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ALLEVIATION OF THE ADVERSE EFFECTS OF SALT STRESS BY FOLIAR APPLICATION OF SODIUM ANTAGONISTIC ESSENTIAL MINERALS ON COTTON (*GOSSYPIUM HIRSUTUM*)

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Abstract

Experiments were carried out in drum pot culture to investigate the response of cotton (*Gossypium hirsutum)* cv. "CIM 496" grown at high salinity supplemented with foliar application of KCl (500 ppm= 500 mg/L) and NH_4NO_3 (500 ppm= 500 mg/L) alone and in mixture. Soil salinity was maintained through irrigation water of sea salt concentrations i.e., 0.4% (EC: 6.2 dS/m) and 0.8% (EC: 10.8 dS/m). Plants were tested during a period from germination to vegetative growth as well as reproductive stages. To determine effects on vegetative growth plants were harvested at grand period of growth. Reproductive parameters were mentioned in terms number of squares, flower and balls, seed and lint weight; seed number and seed cotton yield per plant. Values on above-mentioned parameters were reduced significantly at high salinity. Foliar spray of NH_4NO_3 and KCl in combination showed better result as compare to that of their individual spray. Pattern of the comparative performances at various vegetative and reproductive growth parameters under nonsaline as well as saline conditions remained same, which is produced as follows: *Non-spray< water spray< KCl<* NH_4NO_3< NH_4NO_3+ *KCl*. Foliar nutrient spray of above mentioned spray material showed beneficial effect both on vegetative and reproductive parameters in *Cotton,* under saline environment.

Introduction

Salinity is one of the key factors causing decrease in growth and productivity of almost all the crops (Szabolcs, 1994; Ashraf, 1994; 2004). An alternative approach for coping with salinity could, therefore, be to attempt to supplement essential sodium antagonistic minerals through foliar application. This idea behind the present work is to diminish effect of salinity in plant to a tolerable level. Foliar application of nutrients partially can overcome the negative effect of stress condition. (Abdullah & Mubarak, 1992; Salama *et al.*, 1996; El-Flouly & Abou El- Nour, 1998). In this respect, El-Flouly & El-Sayad (1997) have stated that foliar feeding of both macro and micronutrient helps whenever; uptake of certain essential mineral through the root system is restricted due to salt stress.

Cotton is a major cash crop grown in the plains of Pakistan. In country cotton occupies 5th and in world 3rd for its production (Makhdum, 2003). Cotton (*Gossypium hirsutum* L.) crop occupies a unique position in the agrarian economy and plays an important role in the economic viability of Pakistan. It provides raw material for the textile industry and is also a major source of high quality vegetable oil and feed for livestock. This crop is also the second source of plant proteins after soybean, and the fifth oil-producing plant after soybean, palm oil, canola and sunflower (Texier, 1993). Although it is classified as salt tolerant crop with threshold 7.7 dS/m (Maas & Hoffmann, 1977), and slope is at 5.2 dS/m yet it is sensitive at germination stage. Hence the percentage of germination is reduced and emergence of seedling is delayed under salinity (Qadir & Shams, 1997).

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Morphology and organization of cotton leaf tissue is such that it accommodates the uptake of plant nutrients. In cases where nutrients are strongly fixed by soils or uptake of certain essential mineral elements is inhibited due to presence of excessive sodium ions in rooting medium the foliar application can be adopted as a alternative fertilization measure. Cotton response to foliar nitrogen (N) fertilizer is most likely when: 1) an inadequate amount of N has been applied through soil, 2) when N is lost from the soil through leaching, denitrification, volatilization, immobilization etc. 3) when soil moisture temporarily limits N availability, 4) where irrigation or timely rainfall enhances the yield potential (Snyder, 1998).

Rosolem & Mikkelsen (1991) observed a sequence of increasing sensitivity to K deficiency in parts of cotton plant: leaves < balls < roots < stems. These results indicate that by the time the K deficiency symptoms are manifested in the leaves, all other plant parts are already affected.

Experiment in following investigations was performed to minimize the effects of root zone salinity by application of supplementary potassium and nitrogen through foliar application on cotton plants.

Materials and Methods

Drum Pot Culture technique as outlined by Boyko (1966) and later modified by Ahmad & Abdullah (1982) was used. A set of 48 plastic drums installed at cemented platform in a slightly slanting position were used in these experiments. These drums had a basal outlet for draining the excess amount of water thus minimizing accumulation of salts in the soil profile. They were filled with 300 kg of coastal sand, which was capable of retaining 45 liters of water at saturation capacity. Any additional amount of water easily leached out from the drainage outlet. The practice of over irrigation not only provided the moisture to the root system but also avoided salt accumulation in the rhizosphere.

Experiment was divided into five sets, viz.,

a. Non-spray
b. Foliar spray with water
c. Foliar spray with KCl (500 ppm)
d. Foliar spray with NH_4NO_3 (500 ppm)
e. Foliar spray with KCl (500 ppm)+ NH_4NO_3 (500 ppm)

Each foliar spray medium was amended with 10 ppm liquid soap (Nivea facial wash) as a surfactant.

Out of a total 45 drum pot 9 drums were used in each set, with three replicates each undergoing three different following irrigation treatments:

a. Nonsaline water (Control) (EC: 0.6 dS/ m)
b. 0.4% sea salt irrigation water (EC: 6.2 dS/m)
c. 0.8% sea salt irrigation water (EC: 10.8 dS/m)

The seeds of *Cotton* variety *CIM 496* were used for the current investigations. The seeds were delinted with concentrated H_2SO_4 for one minute to remove the fiber and immediately washed with running water. They were then surface sterilized with 0.1% $HgCl_2$ for 5 minutes. Since cotton seeds were found sensitive to salt at germination and emergence stage in earlier experiments reference it was decided to raise them by irrigating with nonsaline water and later subject them to various saline water irrigations.

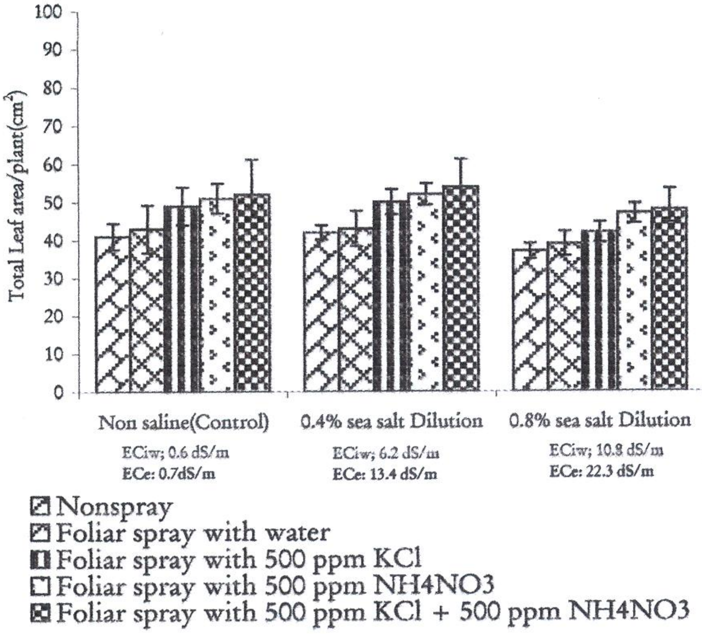

Fig. 1. Effect of foliar spray of different mineral elements and irrigation water of different salinity levels on leaf area (cm2) per plant in *Gossypium hirsutum.*

Sterilized seeds of *Cotton* were directly sown in nonsaline soil and irrigated with nonsaline water. Seedlings were thinned to one per drum pot prior to starting salinity. Since seedling was found sensitive to salinity at early stage in above mentioned seeding establishment experiment, Irrigation with gradually increasing concentration of sea salt in irrigation water was started in plant at five-leaf stage (including cotyledonary leaves) till it reached to the salinity levels of 0.4% (EC: 6.2 dS/m) and 0.8% (E.C: 10.8 dS/m). Drum was irrigated with 10 litre tap water/ salt solution twice a week. Cow dung manure was added in the soil at 9:1 ratio, whereas NPK (1:2:1) was given through urea (N), di-ammonium phosphate (DAP) and potassium muriate (MOP) in three split dozes in ratio of. Insecticide and fungicide was used whenever needed.

Few plants were harvested for measurement of vegetative performance, at grand period of growth plant biomass was recorded and leaf area was measured. Reproductive parameters were studied by counting number of squares, flower, balls and seed. Seed and lint weight and seed cotton yield per plant was recorded at termination of experiment. All the data were statistically analyzed by computer program *SPSS VERSION 11*.

Results and Discussion

The effect of different salinity levels and spray of various sodium antagonistic mineral elements on the vegetative biomass and leaf area per plant is presented in Figures 1-2. The vegetative biomass and total leaf area per plant decreased proportionally under EC: 6.2 dS/m and EC: 10.8 dS/m whereas an increase was shown by different foliar spray medium in control as well as in plants growing under saline water irrigation. The increase in mixture of foliar spray (500 ppm NH_4NO_3 and 500 ppm KCl) was more whereas, foliar spray of 500 ppm NH_4NO_3, 500 KNO_3 was less effective while water spray was least effective in improving plant biomass and leaf area under saline condition.

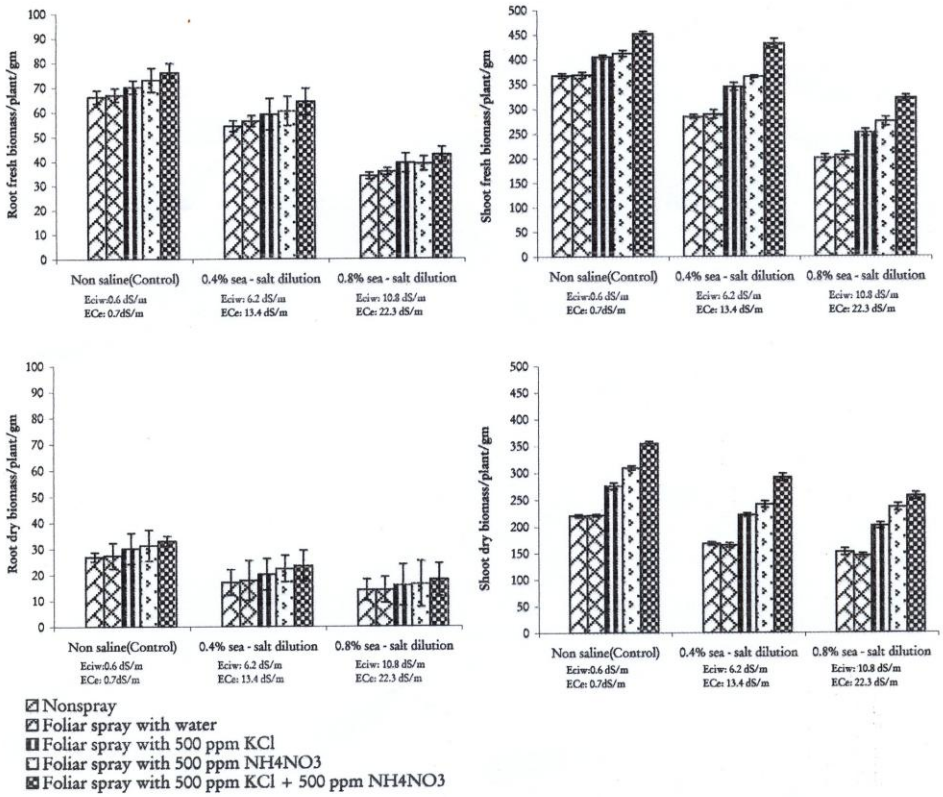

Fig. 2. Effect of foliar spray of different mineral elements and irrigation water of different salinity levels on vegetatative biomass (gm) per plant in *Gossypium hirsutum.*

Reproductive parameters presented in Figures 3-4 are based on production of total number of squares, flowers, balls and seed per plant, weight of seed and lint / per plant, seed cotton yield as a result of foliar spray of different compositions at cotton plants raised by sea salt irrigation water. Increasing salinity of irrigation water proportionally decreased the yield and all the above-mentioned parameters, which was offset upto various degree by the spray of different mineral nutrients. This effect is well documented in light of seed cotton yield, which is considered main parameter for determining economical feasibility. Foliar spray of the mixture of 500 ppm NH_4NO_3 and 500 ppm KCl was of highest order whereas, foliar spray of 500 ppm NH_4NO_3, 500 KNO_3 was less effective while water spray was least effective in improving reproductive growth under saline condition.

Pattern of the comparative performances at various vegetative as well as reproductive growth parameters due to different foliar treatments under nonsaline as well as saline conditions remained same.

The degree of reduction in growth by increase per unit of electric conductivity due to presence of salt in rhizosphere has been reported by different research workers (Maas, 1983; Mass & Hoffmann, 1977). Additionally reduction in vegetative growth under saline environment in cotton was found by Qadir & Shams (1997); Ye *et al*., (1997).

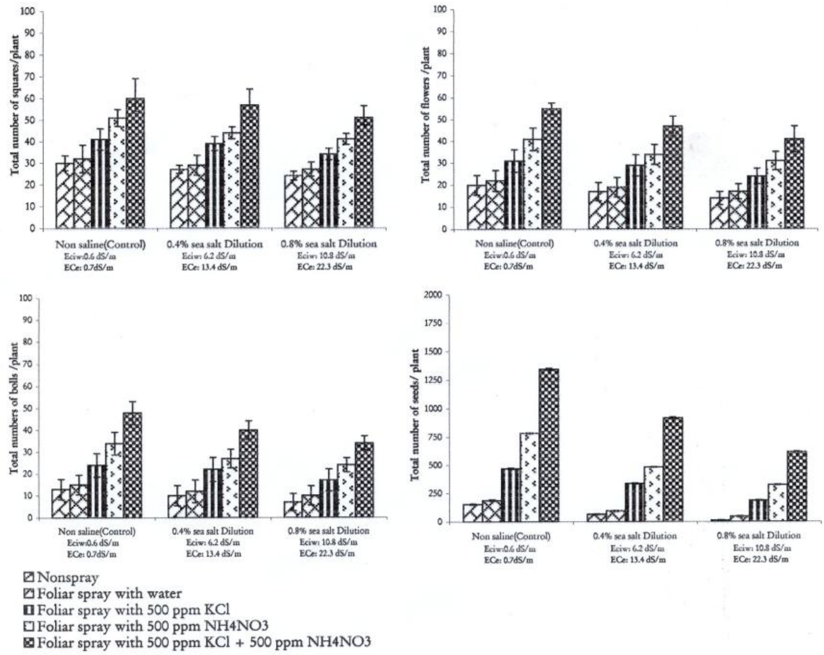

Fig. 3. Effect of foliar spray of different mineral elements and irrigation water of different salinity levels on total number of squares, flowers balls and seed per plant in *Gossypium hirsutum*.

In present investigation decrease in total leaf area and biomass production was found at EC: 6.2 and EC: 10.8 dS/m in *Gossypium hirsutum*. Huang & Redmann (1995) found that osmotic stress induced by salinity was responsible for the reduction in leaf area in canola and wild mustard. The decline in the photosynthetic activity in most glycophytes is found to be partially attributable to stomatal closure (Seemann & Chritchley, 1985), which is generally associated with salinization of salt species (Walker *et al.*, 1983). Biomass production is a measure of net photosynthesis and it is reduced by factors limiting plant growth (Reddy et al., 1997). Decrease in biomass production has also been reported in different cultivars of cotton grown at ECe: 10-20 dS/m soil salinity (Qadir & Shams; Ye *et al*., 1997).

Pattern of the comparative performances at various vegetative growth parameters in present research work under nonsaline as well as saline conditions due to foliar spray remained same; it is being produced as follows: *Non-spray<water spray<KCl*< NH_4NO_3 <NH_4NO_3+ *KCl*

Kaya *et al*., (2001) reported significant reduction in fresh biomass of Spinach significantly reduced at 60 mM salinity, but foliar sprays of 5 mM KH_2PO_4 mitigated the detrimental effect of high salt. Kaya *et al*., (2001a) reported similar results in Cucumber and Pepper, Leidi & Saiz, 1997 in Cotton; Kaya *et al*., (2007) in Melon and for Strawberry (2003) whereas foliar spray of Ca $(NO_3)_2$, $MnSO_4$ and K_2HPO_4 has been reported to partially minimized the salt induced nutrient deficiency, increased and dry matter under different salinity regimes in rice (Sultana *et al.,* 2002. Bernardo Murillo-Amador *et al.*, (2005) did not find any beneficial effect on dry matter production of the root and shoot when plant was sprayed with the foliar Ca $(NO_3)_2$ sprays. Whereas foliar spray of 250 ppm of KNO_3 was found growth promotive in *Lagenaria siceraria* (Ahmad & Jabeen, 2005).

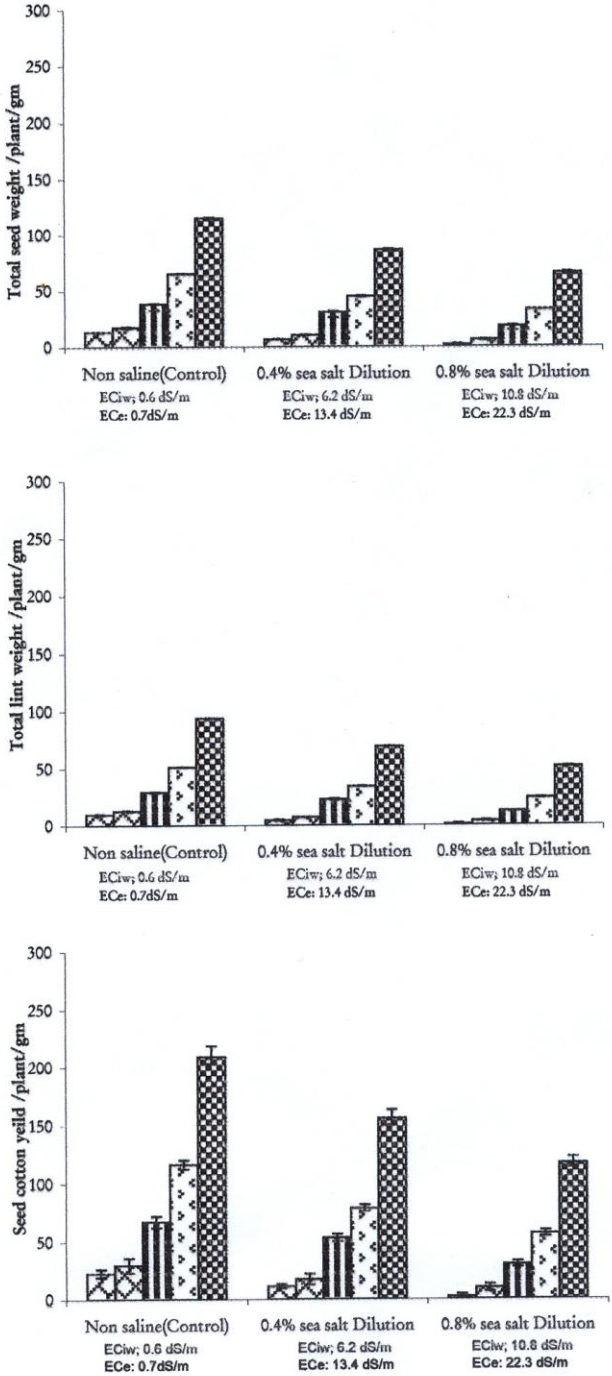

Fig. 4. Effect of foliar spray of different mineral elements and irrigation water of different salinity levels on total lint, seed weight and seed cotton yield per plant in *Gossypium hirsutum*.

Provision of nitrogen in the form NH_4NO_3 may have contributed to this better performance, as some research worker considers chlorine found in KCl being non-essential element and is considered growth inhibitor in low concentration. Chlorine ions are generally toxic to plants at relatively low concentrations and may cause irreversible damage to plant development (Welch, 1995). It is evident that salt stress has a significant effect on nitrogen nutrition in plants. Salinity reduces the uptake of NO^{-3} in many plant species mostly due to high Cl^- content of saline soil (Grattan & Grieve, 1994; Khan & Srivastava, 1998). However, supplementing soil with nitrogen has shown improvement in plant growth under salt stress (Dubey & Pessarakli, 1995). Irvin (1995) reported the effect of foliar nitrogen (N) applications on Blueberries, the N derived from the foliar sprays comprised only a small percentage of the total N in leaves, and leaves contained more foliar derived N than shoots.

Early flower initiation was noticed in present study under sea salt irrigation water at EC: 6.2 dS/m in *Gossypium hirsutum* over control. Foliar spray of different nutrient used in present investigations reduced the inhibitory effect of rhizosphere salinity created by saline water irrigation. No doubt these foliar spray were responsible for increasing reproductive growth in non saline medium as well, but inspite of the growth inhibition caused by salinity their application retained supremacy over the growth retarding toxic effects of excessive sodium in rooting medium. It appears that inhibition in reproductive yield due to salinity presented in terms of number and weight of fruit per plant is reduced due to shy bearing of flowers, shedding of flowers and fruits, development of pollen grain and ovules, failure in fertilization, and lack of filling of seeds/fruits etc. Mans (1996) found that mineral nutrient spray which included nitrogen and boron if applied at flower initiation stage of wheat, increases yield and size of grain whereas sprays at pre-bloom, or at fruitlets stage were not of much effect.

The K deficiency symptom first described by Sprague (1964) was a yellowish-white mottling of the older foliage that changes the leaf color to light yellowish-green. Brevandan & Hodges (1973) have shown that spray of KNO_3 0.50% solution during flowering supplied both N and K which were effectively absorbed as anion and cation by plants, delay the synthesis of abscisic acid and promoted cytokinin activity resulting an increase in chlorophyll content for delaying senescence. Foliar spray of $Ca(NO_3)_2$, $MnSO_4$ and K_2HPO_4 is reported to partially minimize the salt induced nutrient deficiency and increase panicle number, fertile spikelete, grain dry matter accumulation and yield under different salinity levels (Sultana *et al*., 2002).

El-Gharib & Kardy (1983) and Salih & Abdul Halim (1985) reported that at low salinity level of rooting medium when supplemented with essential nutrients to the soil, increase the seed cotton yield. According to Jafri (1990) seed cotton yield is greatly affected by high salinity stress in the different cotton cultivars.

Recommendation to supply foliar Nitrogen (N) and Potassium (K) to cotton has been made at appearance of at first flower and later continued by weekly or biweekly intervals. (Snyder, 1998). Brar & Tiwari (2004) reported increase in yield of cotton by 22%, 27% and 36% by foliar application of KCl, urea and KNO_3 respectively. Russo & Bakker (1987) found that irrigation water ranging from 6.7-10.5 dS/m decreased cotton yield from 6.5-30.0%. Whereas in present investigation salinity levels ranging from 6.2 - 10.8 dS/m decreased seed cotton yield from 49.82-90.28%. Foliar spray of NH_4NO_3 and KCl in combination increase seed cotton yield by 89.02%, 92.00% and 98.00% under nonsaline control 0.6 dS/m and sea salt dilutions ranging from 6.2-10.8 dS/m irrigation water respectively as compare to that of their single spray of both NH_4NO_3 and KCl. Foliar nutrient spray had beneficial effect on various reproductive parameters in *Cotton*, under saline environment. The spray material had increased productivity under nonsaline conditions as well but at the same time it has offset the toxic effect of saline substrate upto economically feasible value. The productivity at saline substrate without foliar spray was below economically feasible value.

Abaye (1998) has shown that supplementing potassium by any method increases lint yields compared with the untreated control. The soil provided with split dozes of potassium fertilizers supplemented with foliar KNO_3 treatments yielded the higher lint yield. The yield of plants given only K^+ through spray medium was found not as good as those given additional potassium through soil. Howard *et al*., (2000) sprayed *Cotton* with buffer solutions of pH 4 and 6 containing boric acid potassium nitrate separately or in mixture. The highest yield was found when buffer solution of pH 4 was sprayed containing both the above-mentioned chemicals.

Hodgson & MacLeod (2006) reported proportionate increase in the yield of *Cotton* due to foliar spray of 2.8, 5.9, 8.4 and 10.5 kg/hac of Nitrogen. Ali *et al.*, (2007) found increase in seed cotton yield by 6.31% and 12.30% due to extra supply of soil urea 50 and 75 kg/acre Urea through soil respectively as compare with 25 kg/acre. Uma & Patil (1996) reported that with increase in salinity levels all the growth and yield parameters were reduced. Reduction in reproductive growth as shown in seed number could be due to either lesser number of ovule formation per ovary under salinity stresses or failure in fertilization The application of above mentioned nutrients appear to have minimized these toxic affects. The increase seed weight per ball due to increase in salinity could be associated by reduction in number of developing fruits thus, fruits providing less number of sink for the translocation of photosynthetate produced by entire plant.

Conclusion

Overall, from the results of this experiment, it can be concluded that salinity stress significantly decreased, plant growth and fruit yield. The decrease in vegetative and reproductive parameters could be improved with the application of different foliar nutrient spray. The best concentration was found in a mixture of KCl and NH_4NO_3 as compare to the spray of both the chemicals alone. Supply of essential mineral elements (nitrogen, potassium) contributed towards an increase in growth irrespective of nonsaline and saline conditions in all the three plants studied in present investigations. The toxic effect of excessive sodium was of course inhibited due to provision of potassium through foliar spray and supplement of nitrogen through nitrate spray resulted in its sufficiency for better growth.

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