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Provision of Essential Minerals Through Foliar Sprays

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1. Introduction

Approximately half of the world's land surface is 'perennial desert or dry lands'. These areas can only be made more productive by irrigation. Indiscriminate use of irrigation water without any management has created salinity problem at many places. Consequently, salinity has become a threat to food supply. Although, currently there is enough food for chronically undernourished (Conway, 1997). Growth of human population will increase by 50%, from 6.1 billion in mid – 2001 to 9.3 billion by 2050, it means that crop production must be increased if food security be ensured, especially for those who live on about $ 1 per day (UN Millennium Declaration, 2000). Therefore, in view an estimates, there is a requirement for raising yield by 20% in Developed Countries and by 60% in Developing Countries (Owen, 2001). Unfortunately, a strong link with salinization throws an immediate question over the sustainability of using irrigation to increase food production and it has been argued elsewhere (Shannon & Noble, 1990; Flowers & Yeo, 1995) that the primary value of increasing the salt tolerance of crops will be to the sustainability of irrigation. In order to achieve this challenge different ways and means must be find out without major increase in the amount of new land under cultivation, which would further threaten forests and biodiversity. In the light of these demographic, agricultural and ecological issues, the threat and effects of salinity become even more alarming.

Most horticultural crops are glycophytes (Greenway & Munns, 1980) and have evolved under conditions of low soil salinity. The glycophytes cannot absorb, transport and utilize mineral nutrients as efficiently or as effectively under saline as non-saline conditions. Therefore, high concentrations of Na^+ and Cl^- in the soil solution may depress nutrients – ion activities and produce extreme ratios of Na^+/Cl^-, Na^+/K^+ Ca^+/Mg^+ and Cl^-, NO^{-3}. As a result plant becomes susceptible to osmotic specific ion injury as well as to nutritional disorders that may results in reduced yield or quality. Therefore, an alternative strategy for coping with salinity could, therefore, is to attempt to supplementary foliar irrigation of sodium antagonistic minerals where the growth medium is known to be or may become saline at some time during the plant growth cycle. Antagonistic behavior of excessive monovalent cations (especially sodium present in rhizosphere under saline condition) with monovalent and divalent cations of essential mineral creates physiological disorders for plant growth.

2. Brief history of mineral nutrition

A brief resume of essential minerals for plant growth is given below in interest to show that their availability of uptake and utilization is adversely affected under excessive salinity (with special reference of sodium) of rhizosphere.

Glimpses of early history for starting research on essential minerals for plant growth appear in literature, which shows that Theophrastus --- a Greek Philosopher performed experiments in crop nutrition during 287-372 B.C. After him along chain of experiment were carried out from different Scientist to know the importance of mineral nutrients for the plant growth.

The question of the nature of the mineral nutrients remained unanswered since the composition of a plant's ashes does not show whether a certain element found is actually necessary for the survival or whether it is merely roughage. The problem was solved when the plant physiologist J.V. Sachs (1832-1897) rediscovered the hydro-culture technique (hydroponics). J.V. Sachs produced the first useable synthetic nutrient solution together with the chemist J. A. Stockhardt. These experiments let Sachs understand the importance of the root hairs for the uptake of solute nutrients. At about the same time, J. A. L. W. Knop (1861) developed the nutrient solution still used very often. The experiments showed that the cations K^+, Ca^{2+}, Mg^{2+} and small amounts of Fe^{2+} or Fe^{3+}, as well as the anions SO_4^{2-}, H_2PO^{4-} (or H_3PO_4) and NO^{3-} are essential for the growth and survival of the plants. From the 1860's to the 1940's several other scientists studied plant mineral nutrition.

When in the 20th century the demands for the purity of chemicals grew, it did become apparent that plants need a number of additional elements, identified other minerals needed by plants in much smaller amounts, so-called trace elements like boron, copper, manganese, zinc and molybdenum are necessary for the plant normal nutrition. During this time several plant nutrition scientists also developed nutrient recipes for optimum plant growth, together with (Hoagland, 1919; Arnon & Hoagland 1940).

A most comprehensive review elaborating the methodology for determining essential mineral elements appears in the book of Sand and Water Culture Methods Used in the Study of Plant Nutrition by (Hewitt, 1966). Another book Mineral Nutrition of Plants: Principles and Perspectives by (Epstein, 1971) described fundamental concepts about plant nutrition. Horst Marschner in 1986 published an inclusive book "Mineral Nutrition of Higher plants" and its next edition in 1996 narrating full knowledge about plant essential minerals.

3. Problems faced for uptake of essential minerals by plants at saline soil

3.1 Salinity

Plant performance, usually expressed as crop yield, plant biomass, or crop quality, is affected adversely by salinity. Salinity is a major environmental stress and one of the most severe abiotic factors limiting agricultural production, since it alters the availability of water and nutrients. This effect is mostly reported in semi-arid to arid regions due to accumulation of salts at the soil surface where it inhibits the growth and yields of crop plants especially where irrigation is practiced (Greenway & Munns 1980; Tanji, 1990). The physiology of plant responses to salinity and their relation to salinity resistance have been much researched and frequently reviewed in recent years e.g. (Lauchli, 1990; Munns, 1993; & Neumann, 1997.

Salinity has affected, and continues to affect, the land on which crops are, or might be, grown. Although the amount of salt affected land (about 900×10^6 ha) is imprecisely known its extent is sufficient to pose a threat to agriculture (Flower & Yeo, 1995; Munns, 2002) since most plants,

and certainly most crop plants, will not grow in high concentrations of salt: only halophytes (by definition) grow in concentrations of sodium chloride higher than about 400 mM.
Crop species in general require a substantial quantity of water with lower salt contents. Moderately and highly salt tolerant crop species and non-conventional wild plants (including halophytes) can survive and grow on water with relatively higher salt contents.
Salts accumulate in the soil will depend upon the irrigation water quality, irrigation management and the adequacy of drainage. If salts become excessive, will result in yield reduction. As water salinity increases, greater care must be taken to leach salts out of the root zone before their accumulation reaches a concentration, which might affect yields. The frequency of leaching depends on water quality and the crop sensitivity to salinity. Salts are present in irrigation water in relatively small but significant amounts. They originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. The suitability of water for irrigation is determined not only by the total amount of salt present but also by the kind of salt.
The problems that result vary both in kind and degree, and are modified by soil, climate and crop, as well as by the skill and knowledge of the water user. As a result, there is no set limit on water quality; rather, its suitability for use is determined by the conditions of use which affect the accumulation of the water constituents and which may restrict crop yield. The more complex the problem, the more difficult it is to formulate an economical management programme for solution.

3.2 Osmotic imbalances

The most common effect of salinity on plant growth is of water stress. Some plants will tolerate high levels of salinity while others can tolerate little or no salinity. This is because some are better able to make the needed osmotic adjustments enabling them to extract more water from a saline soil. The osmotic effects of salinity are result of increased sodium ion concentrations at the root – soil water interface that creates lower water potential. It is well documented that salt stress causes removal of water from the cytoplasm into the extra cellular spaces resulting in a reduction of cytosolic and vacuolar volume (Ashraf, 2004; Munns, 2002). Munns & Termaat, (1986) have shown that the earliest response of a non-halophyte to salinity is that leaves grow more slowly. Although the plants may experience water stress for a short period until they adjust osmotically, water deficit is not the only factor for limited growth, even at relatively high salinities. Growth is reduced as a function of total electrolyte concentration, soil water content and soil matrix effect and is evidenced by reduction in cell division, cell enlargement, cell expansion, cell wall plasticity in the growing region of roots and leaves (Neumann, 1997).

3.3 Ionic toxicity

Ionic toxicity considered responsible for growth inhibitions under excessive saline environment. Salinity reduces plant growth through ionic influences. It has been reported that salinity affects ion activities in solution by changing the ionic strength, by ion-pair formation, and by precipitation (Cramer et al., 1987), resulting in excessive uptake and transport of the salt ions (Na^+, Cl^- and $SO_4^{-2)}$ and/or an inadequate uptake and transport of essential elements, to produce changes in mineral nutrient uptake that affect plant growth and reduce yields and cause crop failure (Bayuelo-Jiménez et al., 2003). Also, significant entry of Na^+ or Cl^- results in severe growth reduction or death in salt-sensitive or

glycophytic species, at the same time as producing mild toxicity symptoms in salt-tolerant species (Maathuis & Amtmann, 1999). Ion uptake is the cheapest form of osmotic adjustment under soil saline conditions, but it could also lead to problems of decline in leaf function and ionic imbalance and toxicity (Yildirim et al., 2009). In particular, salinity alters uptake and absorption rates of all mineral nutrients resulting in deficiency symptoms. Bonilla et al. (2004) found that most toxic effects of NaCl can be attributed to Na^+ toxicity. Excessive accumulation of Na^+ can cause a range of ionic and metabolic problems for plants (Hoai et al., 2003). It can be concluded that excessive amounts of any ion (cat or anion) in growth medium can cause toxicity which is species or cultivar specific. However, sodium ion toxicity is more prevalent and more toxic to plants.

3.4 Nutritional imbalance

Salinity acts like drought on plants, preventing roots from performing their osmotic activity where water and nutrients move from an area of low concentration into an area of high concentration. Therefore, because of the salt levels in the soil, water and nutrients cannot move into the plant roots. Salt tolerance of a plant is affected under low nutrient availability. Accumulation of Na^+ and Cl^- in leaves through the transpiration flow is a general and long-term process taking place in salt-stress plants (Munns & Termaat, 1986). Nutrient uptake and accumulation by plants is often reduced under saline conditions as a result of competitive process between the nutrient and a major salt species. However, this depends on the type of nutrients and composition of soil solution (Grattan & Grieve 1999; Homaee et al., 2002). Although plants selectively absorb potassium over sodium, Na^+- induced K^+ deficiency can develop on crops under salinity stress by Na^+ salt (Maas & Grattan, 1999). In some cases the uptake and translocation of ions such as K^+ and Ca^{+2} are affected by salt stress. In few examples under saline conditions uptake of some mineral elements is known to increase, which can sustain the growth of plants when tissue elements is higher, like Nitrogen (Sweby et al., 1994). Phosphorus (Awad et al., 1990), Potassium (Hawkins and Lewis, 1993), Calcium (Rengel, 1992) and Manganese (Cramer & Nowak, 1992). There might still be cases, when the imbalance of minerals might not be detectable depending upon the localization of the element rather than the total tissue concentration (Cramer, 1997).

Most studies related to plant nutrition and salinity interactions have been conducted in sand or solution cultures. A major difficulty in understanding plant nutrition status as affected by soil salinity is reconciling results obtained in experiments conducted in the field and in solution cultures (Grattan & Grieve 1999). While application of fertilizers could improve plant nutritional status, it may also increase the salinity of soil solution. 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 stomates, 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. Antagonistic effect of excessive sodium could be avoided in root zone if these essential mono and divalent cations are provided through foliar irrigation to plants. In view of Foliar application of soluble salts is being undertaken in present work containing cations of essential mineral elements (which are antagonized by sodium) along with some anions, which are essential for plant growth; its main objective was to investigate the interactive effects of salinity and foliar spray of different nutrients compositions on growth of *Gossypium hirsutum*.

4. Control measures for salinity

An integrated, holistic approach is needed to conserve water and prevent soil salinization and water logging while protecting the environment and ecology. Firstly, source control through the implementation of more efficient irrigation systems and practices should be undertaken to minimize water application and reduce deep percolation. Unavoidable drainage waters should be intercepted, isolated and reused to irrigate a succession of crops of increasing salt tolerance, possibly including eucalyptus and halophyte species, so as to reduce drainage water volumes further and to conserve water and minimize pollution, while producing useful biomass. Conjunctive use of saline groundwater and surface water should also be undertaken to aid in lowering water table elevations, hence to reduce the need for drainage and its disposal, and to conserve water.

To achieve these goals, new technologies and management practices must be developed and implemented. Efficiency of irrigation must be increased by the adoption of appropriate management strategies, systems and practices and through education and training. Some practices can be used to control salinity within the crop root zone, while other practices can be used to control salinity within larger units of management, such as irrigation projects and river basins. Additional practices can be used to protect offsite environment and ecological systems - including the associated surface and groundwater resources.

There is usually no single way to achieve salinity control in irrigated lands and associated waters. Many different approaches and practices can be combined into satisfactory control systems; the appropriate combination depends upon economic, climatic, social, as well as edaphic and hydrogeologic situations.

The objective of salinity control is to maintain an acceptable crop yield. Management need not necessarily attempt to control salinity at the lowest possible level, but rather to keep it within limits commensurate with sustained productivity crop; soil and irrigation practices can be modified to help achieve these limits. The problem can be managed through Engineering, Reclamation and Saline Agricultural approach.

4.1 Use of salt tolerant plants

Salt tolerance of a plant may be considered as the ability to germinate, maintain growth and reproduce under persistent or interrupted salt stress. The salt tolerance of plants is a very acute and complex phenomenon, not only because different plants respond to saline conditions in fundamentally different ways, but also because of the great variation in the stress itself. The relative growth of plants in the presence of salinity is termed as their salt tolerance. The ability of plants to tolerate salt is determined by multiple biochemical pathways that facilitate retention and/or acquisition of water, protect chloroplast functions, and maintain ion homeostasis. Essential pathways in this connection are referred those which lead to synthesis of osmotically active metabolites, specific proteins, and certain free radical scavenging enzymes (Parida & Das, 2005). All salts can affect plants growth, but not all inhibit growth within permissible concentration. In addition, salts do not act alone in the soil, but interact in their effects on plants; some of these interactions are simple (e.g. interactions between Na^+ and Ca^+), whereas some are complex (e.g. Carbonates and their effects via increased soil pH). Among the most common effects of soil salinity is growth inhibition by Na^+ and Cl^-. For some plants, especially woody perennials (such as citrus and grapevines), Na^+ retained in the woody roots and stems and it is the Cl^- that accumulates in the shoot and is most damaging to plant often by inhibiting photosynthesis (Flowers, 1988).

However, for many plants (such as Germinaceous crops), Na^+ is the primary case of ion-specific damage (Tester & Davenport, 2003). It attracted the attention of many investigators and practical agricultural workers because of the need to increase yields on saline soil and to develop and utilize new saline areas. Plant species vary in how well they tolerate salt-affected soils. Many lists of salt tolerant cultivars of important crops and those grown for forage, fodder, wood or others economical purposes are available in literature , (Ahmad, R. & Ismail, S. 1993; Francois, L.E., 1994; Maas, E.V., 1996; Marcar, N.E. et al., 1999; Ahmad, R., & Chang, M.H. 2000). Depending upon prevailing range of saline soil or saline irrigation water(being used in irrigation) edaphic and environmental factors one can select a plant for providing economically feasible yield under saline prevailing adverse condition.

4.2 Mineral nutrition through foliar spray

The following information has been cited out of some important reviews related to foliar application of mineral nutrients, which have appeared in literature towards the end of the last century, beginning of the present century since they provide precise knowledge on the subject. Foliar fertilization is an effective method of providing a steady flow of nutrients, in combination with some traditional types of root-uptake fertilizers, to achieve better control of nutrients. Foliar irrigation is widely used to supply specific nutrients to many crops growing under saline environment. Foliar application of nutrients is partially overcoming the negative effect of stress condition influencing root growth and absorption capacity (Salama et al., 1996; El-Flouly & Abou El- Nour, 1998). In this respect, (El-Flouly & El-Sayad, 1997) stated that foliar fertilization of both macro and micronutrient is practiced whenever, nutrients uptake through the root system is restricted due to salt stress. The advantages of foliar spray compared to soil fertilization include: immediate response, convenience of combination spray and comparatively low cost. On the other hand foliar spray have some disadvantages, the main disadvantage is these must be repeatedly applied because of the constant loss of leaf blades to mowing. Other includes, the response is only temporary, only very low doses can be applied and there are limitations due to foliar toxicity. When nutrients are applied directly to the foliage, they must penetrate three barriers: i) The waxy cuticle covering on the epidermal cell, ii) The cell wall of the epidermal cell and iii) The plasma membrane of the epidermal cells. Morphology and organization of leaf tissue is such that it accommodates the uptake of gaseous plant nutrients, whilst that of roots the uptake of water-soluble solutes. These water-soluble plant nutrients are mainly supplied with fertilizers. Only in exceptional cases where nutrients are strongly fixed by soils or where aerial nutrient requirement of a crop is higher than the root uptake rates, foliar application can be adopted as a routine fertilization measure.

Similarly, for maximum stomatal entry, nutrient sprays must be applied when the stomata are open, early morning applications are the best. Also, there is less evaporation during the early morning thus giving a better chance for maximum uptake by leaves. Timing is keeping this point in mind spray so did both in regard to time of the season and time of the day a critical factor in foliar spray. High relative humidity during the time of application will also enhance uptake by minimizing evaporation. Foliar sprays may be effective only during “critical stages” of plants growth cycle and must be applied during or shortly before the critical period to be effective. Since immature foliage does not have well-developed cuticular layer, application of nutrient sprays when there is a significant amount of young foliage present will enhance cuticular entry. Factors that affect foliar

absorption include relative humidity, temperature, pH of the nutrient solution, age of leaf, concentration of the nutrient solution, difference in the nutrient compounds (formulations), use of surfactants and addition of non-nutrient facilitating or carriers-mediated agents (Gary & Grigg, 1999).

4.2.1 Foliar spray of macronutrients

The efficiency with which foliar applied macronutrients are utilized depends on the mobility of the specific nutrient throughout the entire plant, mobility comprising long distance transport especially phloem transport as well as the symplastic transport. Potassium and nitrogen are examples of nutrients showing high mobility and when taken up by leaves they can be rapidly distributed throughout the entire plant. Calcium and sulfur show a low mobility and Ca^{2+} taken up by leaves cannot be transported to younger tissues or fruits where it may be required. Most nutrients will move freely in the water stream but the movement of many is restricted in the phloem, hence leaf applications do not meet the requirements of deficient trees.

Foliar application of potassium is an efficient method of potassium supply to plants to avoid interaction both antagonistic and synergistic with essential major secondary and micronutrients (Dibb & Thompson, 1985). Foliar K^+ may be a supplemental nutrient management practice when conditions reduce plant K^+ uptake from soil, therefore, foliar application of potassium may be possible management tool to alleviate reduced yields caused by K^+ deficiency under saline irrigation. Foliar spray did not only increase the crop yields but also reduce the quantities of fertilizer applied through soil. Islam et al., (2003) used 0.1% KNO_3 as foliar spray on jute plant leaves and obtained good results whereas, 250 ppm of KNO_3 produce promising results in *Lagenaria siceraria* , (Ahmad & Jabeen, 2005).

Similarly, foliar spray of nitrogen also provides best platform to enhance the plant growth when growing in saline strata. Foliar application of nitrogen results in increased grain protein content and bread making quality of wheat when applied at or after anthesis (Gooding & Davies, 1992). Rajput et al., (1995) concluded that foliar application increased heading, maturity, grain and biological yield and gain highest return. Due to high importance of foliar fertilizer and the initial role of nitrogen, in the present study KNO_3 was selected which can provide both K and N sources to the plant.

4.2.2 Foliar spray of micronutrients

Role of essential mineral element required in traces for growth and development of plants is known since long in literature (Hewitt, 1966). Small amount of Cu, Zn, B, Fe, Mo, and Mn are essential for growth and quality of the crop because they control most of the physiological activities of the crop by interrupting the level of chlorophyll content in leaves, which ultimately influence the photosynthetic activity of the plant (Kanwar & Randhawa, 1967).

Jamro et al., (2002), showed that the effect of foliar application of micronutrients significantly increased the cane length at lowest rates of zinc and copper (1.5 kg and 2.5 kg /ha), produced highest cane length of 145.40 cm and 144.93 cm, respectively, whereas, the lowest cane length of 113.07 cm was recorded in untreated plants.

Gregoriou et al., (1983) found that the quickest and most successful treatment of trees suffering from iron chlorosis on calcareous soils was obtained by incorporating Sequestrene 138 Fe - EDDHA in the soil. Kassab (2005) indicated that foliar spray of zinc, manganese and

iron significantly increased growth parameter yield and its components of mung bean plants. In addition, spraying salinity stressed plants with micronutrients can reduce the undesirable effect of salinity through improving growth and nutrient status of plants as well. Micronutrient requirements can generally be better met by foliar application than requirements of macronutrients because in absolute terms higher quantities of macronutrients are needed. Abou El-Nour (2002) reported that plants irrigated with 5.6 dS/m irrigation water and sprayed with supplementary micronutrients foliar spray with an EDTA micronutrient compound contained 2.8% Fe + 2.8% Mn + 2.8% Zn + 14% N applied to maize showed significant increment in root dry weight as compared to control, where the increment reached to 19%.

4.2.3 Preparation of spray medium

Recipe of spray medium is also important in which surfactant /adjuvant are mixed with desired minerals to spread liquid on the surface of the leaf and let it stay there for some time for stomatal absorption (Mengel & Kirkby, 1987). Surfactants (surface active agents) are a type of substances designed to improve the dispersing/emulsifying, absorbing spreading, sticking and / penetrating properties of the spray mixture. Pure water will stand as a droplet with a small area of contact with the waxy leaf surface. Water droplet containing a surfactant will spread in a thin layer over a waxy leaf surface. Surfactant lowers the contact angle of spray droplets on the leaves thus enhancing absorption.

It is commonly believed that the optimal pH values of spray solutions for the maximum uptake of most mineral nutrients are within the range of 3.0-5.5 (Kannan, 1980). Acidic foliar sprays can penetrate leaf surfaces more effectively, but it is possible for a negative effect to occur when too much acidity is present. Each type of organic acid has its own pH disassociation range with the mineral as the pH drops (increased acidity). Blanpied (1979) reported that maximum Ca^{+2} absorption by apple leaves are at pH 3.3 - 5.2. Reed & Tukey (1978) found that maximum phosphorus absorption by Chrysanthemum (*Dendranthema gradiflora*) leaves was at pH 3-6 for Na-Phosphate and pH 7-10 for K-phosphate. 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.

5. Materials and methods

Keeping in view that broad leave plants will have better chance of retaining minerals given through foliar spray medium, commercially important plant *Gossypium hirsutum* belonging to family Malvaceae and grown for lint and oil was selected for present work. Plants were grown with saline water irrigation at sand and foliar application of some sodium antagonistic essential minerals was practiced at different stages of growth. The cotton seeds were obtained from Central Cotton Institute of Multan, Pakistan.

Experiments on growth of *Gossypium hirsutum* was conducted at Biosaline Nursery, Department of Botany (University of Karachi) in large size plastic pots using various combinations of nutrients in foliar spray medium. Some essential trace elements were included which is being di and trivalent show antagonism with monovalent Na^{+}. They were given with K^{+}, which is used as growth promoter for plants raised under saline condition. The pots were filled with 18 kg of costal sand each, having basal outlet for drainage and

capable of retaining 3 liter 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.

Experiment was divided into 12 sets, viz., 1. Non-spray 2. Foliar spray with water 3. Foliar spray with Fe-EDTA (5-ppm) 4. Foliar spray with $MnCl_2$ (5-ppm) 5. Foliar spray with MoO_3 (5-ppm) 6. Foliar spray with KNO_3 (500-ppm) 7. Foliar spray with KCl 500-ppm) 8. Foliar spray with Urea (1000-ppm) 9. Foliar spray with KNO_3 (500-ppm) + Fe-EDTA (5-ppm) 10. Foliar spray with KNO_3 (500-ppm) + $MnCl_2$ (5-ppm) 11. Foliar spray with KNO_3 (500-ppm) + MoO_3 (5-ppm) 12. Foliar spray with KNO_3 (500ppm) + Fe-EDTA (5-ppm) + $MnCl_2$ (5-ppm) +MoO_3 (5-ppm). Out of a total 180 pots used in present experiment 15 were used in each set, exposed to three different irrigation regimes given to 5 pots under each treatment viz., i) Nonsaline water ($E.C_{iw}$: 0.6 dS/m), ii) 0.4% sea-salt solution ($E.C_{iw}$:6.2 dS/m) and iii) 0.8%: sea-salt solution ($E.C_{iw}$: 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. The seeds were then surface sterilized with 0.1% $HgCl_2$ for 5 minutes. Five seeds were sown in each plastic pot irrigated with non- saline water. Irrigation with gradually increasing concentrations of sea- salt(S.S) in irrigation water was started in plants at five leaf stages (including cotyledonary leaves) and continued till it reached to the salinity levels of 6.2 and 10.8 dS/m. Pot was irrigated with 3-litre tap water/ salt solution twice a week. Three plants were kept in each pot. Cow dung manure was added in the soil at 9:1 ratio to plastic pots. Whereas NPK (1:2:1) was given in three split dozes. Insecticide and fungicide was used whenever needed. Spray medium was containing 10 ppm of liquid soap as a surfactant. Foliar spray was started at five leaf stage, and followed by at just beginning flowering, and intermediate fruiting stage, plants were completely sprayed with 300 ml/plant of respective spray nutrient solution.

Complete data on growth of various vegetative parameters i.e. plant height (cm) ,number of leaves and monopodial and sympodial branches, total leaf area, fresh and dry biomass was taken and reported in PhD Thesis (Jabeen, 2009),but due to limitations in number of printed pages only the data on fresh and dry biomass is presented in this chapter. Whereas reproductive parameters is presented in terms of number of squares, flower and balls/ plant, seed and lint weight; seed number per plant, seed cotton yield and lint/ seed ratio was recorded at termination of experiment. Fiber characteristics are reported in PhD Thesis (Jabeen, 2009).

Samples of leaf and stem, were taken at grand period of growth, and were dried separately overnight in oven at 70^0C for the analysis of Na^+ and K^+ (A.O.A.C., 1984). Concentration of Na^+ and K^+ cations in samples was measured using a Petracourt PFP.1 Photometer.

Leaves samples were collected at grand period of growth, from 3^{rd} /4^{th} node below the apex for biochemical analysis. i) Chlorophyll was extracted from the leaves in 80%acetone and measured at 663 nm and 645 nm in a Spectrophotometer as outlined by Machlaclam & Zalik, (1963). ii) A total Soluble Carbohydrates content was measured in an aqueous extract of leaf sample according to Ciha & Brun, (1978). Extraction was done in extraction solution (glacial acetic acid: methanol: water, 1:4:5) and optical density was recorded at 490 nm. iii) Protein was estimated by Hartree (1972). Extraction was done in 5% Trichloroacetic acid (TCA) and estimated after color reaction with Folin Ciocalteu's reagent at 650 nm.

Soil samples were collected fortnightly for salinity measurements. They were dried, saturated with de – ionized water, kept overnight followed by water extraction under vacuum (USDA, 1954). This extract was used for pH and electrical conductivity (dS/m) measurements using a Canterbury Conductivity meter (Model AGR 1000).
Statistical analysis of the data was carried out as outlined by Little & Hills (1975) and Gomez & Gomez (1976). All the data were statistically analyzed by computer program Costat 3.03. and *SPSS VERSION 11*.Mean separation of data was carried out using Duncan Multiple Range Test (Duncan, 1955).

6. Results

6.1 Vegetative growth

Interaction of sea salt irrigation and foliar spray of different minerals on vegetative biomass (gm) per plant are presented in Figure 1-2.

6.1.1 Vegetative biomass

Following conclusions are made on cotton vegetative biomass after consulting results of interaction of sea salt irrigation with foliar spray of different compositions (Figure 1-2).

i. Vegetative biomass of the plants growing with irrigation water of different sea salt dilutions without any foliar spray remained comparatively less than that of sprayed with water.
ii. Those undergoing with single salt spray of micronutrient (Fe, Mn, Mo) show increase in plant biomass in comparison with non-spray or only water spray, whereas plant biomass among themselves was in the order of Mo< Mn <Fe respectively.
iii. The plants undergoing spray medium for supply of Nitrogen (N) through potassium nitrate or urea though show increase in biomass in comparison with spray of single micronutrients in mentioned above. Whereas, increase in biomass in KNO_3 spray was significantly more than irrespective of salinity treatments.
iv. Supply of potassium (K) through potassium nitrate and potassium chloride shows that biomass of plants sprayed with former is increased than the later. This could be attributed as a result of accompanying Nitrogen.
v. Spray medium of potassium in combination with individual micronutrient (i.e. Fe, Mn and Mo) show significant effect of Fe in increasing plant biomass among these treatments. Their grading would be KNO_3 + Mo < KNO_3 + Mn < KNO_3 + Fe for performance at this parameter.
vi. Spray medium of K in combination with all the three micronutrient (Fe, Mn and Mo) show significant increase in biomass in comparison with all the above-mentioned composition.
vii. The increase in biomass shown by different medium in control plants follow similar pattern in plants growing at 6.2 and 10.8 dS/m sea salt irrigation water. The slight fluctuation shown in KCl and KNO_3 +Fe + Mn + Mo micronutrient spray at earlier period of growth is non significant.
viii. ANOVA for fresh and dry biomass production showed significant difference at level $P<0.0001$ in respect to salinity and spray, whereas their interaction was not significant.

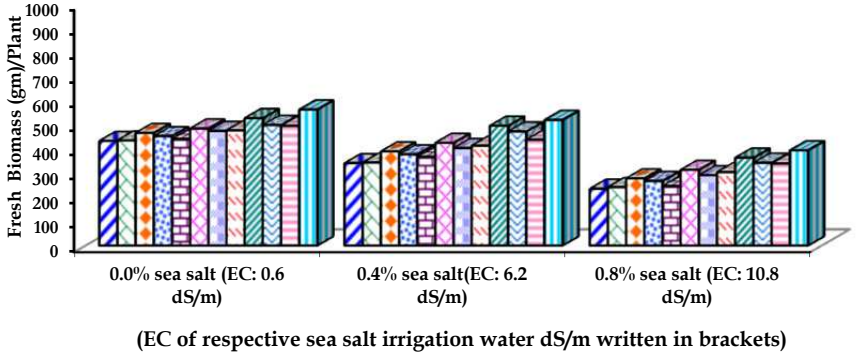

Fig. 1. Effect of foliar spray of different mineral nutrients and irrigation water of different salinity levels on Fresh Biomass (gm) in *Gossypium hirsutum*.

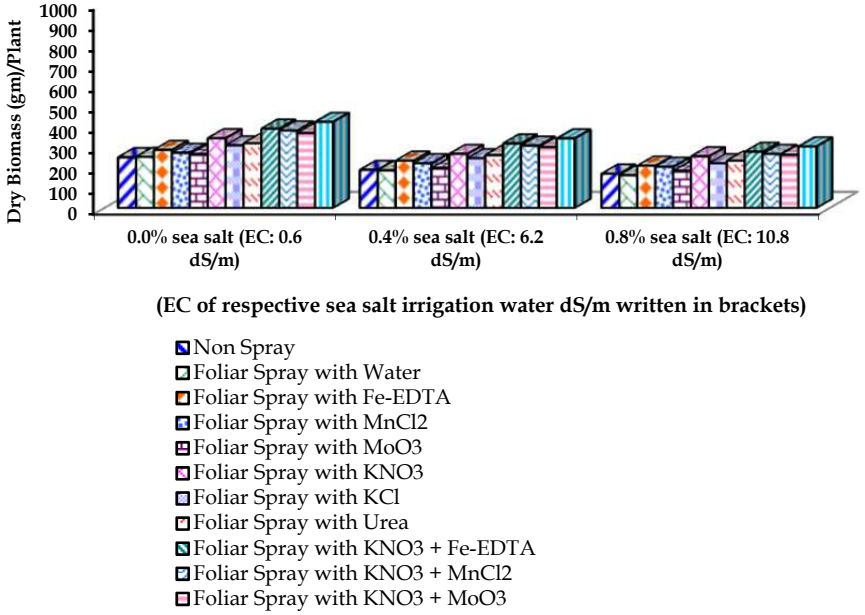

Fig. 2. Effect of foliar spray of different mineral nutrients and irrigation water of different salinity levels on Dry Biomass (gm) in *Gossypium hirsutum*.

6.2 Reproductive growth

6.2.1 Number of flowers, balls and seed per plant, seed and lint weight / per plant, seed cotton yield, seed / lint ratio

Reproductive parameters presented in Table 1 are based on production of number of flowers, bolls and seed per plant, weight of seed and lint / per plant, seed cotton yield and seed / lint Ratio as a result of foliar spray of different compositions at cotton plants raised by sea salt irrigation water.

Promotion /reduction percentage calculated on the basis above mentioned parameters is given in the Table 1.

Salinity stresses seemed to have reduced the yield on all the above-mentioned reproductive parameters with increase in salinity of irrigation water. Growth was promoted up to various degrees by foliar spray of mineral nutrients under nonsaline as well as saline conditions.

Increasing salinity of rooting medium has proportionally decreased the yield at all the above-mentioned parameters, which was offset up to 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 the growth.

ANOVA for reproductive data exhibited significant difference at level $P<0.001$ in respect to salinity, at level ($P<0.0001$) spray and while their interaction was not significant.

Treatment	Flowers/plant	Balls/plant	Seeds/plant	Seed weight (g)/plant	Lint weight (gm)/plant
Non Spray					
0.6 dS/m	58.00 [a] ±4.08	41.00 [a]±2.95	902.00 [a]±5.32	77.49 [a]±0.01	56.98 [a]±0.01
	-	-	-	-	-
6.2 dS/m	51.00 [a b]±3.8	32.00 [a]±3.44	512.00 [b]±3.39	54.08 [b]±0.01	38.09 [b]±0.01
	(-15.00)	(-23.08)	(-55.84)	(-48.90)	(-51.08)
10.8 dS/m	35.00 [a] ±2.64	21.00 [a]±2.68	252.00 [c]±2.68	29.19 [c]±0.01	18.71 [c]±0.01
	(-30.00)	(-46.15)	(-92.21)	(-89.49)	(-90.85)
LSD $_{0.05}$	19.97	19.84	19.7	0.25	0.21
Foliar spray with water					
0.6 dS/m	60.00 [a]±3.1	45.00 [a]±3.19	945.00 [a]±4.78	85.95 [a]±4.78	63.47 [a]±0.02
	(+10.00)	(+15.38)	(+22.73)	(+29.93)	(+30.42)
6.2 dS/m	52.00 [a]±3.96	34.00 [a]±3.96	518.00 [b]±2.18	58.14 [b]±0.01	41.29 [b]±0.12
	(-5.00)	(-7.69)	(-37.66)	(-22.45)	(-25.39)
10.8 dS/m	2.58 [a]±5.77	25.00 [a]±3.04	300.00 [c]±2.83	37.25 [c]±0.01	24.81 [c]±0.07
	(-15.00)	(-23.08)	(-68.83)	(-54.95)	(-59.30)
LSD $_{0.05}$	19.97	19.97	1.99	0.01	0.27
Foliar spray with Fe-EDTA (5 ppm)					
0.6 dS/m	74.00 [a]±4.6	57.00 [a]±4.41	1425.00 [a]±3.55	114.57 [a]±0.01	86.42 [a]±0.27
	(+20.00)	(+30.77)	(+57.14)	(+62.13)	(+63.93)
6.2 dS/m	69.00 [a]±4.12	52.00 [a]±5.30	1040.00 [b]±1.18	94.12 [b]±0.01	68.23 [b]±0.11
	(+5.00)	(+7.69)	(-11.69)	(+5.82)	(+2.77)
10.8 dS/m	55.00 [a]±2.89	41.00 [a]±4.22	615.00 [c]±1.99	61.91 [c]±0.01	43.32 [c]±0.18
	(-10.00)	(-15.38)	(-61.04)	(-43.69)	(-49.13)
LSD $_{0.05}$	19.97	19.97	1.99	1.99	0.67

Treatment	Flowers/plant	Balls/plant	Seeds/plant	Seed weight (g)/plant	Lint weight (gm)/plant
Foliar spray with $MnCl_2$ (5 ppm)					
0.6 dS/m	69.00 [a]±4.02	51.00 [a]±3.96	1224.00 [a]±3.97	101.49 [a]±0.01	75.72 [a]±0.26
	(+25.00)	(+38.46)	(+87.01)	(+80.50)	(+83.76)
6.2 dS/m	61.00 [a]±4.14	47.00 [a]±4.59	893.00 [b]±1.52	38.78 [b]±22.67	60.36 [b]±0.14
	(+10.00)	(+15.38)	(+11.04)	(+21.77)	(+19.32)
10.8 dS/m	53.00 [a]±2.66	34.00 [a]±3.69	476.00 [c]±1.99	50.66 [c]±0.00	33.52 [c]±0.02
	(-5.00)	(-7.69)	(-45.45)	(-32.43)	(-38.95)
$LSD_{0.05}$	19.25	125	14.25	14.81	0.21
Foliar spray with MoO_3 (5 ppm)					
0.6 dS/m	66.00 [a]±3.94	48.00 [a]±4.34	836.00 [a]±4.44	24.70 [a]±0.02	55.21 [a]±0.012
	(+40.00)	(+61.54)	(+173.51)	(+127.89)	(+132.79)
6.2 dS/m	59.00 [a]±3.95	41.00 [a]±4.82	697.00 [b]±2.36	71.75 [b]±0.012	51.31 [b]±0.02
	(+20.00)	(+30.77)	(+42.86)	(+50.49)	(+48.10)
10.8 dS/m	49.00 [a]±2.59	30.00 [a]±3.87	360.00 [c]±2.36	44.70 [c]±0.16	29.76 [c]±0.01
	(+10.00)	(+15.38)	(-12.34)	(+2.79)	(-2.88)
$LSD_{0.05}$	19.97	19.24	14.25	0.14	0.21
Foliar spray with KNO_3 (500 ppm)					
0.6 dS/m	85.00 [a]±3.83	67.00 [a]±3.64	1876.00 [a]±3.68	156.11 [a]±0.07	122.63 [a]±0.01
	(+105.00)	(+161.54)	(+409.09)	(+393.12)	(+426.62)
6.2 dS/m	78.00 [a]±4.53	68.00 [a]±3.95	1564.00 [b]±2.75	144.84 [b]±0.09	110.86 [b]±1.25
	(+70.00)	(+107.69)	(+213.64)	(+238.10)	(+251.80)
10.8 dS/m	66.00 [a]±3.00	51.00 [a]±3.11	918.00 [c]±2.71	93.33 [c]±012	67.71 [c]±0.15
	(+55.00)	(+84.62)	(+110.39)	(+148.98)	(+146.04)
$LSD_{0.05}$	19.25	17.25	14.25	1.01	0.21
Foliar spray with KCl (500 ppm)					
0.6 dS/m	77.00 [a]±4.36	60.00 [a]±4.63	1560.33 [a]±3.38	127.20 [a]±0.10	97.22 [a]±0.07
	(+94.74)	(+150.00)	(+320.78)	(+304.54)	(+326.72)
6.2 dS/m	71.00 [a]±4.3	55.00 [a]±4.59	1155.00 [b]±1.51	105.60 [b]±0.01	78.24 [b]±0.09
	(+76.47)	(+130.00)	(+153.90)	(+159.56)	(+165.57)
10.8 dS/m	58.00 [a]±3.0	44.00 [a]±3.9	748.00 [c]±1.95	71.28 [c]±0.01	49.36 [c]±0.11
	(-10.71)	(-14.29)	(+40.26)	(+56.01)	(+50.46)
$LSD_{0.05}$	19.87	19.21	19.24	0.05	0.01
Foliar spray with Urea (1000 ppm)					
0.6 dS/m	81.00 [a]±4.47	64.00 [a]±4.63	1728.00 [a]±3.48	142.72 [a]±0.01	110.58 [a]±0.17
	(+82.35)	(+140.00)	(+203.90)	(+188.44)	(+199.69)
6.2 dS/m	74.00 [a]±4.13	61.00 [a]±4.59	1403.00 [b]±1.87	123.21 [b]±0.01	92.82 [b]±0.18
	(+107.14)	(+214.29)	(+118.18)	(+132.20)	(+133.50)
10.8 dS/m	62.00 [b]±2.99	47.00 [b]±3.9	846.00 [c]±2.05	80.85 [c]±0.01	57.55 [c]±0.01
	(+9.09)	(+13.33)	(+21.43)	(+34.69)	(+26.62)
$LSD_{0.05}$	19.97	19.97	1.99	0.01	0.02

Treatment	Flowers/plant	Balls/plant	Seeds/plant	Seed weight (g)/plant	Lint weight (gm)/plant
Foliar spray with KNO_3 (500 ppm) + Fe-EDTA (5 ppm)					
0.6 dS/m	95.00 [a]±4.66	78.00 [a]±4.53	2496.00 [a]±6.33	213.72 [a]±0.21	174.86 [a]±1.02
	(+120.00)	(+184.62)	(+483.77)	(+474.07)	(+521.27)
6.2 dS/m	90.00 [a]±4.38	74.00 [a]±5.23	1998.00 [b]±4.63	187.79 [b]±10.2	150.78 [b]±1.25
	(+85.00)	(+130.77)	(+274.03)	(+308.16)	(+331.65)
10.8 dS/m	78.00 [b]±3.43	61.00 [b]±4.41	1342.00 [c]±3.28	142.74 [c]±1.36	112.68 [c]±1.47
	(+3.33)	(+23.08)	(+122.08)	(+165.31)	(+168.24)
$LSD_{0.05}$	19.78	19.97	4.25	4.25	0.25
Foliar spray with KNO_3 (500 ppm) + $MnCl_2$ (5 ppm)					
0.6 dS/m	91.00 [a]±5.18	74.00 [a]±5.38	2220.00 [a]±4.97	195.37 [a]±10.4	195.38 [a]±14.25
	(+113.64)	(+166.67)	(+562.34)	(+578.46)	(+822.51)
6.2 dS/m	84.00 [a]±4.94	71.00 [a]±5.56	1775.00 [b]±3.25	173.25 [b]±1.25	137.68 [b]±1.25
	(+121.05)	(+191.67)	(+370.78)	(+434.85)	(+478.21)
10.8 dS/m	76.00 [a]±3.56	58.00 [b]±5.01	1160.00 [c]±2.69	124.14 [c]±3.2	95.25 [c]±3.4
	(+58.33)	(+82.35)	(+224.68)	(+304.38)	(+321.38)
$LSD_{0.05}$	19.97	19.97	1.99	0.01	0.02
Foliar spray with KNO_3 (500 ppm) + MoO_3 (5 ppm)					
0.6 dS/m	89.00 [a]±5.21	70.00 [a]±5.2	2030.00 [a]±3.9	171.52 [a]±3.10	136.81 [a]±2.36
	(+129.17)	(+182.35)	(+772.73)	(+769.84)	(+866.91)
6.2 dS/m	81.00 [a]±4.52	68.00 [a]±4.25	1632.00 [b]±2.76	153.07 [b]±3.11	119.47 [b]±3.42
	(+113.64)	(+166.67)	(+496.10)	(+552.76)	(+612.85)
10.8 dS/m	70.00 [a]±4.23	54.00 [a]±3.25	1026.00 [c]±2.59	105.38 [c]±3.4	78.36 [c]±.014
	(+64.00)	(+88.89)	(+300.0)	(+395.24)	(+429.50)
$LSD_{0.05}$	1.28	5.24	1.99	0.12	0.04
Foliar spray with KNO_3 (500 ppm) + Fe-EDTA (5 ppm)+ $MnCl_2$ (5 ppm)+ MoO_3 (5 ppm)					
0.6 dS/m	105.00 [a]±2.58	85.00 [a]±5.21	2975.00 [a]±9.19	255.01 [a]±0.12	212.47 [a]±10.2
	(+225.00)	(+346.15)	(+1081.82)	(+1079.17)	(+1236.07)
6.2 dS/m	95.00 [a]±4.56	78.00 [a]±4.25	2340.00 [b]±7.24	143.60 [b]±1.25	179.49 [b]±10.6
	(+155.00)	(+238.46)	(+640.26)	(+704.23)	(+798.25)
10.8 dS/m	80.00 [a]±5.96	65.00 [a]±3.25	1625.00 [c]±5.39	162.51 [c]±1.25	130.59 [c]±1.24
	(+140.00)	(+215.38)	(+468.18)	(+561.38)	(+619.42)
$LSD_{0.05}$	1.25	1.97	19.9	0.01	0.27

Values are means of five replicates ± SE. Different letters in the same column are significantly different at P <0.05 level, as determined by Duncan's Multiple Range Test. Figures in parenthesis indicate % promotion (+) and reduction (-) over control.

Table 1. Effect of foliar spray of mineral nutrients and irrigation water of different salinity levels on Promotion and Reduction percentage of reproductive parameters in *Gossypium hirsutum.*

6.3 Analytical analysis

6.3.1 Minerals analysis

Na^+ and K^+ ion concentration (ppm) and Na+/ K+ ratio performed in the stem and leaf samples are presented in Table 2.

i. In leaf and stem Na^+ concentrations increased at both 6.2 and 10.8 dS/m salinity levels of sea salt irrigation water.
ii. Though degree of reduction was reduced by different mineral nutrients spray up to greater extent and by only water spray up to lesser extent.
iii. Foliar spray of potassium with the mixture each single (Fe, Mn, Mo) microelement at control plants and those growing under both the salinities in above mentioned plant parts showed best result as compare to potassium nitrate with the mixture single microelement, alone KNO_3 , KCl, Urea, Fe, Mn and Mo spray which is evident from (Table 2.) as well.
iv. Increase in Na^+, decreased is found in the K^+ accumulation in leaf and stem under low and high salinity levels, irrespective of any foliar treatment.
v. Due to increase in N^{a+} concentrations, K+ concentrations decrease in leaves and stems, resulted increase in N^{a+} / K^+ ratio under increasing salinities which adversely affect growth but the spray of KNO_3 KCl, Urea, Fe, Mn and Mo alone and potassium with the mixture each single (Fe, Mn, Mo) microelement decreased this ratio suppressing the inhibitory effect of excessive sodium on growth.

	LEAF			STEM		
Treatment	Na^+ (ppm)	K^+ (ppm)	Na^+/ K^+	Na^+(ppm)	K^+ (ppm)	Na^+/ K^+
Nonspray						
0.6 dS/m	181.67 ^{c}±0.88	52.00 ^{a}±0.58	3.49 ^{c}±0.02	184.27 ^{c}±0.88	48.40 ^{a}□0.58	3.81 ^{c}±0.03
6.2 dS/m	232.33 ^{b}±0.88	47.00 ^{b}±0.58	4.95 ^{b}±0.08	234.93 ^{b}±0.88	43.40 ^{b}±0.58	5.42 ^{b}±0.09
10.8 dS/m	244.33 ^{a}±0.67	47.00 ^{b}±0.58	5.20 ^{a}±0.08	247.49 ^{a}±0.67	43.40 ^{b}±0.58	5.69 ^{a}±0.09
LSD $_{0.05}$	2.82	1.99	0.22	2.82	1.99	0.26
Foliar spray with water						
0.6 dS/m	184.33 ^{c}±1.53	58.00 ^{a}±1.00	3.18 ^{c}±0.03	186.93 ^{c}±1.53	54.40 ^{a}±1.00	3.44 ^{c}±0.04
6.2 dS/m	193.33 ^{b}±0.88	57.00 ^{b}±0.58	3.39 ^{b}±0.03	195.93 ^{b}±0.88	53.40 ^{a}±0.58	3.67 ^{b}±0.03
10.8 dS/m	224.67 ^{a}±0.67	53.00 ^{b}±0.58	4.24 ^{a}±0.04	227.27 ^{a}±0.67	49.40 ^{b}±0.58	4.60 ^{a}±0.04
LSD $_{0.05}$	2.82	1.99	0.10	2.82	1.99	0.12
Foliar spray with Fe-EDTA (5 ppm)						
0.6 dS/m	130.00 ^{b}±0.58	85.00 ^{a}±0.58	1.53 ^{c}±0.02	132.60 ^{b}±0.58	81.40 ^{a}±0.58	1.63 ^{c}±0.02
6.2 dS/m	131.00 ^{ab}±0.58	82.00 ^{b}±0.58	1.60 ^{b}±0.02	133.60 ^{ab}±0.58	78.40 ^{b}±0.58	1.70 ^{b}±0.02
10.8 dS/m	132.33 ^{a}±0.33	79.33 ^{c}±0.88	1.67 ^{a}±0.02	134.93 ^{a}±0.33	75.73 ^{c}±0.88	1.78 ^{a}±0.02
LSD $_{0.05}$	1.76	2.40	0.06	1.76	2.40	0.06
Foliar spray with $MnCl_2$ (5 ppm)						
0.6 dS/m	152.00 ^{a}±0.58	78.00 ^{a}±0.58	1.95 ^{c}±0.01	154.60 ^{a}±0.58	74.40 ^{a}±0.58	2.08 ^{c}±0.01
6.2 dS/m	143.67 ^{b}±0.88	66.00 ^{b}±0.58	2.18 ^{b}±0.01	146.27 ^{c}±0.88	62.40 ^{b}±0.58	2.34 ^{b}±0.01
10.8 dS/m	148.33 ^{c}±0.88	63.33 ^{c}±0.88	2.34 ^{a}±0.04	150.93 ^{b}±0.88	59.73 ^{c}±0.88	2.53 ^{a}±0.05
LSD $_{0.05}$	2.74	2.40	0.088	2.74	2.40	0.09
Foliar spray with MoO_3 (5 ppm)						
0.6 dS/m	153.33 ^{a}±0.88	62.33 ^{a}±0.88	2.46 ^{c}±0.02	155.93 ^{a}±0.88	58.73 ^{a}±0.88	2.66 ^{c}±0.02
6.2 dS/m	157.00 ^{ab}±0.58	60.67 ^{b}±0.88	2.59 ^{b}±0.03	159.60 ^{ab}±0.58	57.07 ^{b}±0.88	2.80 ^{b}±0.03
10.8 dS/m	162.33 ^{a}±0.88	59.67 ^{c}±0.67	2.72 ^{a}±0.02	164.93 ^{a}±0.88	56.07 ^{c}±0.67	2.94 ^{a}±0.02
LSD $_{0.05}$	1.76	2.40	0.06	1.76	2.40	0.06

	LEAF			STEM		
Treatment	Na^+ (ppm)	K^+ (ppm)	Na^+/K^+	Na^+(ppm)	K^+ (ppm)	Na^+/K^+
Foliar spray with KNO_3 (500 ppm)						
0.6 dS/m	90.33 ^{a}±0.88	124.00 ^{a}±0.58	0.73 ^{c}±0.01	92.93 ^{a}±0.88	120.40 ^{a}±0.58	0.77 ^{c}±0.01
6.2 dS/m	110.00 ^{b}±5.04	121.67 ^{b}±0.88	0.90 ^{b}±0.04	112.60 ^{c}±5.04	118.07 ^{b}±0.88	0.95 ^{b}±0.04
10.8 dS/m	122.67 ^{c}±0.67	101.33 ^{c}±0.67	1.21 ^{a}±0.01	125.27 ^{b}±0.67	97.73 ^{c}±0.67	1.28 ^{a}±0.01
$LSD_{0.05}$	2.74	2.40	0.08	2.74	2.40	0.09
Foliar spray with KCl (500 ppm)						
0.6 dS/m	85.33 ^{c}±3.18	99.00 ^{a}±3.79	0.86 ^{c}±0.04	87.93 ^{c}±3.18	95.40 ^{a}±3.79	0.92 ^{c}±0.04
6.2 dS/m	126.00 ^{b}±0.58	103.00 ^{a}±1.53	1.22 ^{b}±0.01	128.60 ^{b}±0.58	99.40 ^{a}±1.53	1.29 ^{b}±0.02
10.8 dS/m	134.33 ^{c}±1.20	100.00 ^{a}±0.58	1.34 ^{a}±0.01	136.93 ^{a}±1.20	96.40 ^{a}±0.58	1.42 ^{a}±0.00
$LSD_{0.05}$	6.88	8.23	0.07	6.88	8.25	0.08
Foliar spray with Urea (1000 ppm)						
0.6 dS/m	103.67 ^{c}±1.86	93.33 ^{a}±0.88	1.11 ^{c}±0.01	106.27 ^{c}±1.86	89.73 ^{a}±0.88	1.18 ^{c}±0.01
6.2 dS/m	133.00 ^{b}±1.53	93.00 ^{a}±2.08	1.43 ^{b}±0.03	135.60 ^{b}±1.53	89.40 ^{a}±2.08	1.52 ^{b}±0.03
10.8 dS/m	141.33 ^{a}±1.86	91.67 ^{a}±1.45	1.54 ^{a}±0.01	143.93 ^{a}±1.86	88.07 ^{a}±1.45	1.63 ^{a}±0.01
$LSD_{0.05}$	6.06	5.36	0.06	6.06	5.36	0.07
Foliar spray with KNO_3 (500 ppm) + Fe-EDTA (5 ppm)						
0.6 dS/m	76.33 ^{c}±1.20	168.00 ^{b}±3.00	0.45 ^{c}±0.01	78.93 ^{c}±1.20	164.40 ^{b}±3.00	0.48 ^{c}±0.02
6.2 dS/m	102.00 ^{b}±1.53	158.33 ^{a}±1.20	0.64 ^{b}±0.01	104.60 ^{b}±1.53	154.73 ^{a}±1.20	0.68 ^{b}±0.02
10.8 dS/m	117.00 ^{a}±0.58	146.67 ^{a}±2.19	0.80 ^{a}±0.01	119.60 ^{a}±0.58	143.07 ^{a}±2.19	0.84 ^{a}±0.01
$LSD_{0.05}$	4.05	7.79	0.04	4.05	7.79	0.04
Foliar spray with KNO_3 (500 ppm) + $MnCl_2$ (5 ppm)						
0.6 dS/m	81.00 ^{c}±0.58	131.33 ^{b}±0.67	0.62 ^{c}±0.00	83.60 ^{c}±0.58	127.73 ^{b}±0.67	0.65 ^{c}±0.00
6.2 dS/m	111.00 ^{b}±0.58	136.33 ^{a}±0.33	0.81 ^{b}±0.00	113.60 ^{b}±0.58	132.73 ^{a}±0.33	0.86 ^{b}±0.00
10.8 dS/m	121.00 ^{a}±0.58	134.33 ^{a}±0.88	0.90 ^{a}±0.00	123.60 ^{a}±0.58	130.73 ^{c}±0.88	0.95 ^{a}±0.00
$LSD_{0.05}$	1.99	2.36	0.004	1.99	2.30	0.016
Foliar spray with KNO_3 (500 ppm) + MoO_3 (5 ppm)						
0.6 dS/m	84.67 ^{b}±7.76	126.33 ^{a}±0.88	0.67 ^{b}±0.06	87.27 ^{b}±7.76	122.73 ^{a}±0.88	0.71 ^{b}±0.07
6.2 dS/m	84.33 ^{b}±1.45	126.00 ^{a}±8.09	0.67 ^{b}±0.04	86.93 ^{b}±1.45	122.40 ^{a}±8.09	0.72 ^{b}±0.04
10.8 dS/m	126.67 ^{a}±1.77	135.00 ^{a}±0.58	0.94 ^{a}±0.01	129.27 ^{a}±1.77	131.40 ^{a}±0.58	0.98 ^{a}±0.02
$LSD_{0.05}$	16.1	16.28	0.15	16.12	16.28	0.16
Foliar spray with KNO_3 (500 ppm) + Fe-EDTA (5 ppm)+ $MnCl_2$ (5 ppm)+ MoO_3 (5 ppm)						
0.6 dS/m	57.33 ^{b}±0.88	187.00 ^{a}±1.16	0.31 ^{c}±0.00	59.93 ^{b}±0.88	183.40 ^{a}±1.16	0.33 ^{c}±0.00
6.2 dS/m	86.67 ^{a}±5.70	179.67 ^{ab}±4.98	0.48 ^{b}±0.02	89.27 ^{a}±5.70	176.07 ^{ab}±4.98	0.51 ^{b}±0.02
10.8 dS/m	89.67 ^{a}±1.20	168.33 ^{b}±2.73	0.53 ^{a}±0.00	92.27 ^{a}±1.20	164.73 ^{a}±2.73	0.56 ^{a}±0.01
$LSD_{0.05}$	11.7	11.57	0.04	11.76	11.57	0.03

Values are means of five replicates ± SE. Different letters in the same column are significantly different at $P < 0.05$ level, as determined by Duncan's Multiple Range Test.

Table 2. Effect of foliar spray of mineral nutrients and irrigation water of different salinity levels on sodium and potassium compositions in *Gossypium hirsutum*.

6.3.2 Biochemical analysis (chlorophyll, protein and carbohydrate content)

Biochemical estimation (i.e. chlorophyll content, carbohydrates and proteins) performed in the leaf samples collected at grand period of growth are presented in Table 3. Chlorophyll

content, carbohydrates and proteins were proportionally reduced with increase of salinity of sea salt irrigation water irrespective of any foliar spray medium. Foliar spray of KNO_3 with the mixture each single (Fe, Mn, Mo) microelement at control plants and those growing under both the salinities chlorophyll content, carbohydrates and proteins showed increase as compare to KNO_3 with the mixture single microelement, alone KNO_3 KCl, Urea, Fe, Mn and Mo spray. The spray of only water shows non-significant increase over control.

Treatment	Chlorophyll "a"	Chlorophyll "b"	Total Chlorophyll	Chlorophyll a/b	Total Sugars	Total Protein
	(mg/gm fresh weight)				(mg/gm dry weight)	
Non spray						
0.6 dS/m	0.637 a±0.003	0.903 a±0.003	1.490 a±0.005	0.738 a±0.005	25.450a±0.483	28.403 a±0.641
6.2 dS/m	0.531 a±0.082	0.827 b±0.012	1.308 a±0.091	0.666 a±0.098	23.283a±0.606	26.243 a±0.572
10.8 dS/m	0.308 b±0.006	0.509 c±0.000	0.767 b±0.006	0.613 a±0.014	20.100b±1.094	21.047 ±1.041
LSD 0.05	0.16	0.02	0.18	0.19	2.67	2.69
Foliar spray with water						
0.6 dS/m	0.667 a±0.003	0.933 a±0.003	1.520 a±0.005	0.768 a±0.005	25.950 a±0.483	28.903 a±0.641
6.2 dS/m	0.561 a±0.082	0.857 b±0.012	1.338 a±0.091	0.696 a±0.098	23.783 a±0.606	26.743 a±0.572
10.8 dS/m	0.338 b±0.006	0.539 c±0.000	0.797 b±0.006	0.643 a±0.014	20.600 b±1.094	21.547 b±1.041
LSD 0.05	0.16	0.02	0.18	0.19	2.67	2.69
Foliar spray with Fe-EDTA (5 ppm)						
0.6 dS/m	0.707 a±0.003	0.973 a±0.003	1.560 a±0.005	0.808 a±0.005	26.750 b±0.483	29.703 a±0.641
6.2 dS/m	0.601 a±0.082	0.897 b±0.012	1.378 a±0.091	0.736 a±0.098	24.583 a±0.606	27.543 b±0.572
10.8 dS/m	0.378 b±0.006	0.579 c±0.000	0.837 b±0.006	0.683 a±0.014	21.400 a±1.094	22.347 a±1.041
LSD 0.05	0.163	0.024	0.18	0.198	2.67	2.69
Foliar spray with $MnCl_2$ (5 ppm)						
0.6 dS/m	0.699 a±0.003	0.965 a±0.003	1.552 a±0.005	0.800 a±0.005	26.450 b±0.483	29.403 b±0.641
6.2 dS/m	0.593 a±0.082	0.889 b±0.012	1.370 a±0.091	0.728 a±0.098	24.283 a±0.606	27.243 a±0.572
10.8 dS/m	0.370 b±0.006	0.571 c±0.000	0.829±0.006	0.675 a±0.014	21.100 a±1.094	22.047 a±1.041
LSD 0.05	0.16	0.024	0.18	0.198	2.67	2.69
Foliar spray with MoO_3 (5 ppm)						
0.6 dS/m	0.687 a±0.003	0.953 a±0.003	1.540 a±0.005	0.788 a±0.005	26.340 a±0.483	29.293 a±0.641
6.2 dS/m	0.581 a±0.082	0.877 b±0.012	1.358 a±0.091	0.716 a±0.098	24.173 a±0.606	27.133 a±0.572
10.8 dS/m	0.358 b±0.006	0.559 c±0.000	0.817 b±0.006	0.663 a±0.014	20.990 b±1.094	21.937 cb±1.041
LSD 0.05	0.16	0.024	0.18	0.19	2.67	2.69
Foliar spray with Urea (1000 ppm)						
0.6 dS/m	0.722 a±0.003	0.988 a±0.003	1.575 a±0.005	0.823 a±0.005	27.020 a±0.483	29.973 a±0.641
6.2 dS/m	0.616 a±0.082	0.912 b±0.012	1.393 a±0.091	0.751 a±0.098	24.853 a±0.606	27.813 a±0.572
10.8 dS/m	0.393 b±0.006	0.594 c±0.000	0.852 b±0.006	0.698 a±0.014	21.670 b±1.094	22.617 b±1.041
LSD 0.05	0.16	0.02	0.18	0.19	2.67	2.69
Foliar spray with KCl (500ppm)						
0.6 dS/m	0.717 a±0.003	0.983 a±0.003	1.570 a±0.005	0.818 a±0.005	26.950 b±0.483	29.903 b±0.641
6.2 dS/m	0.611 a±0.082	0.907 b±0.012	1.388 a±0.091	0.746 a±0.098	24.783 a±0.606	27.743 a±0.572
10.8 dS/m	0.388 b±0.006	0.589 c±0.000	0.847 b±0.006	0.693 a±0.014	21.600 a±1.094	22.547 a±1.041
LSD 0.05	0.16	0.02	0.18	0.198	2.67	2.69

Treatment	Chlorophyll "a"	Chlorophyll "b"	Total Chlorophyll	Chlorophyll a/b	Total Sugars	Total Protein
	(mg/gm fresh weight)				(mg/gm dry weight)	
Foliar spray with KNO_3 (500 ppm)						
0.6 dS/m	0.732 ^{a}±0.003	0.998 ^{a}±0.003	1.585 ^{a}±0.005	0.833 ^{a}±0.005	27.450 ^{b}±0.483	30.403 ^{b}±0.641
6.2 dS/m	0.626 ^{a}±0.641	0.922 ^{b}±0.012	1.403 ^{a}±0.091	0.761 ^{a}±0.098	25.283 ^{a}±0.606	28.243 ^{a}±0.572
10.8 dS/m	0.403 ^{b}±0.006	0.604 ^{c}±0.000	0.862 ^{b}±0.006	0.708 ^{a}±0.014	22.100 ^{a}±1.094	23.047 ^{a}±1.041
LSD $_{0.05}$	0.16	0.02	0.18	0.198	2.67	2.69
Foliar spray with KNO_3 (500 ppm) +Fe-EDTA (5 ppm)						
0.6 dS/m	0.745 ^{a}±0.003	1.012 ^{a}±0.003	1.598 ^{a}±0.005	0.846 ^{a}±0.005	28.450 ^{a}±0.483	31.403 ^{a}±0.641
6.2 dS/m	0.639 ^{a}±0.082	0.936 ^{b}±0.012	1.416 ^{a}±0.091	0.775 ^{a}±0.098	26.283 ^{a}±0.606	29.243 ^{a}±0.572
10.8 dS/m	0.416 ^{b}±0.006	0.617 ^{c}±0.000	0.875 ^{b}±0.006	0.721 ^{a}±0.014	23.100 ^{b}±1.094	24.047 ^{b}±1.094
LSD $_{0.05}$	0.16	0.02	0.18	0.19	2.67	2.69
Foliar spray with KNO_3 (500 ppm) + $MnCl_2$ (5ppm)						
0.6 dS/m	0.742 ^{a}±0.003	1.009 ^{a}±0.003	1.596 ^{a}±0.005	0.843 ^{a}±0.005	28.340 ^{a}±0.483	31.293 ^{a}±0.641
6.2 dS/m	0.636 ^{a}±0.082	0.933 ^{b}±0.012	1.414 ^{a}±0.091	0.772 ^{a}±0.098	26.173 ^{a}±0.606	29.133 ^{a}±0.572
10.8 dS/m	0.414 ^{b}±0.006	0.614 ^{c}±0.000	0.872 ^{b}±0.006	0.718 ^{a}±0.014	22.990 ^{b}±1.094	23.937 ^{b}±1.041
LSD $_{0.05}$	0.16	0.024	0.18	0.198	2.37	2.69
Foliar spray with KNO_3 (500 ppm) + MoO_3 (5ppm)						
0.6 dS/m	0.737 ^{a}±0.003	1.003 ^{a}±0.003	1.590 ^{a}±0.005	0.838 ^{a}±0.005	28.020 ^{b}±0.483	30.973 ^{b}±0.641
6.2 dS/m	0.631 ^{a}±0.082	0.927 ^{b}±0.012	1.408 ^{a}±0.091	0.766 ^{a}±0.098	25.853 ^{a}±0.606	28.813 ^{a}±0.572
10.8 dS/m	0.408 ^{b}±0.006	0.609 ^{c}±0.000	0.867 ^{b}±0.006	0.713 ^{a}±0.014	22.670 ^{a}±1.094	23.617 ^{a}±1.041
LSD $_{0.05}$	0.16	0.024	0.18	0.19	2.67	2.69
Foliar spray with KNO_3 (500 ppm) + Fe- EDTA (5ppm)+ $MnCl_2$ (5ppm) + MoO_3 (5ppm)						
0.6 dS/m	0.747 ^{a}±0.003	1.013 ^{a}±0.003	1.600 ^{a}±0.005	0.848 ^{a}±0.005	29.040 ^{a}±0.483	31.993 ^{b}±0.641
6.2 dS/m	0.641 ^{a}±0.082	0.937 ^{b}±0.012	1.418 ^{a}±0.091	0.776 ^{a}±0.098	26.873 ^{a}±0.606	29.833 ^{a}±0.572
10.8 dS/m	0.418 ^{b}±0.006	0.619 ^{c}±0.000	0.877 ^{b}±0.006	0.723 ^{a}±0.014	23.690 ^{a}±1.094	24.637 ^{a}±1.041
LSD $_{0.05}$	0.16	0.02	0.18	0.19	2.67	2.69

Values are means of five replicates ± SE. Different letters in the same column are significantly different at P <0.05 level, as determined by Duncan's Multiple Range Test.

Table 3. Effect of foliar spray of mineral nutrients and irrigation water of different salinity levels on chlorophyll, sugar and protein content in *Gossypium hirsutum*.

6.3.3 Electrical conductivity and pH of Soil

Changes in electrical conductivity and pH of irrigation water, leachate and soil was monitored at different stages of growth during the course of experiment and only data of at termination of experiment is presented in Table 4. Increase in EC was seen as the concentration of sea salt irrigation increased but in spite of good amount of salt drained out through leachate with subsequent irrigation. The schedule of irrigation kept the increase in EC of soil about twice that of irrigation water. The resultant EC of the rooting medium was about twice at low and thrice at high levels than threshold values 6.2 and10.8 dS/m. Foliar application seems to have non-significant effect on the above-mentioned parameter irrespective of any salinity.

Treatment	Irrigation Water		Leachate		Soil	
	EC_{iw} (dS/m)	pH	EC (dS/m)	pH	EC_e (dS/m)	pH
Nonspray						
0.6 dS/m	0.6 ^{c}±0.06	7.34±0.07	3.20 ^{c}±0.12	8.31 ^{a}±0.17	1.53 ^{c}±0.07	7.00 ^{a}±0.81
6.2 dS/m	6.4 ^{b}±0.09	8.22 ^{a}±0.25	18.95 ^{b}±0.09	8.21 ^{a}±0.12	14.01 ^{b}±0.09	8.00 ^{a}±0.12
10.8 dS/m	10.9 ^{a}±0.09	8.55^{a}±0.16	24.51 ^{a}±0.09	8.51 ^{a}±0.02	21.03 ^{a}±0.09	8.31 ^{a}±0.02
LSD $_{0.05}$	0.71	0.608	0.90	0.42	1.16	1.63
Foliar spray with water						
0.6 dS/m	0.67 ^{b}±0.03	7.31 ^{b}±0.04	3.20 ^{c}±0.12	8.34 ^{a}±0.08	1.60 ^{c}±0.06	8.14 ^{a}±0.28
6.2 dS/m	6.2 ^{a}±0.12	8.35 ^{a}±0.20	17.89 ^{b}±0.12	8.35 ^{a}±0.18	14.33 ^{b}±0.12	8.28 ^{a}±0.18
10.8 dS/m	10.8 ^{a}±0.09	8.40 ^{a}±0.19	25.14 ^{a}±0.09	8.55 ^{a}±0.06	22.97 ^{a}±0.09	8.21 ^{a}±0.06
LSD $_{0.05}$	0.55	0.55	0.37	0.40	1.63	0.66
Foliar spray with Fe-EDTA (5ppm)						
0.6 dS/m	0.67 ^{c}±0.03	7.34 ^{a}±0.04	3.20 ^{c}±0.12	8.34 ^{a}±0.08	1.60 ^{c}±0.06	8.23 ^{a}±0.28
6.2 dS/m	6.3 ^{b}±0.15	8.24 ^{a}±0.22	18.54 ^{b}±0.15	8.24 ^{a}±0.09	14.07 ^{b}±0.15	8.12 ^{a}±0.09
10.8 dS/m	10.9 ^{a}±0.09	8.54±0.16	24.12 ^{a}±0.09	8.54 ^{a}±0.02	22.98 ^{a}±0.09	8.12 ^{a}±0.02
LSD $_{0.05}$	1.65	1.85	0.38	1.66	1.63	1.62
Foliar spray with $MnCl_2$ (5 ppm)						
0.6 dS/m	0.77 ^{c}±0.12	7.64 ^{b}±0.22	3.27 ^{c}±0.18	8.52 ^{a}±0.23	1.83 ^{c}±0.12	8.44 $^{a\ b}$±0.09
6.2 dS/m	6.3 ^{b}±0.09	8.21 ^{a}±0.19	17.89 ^{b}±0.09	8.32 ^{a}±0.06	14.12 ^{b}±0.09	8.12 ^{a}±0.06
10.8 dS/m	10.8 ^{a}±0.15	8.72 ^{a}±0.05	24.65 ^{a}±0.15	8.72 ^{a}±0.18	21.07 ^{a}±0.15	8.52 ^{a}±0.18
LSD $_{0.05}$	1.64	0.58	0.48	0.59	1.64	041
Foliar spray with MoO_3 (5 ppm)						
0.6 dS/m	0.61 ^{c}±0.07	7.47 ^{b}±0.01	3.24 ^{c}±0.14	8.21 ^{b}±0.12	1.57 ^{c}±0.09	8.12 ^{b} ±0.10
6.2 dS/m	6.2 ^{b}±0.17	8.25 ^{a}±0.25	18.93 ^{b}±0.17	8.24 ^{a}±0.12	14.10 ^{b}±0.17	8.02 ^{b} ±0.12
10.8 dS/m	10.8 ^{a}±0.09	8.66 ^{a}±0.12	25.63 ^{a}±0.09	8.64 ^{a}±0.06	21.12 ^{a}±0.09	8.45 ^{a}±0.06
LSD $_{0.05}$	1.64	0.44	0.61	0.27	1.64	0.24
Foliar spray with KNO_3 (500 ppm)						
0.6 dS/m	0.73 ^{c}±0.09	7.45±0.01	3.37 ^{c}±0.27	8.24 ^{a}±0.12	1.57 ^{c}±0.09	8.12 ^{a}±0.10
6.2 dS/m	6.2 ^{b}±0.10	8.34 ^{a}±0.15	18.21 ^{b}±0.10	8.34 ^{a}±0.03	14.00 ^{b}±0.10	8.11 ^{a}±0.03
10.8 dS/m	10.78 ^{a}±0.10	8.64 ^{a}±0.16	24.12 ^{a}±0.10	8.64 ^{a}±0.06	21.90 ^{a}±0.10	8.42 ^{a}±0.06
LSD 0.05	1.68	0.36	0.65	0.33	1.65	0.43
Foliar spray with Urea (1000 ppm)						
EC: 0.6 dS/m	0.67 ^{c}±0.07	7.52 ^{b}±0.09	3.40 ^{a}±0.30	8.60 ^{c}±0.16	1.63 ^{a}±0.15	8.73 ^{a}±0.21
EC: 6.2 dS/m	6.27 ^{b}±0.58	8.36 ^{a}±0.09	14.97 ^{b}±0.09	8.39 ^{a}±0.05	14.52 ^{b}±0.58	8.19 ^{a}±0.05
10.8 dS/m	10.25 ^{a}±0.58	8.55 ^{a}±0.13	22.97 ^{a}±0.09	8.59 ^{a}±0.02	21.36 ^{a}±0.58	8.39 ^{a}±0.02
LSD $_{0.05}$	1.64	0.50	0.62	0.43	1.66	0.47
Foliar spray with KCl (500 ppm)						
0.6 dS/	0.72 ^{c}±0.06	7.63 ^{b}±0.10	3.34 ^{c}±0.24	8.57 ^{a}±0.18	1.73 ^{c}±0.17	8.48 ^{a}±0.20
6.2 dS/m	6.50 ^{b}±0.58	8.23 ^{a}±0.22	15.10 ^{b}±0.17	8.27 ^{a}±0.09	14.52 ^{b}±0.58	8.07 ^{a}±0.09
10.8 dS/m	10.20 ^{a}±0.58	8.59 ^{a}±0.08	23.00 ^{a}±0.10	8.62 ^{a}±0.07	22.65 ^{a}±0.58	10.20 ^{a}±0.07
LSD $_{0.05}$	1.64	0.29	0.85	0.49	1.65	0.33

Treatment	Irrigation Water		Leachate		Soil	
	EC_{iw} (dS/m)	pH	EC (dS/m)	pH	EC_e (dS/m)	pH
Foliar spray with KNO_3 (500 ppm) + Fe-EDTA (5 ppm)						
0.6 dS/m	0.61 ^{c}±0.06	7.62 ^{c}±0.10	3.34 ^{c}±0.24	8.51 ^{a}±0.18	1.73 ^{c}±0.17	8.41 ^{a}±0.20
6.2 dS/m	6.32 ^{b}±0.17	8.23 ^{b}±0.22	17.58 ^{b}±0.17	8.23 ^{a}±0.09	14.10 ^{b}±0.17	8.01 ^{a}±0.09
10.8 dS/m	10.7 ^{a}±0.10	8.54 ^{a}±0.08	25.63 ^{a}±0.10	8.63 ^{a}±0.07	21.00 ^{a}±0.10	8.41 ^{a}±0.07
$LSD_{0.05}$	1.63	0.29	0.85	0.49	1.65	0.33
Foliar spray with KNO_3 (500 ppm) + $MnCl_2$ (5 ppm)						
0.6 dS/m	0.61 ^{c}±0.07	7.51 ^{b}±0.09	3.40 ^{c}±0.30	8.64 ^{a}±0.16	1.63 ^{c}±0.15	8.71 ^{a}±0.21
6.2 dS/m	6.1 ^{b}±0.09	8.31 ^{a}±0.09	16.39 ^{b}±0.09	8.31 ^{a}±0.05	14.12 ^{b}±0.09	8.11 ^{a}±0.05
10.8 dS/m	10.8 ^{a}±0.09	8.51 ^{a}±0.13	23.36 ^{a}±0.09	8.51 ^{a}±0.02	21.03 ^{a}±0.09	8.31 ^{a}±0.02
$LSD_{0.05}$	1.63	0.505	0.62	0.43	1.66	0.46
Foliar spray with KNO_3 (500 ppm) + MoO_3 (5 ppm)						
0.6 dS/m	0.62 ^{c}±0.07	7.54 ^{b}±0.08	3.50 ^{c}±0.40	8.52 ^{a}±0.22	1.67 ^{c}±0.15	8.41 ^{a}±0.12
6.2 dS/m	6.2 ^{b}±0.10	8.24 ^{a}±0.09	18.65 ^{b}±0.10	8.22 ^{a}±0.09	14.12 ^{b}±0.10	8.01 ^{a}±0.09
10.8 dS/m	10.8 ^{a}±0.10	8.54 ^{a}±0.08	24.78 ^{a}±0.10	8.62 ^{a}±0.06	21.36 ^{a}±0.10	8.41 ^{a}±0.06
$LSD_{0.05}$	1.63	0.56	0.49	0.49	1.64	0.42
Foliar spray with KNO_3 (500 ppm) + Fe-EDTA (5 ppm) + $MnCl_2$ (5 ppm) + MoO_3 (5 ppm)						
0.6 dS/m	0.62 ^{c}±0.06	7.57 ^{a}±0.12	3.27 ^{c}±0.18	8.33 ^{a}±0.14	1.53 ^{c}±0.09	8.53 ^{a}±0.06
6.2 dS/m	6.2 ^{b}±0.03	8.17 ^{a}±0.20	19.36 ^{b}±0.03	8.12 ^{a}±0.12	14.17 ^{b}±0.03	8.97 ^{a}±0.12
10.8 dS/m	10.8 ^{a}±0.10	8.44 ^{a}±0.16	24.56 ^{a}±0.10	8.42 ^{a}±0.17	21.3 ^{a}±0.10	8.94 ^{a}±0.17
$LSD_{0.05}$	1.63	1.99	1.99	1.99	1.99	1.99

Values are means of five replicates ± SE. Different letters in the same column are significantly different at P <0.05 level, as determined by Duncan's Multiple Range Test.

Table 4. Effect of foliar spray of mineral nutrients and irrigation water of different salinity levels on Electrical conductivity (EC) and pH of irrigation water, leachate and soil in *Gossypium hirsutum*.

7. Discussion

7.1 Vegetative growth

Growth is an end result between anabolic and catabolic reactions within a plant. Saline environment has shown reduction in growth depending upon their degree of salt tolerance. The degree of reduction in growth by increase in electric conductivity unit of growth medium (due to presence of salt) has also been worked out by different research work (Maas, 1986; Maas & Hoffmann, 1977).

Vegetative growth vigor as result of sea salt irrigation water and foliar application of minerals determined by measuring fresh and dry biomass in present investigations is described below:

Biomass production is a measure of net photosynthesis and factors limiting plant growth limited net photosynthesis (Reddy et al., 1997). (Kuznetsov et al., 1990) found that rhizosphere salinity of rooting medium caused decrease in the biomass production in cotton plants. Qadir & Shams (1997) reported decrease in biomass production in cultivars of cotton grown at ECe: 10 – 20 dS/m soil salinity.

Above-mentioned problem created by presence of extra sodium ions in root zone could be avoided if essential sodium antagonistic mineral are provide through foliar spray as shown by different workers in following references text. Oosterhuis (1998) reported that foliar feeding of a nutrient might actually promote the root absorption of the same nutrient. Spraying nutrients not only can increase the crop yield but also can reduce the quantities of fertilizer applied through soil Ahmad (1998). Being given through spray medium of single salt composition, there is an advantage of not facing the problems of ion antagonistism, which is encountered in mineral uptake through roots under saline environment.

The method of foliar application is practical only in those plants that are compassionate to aerial spray and are not injured by this treatment. Examples of plants which accept foliar application are orchid, forest trees, cereals crops like wheat, maize, rice and barley; oil seeds crops; potato, tomato sugar beet and many other vegetables (Kochhar & Krishnamorthy, 1988). Saline substrate is found to decline values of potassium in xylem vessels of plants (Wolf et al., 1990). Inhibition of cation uptake in presence of excessive sodium through root system with special reference to monovalent potassium ion is well documented in literature by, Lopez & Satti, 1996; in spinach, Chow et al., 1990 in fennel, Botella et al., 1997 in maize. Favorable growth response of including K^+ in composition of foliar spray has been demonstrated by many research workers and is confirmed by the work reported in present investigation even under saline environment.

Fageria (2001) reported following regarding reasonable supply of essential nutrients is one of the most significant factors in increasing crop yields. In crop plants, the nutrient relations are generally considered in terms of growth response and change in concentration of nutrients. Upon addition of two nutrients, an increase in crop yield that is more than adding only one, the interaction is constructive (synergistic). Similarly, if adding the two nutrients together produced fewer yields as compared to individual ones, the relations are unconstructive (antagonistic). However, most interactions are multipart; a nutrient interacting simultaneously with more than one nutrient this may induce deficiencies, toxicities, modified growth responses, and/or modified nutrient composition. Better understanding of nutrient interactions may be useful in understanding importance of balanced supply of nutrients and consequently improvement in plant growth or yields

Foliar application of essential microelements like iron, manganese and copper may be more practical than application to soil, where they are adsorbed on the soil particles and hence are less obtainable to the root system.

Selection of microelement was done on the basis of their specific role on plant growth. Iron forms two types iron containing protein haem proteins and iron sulphur - proteins in plant metabolism. Cytocrome are haem proteins, which are constituents of the redox system in chloroplast and mitochondria. While in case of iron sulphur proteins ferredoxin is the most prominent iron sulphur protein, which acts as an electron transmitter in number of basic metabolic, processes. In iron deficient leaves the rate of photosynthesis decreases unit leaf per area but not per unit chloroplast (Terry, 1980). Chelates of iron (III) and occasionally of iron (II) are therefore the dominant forms of soluble iron in soil and nutrient solution. As a rule iron (II) is the species taken up. Iron (III) therefore has to be reduced at the root surface before transport into the cytoplasm (Roemheld & Marschner, 1983).

Manganese is absorbed mainly as Mn (II) and translocated predominantly as the free divalent cation in the xylem from the root to the shoot. The specific role of Mn as a mineral nutrient is presumably related to its tightly bound form in metalloprotein, where it acts as a structural constituent, as an active binding site. The most well known and extensively

studied function of Mn in green plants is its involvement in photosynthetic oxygen evolution. It is now established that Mn is required in both lower and high plants for the Hill reaction – the water splitting and oxygen evolving system in photosynthesis (Chenaie & Martin, 1968).

Molybdenum is a metal, it occurs in aqueous solution mainly as a molybdate oxyanion, MoO_4^{-2}, in its highest oxidized form [Mo (VI)]. The requirement of plants for Mo is lower than that for any of the other mineral nutrient. Nitrogenase and nitrate reductase are two well-defined enzymes containing Mo. Mo requirement of higher plants therefore depends on the mode of nitrogen supply.

In present investigations potassium in foliar spray medium was given in concentration 500ppm keeping in view the leaf morphology of cotton leaves. In addition, three bi and trivalent essential minerals (i.e. iron, manganese and molybdenum) were included in spray medium, considering possibility of inhibition in their uptake from sodium rich substrate thus not being sufficiently available for growth. Urea was included to see the effect of different sources for supply of nitrogen through foliar application on growth. The foliar spray of KNO_3 or KCl individually is expected to throw some light on the effect of nitrogen and chlorine on growth. The following discussion deals with the effect of foliar spray comprising of potassium and other micronutrients in plants growing at saline substrate with reference to our work.

Foliar nutrient spray had beneficial effect on plant fresh and dry biomass which persists even in salinity. Foliar spray of with KNO_3 with three micronutrient (Fe, Mn, Mo) was of highest order whereas, foliar spray of KNO_3 with Fe, KNO_3 with Mn and KNO_3 with Mo, occupies second, third and fourth position respectively. Foliar spray of alone KNO_3, Urea, KCl, Fe, Mn, Mo and water, occupies fifth, sixth, seven, eight, ninth, tenth and eleventh position respectively.

Kaya et al., (2001) reported that 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 the same results in Cucumber and Pepper and Leidi & Saiz, 1997 in Cotton. Foliar spray of Ca $(NO_3)_2$, $MnSO_4$ and K_2HPO_4 partially minimized the salt induced nutrient deficiency increased in dry matter grown in different salinity levels Sultana et al., (2002). Whereas, Bernardo Murillo-Amador et al., (2005) reported that salt-stressed plants had less dry matter in the root and shoot when sprayed with the foliar Ca $(NO_3)_2$ sprays.

Foliar spray of KNO_3 alone or in combination with one or three microelement the accumulation of dry matter increased in contrast to control nonspray, water spray or micro nutrient alone, indicating that toxic ions such Na^+, Cl^- in the leaves, may interfere with phloem loading restricting the uptake of nutrients from roots to shoots. The rate of foliar absorption of Cl^- increases in the following order: sorghum < cotton, sunflower < cauliflower < sesame, alfalfa, sugar beet < barley, tomato < potato, safflower (Maas et al., 1982). However, the above order does not apply to foliar injury. Thus, when nutrients are applied to the leaves, and restricts the inhibition due to toxic effect of Na^+, Cl^- or minimizing the salinity induced nutrient deficiency.

Findings in our experiment showed that both the sprays of 500 ppm KNO_3 and 500 ppm KCl resulted in significant growth promotion under non-saline as well as condition. In addition former up to greater extent and later in smaller extant show considerable inhibition in offsetting sodium-induced toxicity of saline rooting medium. Provision of nitrogen attached with potassium in KNO_3 may have contributed to this better performance, as some

research worker considers chlorine attached with KCl being non-essential element is considered growth inhibitor in higher concentration. 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 (Khan & Srivastava, 1998). Recent preliminary studies indicate that adequate levels of chloride in the nutrient solution may reduce the amount of nitrogen required without effecting plant growth or yield. The negatively charged chloride anion also acts as a counter ion to the positively charged cations in the cell. Chloride is involved in regulating turgor pressure and growth of cells and is important in drought resistance. Chloride may also be beneficial in disease prevention, especially of the roots, by promoting healthy growth of the plant while creating a root zone environment (pH and osmotic properties) detrimental to pathogens (disease causing organisms) Mengel & Kirkby (1982).

Supply of Nitrogen foliar application through KNO_3 and urea has shown betterment in growth irrespective at non-saline as well as saline rooting medium, but growth under spray of former salt was better than later. This effect could be probably due to presence of growth promoting essential mineral K^+ attached with it. Since plants do not directly utilize urea nitrogen in comparison with nitrate nitrogen during uptake. This behavior could be probably due to there being inorganic or organic nature. It appears that salt bearing sodium antagonistic potassium along with inorganic nitrogen provides a better spray material for promoting growth.

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. Plants did absorb more N from urea than KNO_3 applications. Nevin et al., (1990) reviewed urea foliar fertilization of avocado and found better growth with supply of foliar supplied urea.

Salinity stress has been reported stimulatory as well as inhibitory effects on the uptake of some micronutrients by plants. The uptake of Fe, Mn, Zn and Cu generally increases in crop plants under salinity stress (Alam, 1994). The detrimental effects of NaCl stress on the nutrition of bean plants are reflected in higher concentrations of Cl and Mn in roots and Cl, Fe and Mn in leaves and Cl and Fe in fruits Carbonell-Barrachina et al., (1998). Briefly, it is reasonable to believe that numerous salinity-nutrient interactions are occurring at the same time but whether these ultimately affect crop yield or quality depends upon the salinity level and composition of salts, the crop species, the nutrient in question and a number of environmental factors.

Foliar application of micronutrients showed encouraging effects on vegetative growth and nutrient uptake either before or after the salinization treatment El-Fouly et al., (2006). While in our studies spray of individual micronutrient (i.e. Fe, Mn, and Mo) show significant growth-promoting effect specially that of Fe in increasing various vegetative and reproductive growth parameters. Their grading in would be Mo <Mn <Fe respectively under control as well as high salinity level. Whereas spray of potassium in combination with individual micronutrient (i.e. Fe, Mn, and Mo) shows significant growth promoting specially affect specially that of Fe in increasing various vegetative and reproductive growth parameters. Its grading would be (KNO_3 + Mo) < (KNO_3 + Mn) < (KNO_3 + Fe) respectively. Similarly, when spray medium of K was done with all the three micronutrient Fe, Mn and Mo show significant increase at various vegetative and reproductive growth parameters in comparison with their individual spray of above-mentioned elements under control as well

as high salinity level. Supply of essential mineral element (Nitrogen, Potassium, Chlorine, Iron, Zinc, Manganese and Molybdenum) contributed for an increase in vegetative parameters 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 spray of above-mentioned mineral nutrients.

7.2 Reproductive growth

The following discussion is based on reproductive growth vigor with reference to number of flowers, balls and seed per plant, weight of seed and lint / per plant, seed cotton yield, seed/ lint ratio.

Plants normally take up nutrients from soils sediments through their roots although nutrients can be also supplied to plants as fertilizers by foliar sprays. Dhingra et al., (1995) reported that salinity of rhizosphere has been found accountable for reduction in reproductive yield. Reduction could be cumulative effect of various factors such as decline in number of flowers (Bishnoi et al., 1990; Sharma, 1992) faulty development of pollen grain and ovules resulting improper fertilization and denature embryo, reduction in number of pods per plant and seeds per pod, production of shrived seeds etc. Kumar et al., (1980). Early flower initiation was noticed in present study at 6.2 dS/m in *Gossypium hirsutum* over control. Increased production of flowers alone does not help in achieving high yield both in terms of number of fruits or weight of seeds (Dhingra & Varghese, 1997).

Foliar spray of different nutrient solutions used in present investigations reduced the inhibitory effect of saline water irrigation on various reproductive parameters. 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 seed per plant is reduced due to shy bearing of flowers, shedding of flowers and balls, development of pollen grain and ovules, fertilization, filling of seeds/ball etc.

According to Sarkar & Malik (2001) foliar spray of KNO_3 as well as Ca $(NO_3)_2$ exerted growth promoting effects on *Lathyrus sativus* L. (Grasspea). They further showed that foliar spray of at 0.50% KNO_3 during 50% flowering stage resulted in higher rate of pods formation /plant, increase in length of pod, number of seeds/pod and weight of 1000 seed in comparison with spray of 0.25 and 1.00% KNO_3 water spray and nonspray (control). However the spray of 0.406% Ca $(NO_3)_2$ gave result equivalent to 0.50% spray of KNO_3.

Brar & Tiwari (2004) reported increase in yield of cotton by 22%, 27% and 36% due to foliar application KCl, Urea and KNO_3 respectively. In the present investigation it is observed that number of flowers and balls per plant decreased at 6.2 and 10.8 dS/m respectively. The salinity of the rooting medium also reduces seed cotton yield 12.1% and 30.0% at 6.2 and 10.8 dS/m respectively. The foliar spray of KNO_3 along with mixture of three microelement (Fe, Mn, and Mo) occupies 1st position increasing seed cotton yield whereas the spray medium of KNO_3 with individual microelement Fe, Mn, Mo occupied 2nd, 3rd and 4th position respectively. The spray of all the above-mentioned individual nutrient namely KNO_3, Urea, KCl, Fe, Mn, Mo were capable of reducing the effect of sodium toxicity of rooting medium up to smaller extent but their spray was still promoting growth over water spray and nonspray treatments.

Hodgson & MacLeod (2006) reported proportionate increase in the yield of *Cotton* due foliar spray of 2.8, 5.9, 8.4 and 10.5 kg/hectare 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 25 kg/acre.

Table 5 A and B was compiled for the purpose of discussion out results presented in various figures of some important reproductive parameters to determine extent of promoting various spray medium. Taking into consideration "Seed *Cotton yield*" which is the main parameter for determining tonnage of production, one can reach to the following profitable salient features.

Concentrations of irrigation water	Seed Cotton yield (gm) /plant	Reduction percent in yield for seed cotton yield
0.6 dS/m	134.48	-
6.2 dS/m	92.16	31.64
10.8 dS/m	47.88	64.39

Table 5.A. Reduction percent Seed Cotton yield in Cotton plants undergoing sea salt irrigation water of different salinity levels.

	0.6 dS/m		6.2 dS/m		10.8 dS/m	
Spray Treatment	Seed Cotton yield (gm) /plant	% Increase	Seed Cotton yield (gm) /plant	%Increase	Seed Cotton yield (gm) /plant	%Increase
Non Spray	134.48		92.16		47.88	
Foliar Spray with water	149.40	9.99	99.28	7.17	62.00	22.77
Foliar Spray with Mo	163.20	17.60	123.00	25.07	74.40	35.65
Foliar Spray with Mn	177.48	24.23	144.76	36.34	84.32	43.22
Foliar Spray with Fe	200.64	32.97	162.24	43.20	104.96	54.38
Foliar Spray with KCl	224.40	40.07	183.70	49.83	120.56	60.29
Foliar Spray with Urea	253.44	46.92	215.94	57.32	138.18	65.35
Foliar Spray with KNO_3	278.72	51.75	255.68	63.95	161.16	70.29
Foliar Spray with KNO_3 + Mo	308.00	56.34	272.00	66.12	183.60	73.92
Foliar Spray with KNO3 + Mn	390.72	65.58	310.98	70.36	219.24	78.16
Foliar Spray with KNO_3 + Fe	419.64	67.95	338.92	72.81	254.98	81.22
Foliar Spray with KNO_3 + Fe +Mn + Mo	467.50	71.23	397.80	76.83	292.50	83.63

Promotion % calculates over the values obtained under nonspray treatment.

Table 5.B. Percent increase Seed Cotton yield due to foliar spray of different mineral nutrients in Cotton plants undergoing sea salt irrigation water of different salinity levels.

i. Reduction in seed cotton yield found 31.46 % at 6.2 dS/m and 64.39 % at 10.8 dS/m under sea salt water irrigation.
ii. The seed cotton yield under nonsaline condition in comparison with nonspray control plants after showing various figures of increase under different foliar spray medium shows a maximum of 71.23% when sprayed with the mixture of all the nutrients.
iii. Seed cotton yield in plants irrigated with sea salt solution 6.2 dS/m after showing various figures of increase under different foliar spray medium shows a maximum of 76.83%. Hence in reality total improvement in growth under above mentioned saline condition first by overcoming the toxic effect of salinity being 31.46%(Table 5 A), plus the improvement due to spray of a mixture of all the nutrient medium being 76.83% will be a total of 108.29% under above mentioned treatment.
iv. Seed cotton yield in plants irrigated with sea salt solution 10.8 dS/m after showing various figures of increase under different foliar spray medium shows a maximum of 83.63%. Hence in reality total improvement in growth under above mentioned saline condition first by overcoming the toxic effect of salinity being 64.39%(Table 5 A), plus the improvement due to spray of a mixture of all the nutrient medium being 83.62% will be a total of 148.01% under above mentioned treatment.

The overall comparative pattern of increase in different reproductive growth parameters in relation to their interaction with irrigation of different sea salt concentration and spray of different various mineral elements studied is given below:

Non-spray< water spray< Mo < Mn< Fe< KCl<Urea< KNO_3 < (KNO_3 + Mo) < (KNO_3 + Mn) < (KNO_3+Fe) < (KNO3 +Fe + Mn + Mo)

7.3 Mineral analysis

The effect of sea salt irrigation water on presence of Na^+ and K^+ in aerial vegetative parts of cotton plants was undertaken to find out their uptake from roots at saline rhizosphere and visualize uptake of K given through leaves along with different mineral composition.

In present investigation Na^+ concentration significantly increased in both stem and leaf with increase in salinity of substrate at 6.2 and 10.8 dS/m. Humera (2003) reported increase in Na^+ content in different plant parts with increase in salinity levels of substrate in the different species of family Crucifarea. Increase of Na^+ in the plant parts could be due to many reasons. i) Roots may be unable to check entry of sodium and their upward translocation due to its excessive presence in the rooting medium. ii) Plants may respond to accumulate high sodium ions to maintain osmotic adjustments against the low water potential in the saline soil.

The concentration of K^+ significantly decreased in both stem and leaf of in above-mentioned with increase in salinity levels of rooting medium. The influx of Na^+ to the root competes with K^+ uptake, since the uptake mechanisms for both ions are similar (Niu et al., 1995) but Na^+ ions having lower atomic weight and less electron positivity have better opportunity for uptake. High concentrations of Na^+ in the rooting medium of plants have been reported having antagonistic effect on K^+ uptake (Greenway & Munns, 1980; Jeschke, 1984). Jafri, 1990; Ahmad et al., 2002 reported an increase in Na^+ and decrease in K^+ uptake in cotton plants with increase in salinity of rooting medium. Maggio Albino et al., 2007 found leaf Na^+ increases whereas potassium and calcium ions decreased in tomato plant at increasing salinity which indicates that possibility of adsorption of K^+ and other di and trivalent cations at root are reduce in the presence of higher levels of Na^+ in rooting medium. Accumulation of toxic ions such as Na^+ and Cl^- was found accompanied by a reduction in K^+ content and the Na^+/ K^+ ratio of leaf blades in salt-sensitive sorghum increased with increase in salinity levels (Lacerda et al., 2003).

The failure to maintain required Na^+/ K^+ ratio reduces the survival potential of the plant under higher salinity regimes.
Some workers used K^+ / Na^+ ratio instead of Na^+/ K^+ ratio in their experiment and have shown that K^+, Na^+ decreases with increases in salinity (Akhavan-Kharazian et al., 1991; Cachorro et al., 1993).
The situation of providing monovalent K^+ and some essential di and trivalent ions through foliar uptake is changed in plants growing under high sodium rhizosphere; the following text throws some light with reference to present investigation.
Na^+ concentrations increased as the salinity level of irrigation water increased whereas K^+ concentrations were reduced. Foliar spray of potassium with the mixture each single (Fe, Mn, Mo) microelement at control plants and those growing under both the salinities at all the above mentioned plant parts occupy 1st position growth performance as compare to potassium with the mixture single microelement (Fe), (Mn) and (Mo), respectively having 2nd, 3rd and 4th position whereas alone potassium, Urea, KCl, Fe, Mn and Mo spray occupied 5th, 6th, 7th 8th , 9th and 10th position.
Na^+ / K^+ ratio have been discussed together due to application of many minerals in foliar medium, Na^+ / K^+ ratio in these plants under increasing salinities which adversely effect growth but the spray of foliar spray medium of different mineral nutrients alone or in combination with KNO^3 decreased this ratio suppressing the inhibitory effect of excessive sodium on growth.
Kaya et al., (2001) reported that a K^+ concentration of spinach was significantly reduced at 60 mM salinity, but foliar sprays of KH_2PO_4 mitigated the detrimental effect of high salt. Foliar spray of Ca $(NO_3)_2$, $MnSO_4$ and K_2HPO_4 in *rice* plant is reported to partially minimized the salt induced nutrient deficiency and increase potassium content grown in different salinity levels (Sultana et al. 2002). Kaya et al., (2007) while working on *Cucumis melo* found that 150 mM NaCl levels significantly increases Na^+ concentrations and decreases K^+ concentrations, but supplementary 5 mM $KNO^3$and 10 mM proline significantly ameliorated the adverse effects of salinity resulting increase in plant growth. Levent et al., (2007) reported in wheat cultivars that increasing levels of NaCl significantly increase in Na^+ concentrations and decrease K^+ concentrations but spray of soluble silicon significantly ameliorated the adverse effects of salinity resulting increase in plant growth.

7.4 Chlorophyll, protein and carbohydrate

The amount of chlorophyll, protein and carbohydrate was proportionally reduced with increase of salinity of irrigation water. Whereas the spray of different sodium antagonistic essential mineral elements recorded an increase in their quantity that suppressing the inhibitory effect of salt on the growth. However the pattern of decrease in the amount of these biochemicals persists proportionate to increase in salinity treatment. Changes in the quantity of above mentioned biochemical's in plants subjected to spray medium of different chemical composition under same as well as nonsaline environment is given below:
Foliar spray of potassium with the mixture each single (Fe, Mn, Mo) microelement at control plants and those growing under both the salinities Chlorophyll content, carbohydrates and proteins showed significant increase as compare to potassium with the mixture single microelement, alone KNO_3 KCl, Urea, Fe, Mn and Mo spray. The spray of only water shows non-significant increase over control. Decrease in chlorophyll content at high salt concentrations is reported by Ahmad & Abdullah (1979) in cotton. The mechanism of salt

effect on pigment is not yet clearly understood but decrease in the leaf pigment under higher salinity of rooting medium is attributed to the inhibition of iron containing enzymes, which inactivate the biosynthesis of chlorophyll (Rubin and Chernavina, 1960). On the other hand increase in chlorophyll content is reported by (Reddy et al., 1992) in some salt tolerant plants under saline substrate. Kaya et al., (2007) have shown that 150 mM NaCl levels significantly decreased chlorophyll content, in *Cucumis melo* but supplementing 5 mM KNO_3 and 10 mM proline in spray medium significantly ameliorated the adverse effects of salinity resulting increase in plant growth. According to Sarkar & Malik (2001) reported that improvement in growth due to foliar spray of 0.5% KNO_3 in Grasspea at 0.50%, which resulted in sufficient, supply of Nitrogen, which increase, chlorophyll and protein content in plants. The concentration of some organic solutes such as proline, polyamines, amino acids, soluble sugars, and sugar alcohols increases in leaves under saline conditions, contributing in the osmoregulation of plants Kafi et al., (2003).

Diego et al., (2004) reported that total soluble carbohydrates increased only in roots but proline content was decreased in both roots and leaves of *Prosopis alba* under increasing saline rooting medium. Carbohydrates can be accumulated and used by leaves for osmotic adjustment under salt stress (Cheesman, 1988). Under saline conditions, an increase observed in soluble carbohydrate composition of olive leaves (Tattini et al., 1996).

7.4 Changes in EC and pH values in soil

Changes in EC and pH values in soil due to salt accumulation during saline water irrigation have been presented in tabulated form. An increase in ECe values with the increase of salt of irrigation water is evident. The presence of sodium in irrigation water increases the exchangeable sodium in the colloidal system of the soil, which results in the deterioration of soil physical properties, and affects the plant growth and productivity (El-Saidi, 1997). Increasing amount of EC in leachate shows that salts accumulated in soil due to saline water irrigation are being regularly washed down in subsequent irrigation. Hence the plants are in reality growing under resultant ECe of rhizosphere, which is about twice that of irrigation water which considering in terms of reported EC values at threshold points (Maas & Hoffmann, 1977). The foliar sprays of Sodium antagonistic essential minerals have definitely extended these limits.

8. Conclusion

Considerable improvement was observed by spray of essential minerals used in present investigations on various vegetative and reproductive growth parameters in *Gossypium hirsutum* raised at saline rooting medium created by increasing concentrations of sea salt irrigation. Their overall performance is concluded below:

i. Irrigation with water of different sea salt (S.S) concentrations without any foliar spray resulted in growth inhibition in the order of increasing sea salt concentrations of rooting medium both on vegetative and reproductive parameter.
ii. Foliar spray of only water under nonsaline as well as saline irrigation resulted in some growth promotion both on vegetative and reproductive parameter over their respective non-spray treatments, but the enhancement in growth due to foliar spray of various mineral compositions increased considerably.
iii. Control plants (non saline) as well as those undergoing sea salt irrigation provided with single salt spray of micronutrient (Fe/Mn/ Mo) show various degrees of increase at different vegetative and reproductive growth parameters in comparison with non-spray

or those sprayed only with water, whereas plant growth among themselves was in the order of Fe> Mn> Mo respectively.

iv. Sprays of KNO_3 and KCl both have shown significant growth improvement both under non-saline and saline condition. Provision of nitrogen attached with potassium in KNO_3 may have contributed to this better performance, as chlorine attached with KCl is considered growth inhibitor. Provision of Potassium was definitely antagonistic to toxic sodium helping in water relation and intermediary metabolism.

v. Supply of Nitrogen in the foliar application through KNO_3 and urea has shown betterment in growth irrespective at non-saline as well as saline rooting medium, but growth under spray of former salt was better than later, probably due to presence of growth promoting K^+ attached with it.

vi. Spray of potassium nitrate in combination with individual micronutrient (i.e. Fe, Mn, and Mo) show significant growth promoting effect specially that of Fe in increasing various vegetative and reproductive growth parameters. Their grading would be (KNO_3 + Fe)> (KNO_3 + Mn)> (KNO_3 + Mo) respectively.

vii. Spray medium of potassium nitrate in combination with all the three micronutrient Fe, Mn and Mo show significant increase at various vegetative and reproductive growth parameters in comparison with individual spray of above-mentioned elements.

viii. The overall comparative pattern of promotion in different vegetative and reproductive growth parameters in relation to interaction with irrigation of different sea salt solution and spray of different various mineral elements is given below:
Non-spray< water spray< Mo < Mn< Fe< KCl< Urea < KNO_3 < (KNO_3 + Mo) < (KNO_3 + Mn) < (KNO_3+Fe) < (KNO_3 +Fe + Mn + Mo)

ix. The amount of chlorophyll, protein and carbohydrate was proportionally reduced with increase of salinity of irrigation water but the spray of above mentioned sodium antagonistic essential mineral elements suppressed the inhibitory effect of salt and increased their quantities following the same order as mentioned for various growth parameters.

x. Ionic distribution indicated greater uptake of Na^+ to the aerial parts of the plants under increasing salinity, which adversely affected the Na^+ /K^+ ratio but the spray of sodium antagonistic different essential mineral elements decreased this ratio suppressing the inhibitory effect of salt thus increasing growth following the same order as mentioned for different growth parameters.

xi. An increase in ECe values of soil with increase in salt of irrigation water is evident. Increasing amount of EC in leachate shows that salt accumulated in soil due to saline water irrigation is being regularly washed down in subsequent irrigation. Hence the plants are in reality growing under resulted ECe of rhizosphere, which is about twice that of irrigation water under prevalent soil texture.

xii. In general, growth of *Gossypium hirsutum* was inhibited under soil salinity beyond their threshold values whereas foliar spray of potassium alone or with other essential microelement released sodium induced toxic effect, increasing growth vigor.

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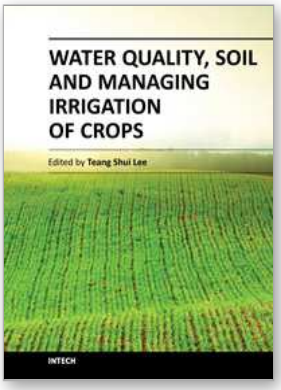

Water Quality, Soil and Managing Irrigation of Crops

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The book entitled Water Quality, Soil and Managing Irrigation of Crops comprises three sections, specifically: Reuse Water Quality, Soil and Pollution which comprises five technical chapters, Managing Irrigation of Crops with four, and Examples of Irrigation Systems three technical chapters, all presented by the respective authors in their own fields of expertise. This text should be of interest to those who are interested in the safe reuse of water for irrigation purposes in terms of effluent quality and quality of urban drainage basins, as well as to those who are involved with research into the problems of soils in relation to pollution and health, infiltration and effects of irrigation and managing irrigation systems including basin type of irrigation, as well as the subsurface method of irrigation. The many examples are indeed a semblance of real world irrigation practices of general interest to practitioners, more so when the venues of these projects illustrated cover a fair range of climate environments.

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