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IMPROVING TOLERANCE OF SUNFLOWER AND SAFFLOWER DURING GROWTH STAGES TO SALINITY THROUGH FOLIAR SPRAY OF NUTRIENT SOLUTIONS

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Abstract

The effect of salinity and foliar application of nutrient solutions on sunflower and safflower in vegetative and reproductive phases of the growth were investigated in Biosaline Research Field, University of Karachi, Pakistan. The seeds were sown in pots under non saline condition and saline water irrigation was started at three leaf stage after germination. Different concentration of saline water were made by dissolving 3g and 6g sea salt per litre of tap water, equivalent to an EC of 4.8 and 8.6 dS/m respectively. Nutrient solution (KNO_3, H_3BO_3, Fe-EDTA or its mixture) was sprayed thrice, i.e., 45, 75 and 95 days after planting. KNO_3 was given @ 250ppm and other $H_3BO_3$and Fe-EDTA was given @ 5ppm. Salinity caused a significant reduction in nutrient uptake, height, biomass and yield of both sunflower and safflower. Foliar application of macro and micronutrients (i.e.KNO_3, H_3BO_3, Fe-EDTA and mixture of KNO_3+ H_3BO_3+Fe-EDTA) partially minimized the salt induced deficiency and showed significant increase in height, fresh and dry biomass, number and weight of seeds, and amount of oil per sunflower and safflower plant irrespective to their growth under non saline or saline conditions. Among the nutrient solutions, mixture of KNO_3+ H_3BO_3+Fe-EDTA seemed to be the most effective followed by H_3BO_3 and Fe-EDTA. These results suggested that foliar application of nutrients could be used to improve plant tolerance to salinity by alleviating the adverse effects of salinity on growth and reproductive yield.

Abbreviations: EC, electrical conductivity; EC_{iw}, electrical conductivity of irrigation water, EC_e, electrical conductivity of soil extract; cv, cultivar

Introduction

Soil salinity refers to the presence of high concentration of soluble salts in the soil moisture of the root zone. Salinity is a major factor which limits the crop productivity in the arid and semi arid areas as a result of high evaporation and inappropriate irrigation techniques (Khan & Duke, 2001). It is the most important problem of irrigated agriculture while one fifth of the irrigated land of the world is salt affected. Every year 0.2-0.4% of the total arable land is going out of cultivation because of salinity and water logging. So, it is essential that income generating agriculture system should be adopted in severely salt affected areas. Due to scarcity of good quality water, sea water utilization in irrigation has also been a recent effort to explore the possibility of obtaining reasonable yield and quality from different crops.

Salinity either of soil or water cause reduction in growth and plants cope by either avoiding or tolerating salt stress before growth is impaired (Yokoi *et al.,* 2002). Glycophytes respond differently at lower levels of salinity but at higher level of salinity all of them show reduction in growth. Salt salinity limits plant growth by adversely affecting various physiological and biochemical processes including photosynthesis, antioxidant capacity, and ion homeostasis (Ashraf, 2004). Ionic imbalance occurs in the cells due to excessive accumulation of Na^+ and Cl^- and reduces the uptake of other essential minerals, such as K, Fe, B, Ca, Mn (Khan *et al.,* 1997; Lutts *et al.,* 1999). Potassium plays a key role in osmoregulation processes and protein synthesis, maintaining cell turgor and stimulating photosynthesis (Sultana *et al.,* 2001). Higher levels of K^+ in young expanding tissues are associated with salt tolerance in many plants (Khatun & Flowers, 1995). Foliar application of K^+ increased growth and yield of sunflower under salinity (Akram *et al.,* 2009). Iron plays essential role in the metabolism of chlorophyll. External application of iron has been shown to ameliorate the adverse effect of the soil moisture stress and increased growth and yield of mungbean plant (Kassab, 2005). Boron is involved in many processes including sugar transport, cell wall synthesis and maintenance, membrane integrity and RNA, indole acetic acid (IAA) and phenol metabolism (Loomis & Durst, 1992; Dordas & Brown, 2001). The need of boron for seed and grain production is higher than vegetative growth only (Vaughan, 1977). External application of boron was found to increase the vegetative and reproductive growth of the sunflower plant (Asad *et al.,* 2003).

Salinity can affect the growth of two very important oil yielding crops, sunflower (*Helianthus annuus* L.) and safflower (*Carthamus tinctorius* L.) at all the developmental stages (Kaya *et al.,* 2003; Jamil *et al.,* 2006; Flagella *et al.,* 2004; Siddiqi *et al.,* 2007). But the response to salinity varies with different sunflower and safflower genotypes (Rehman & Hussain 1998; Ashraf & Fatima, 1995). The reduction in growth of the salinized plants may result from the effect of salt on water and nutrient status, physiological and biochemical processes, and ionic imbalance (Hasegawa *et al.,* 2000). Low reproductive yield under salinity may result in a disturbance in photosynthesis, enzyme activities, protein synthesis, energy and lipid metabolism which effects the metabolites transportation to the seeds and hence reduced yield (Parvaiz & Satyawati, 2008). Mass & Hoffman (1977) have classified both the crops as moderately tolerant to salinity. Although the threshold of both the species is nearly identical, but the rate of yield decline above the threshold is much greater for safflower. There is a need of time to develop salt tolerant cultivars and agro-managemnet techniques to improve the physio-chemical properties of plants grown under saline conditions. Fertilizer application is now being tried to alleviate or neutralize growth inhibition due to salinization. Many physiological and chemical studies have also been conducted on the addition of nutrients to the soil medium in response to condition of salt stress (Song & Fujiyama, 1996a, b; Abdel-Rehman, 1999) but foliar application of fertilizer was found most effective and economical to improve the tolerance of the plant to salinity. The problems created by the presence of extra sodium ions in rhizophere can be avoided by providing some sodium antagonistic minerals through foliar spray that function to minimize osmotic stress or ion disequilibrium or alleviate the consequent secondary effects caused by the salt stress. Foliar application of minerals like potassium, iron, boron, manganese and copper may be more practical than application to soil where they adsorbed to the soil particles and less available to the rooting medium (El-Fouly *et al.,* 2002; El-Fouly *et al.*, 2004; Sarkar *et al.*, 2007; Cakmak, 2008).

The aim of the present investigation was to determine the extent of salt concentration in saline irrigation water which can still give feasible economic return in combination with foliar spray of some essential minerals (K, Fe, and B). For this purpose two important oil yielding crops, sunflower and safflower were grown under different concentration of saline irrigation and were sprayed with solution of KNO_3, H_3BO_3, Fe-EDTA, or its mixture to study their effects on vegetative and reproductive yield of the crops.

Materials and Methods

A moderately salt tolerant variety of sunflower (*Helianthus annuus* L. cv NuSun 636) and safflower (*Carthamus tinctorius* L. cv Spiny 061357) were sown in plastic pot. These pots were 0.28m in diameter, and 0.30m deep, having basal holes for leaching irrigation water, filled with 20 kg of sandy loam and cow dung manure (9:1) having pH 7.4 dS/m. The air temperature and relative humidity through out the growing period was 25-32°C and 60-80% respectively. Prior to NPK application the soil characteristics were determined (Table 1a) according to methods detailed in Sparks *et al.,* (1996). NPK ratio in fertilizer was given 4:3:2 through urea, DAP and sulphates of potash (SOP) for sunflower as recommended by Nawaz *et al.,* (2003), which amounts to 0.744g Nitrogen (N), 0.558g Phosphorus (P) and 0.372g Potassium (K) per pot and 7:15:7 for safflower as recommended by Naik *et al.,* (2007), which amounts to 0.217g Nitrogen (N), 0.465g Phosphorus (P) and 0.217g Potassium (K) per pot, given at the time of sowing and at the time of flowering. A certain amount of micronutrients were given in soil vide Hoagland solution (Hoagland & Arnon, 1938) twice along with irrigation water.

Table 1a. Soil phyico-chemical characteristics

Soil phyico-chemical characteristics	
Soil texture	**Sandy loam**
pH (1:1 H_2O)	7.8
EC (dS/m)	1.7
Organic matter (g kg^{-1})	16.2
NO_3^- (mg kg^{-1})	29
Total N (g kg^{-1})	1.5
P (Olsen mg kg^{-1})	18.1
$CaCO_3$ (g kg^{-1})	50
Ca^{2+} (g kg^{-1})	5.8
Mg^{2+} (g kg^{-1})	0.6
K (mg kg^{-1})	220
Na (mg kg^{-1})	123
Fe^{2+} (mg kg^{-1})	7.4
Zn^{2+} (mg kg^{-1})	1.1
Mn^{2+} (mg kg^{-1})	2.8
Cu^{2+} (mg kg^{-1})	5
B (mg kg^{-1})	0.7

We conducted 2 separate experiments for sunflower and safflower in November 2008 in a randomized complete block design with five replications. 90 pots, of each experiment, were divided in six sets comprising of 15 pots each.

	Sets	Treatments	
1.	Non spray	Control	
2.	Foliar spray	H_2O	
3.	Foliar spray	KNO_3	for K
4.	Foliar spray	H_3BO_3	for B
5.	Foliar spray	Fe-EDTA	for Fe
6.	Foliar spray	KNO_3+H_3BO_3+Fe-EDTA	for K, B and Fe

Out of 15 pots of above mentioned each sets, 5 pots of each were subjected to following different levels of saline water irrigation.

a) Non saline water (control) (EC 0.5 dS/m)
b) 0.3 % sea salt solution* (EC 4.8 dS/m)
c) 0.6 % sea salt solution (EC 8.6 dS/m)

* Sea salt solutions for irrigation were prepared by adding required amount of sea salt in tap water per liter. Sea salt is available in crude form in market. About 4% of its concentration was found equivalent to concentration of salts in the water of Indian Ocean. Sea water contains about 85% of NaCl and remaining percent may be of other elements such as sulfate, magnesium, calcium, potassium, bicarbonate, bromide, borate, strontium and fluoride (Castro & Huber, 2005).

The seeds were sown in pots under non saline condition and saline water irrigation was started at three leaf stage after germination to get seedlings of equal size. After thinning only one seedling was kept in each pot for further work. They were irrigated with gradual increasing sea salt concentration weekly up to reaching the desired salinity levels of the experiment mentioned above. To maintain the required soil medium salt levels the EC of the soil medium was measured periodically by portable EC meter. Plants were sprayed with water and nutrient solution of KNO_3, H_3BO_3, FeDTA or its mixture after 45, 75 and 95 days of planting i.e., during seedlings establishment, incipient of floral heads and start of seed formation, respectively. K was given @ 250ppm and other B and Fe was given @ 5ppm. The concentration of K, B and Fe in their respective solution, applied to the plants through foliar application was 96.5ppm, 0.85ppm and 0.76 ppm respectively. Tween-20 (0.1%) was used as a wetting agent for each treatment. A volume 300ml/plant, of the solution was sprayed on all pots with a manual sprayer. Spray was carried out between 09:00 and 11:00AM. The plants were sprayed with solutions with uniform coverage until the leaves were completely wet and the solution ran off the leaves. At the time of spray other plants were covered with plastic sheet to prevent the contamination of sprayed nutrients.

Control (non saline) plants were irrigated with 3.5L of tap water and plants under saline treatments were irrigated with 3.5L of their respective sea salt solution ensuring about 40% leaching. The tap water was analyzed (Table 1b) according to Chapman & Pratt (1982).

Pest management was carried out during the growth season according to local practice.

Table 1b. Chemical characteristics of irrigation water.

Chemical characteristics of irrigation water	
pH	**7.8**
EC (dS/m)	0.5
Total dissolved solids (mgL^{-1})	512
Nitrite(NO_2) as nitrogen (mgL^{-1})	1.2
Chloride (mgL^{-1})	270
Sulphate (mgL^{-1})	250
Ca^{2+} (mgL^{-1})	130
Mg^{2+} (mgL^{-1})	43.1
K (mgL^{-1})	8
Na (mgL^{-1})	30
Fe^{2+} (mgL^{-1})	0.1
Zn^{2+} (mgL^{-1})	0.3
Mn^{2+} (mgL^{-1})	0.01
Cu^{2+} (mgL^{-1})	0.8

Estimation of mineral concentrations: At flowering stage four upper leaves were taken for determination of Na, K, Fe, and B content of leaves. Samples were prepared for macro- and micro nutrients analysis according to Chapman & Pratt(1982), where the weighed plant organ were dry ashed in Muffle furnace at 823K (550^{o}C), then extracted by 2 mol HCl solution. Total Na and K content were determined through flame photometer (JENWAY PFP7) while Fe through atomic absorption spectrophotometer (Perkinelmer 1012, USA). Boron was analyzed by colorimeter using azomethine-H as color developing reagent (Niaz *et al.*, 2002).

Measurement of height and biomass: Plants height, fresh and dry biomass of the plant was measured at the end of flowering stage. After taking the fresh biomass the samples were oven-dried at 60^{o}C for 72 hours and dry weight was recorded.

Measurement of reproductive yield: At the physiological maturity plants were harvested and seeds were air dried. Number of seeds per plant, along with their weight and amount of oil per plant were measured.

Statistical analyses: SPSS version 13 was used for data analysis. Data sets were subjected to two-way analysis of variance (ANOVA). Duncan's multiple range test (DMRT) was used to measure least significant differences (LSD) between treatment methods and controls (Duncan, 1955).

Results and Discussion

Effect of salinity and foliar spray on mineral content: Mineral contents in the plants treated with sea salt solution are presented in Fig. 1A & 2A. The analysis of data revealed a significant increase in Na^+ concentration in sunflower and safflower leaves with the increasing salinity levels. Na^+ accumulation in sunflower treated with saline solutions of 4.8 dS/m and 8.6 dS/m is 28.9% and 66.2%, in safflower 18.1% and 32.5% respectively in comparison with their non saline control.

Sea salt salinity decreased K^+ by 52%, Fe by 50% and B by 46.4% in sunflower treated with saline solution of 8.6 dS/m in comparison with non saline control. Foliar application of nutrient solution increased K^+ by 21%, Fe by 20% and B by 18% in plants treated with saline solution of 8.6 dS/m (Fig. 1A, b-d). The safflower plants treated with saline solution of 8.6 dS/m the reduction in K^+ is 38%, in Fe, 41%, and in B, 44% in comparison with non saline control. Foliar application of nutrient solution increased K^+ by 20%, Fe by 20% and B by 18 % in plants treated with saline solution of 8.6 dS/m (Fig. 2A, b-d). Salt induced nutrient deficiency has been reported by many researchers (Cramer *et al.,* 1991; Khan *et al.*, 1997; *Lutts et al.,* 1999). The reduction of nutrient uptake may be attributed to that the high concentration of ions (i.e. Na^+ and Cl^-) in the soil solution are taken up at high rate which may lead to excessive accumulation in the tissue. These ions may inhibit the uptake of other ions into the root and their transport into the shoot through the xylem, eventually leading to the deficiency in the tissue (Tester & Davenports, 2003; Thalooth *et al.*, 2006). Grattan & Grieve (1994) reported that imbalanced absorption of essential nutritional ions by plants results an increase in the plants internal requirement for that essential element. However, our important target is how to minimize the salt-induced nutrient deficiency in both the plants. To overcome salt-induced nutrient deficiency, we sprayed respective nutrient solution combined with surfactant in the shoot. At 8.6 dS/m salinity, treated leaves contained 20% higher element concentration compared to unsprayed leaves. Many other workers in different plant species found that nutrients were absorbed by the leaves when applied onto the shoot (Smith *et al*, 1991; Abdel-Rehman, 1999). Foliar feeding with macro-or micronutrients could partially counteract the negative effect of NaCl on nutrients uptake through improving root growth and prevented the nutritional disorder and consequently caused an increase for the uptake of nutrient by roots (El-Fouly *et al.,* 2002).

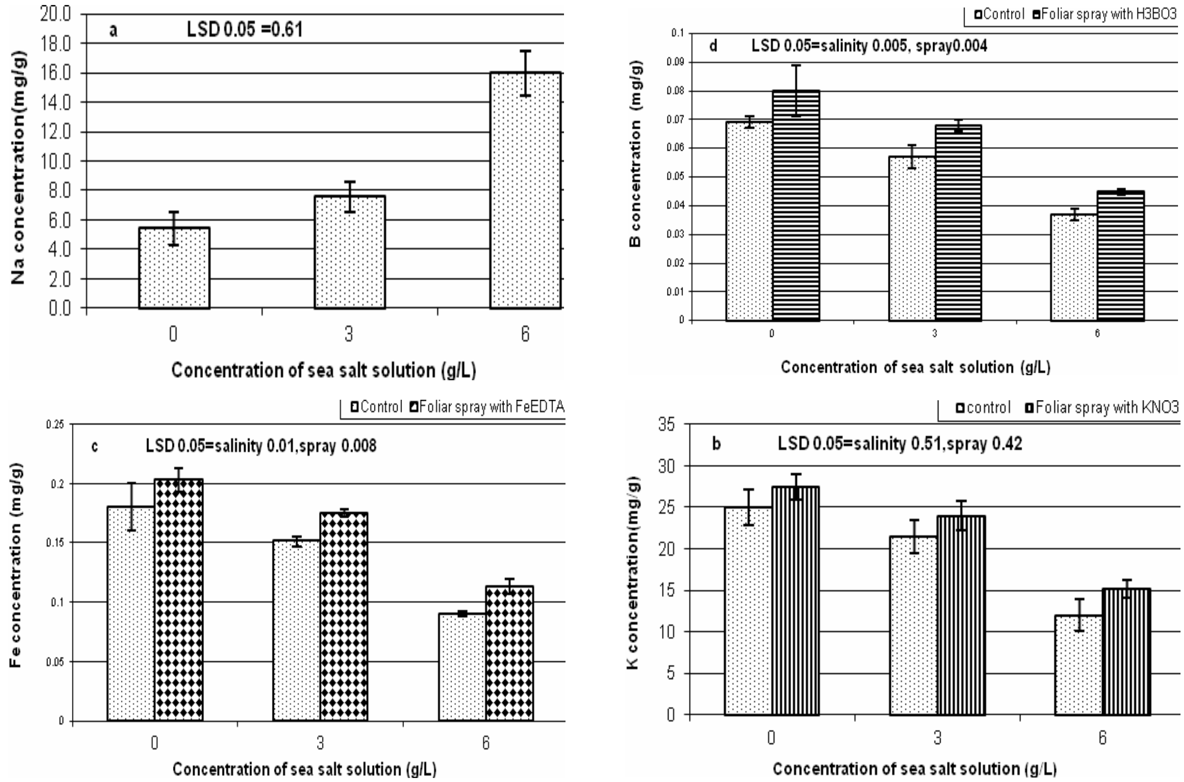


Fig. 1A. Effect of salinity and foliar spray of nutrient solution either potassium, iron or boron on K, Fe and B concentration in sunflower leaves. Vertical bars mean ± S.E. (n=3).

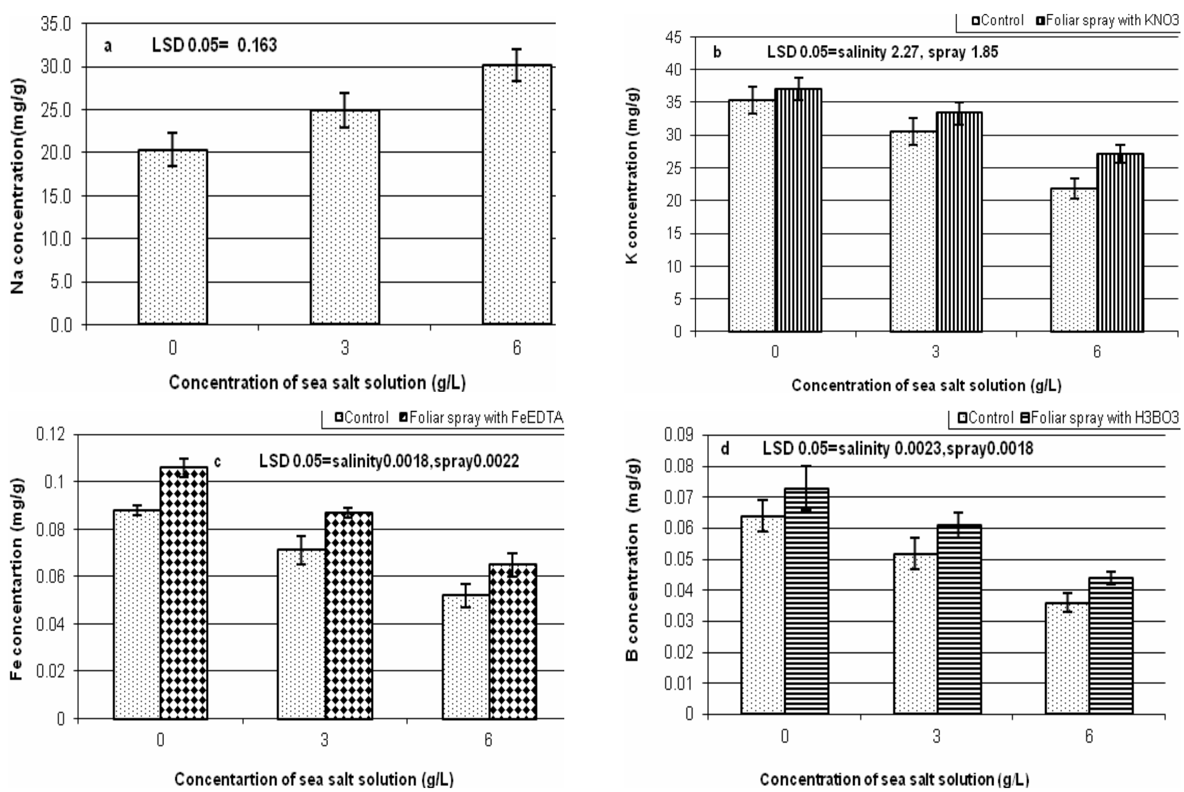


Fig. 2A. Effect of salinity and foliar spray of nutrient solution either potassium, iron or boron on K, Fe and B concentration in safflower leaves. Vertical bars mean ± S.E. (n=3).

Effect of salinity and foliar spray on plant growth

Plant height: Height of both the plant sunflower and safflower growing under different sea salt concentrations without any foliar application was reduced. Height of those plants sprayed with only water showed little betterment. A significant increase in height was observed in plants sprayed by individual macro or micronutrient solutions (i.e. K, B and Fe) but combined effects of their mixture was more significant irrespective to their growth under non saline (control) or saline conditions (Fig. 1B & 2B). El-Kader *et al.,* (2006) and Ahmad & Jabeen (2009) found similar reduction in plant growth parameters under salinity. Bassil & Kaffka (2002) reported that some growth parameter of safflower decreased at higher salinity level, height of safflower plant was decreased by 32 cm in higher salinity plot (EC_e: 7.2dS/m) as compare to control and it decreased by 4.8 cm per unit increase in EC_e.

The reduction in growth under saline rooting medium may be due to turgor pressure reduction in expanding tissues, reduction in photosystem activity in leaf cells, reduced ability to produce and utilize assimilates to the growing regions, direct effects of accumulated salts on metabolic steps in dividing and expanding cells (Munns *et al.,* 2004), lower absorption and utilization rate of essential nutrients (Romero & Maranon, 1994). However these detrimental effects of sea salt solution on growth could be partially alleviated by the application of nutrient solution through decreasing the nutrient demand in salt effected plants. Akram *et al.,* (2009) observed an improvement in growth and yield of sunflower due to the foliar spray of K^+ at 1.25% using different salt (KCl, KOH, K_2CO_3, KNO_3, KH_2PO_4, and K_2SO_4) under saline concentration of 150 mM NaCl. Thalooth *et al.,* (2006) observed a significant effect of micronutrients in growth parameters including yield in mungbean plant under water stress condition with the foliar application of zinc, potassium or magnesium. Such enhancement effect might be attributed to the favorable influence of these nutrients on metabolism and biological activity and its stimulating effect on photosynthetic pigments and enzymes activity which in turn encourage growth of plants (Michail *et al.,* 2004).

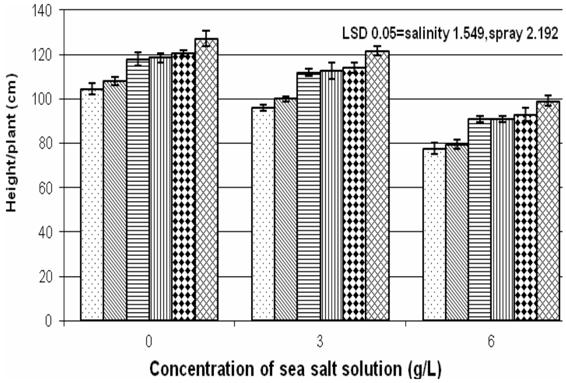
Fresh and dry biomass of plant: The effect of foliar spray and sea salt irrigation on fresh biomass of sunflower and safflower plant is presented in Fig. 1B & 2B. A corresponding significant decrease is observed in fresh biomass of plant under different increasing concentration of sea salt in irrigation. The reduction in sunflower plants treated with saline solutions of 4.8 dS/m and 8.6 dS/m is 16.4% and 32.9% in safflower plant 17.2% and 42.7% respectively in comparison with their non saline control. Dry biomass of the sunflower plants treated with saline solutions of 4.8 dS/m and 8.6 dS/m is reduced by 17.3% and 33.3% of safflower plants 17.8 % and 34.2% respectively in comparison with their non saline control (Fig. 1B & 2B).

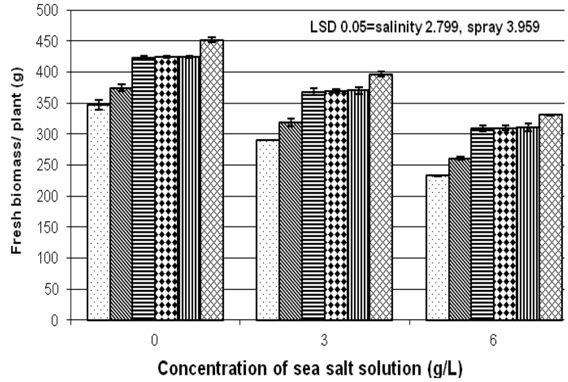
The biomass production in plants mainly depends on the accumulation of carbon products in photosynthesis and plant use the energy of photosynthates for their growth, survival and normal metabolic functions (Rains, 1978). If growth of plant suppressed under salinity the activity of photosynthesis will also be declined. Reduction in total biomass under different salinity levels was also reported by Khan *et al.,* (1989), Tahir & Mehdi (2001) and Bassil *et al.,* (2002). Reduction in biomass with increasing concentration of salinity may be due to reduction in water content both in roots and shoots which indicates that plants were not adjusted osmotically under various levels of salinity. A significant increase in fresh and dry biomass is observed in plants sprayed by individual macro or micronutrient solutions but combined effects of their mixture is more significant irrespective to their growth under non saline control or saline conditions. The obtained results are in agreement with the findings of Asad *et al.,* (2003), Basole *et al.,* (2003), Kassab (2005) and Thalooth *et al.,* (2006). These results suggested that foliar application of nutrient solution partially overcame salt-induced detrimental effects in plant.

Effect of salinity and foliar spray on reproductive yield: In both sunflower and safflower number and weight of seeds per plant, amount of oil per plant were measured after harvesting (Table 2&3). There were significant differences (p<0.05) for salinity and sprayed treatments for these parameters and the interaction effect between salinity and spray was also found significant for these parameters.

Seed yield of both the crops significantly reduced by increasing levels of salinity (Tables 2a, 3a). This reduction was attributed to reduction in seed number per head and weight of seeds per plant (Flagella *et al.,* 2004; Di Caterina *et al.,* 2007). The obtained data of seed yield of sunflower in present investigation showed 45.4% reduction at EC_e 9.9dS/m as compared to control. El-Kader *et al.,* (2006) found 50% reduction in yield at EC_e 9.4dS/m in fedok sunflower cultivar. Rehman & Hussain (1998a) also reported a negative relationship between achene yield and salinity stress in sunflower. The obtained data of seed yield of safflower in present investigation showed 15.5% reduction at EC_e 6.1dS/m and 49% reduction at EC_e 9.9 dS/m as compared to control. Ayers & Westcot (1976) reported 50% reduction in seed yield of safflower at EC_e 9.9dS/m. Francois & Bernstein (1964) found that at 7, 11 and 14 dS/m relative yield reduction were 10, 25 and 50% respectively.

Oil yield of sunflower was decreased significantly after salt imposition which is consistent with the findings of El-Kheir *et al.,* (2000), Flagella *et al.,* (2004), El-Kader *et al.,* (2006) and Di Caterina *et al.,* (2007) who observed significant reduction in oil yield in sunflower grown in saline conditions. In safflower oil yield was also decreased by increasing levels of salinity. In contrast Bassil *et al.,* (2002) reported that seed oil content of safflower remained unaffected by salinity (7.2dS/m). Our present results are similar with the findings of Francois & Bernstein (1964), Irving *et al.,* (1988), Ashraf & Fatima (1995) who reported a decrease in oil percent with the increasing levels of soil salinity. Francois & Bernstein (1964) have attributed this oil decrease to an increase in hull percentage and less developed seeds, caused by faster physiological maturity under salt stress.





Control (non spray)
Foliar spray with KNO_3
Foliar spray with H_3BO_3
Foliar spray with H_2O
Foliar spray with Fe-EDTA
Foliar spray with KNO_3+ H_3BO_3 +Fe-EDTA
ECiw: 0.5dS/m, ECe: 1.8dS/m (non saline)
ECiw: 4.8dS/m, ECe: 6.1dS/m (3g/l sea salt solution)
ECiw: 8.6dS/m, ECe: 9.9dS/m (6g/l sea salt solution)

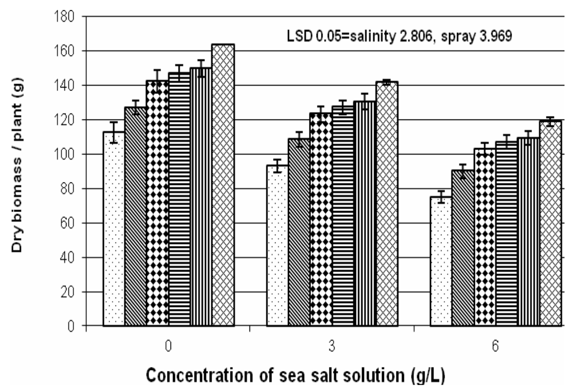
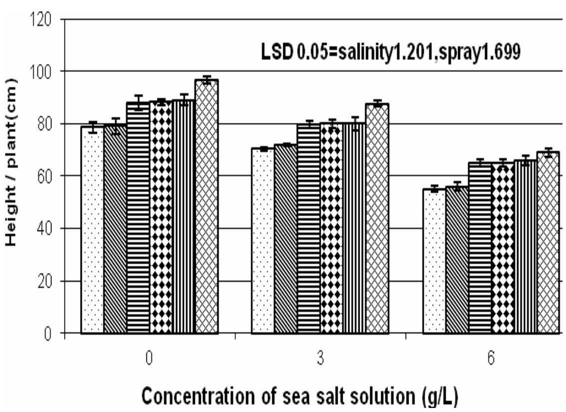
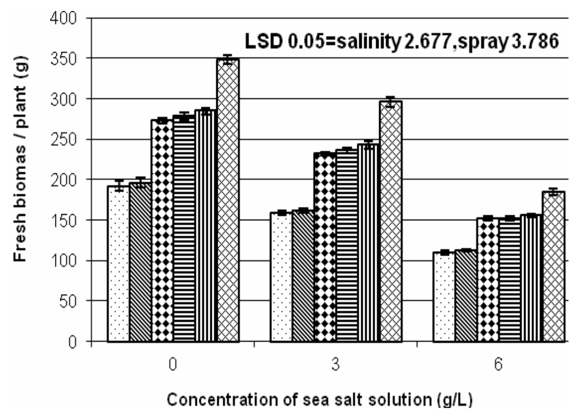


Fig. 1B. Effect of salinity and foliar spray of water, potassium, iron, boron and its mixture on height, fresh and dry biomass of sunflower plant.





Control (non spray)
Foliar spray with KNO_3
Foliar spray with H_3BO_3
Foliar spray with H_2O
Foliar spray with Fe-EDTA
Foliar spray with KNO_3+ H_3BO_3 +Fe-EDTA

EC_{iw}: 0.5dS/m, EC_e: 1.8dS/m (non saline)
EC_{iw}: 4.8dS/m, EC_e: 6.1dS/m (3g/l sea salt solution)
EC_{iw}: 8.6dS/m, EC_e: 9.9dS/m (6g/l sea salt solution)

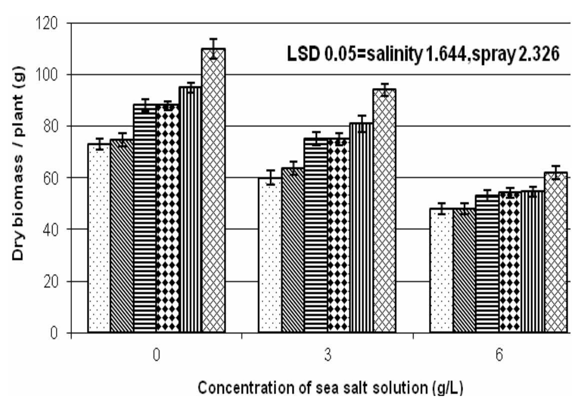


Fig. 2B. Effect of salinity and foliar spray of water, potassium, iron, boron and its mixture on height, fresh and dry biomass of safflower plant.

Table 2a. Comparative statement on reduction percentage of seed and oil yield in sunflower plant irrigated with different levels of sea salt solutions

Sea salt concentration (g/L)		No. of seeds/ plant	% Decrease	Seed weight g/plant	% Decrease	Oil content g/plant	% Decrease
0 (EC_{iw}:0.5dS/m, EC_e:1.8dS/m)	Control-1 (non spray)	380	--	19.76	--	8.87	--
3 (EC_{iw}:4.8dS/m, EC_e:6.1dS/m)	Control-2 (non spray)	355	6.6	17.22	12.8	7.19	18.9
6 (EC_{iw}:8.6dS/m, EC_e:9.9dS/m)	Control-3 (non spray)	280	26.3	10.78	45.4	3.57	59.8
LSD 0.05		3.462		0.223		0.125	

% Decrease is calculated with respect to non saline control

Table 2b. Increase percentages in seed and oil yield of sunflower plant exposed to foliar spray of different minerals under irrigation of different levels of sea salt solutions

Sea salt concentration (g/L)	Foliar spray treatments	No. of seeds/plant	% Increase	Seed weight g / plant	% Increase	Oil content g / plant	% Increase
0 (EC_{iw}:0.5dS/m, EC_e:1.8dS/m)	Control -1 (non spray)	380	--	19.76	--	8.87	--
	H_2O	390	2.6	20.28	2.6	9.13	2.8
	KNO_3	518	26.6	29.52	33.1	13.99	36.6
	H_3BO_3	520	26.9	30.16	34.7	14.63	39.4
	Fe-EDTA	497	23.5	28.34	30.3	13.32	33.4
	KNO_3+H_3BO_3+ Fe-EDTA	539	29.5	31.8	37.9	15.48	42.7
3 (EC_{iw}:4.8dS/m, EC_e:6.1dS/m)	Control -2 (non spray)	355	--	17.22	--	7.19	--
	H_2O	366	3.0	17.75	3.0	7.45	3.5
	KNO_3	498	28.7	27.14	36.6	12.35	41.8
	H_3BO_3	499	28.9	27.74	37.9	12.89	44.2
	Fe-EDTA	478	25.7	26.05	33.9	11.75	38.8
	KNO_3+H_3BO_3+ Fe-EDTA	520	31.7	29.43	41.5	13.74	47.7
6 (EC_{iw}:8.6dS/m, EC_e:9.9dS/m)	Control -3 (non spray)	280	--	10.78	--	3.57	--
	H_2O	292	4.1	11.24	4.1	3.74	4.5
	KNO_3	398	29.6	17.52	38.5	6.43	44.5
	H_3BO_3	401	30.2	17.75	39.3	6.67	46.5
	Fe-EDTA	382	26.7	17.43	38.2	6.34	43.7
	KNO_3+H_3BO_3+ Fe-EDTA	415	32.5	18.84	42.8	7.12	49.9
LSD 0.05	Salt	1.499		0.334		0.107	
	Spray	2.120		0.473		0.333	
	Interaction (spray x salinity)	***		***		***	

% Increase is calculated with respect to their non spray control. LSD= Least significant difference

Table 3a. Comparative statements on reduction percentage of seed and oil yield in safflower plant irrigated with different levels of sea salt solutions.

Sea salt concentration (g/L)		No. of seeds/ plant	% Decrease	Seed weight g/plant	% Decrease	Oil content g/plant	% Decrease
0 (EC_{iw}:0.5dS/m, EC_e:1.8dS/m)	Control-1 (non spray)	860	--	43.2	--	13.08	--
3 (EC_{iw}:4.8dS/m, EC_e:6.1dS/m)	Control-2 (non spray)	755	12.2	36.5	15.5	9.10	30.4
6 (EC_{iw}:8.6dS/m, EC_e:9.9dS/m)	Control-3 (non spray)	588	31.6	22.0	49.0	3.28	74.9
LSD 0.05		1.309		0.425		0.963	

% Decrease is calculated with respect to their non saline control

Table 3b. Increase percentages in seed and oil yield of safflower plant exposed to foliar spray of different minerals under irrigation of different levels of sea salt solutions

Sea salt concentration (g/L)	Foliar spray treatments	No. of seeds/plant	% Increase	Seed weight g / plant	% Increase	Oil content g / plant	% Increase
0 (EC_{iw}:0.5dS/m, EC_e:1.8dS/m)	Control -1 (non spray)	860	--	43.2	--	13.08	--
	H_2O	890	3.5	43.8	1.4	13.35	2.0
	KNO_3	1180	27.1	62.0	30.3	19.96	34.5
	H_3BO_3	1200	28.3	63.6	32.1	21.24	38.4
	Fe-EDTA	1180	27.1	62.5	30.9	20.50	36.2
	KNO_3+H_3BO_3+ Fe-EDTA	1225	29.8	65.8	34.3	22.04	40.6
3 (EC_{iw}:4.8dS/m, EC_e:6.1dS/m)	Control -2 (non spray)	755	--	36.5	--	9.1	--
	H_2O	788	4.2	37.8	3.4	9.6	5.2
	KNO_3	1068	29.3	54.4	32.9	15.5	41.3
	H_3BO_3	1090	30.7	56.0	34.8	16.58	45.1
	Fe-EDTA	1068	29.3	55..0	33.6	15.89	42.7
	KNO_3+H_3BO_3+ Fe-EDTA	1110	32.0	57.9	36.9	17.19	47.1
6 (EC_{iw}:8.6dS/m, EC_e:9.9dS/m)	Control -3 (non spray)	588	--	22.0	--	3.28	--
	H_2O	588	00	22.0	00	3.30	0.6
	KNO_3	850	30.8	33.1	33.5	6.02	45.5
	H_3BO_3	864	31.9	34.3	35.9	6.38	48.6
	Fe-EDTA	850	30.8	33.5	34.3	6.10	46.2
	KNO_3+H_3BO_3+ Fe-EDTA	880	33.2	35.5	38.0	6.82	51.9
LSD 0.05	Salt	3.796		0.261		0.240	
	Spray	5.368		0.369		0.340	
	Interaction (spray x salinity)	***		***		***	

% Increase is calculated with respect to their non spray control. LSD= Least significant difference

Reduction in reproductive yield as shown in seed number may be due to either lesser number of ovule formations per ovary under salinity stresses, or reduced pollen viability due to the ionic toxicity which may cause failure in fertilization (Uma & Patil, 1996). The reduction in seed weight might be through inhibition of photo-assimilation at grain filling stage, because high salinity reduces the content of photosynthetic pigments and proteins in leaves or ovaries which cause the decline in photosynthesis leading to the poor accumulation of sugar in ovaries (Sultana *et al.,* 2001). The disturbances in photosynthesis, enzyme activities, protein synthesis, energy and lipid metabolism under salinity effects the metabolites transportation to the grains and hence reduced yield (Parvaiz & Satyawati, 2008). Because of direct relation between seed yield and oil yield, decrease in seed yield cause decrease in oil yield (Singh, 2000).

Foliar spray of KNO_3, H_3BO_3, Fe-EDTA and their mixture increased the number of seeds and their weight, finally resulted in increased amount of oil per plant (Tables 2b & 3b) irrespective to their growth under non saline or saline condition. Seed and oil yield were higher in both the plants treated with KNO_3, H_3BO_3, Fe-EDTA mixture, followed by H_3BO_3, KNO_3 or Fe-EDTA. When nutrients are applied to the leaves, the nutrient elements might penetrate into the leaves and restrict the inhibition due to toxic effects of Na^+ and Cl^- or minimizes the salinity induced deficiency. These minerals increased photosynthetic and enzymatic activities and an effective translocation of assimilate to reproductive parts resulting in higher yield (Sarkar & Malik, 2001). Bybordi & Mamedov (2010) reported highest seed and oil yield in canola plant from foliar application of iron + zinc. Chandra & Das (2007) found 15000 ppm of $KN0_3$ in improving the morphological traits and yield components of toria (*Brassica campestris* L.).

The overall comparative pattern of promotion in reproductive yield with the interaction of irrigation of sea salt solution and spray of some essential minerals under both the nonsaline and saline conditions is given below:

Sunflower

Non spray control < Fe < K = B < their mixtures

Safflower

Non spray control < Fe = K < B < their mixture

Conclusion

The critical values of salts in rooting medium beyond which retardation occurs at any growth parameter (threshold value) was considerably extended due to foliar spray of above mentioned essential minerals which could provide incentive to farmer about growing plants through foliar application of essential minerals at a bit higher levels of soil salinities or saline water irrigation so far considered non productive for cultivation.

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