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COMPARATIVE GROWTH AND LEAF IONIC COMPOSITION OF FOUR COTTON (*Gossypium hirsutum* L.) GENOTYPES IN RESPONSE TO SALINITY

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Salinity is a major limiting factor for crop production around the globe. Besides many reclamation strategies, selection of crop cultivars tolerant to salinity can also improve crop production on salt affected lands. The present experiment was planned to study growth and ionic composition of four cotton genotypes as affected by salinity. Genotypes were grown either under salinity (150 mol m^{-3} NaCl) or under normal conditions and were compared for growth and leaf ionic composition. NaCl salinity significantly decreased shoot as well as root growth of all the cotton genotypes. The concentration of Na^+ and Cl^- were significantly increased in the leave of plants grown under salinity whereas the K^+: Na^+ ratio was decreased. Cultivars differed significantly for both growth and ionic composition. Genotype CIM-446 performed better under salinity and was categorized as a relatively salt-tolerant genotype. The order of the salinity tolerance of the cotton genotypes is CIM-446 > NIAB-98 > NIAB-999 > Krishma. The tolerant genotype CIM-446 accumulated lower Na^+ and Cl^- in its leaves and maintained higher K^+: Na^+ ratio.
Keywords: Cotton, genotypes, growth, ion imbalance, K^+: Na^+ ratio and salinity.

INTRODUCTION

The excessive accumulation of salts in soils of arid and semi-arid regions is a potential factor for limiting crop production from irrigated agriculture. Low precipitation accompanied by high evapotranspiration results in salt accumulation in the root zone which hinders plant growth. Salinity affects seed germination, growth and reproduction with induced changes in anatomy and morphology of plants. A decline in total leaf area is often first detectable response to salt stress in crop plants (Bradford and Hsiao, 1983). Increase in leaf area has been found to be more sensitive to salinity than either leaf emergence rate or dry matter accumulation (Curtis and Lauchli, 1985).

Different plant species differ in their salinity tolerance. Some plant species are tolerant e.g., barley, cotton and sugar-beet, some are moderately tolerant, e.g. rye, sunflower, sorghum and soybean where as some are salt-sensitive, e.g., carrot, okra, onion and peas (Maas, 1986). Genetic variability has also been found among the genotypes of different crops including cotton (Qadir and Shams, 1997 and Akhtar and Azhar 2001).

In Pakistan about 2.79 mha area was under cotton crop during 2002-2003 (Anonymous, 2004). Cotton genotypes differ in their response to salinity and among the various important varieties tested in past, NIAB-78 and MNH-93 are the most salt tolerant (Qureshi and Barrett-Lennard, 1998). Although cotton is considered as fairly tolerant to salinity (Maas, 1986), yet a decrease of 41% in seed yield in slightly salt affected soils has been reported (Qayyum and Malik, 1988).

Cotton is quite sensitive to salinity at germination and seedling stages but comparatively tolerant thereafter (Bhatti and Rashid, 1980). Therefore, the spotty pattern in crop stand at maturity under saline soil conditions is actually initiated at the time of germination and vegetative growth phase. In saline soils, Na^+ and Cl^- are the dominant ions affecting plant growth (Khan, 1987 and Maas, 1993). Under these conditions, the activities of some essential nutrients may also be reduced (Gratten and Grieve, 1992) and plants may experience nutritional disorders. The situation can be improved by selecting salt tolerant cotton genotypes for moderately salt affected soils.

The selection and development of new genotypes of a particular crop is a continuous need due to natural segregation of parental characters. This situation necessitates a regular selection/screening of genotypes against salinity. The present study was, therefore, conducted to evaluate salinity tolerance of different cotton genotypes under controlled conditions.

MATERIALS AND METHODS

The seeds of four cotton genotypes (Krishma, NIAB-999, NIAB-98 and CIM-446) were obtained from NIAB and Ayub Agricultural Research Institute, Faisalabad. The experiment was carried out in the wire house having glass covered roof and sides with iron wire screen but there was no control on humidity, temperature and light.

Delinted seeds of all the genotypes were sown in pre-washed sand in the polyethylene lined iron trays. The seeds were irrigated regularly with water. At two leaf stage (almost one week after emergence of seedlings), the seedlings were transplanted in foam plugged holes of thermopole sheets floating over half strength Hoagland's nutrient solution (Hoagland and Arnon, 1950) in 25 Liter capacity (55 cm x 35 cm x 17 cm) plastic tubs.

There were two salinity levels viz. control (No salinity) and saline (150 mol m^{-3} NaCl). There were three replications of every genotype in each treatment. Three days after transplanting, salinity was developed in a split way. The pH was monitored and adjusted at 6.0 ± 0.5 daily by adding HCl (1N) or NaOH (1N) as and when required. Treatment solutions were changed fortnightly.

Plants were harvested after four weeks of salinity development. Harvested plants were washed with distilled water and dried with blotting paper. Shoot length, root length, shoot and root fresh and dry weights were recorded after separating plants into roots and shoots.

The youngest fully expanded leaf samples were collected in 1.5 cm^{-3} polypropylene tubes and stored at freezing temperature (Akhtar *et al.*, 1998) for chemical analysis. Frozen leaf samples in polypropylene tubes were thawed and crushed using a stainless steel rod with tapered end. The sap was collected in other polypropylene tubes by Gilson pipette and centrifuged at 6500 rpm for 10 minutes. The supernatant sap was collected and used for ionic analysis. Sodium (Na^+) and potassium (K^+) were determined using flame photometer (Sherwood-410). Chloride in the diluted leaf sap was determined using chloride analyzer (Sherwood-926). Data of the experiment was subjected to statistical analysis using completely randomized design in factorial arrangement (Steel and Torrei, 1980) using MSTAT-C computer software. Standard error was computed to compare the means. The shoot and root growth data for different genotypes were arranged in ascending order and the genotypes were assigned scores from 1 to 4 following Saqib *et al.* (2002). The genotype with the highest score was considered salt-tolerant and the genotype with the lowest score was considered salt-sensitive. The leaf ionic composition of the genotypes is discussed with regard to their salt-tolerance in terms of growth.

RESULTS AND DISCUSSION

Shoot and root growth

Shoot fresh and dry weights, shoot and root lengths and root dry weight (RDW) of cotton plants were significantly reduced by salinity (Table 1). Genotypes also differed for shoot and root growth in response to salinity. Genotype NIAB-98 produced the maximum shoot dry weight under saline conditions where as NIAB-999 produced the minimum shoot dry weight (Table 2). Krishma and CIM-446 were at par but lower than NIAB-98 and better than NIAB-999 in terms of the shoot dry weight production. In case of root dry weight under salinity, CIM-446 was at the top followed by NIAB-98 and NIAB-999 in a descending order where as Krishma produced the lowest root dry weight.

Table 1. Mean shoot and root growth of four cotton genotypes as affected by salinity (150 mol m^{-3} NaCl)

Growth parameters	Control	Salinity (150 mol m^{-3} NaCl)
Shoot fresh weight (g per plant)	19.5 ± 1.5	11.63 ± 1.20
Shoot dry weight (g per plant)	3.20 ± 0.19	1.40 ± 0.04
Root fresh weight (g per plant)	5.05 ± 0.92	5.6 ± 0.29
Root dry weight (g per plant)	0.62 ± 0.01	0.43 ± 0.05
Shoot length (cm)	30.25 ± 2.41	22.75 ± 2.75
Root length (cm)	38.75 ± 1.19	34.5 ± 1.68

Table 2. Shoot and root dry weights of four cotton genotypes as affected by salinity (150 mol m^{-3} NaCl)

Genotypes	Shoot dry weight (g per plant)		Root dry weight (g per plant)	
	Control	Salinity (150 mol m^{-3} NaCl)	Control	Salinity (150 mol m^{-3} NaCl)
Krishma	3.70 ± 0.50	1.40 ± 0.04	0.63 ± 0.01	0.35 ± 0.01
NIAB-999	2.70 ± 0.13	1.30 ± 0.09	0.65 ± 0.08	0.38 ± 0.01
CIM-446	3.40 ± 0.81	1.40 ± 0.10	0.41 ± 0.01	0.58 ± 0.04
NIAB-98	3.00 ± 0.24	1.50 ± 0.07	0.60 ± 0.06	0.39 ± 0.02
Mean	**3. 2**	**1. 4**	**0. 57**	**0. 43**

Table 3. Index score of four cotton genotypes on the basis of their growth performance at 150 mol m^{-3} NaCl

Genotypes	Shoot fresh weight	Shoot dry weight	Root fresh weight	Root dry weight	Shoot length	Root length	Total
Krishma	2	2	1	1	2	1	**9**
NIAB-999	3	1	2	2	4	2	**14**
CIM-446	4	2	4	4	1	3	**18**
NIAB-98	1	3	3	3	3	4	**17**

Note: No. 1 and 4 are respectively, the highest and lowest scores in a column.

Growth differences among the crop species at different salinity levels were also reported by several earlier investigators (Azhar and Raza, 2000; Akhtar and Azhar 2001; Khan *et al.*, 2001; Noor *et al.*, 2001; Saqib *et al.*, 2002). Reduction in leaf emergence (Curtis and Lauchli, 1985), leaf expansion and final leaf area (Jafri and Ahmad, 1995) under saline conditions may limit the process of photosynthesis, dry matter accumulation and ultimately growth. Reduced leaf expansion, shrinkage of cell contents, reduced development and differentiation of tissues and unbalanced nutrition under salt affected soils may also limit the photosynthesis and ultimately growth (Kent and Lauchli, 1985).

Leaf ionic composition

Salinity induction in root medium significantly influenced the ionic composition of cotton leaves (Fig 1-3). Sodium concentration was significantly higher in leaves of cotton plants grown under salinity compared to those grown in control treatment (Fig 1). Maximum Na^+ concentration under saline conditions (150 mole m^{-3} NaCl) was observed in NIAB-999 followed by Krishma and NIAB-98 in a descending order where as CIM-446 accumulated the minimum Na^+ concentration in its leaves. The increase of sodium concentration in leaves with increasing level of salinity may be due to greater uptake of sodium as it was more available under saline conditions. Sodium being a monovalent is very effective for osmotic adjustment (Bernstein, 1975 and Gorham *et al.*, 1985). However, with time the higher concentrations of Na^+ and Cl^- in leaves also become toxic and lead to salt injury (Serrano *et al.*, 1999, Saqib *et al.*, 2005).

Chloride concentration was also increased significantly in the leaves of all the genotypes with salinity (Fig 2). In saline medium, CIM-446 showed the minimum Cl^- concentration and NIAB-98 showed the maximum. K^+: Na^+ ratio was significantly decreased under salinity treatment (Fig 3). In saline conditions, maximum K^+: Na^+ ratio was observed in CIM-446 followed by NIAB-98. The K^+: Na^+ ratio in the leaves of Krishma and NIAB-999 was similar and the lowest among all the genotypes. Higher concentrations of Na^+ results in a decreased K^+ uptake and hence resulted K^+: Na^+ ratio leads to reduce the plant growth (Saqib *et al.*, 2005). Gorham et al, (1985) proposed that plants having higher tolerance to salinity, generally maintain higher K^+: Na^+ in their tissues.

Categorization of the cotton genotypes for their salinity tolerance

A number of possible mechanisms and crop growth parameters are known to be related with salinity tolerance of plants such as relative growth, germination rate, potassium selectivity, Na^+ exclusion, compartmentation of different ions within plant cells and osmotic adjustments (Weimberg, 1987). These parameters are relatively laborious to determine and need more expertise, hence need for a simple and easily determinable parameter is always emphasized. A simple scoring method was proposed by Saqib *et al.* (2002), in which each genotype is awarded with a score for each growth parameter. In the present paper, the cotton genotypes were categorized according to the values of different growth parameters.

Genotype CIM-446 gained the maximum score whereas the genotype Krishma gained the minimum. Therefore, these two genotypes are categorized as the most tolerant and most sensitive cultivars, respectively. The order of salinity tolerance according to this index score is CIM-446 > NIAB-98 > NIAB-999 > Krishma. The salt-tolerant genotype accumulated less Na^+ and Cl^- in its leaves and maintained higher K^+: Na^+ ratio whereas the salt-sensitive genotype accumulated more Na^+ and Cl^- in its leaves and maintained lower K^+: Na^+ ratio.

CONCLUSIONS

Salinity significantly decreased different growth parameters of the cotton plants and the genotypes differed significantly for biomass production under salinity. The genotype CIM-446 was found as relatively salt-tolerant where as Krishma was relatively salt-sensitive based on their growth under salinity. Also, the

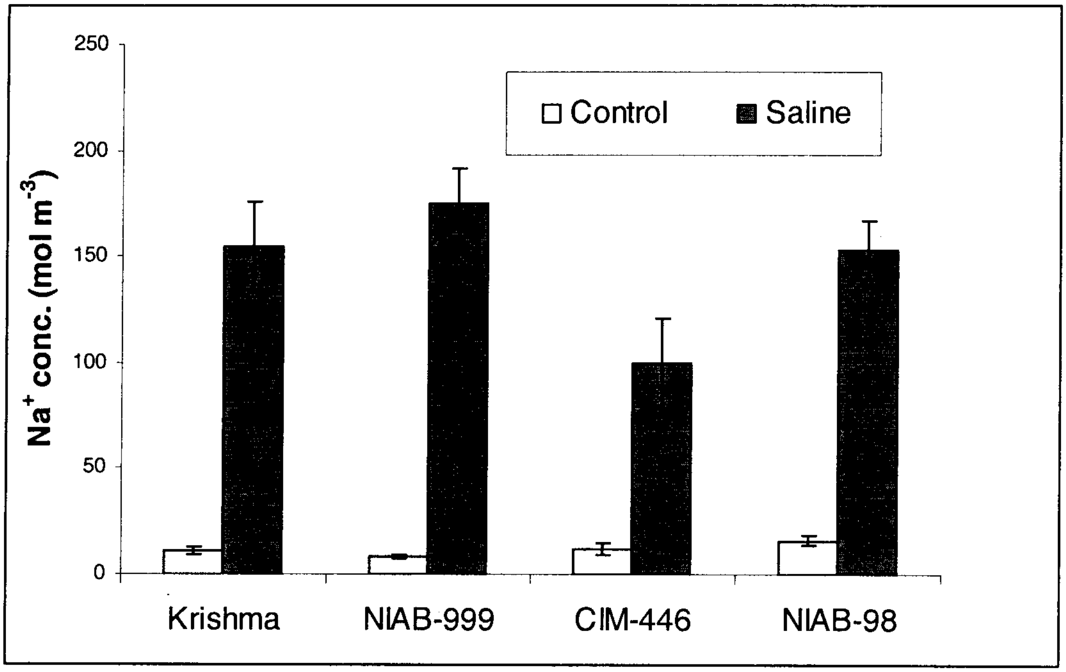

Fig 1. Leaf sodium concentration (mol m^{-3}) of four cotton genotypes as affected by salinity (150 mol m^{-3} NaCl)

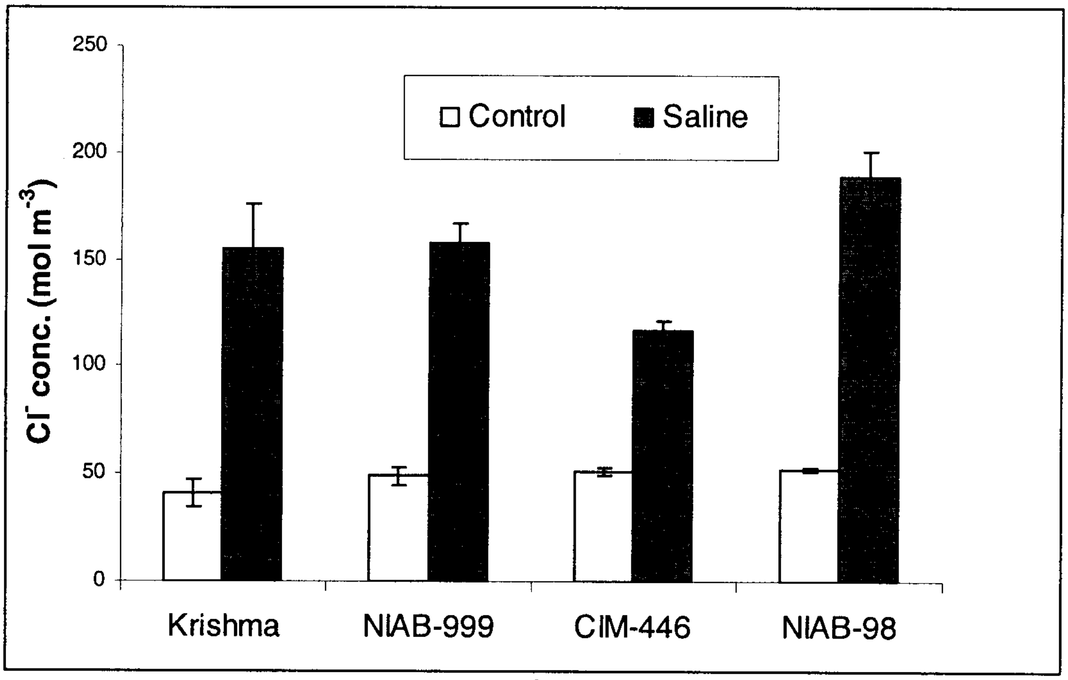

Fig 2. Leaf chloride concentration (mol m^{-3}) of four cotton genotypes as affected by salinity (150 mol m^{-3} NaCl)

most salt-tolerant genotype CIM-446 accumulated less Na^+ and Cl^- in its leaves and maintained higher K^+: Na^+ ratio whereas the most salt-sensitive genotype Krishma accumulated more Na^+ and Cl^- in its leaves and maintained lower K^+: Na^+ ratio.

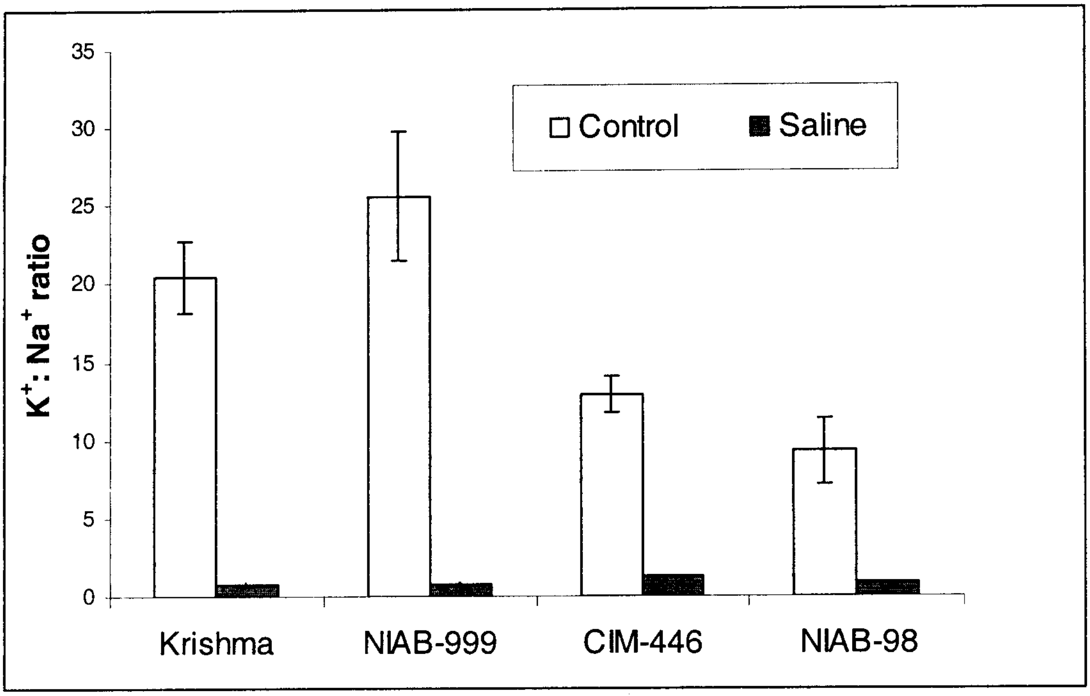

Fig 3. Leaf K^+: Na^+ ratio of four cotton genotypes as affected by salinity (150 mol m^{-3} NaCl)

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