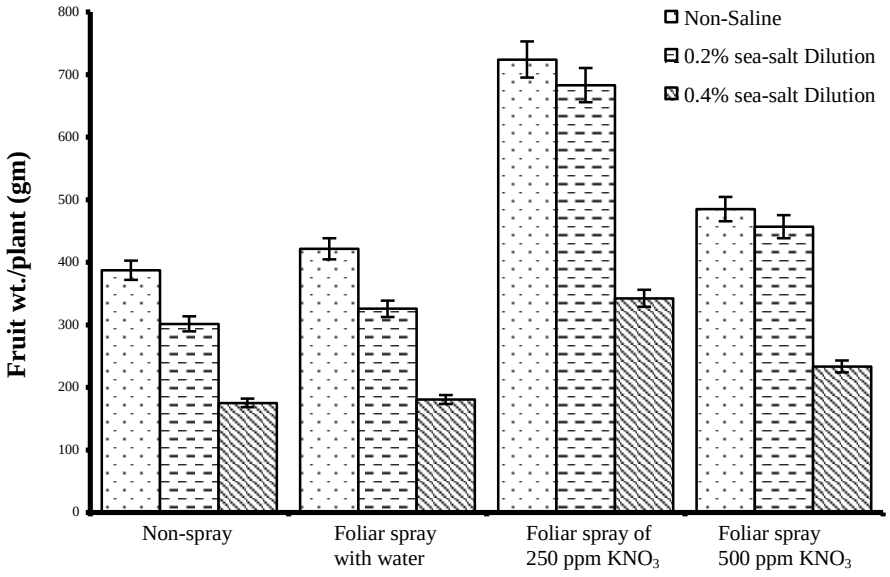

Fig. 4. Effect of foliar spray of KNO_3 on fruit weight per plant (gm) of *Lagenaria siceraria* (varn. lauki) grown through saline water irrigation.

Table 1c.

Irrigation with 0.4 % sea - salt Dilution (EC iw = 6.1 dSm^{-1})		
Non-spray	i) Leaf area = - 17.42 % ii) Fruit wt. = -54.78%	i) Reduction in total leaves area per plant is greater than that of 0.2% sea salt salinity. ii) Maximum reduction has been seen in fruit weight per plant.
Foliar spray with water only	i) Leaf area = - 17.87 % ii) Fruit wt. = -53.36 %	Situation regarding maximum reduction in total leaves area and fruit weight per plant remained same and foliar spray could not over come it.
Foliar spray with 250 ppm KNO_3	i) Leaf area = - 6.71 % ii) Fruit wt. = - 11.59 %	This treatment also could not offset toxic effects of prevailing salinity completely. However there was about 10% recovery in reduction of total leaves area and about 43 % recovery in reduction of fruit weight per plant in comparison with Non spray, or foliar spray with water only.
Foliar spray with 500 ppm KNO_3	i) Leaf area = -13.78 % ii) Fruit wt. = -39.73 %	Both the vegetative (total leaves area) and reproduction (fruit weight) growth per plant was further inhibited at this salinity even by foliar spray of 500 ppm KNO_3.

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