Soil & Environ. 26(1): 59-63, 2007

Selection of cotton (*Gossypium hirsutum* L.) genotypes against NaCl stress

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Abstract

In a solution culture experiment, seven cotton genotypes were examined for comparative performance at three NaCl concentrations viz. control (without salts), 100 and 200 mol m^{-3} NaCl with four repeats in a completely randomized statistical fashion. The plants were harvested four weeks after the imposition of the NaCl salinity stress. Shoot fresh and dry weights and shoot and root lengths were decreased by increasing levels of NaCl salinity. The greatest reduction was observed at 200 mol m^{-3} NaCl salinity stress significantly. K^+: Na^+ ratio of different genotypes differed significantly at both NaCl concentrations. Differences were observed among genotypes with regard to growth and salinity tolerance.

Key words: Cotton genotypes, salinity tolerance, physical and ionic parameters

Introduction

Cotton (*Gossypium hirsutum* L.), the *White Gold*, occupies a pivotal position in Pakistan's economy. Besides providing fiber, food and fuel, it also sustains people for their livelihood by providing raw material to different cotton based industries. Cotton plays a pivotal role in the development and stability of agro-based industry and economy of Pakistan by adding more than 50 percent to our foreign exchange earnings and thus ranks at the top (Anonymous, 2006).

Given the limited land resources and water, the ever increasing demand necessitates the use of poor quality soils and waters to increase cotton production. Salinity is inimical to plant growth through specific ion effects, osmotic effects and induced nutrient deficiency (Wyn Jones, 1981). One easy way to cope with the problem of salinity is to exploit the genetic potential of plants for their adaptability to adverse soil conditions. This approach prompted the crop cultivation on the salt affected fields but considerable variability for salt tolerance was observed among and even within the plant species (Norlyn and Epstein, 1984). Akhtar *et al*. (2003) concluded that salt tolerance improvement might be achieved through selection from already existing germplasm.

Generally, plants are sensitive to salinity during germination and early seedling development (Hoffman and Shannon, 1986). It is due to extreme spatial and temporal variability in soil salinity under field conditions that selection of large number of genotypes under saline field conditions is not feasible (Richards, 1983; Ibrahim, 2003). Therefore, the crop gene stocks are often screened/selected in nutrient solution by adding different amounts of salts to develop the desired salinity levels. This method is relatively quick and reliable for selecting the crop genotypes against salinity (Qureshi *et al*., 1990).

Hence, the present study was conducted with the objective to pre-screen seven newly bred cotton genotypes against NaCl salinity levels of 100 and 200 mol m^{-3}.

Materials and Methods

Healthy seeds of cotton genotypes (source mentioned in Table 1) were delinted using concentrated H_2SO_4 and made acid free by washing with distilled water. The seeds of these genotypes were sown in iron tray (60 cm × 45 cm × 5 cm) having 2-inch layer of sand. At two-leaf stage the seedlings were transplanted in holes in thermo pore sheets floating on ½ strength Hoagland's nutrient solution (Hoagland and Arnon, 1950) in 200 L capacity iron tubs lined with polythene sheet. Solution was changed every week during entire duration of the experiment. The experiment was laid out in CRD factorial fashion with four replicates. After one week of transplanting, NaCl salt stress of 100 and 200 mol m^{-3} was developed in three increments whereas in control, no salt was added. The pH of the solution was maintained between 5.5 ± 0.5 throughout (by adding NaOH or HCl as required). Plants were harvested after four weeks of imposition of NaCl stress and data of shoot fresh and dry weight, root fresh and dry weights were recorded. Leaf samples were collected in 1.5 cm^3 polypropylene micro-centrifuge tubes and stored in freezer. The tissue sap was used for determination of ionic concentrations and on the basis of concentrations of Na^+ and K^+, the K^+: Na^+ ratio was computed (Table 2). The data obtained were subjected to statistical analysis using *SPSS ver. 10.0* software and means were compared by standard errors (Steel and Torrie, 1980).

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Table 1. Seed sources of different cotton genotypes used in the experiment

Sr. No.	Genotype	Source
1	NIAB-98	Nuclear Institute of Agriculture and Biology, Faisalabad.
2	FH-930	Cotton Research Institute, AARI, Faisalabad.
3	B-284	Dept. of Plant Breeding and Genetics, UAF.
4	B-630	Dept. of Plant Breeding and Genetics, UAF.
5	NIAB-111	Nuclear Institute of Agriculture and Biology, Faisalabad.
6	FH-945	Cotton Research Institute, AARI, Faisalabad.
7	MNH-633	Central Cotton Research Institute, Multan.

Results and Discussion

It has been well documented that the physical growth parameters such as root and shoot fresh and dry weights contribute more towards salt tolerance of crop at early growth stages and can be used as selection criteria for salt tolerance (Ashraf *et al*., 1994; Qureshi *et al*., 1990). The investigated parameters are discussed in ensuing paragraphs:

Shoot fresh and dry weight

Data for shoot fresh weight (SFW) and shoot dry weight (SDW) of various cotton genotypes under varying NaCl salinity stress levels are shown in Figure 1 and 2, respectively. With increasing salt stress the shoot fresh and dry weights were reduced in all genotypes. The genotype B-630 gave the highest shoot fresh and dry weight at all salinity levels. The lowest shoot fresh weight was recorded for MNH-633 followed by FH-930 at 100 mol m^{-3} NaCl stress while at 200 mol m^{-3} NaCl stress FH-930 gave the lowest. According to Cheesman (1988) osmotica synthesis to withstand salinity stress utilizes much of carbon and reduces metabolite synthesis and ultimately decreases biomass production. At 100 mol m^{-3} NaCl salinity, the highest SFW was recorded for B-630 followed by B-284, FH-945 and NIAB-111 and at 200 mol m^{-3} NaCl salinity, the highest SFW was observed for A-163 followed by Bamasal-205. The lowest SFW at 100 mol m^{-3} NaCl salinity was observed in case of NIAB-98 and at 200 mol m^{-3} NaCl salinity for FH-930. An important criterion for selection against salinity stress is shoot dry weight (SDW) (Ashraf, 1994). It has been found that with increase in the NaCl stress, SDW was decreased and the highest decrease in SDW was recorded for FH-930.

Various researchers have reported that reduction in SFW and SDW is due to decreased water potential of

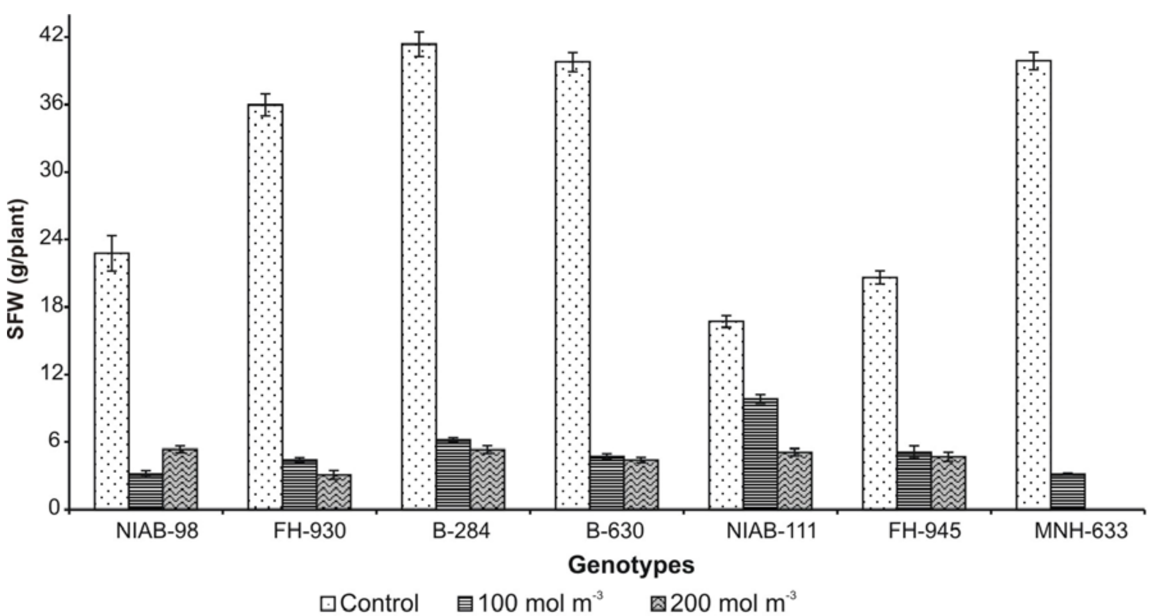

Figure 1. Shoot fresh weight of cotton genotypes at different NaCl salinity levels

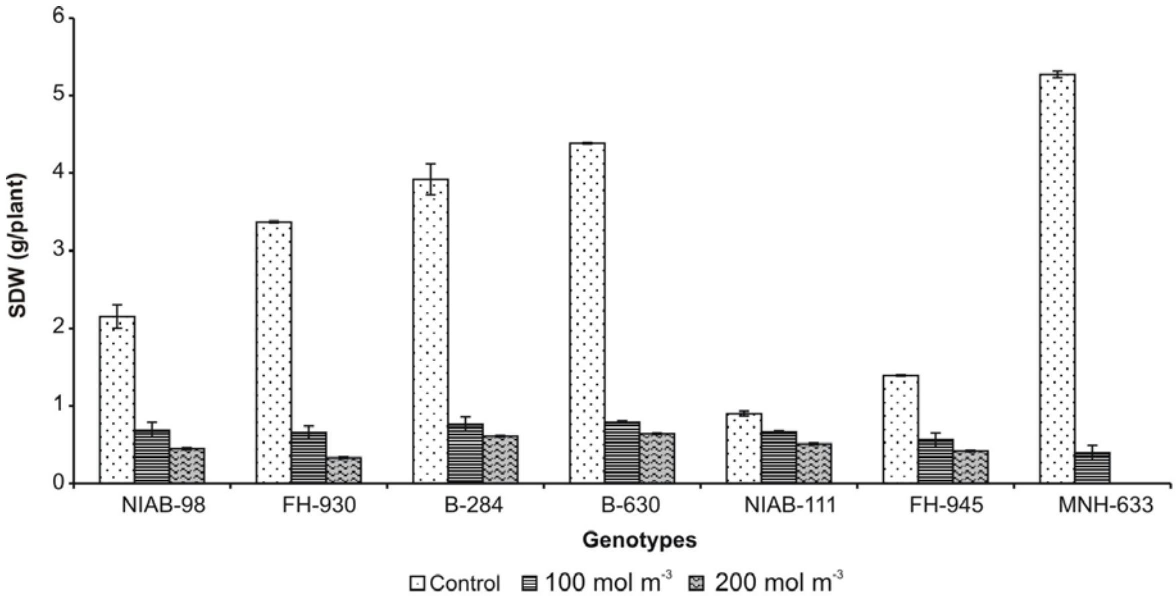

Figure 2. Shoot dry weight of cotton genotypes at different NaCl salinity levels

rooting medium because of higher ionic concentrations and the initial growth inhibition in saline condition is related to osmotic effect (Munns *et al*., 1995; Akhtar, 2003, Ashraf *et al*., 2002). Gale and Zeroni, (1984) concluded that under salt stress, turgor pressure is decreased and closure of stomata takes place causing decreased photosynthesis. Ionic toxicity of Na^+ and Cl^- is considered to be the other reason for decreased SFW with increased salinity (Ibrahim, 2003; Bhatti *et al*., 1983). Moreover the uptake of K^+, Ca^{+2} and NO^-_3 in the root medium is also suppressed due to higher concentration of Na^+ and Cl^- and leading to the suppression in growth (Akhtar *et al.*, 1994; Gorham and Wyn Jones, 1993).

Root fresh and dry weight

As for as root fresh weight (RFW) is concerned it also decreased significantly with increasing stress and the maximum SFW was recorded for B-284, B-630 and FH-930 whereas; at 200 mol m^{-3} stress the genotypes with the maximum SFW were FH-945 and NIAB-111 (Figure 3 and 4). The genotypes B-630 and FH-945 produced the maximum root dry weight (RDW) at all salinity levels. Decreased water availability to plants is considered a major reason for less RFW and RDW because of decrease in osmotic potential at the root surface. Toxic concentrations of ions like Na^+ and Cl^- cause hindrance in both nutrient and water uptake by roots and as a result less assimilation finally resulted in less RFW and RDW (Gorham and Wyn Jones, 1993). Levitt, (1980) concluded that decreased water availability to plants at root surface and ion toxicity (Na^+ and Cl^-) is the primary cause of less root weights under saline environments. Various researchers have reported the similar findings (Akhtar *et al*., 1994 in wheat; Aslam et al., 1993 in rice and Ashraf and Ahmad, 2000 in cotton). The genotypic variability does exit for various plant characteristics and is depicted at various saline stresses. A genotype declared tolerant for a specific character may not be able to perform well for other characteristic.

K^+: Na^+ ratio

K^+: Na^+ ratio is an important parameter for the assessment of degree of salt tolerance in plants. The plants may have certain mechanisms to withstand the problem of excessive salts in the rooting environment. K^+: Na^+ ratio of the cotton genotypes used in this study were greatly influences by salinity stress (Figure 5). Different plant cultivars use different mechanisms for the completion of their life cycles either by the compartmentation or by the synthesis of organic/inorganic osmotica. At both salinity levels FH-945 had the maximum K^+: Na^+ ratio followed by NIAB-111 while the minimum K^+: Na^+ ratio was computed for B-630 at 100 and NIAB-98 at 200 mol m^{-3} NaCl.

Conclusion

A simple and rigorous method for quick screening and categorization of cotton genotypes into salt tolerance groups was employed. The genotypes B-284 and FH-945 were found tolerant against NaCl stress applied whereas the genotypes B-630 and SLH-242 showed moderate tolerance. The genotypes IR-FH-901 and MNH-633 were ranked as the sensitive.

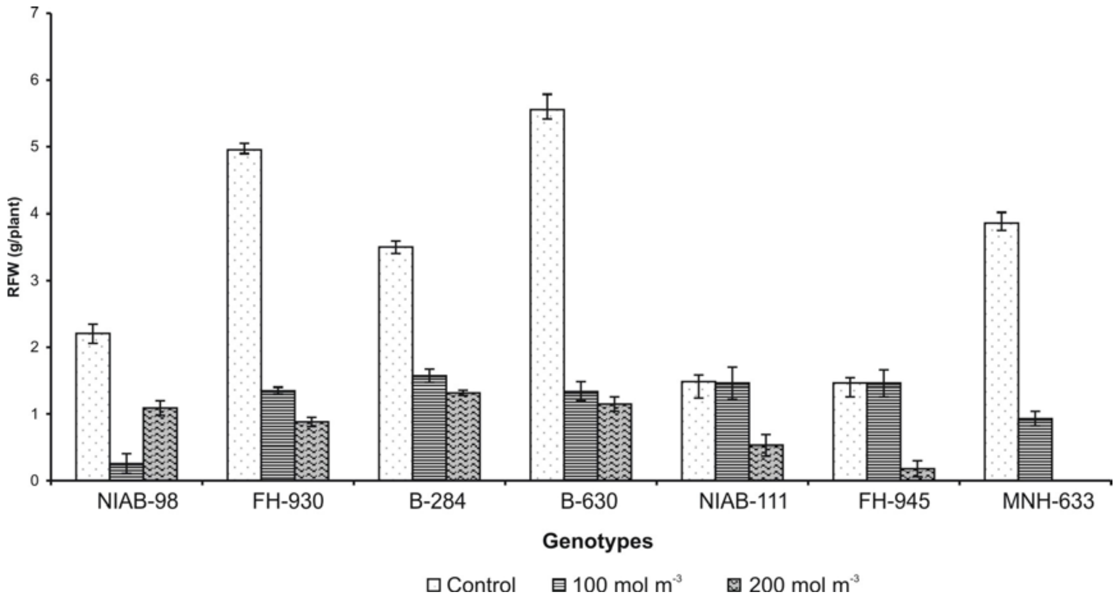

Figure 3. Root fresh weight of cotton genotypes at different NaCl salinity levels

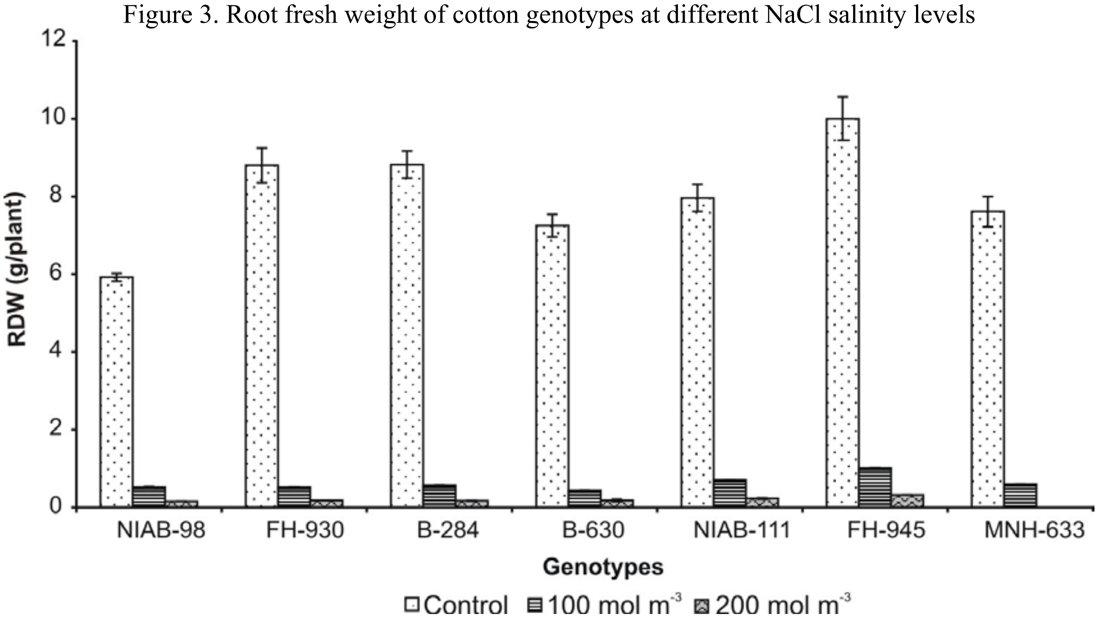

Figure 4. Root dry weight of cotton genotypes at different NaCl salinity levels

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