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Differences in Responses of *Gossypium hirsutum* L. Varieties to NaCl Salinity at Seedling Stage

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ABSTRACT

The responses of 11 varieties of *Gossypium hirsutum* L. to three NaCl concentrations (0, 150 and 200 mM) were compared at seeding stage. The NaCl salinity caused significant reduction in shoot and root lengths of all the genotypes, but the effect was more pronounced on roots. On the basis of relative and absolute salt tolerance, using root length data, three varieties i.e., BH-121, CIM-240 and CIM-1100, were found to be the most tolerant to salinity. The estimates of broadsense heritability of root length was high, and suggested that improvement in salinity tolerance in upland cotton is possible exploiting the existing variation through conventional breeding methods.

Key Words: Cotton; NaCl salinity; Heritability; Relative and absolute values

INTRODUCTION

Crop production in arid and semi-arid areas is greatly hampered by the spread of salinity in root zone. In Pakistan, about 6.3 x 106 hectares of irrigated land has become salt-affected to varying degrees (Malik & Shah, 1996). Although installation of tube wells and use of chemicals like gypsum had proved to be effective in ameliorating the problem of salinity, due to the escalating cost of labour and energy, the continued running of these projects did not appear feasible in poor countries like Pakistan. In these situations development of crop cultivars tolerant to salinity has been suggested as a possible alternative to the expensive engineering approach to utilize the saline lands (Epstein, 1980; Shannon, 1984). Development of such plant material through selection and plant breeding requires significant amount of variation in the plant population. Research work had been done in order to study the response of different crops to salinity. The results of previous studies showed that varieties of maize (Mass *et al.*, 1983), sorghum (Azhar & McNeilly, 1987, 2001; Azhar & Khan, 1997), radish (Waisel & Breckle, 1987), wheat (Ashraf & McNeilly, 1988), red kidney beans (Salim, 1989a), mungbean, sunflower and tomato (Salim, 1989b), triticale, wheat, rye and barley (Salim, 1991) differed from each other for their response to salinity.

Cotton of *Gossypium hirsutum* L. is an important crop of the areas affected by salinity in Pakistan. The previous studies conducted on salt tolerance in cotton are relatively few, and these showed that genotypic variability within the species was present (Randhawa, 1981; Ray, 1987; Khan *et al*., 1995). In the recent studies, Azhar and Raza (2000) and Akhtar and Azhar (2001) found that varieties of upland cotton responded differently to salinity, and the character was heritable in nature. The present work further reports variation within the species for NaCl salinity, and also the estimates of heritability of the character.

MATERIALS AND METHODS

In the present investigations, seeds of 11 varieties of cotton, i.e. CIM-443, BH-121, FVH-137, CIM-448, BH-118, CIM-465, Cargil Hybrid, CIM-1100, FVH-59, CIM-240 and MNH-554 were grown in polythene bags filled with soil. The ECe and pH of the growing material were determined prior to set the experiment. There were three levels of NaCl solutions, i.e. 0, 150 and 200 mM, and three replications of the experiment. The 99 bags were arranged following completely randomised design in a glasshouse. The seeds of each variety were planted in soil under proper moisture condition. The desired concentrations of NaCl in solutions were progressively completed in two doses of equal concentration. First treatment of 75 mM and 100 mM NaCl solution was applied to all the treatment bags one week after germination (at two leaf stage), and the second dose of solution containing 150 mM and 200 mM NaCl was given one day after the first treatment. Three days after achieving the maximum concentration of NaCl, longest shoot and roots of seedlings were measured in each replication.

The preliminary data were subjected to analysis of variance technique in order to find whether the genotypic differences were significant. The responses of 11 varieties to salinity were compared using absolute values, i.e. absolute salt tolerance of Dewey (1960) and relative values, i.e. relative salt tolerance of Maas (1986). The indices of salt tolerance were obtained using the following formula:

$$\text{Relative salt tolerance} = \frac{\text{Mean performance in NaCl solution}}{\text{Mean performance in control solution}} \times 100$$

Estimation of broad sense heritability (h2BS) of the two characters assessed under 150, 200 mM NaCl and in control were made following the formula given by Falconer and Mackey (1996). The calculations were based upon the variance due to between genotypes and within-genotypes.

The formula is given below:

$$H^2 BS = \frac{\text{Variance due to between genotypes}}{\text{Variance due to between genotypes + Variance due to within genotypes}}$$

RESULTS AND DISCUSSION

Development of salinity tolerance in a plant species can easily be made if significant amount of genetically based variation is available to a plant breeder. Significant mean squares obtained from analysis of variance of fresh shoot and root lengths of 11 varieties provided evidence that variation in the material was present, and the varieties responded differently to increasing NaCl salinity (Table I). Although NaCl salinity had affected adversely all the varieties, the effect was more pronounced on some of the varieties than the others (Table II). The comparison of 11 genotypes based upon absolute values of shoot length showed that FH-137 measuring 11.98 cm shoot length was found to be salt tolerant closely followed by CIM-443 (10.96 cm), BH-121 (10.65 cm), CIM-448 (10.69 cm) and Cargil Hybrid (10.72 cm). Varieties BH-118 and CIM-465 with minimum absolute values, 7.43 and 7.90 cm, respectively showed susceptibility to salinity, whilst the remaining cultivars showed poor response to salinity. Comparison based upon indices of salt tolerance as suggested by Maas (1986) revealed that FH-137, Cargil and CIM-443 Hybrid responded favourably to salinity, and showed little reduction in shoot length measuring 91.03, 90.96 and 90.32% of the control, respectively. In contrast, shoot length of MNH-554 was affected greatly by salinity, 84.62% and thus may be considered a susceptible genotype.

Assessment of salinity tolerance using root length data revealed that varieties BH-121, CIM-240 and CIM-1100 with mean absolute values, 5.47, 5.81 and 5.21 cm, respectively were more salt tolerant than the others (Table III). Varieties CIM-448, BH-118, MNH-554 developed minimum root length in stress condition due to NaCl, and thus may be regarded as the least tolerant varieties. The performance of these varieties based upon the relative values was found to be analogous to those assessed using absolute values. Root length of these varieties was affected less under stress conditions as compared to other varieties.

Table I. Mean squares from analysis of variance of eleven varieties of *Gossypium hirsutum* L. grown in control and two NaCl salinity levels

Source of variation	df	Shoot length	Root length
Salinity level (S)	2	0.883**	28.684**
Genotypes (G)	10	13.003**	13.708**
S x G	20	20.302**	1.243**
Error	66	1.000	0.211

Table II. Absolute and relative salt tolerance of eleven varieties of *Gossypium hirsutum* L. based upon shoot length

Varieties	Absolute salt tolerance				Relative salt tolerance		
	Control	150 mM	200 mM	Means	150 mM	200 mM	Means
CIM-443	12.14	11.12	10.81	10.96	91.60	89.04	90.32
BH-121	12.05	11.11	10.19	10.65	92.20	84.56	88.38
FH-137	13.16	12.32	11.64	11.98	93.62	88.45	91.03
CIM-448	11.97	11.24	10.13	10.69	93.90	84.63	89.27
BH-118	8.72	7.83	7.03	7.43	89.80	80.62	85.21
Cargil hybrid	11.78	10.78	10.65	10.72	91.51	90.41	90.96
FH-59	9.95	9.01	8.20	8.61	90.55	82.41	86.48
CIM-240	9.16	8.50	7.73	8.12	92.79	84.39	88.59
MNH-554	10.11	9.00	8.11	8.56	89.02	80.22	84.62
CIM-465	8.94	8.22	7.57	7.90	91.95	84.68	88.32
CIM-1100	10.83	10.05	9.36	9.71	92.80	86.43	89.62

Table III. Absolute and relative salt tolerance of eleven varieties of *Gossypium hirsutum* L. based upon root length

Varieties	Absolute salt tolerance				Relative salt tolerance		
	Control	150 mM	200 mM	Means	150 mM	200 mM	Means
CIM-443	4.22	3.04	3.02	3.03	72.04	71.56	71.80
BH-121	7.40	6.07	4.87	5.47	82.03	65.81	73.92
FH-137	5.75	4.60	3.53	4.07	80.00	61.39	70.70
CIM-448	4.19	3.19	2.49	2.80	76.13	59.43	67.78
BH-118	4.05	3.03	2.21	2.62	74.81	54.57	64.69
Cargil hybrid	5.63	4.36	3.45	3.91	77.44	61.28	69.36
FH-59	5.66	4.79	3.49	4.14	79.63	61.66	73.15
CIM-240	7.83	6.39	5.23	5.81	81.61	66.79	74.20
MNH-554	4.25	3.40	2.29	2.85	80.00	53.88	66.94
CIM-465	6.28	4.37	3.60	3.99	69.59	57.32	63.46
CIM-1100	7.11	5.77	4.64	5.21	81.27	65.26	73.27

Indices of salt tolerance of the three varieties, BH-121, CIM-240 and CIM-1100, are 73.92, 74.20 and 73.27%, respectively. Similar differing responses of *G. hirsutum* L. plant material to salinity had been observed by Azhar and Raza (2000), and Akhtar and Azhar (2001).

In the present investigations, phenomenon of salinity tolerance in *hirsutum* species was studied measuring fresh root and shoot length in control and NaCl salinity. The data given in Table II and III showed that root lengths of the 11 varieties were affected seriously as compared to their shoot lengths, showing that root length is the most sensitive organ of plant. Similar suggestions have been given by Levitt (1980) and Okusanya and Ungar (1984). It had been observed that growth and production of cytokinins in roots were immediately stopped and under severe stresses root growth was ceased altogether (Bottger, 1978), thus root length is a reliable indicator of measuring salt tolerance of a species. There are studies which showed that research workers had been able to distinguish that salt tolerant and non tolerant plants of a number of species, for example, grasses (Hannon & Bradshaw, 1968; Leim *et al.*, 1985), sorghum (Azhar & McNeilly, 1987, 2000), wheat (Ashraf & McNeilly, 1988). Thus based upon root length data reported here three varieties namely BH-121, CIM-240 and CIM-1100 may be regarded as more salt tolerant than the others.

The estimates of broad-sense heritability calculated using root length data were high, 0.89 and 0.88 under 150 and 200 mM NaCl salinity, respectively (Table IV). Similar magnitude of heritability for salinity tolerance in *Gossypium hirsutum* had been reported by Azhar and Raza (2000). It seems likely that these estimates of heritability are inflated and, therefore, must be interpreted with care as suggested by Falconer and Mackey (1996). However, it is suggested that this information must be substantiated involving the same parental material in other studies. These results suggested that this variation might be used advantageously for bringing further improvement in the species if it involves a significant genetic component.

Table IV. Components of variance and broadsense heritabilities of salt tolerance in eleven *Gossypium hirsutum* L. varieties for shoot and root lengths in control and two NaCl salinity levels

Components	Characters	Control	150 mM	200 mM
VP = σ2b + σ2w	Shoot length	0.8282	0.6978	0.5136
	Root length	1.0103	0.5527	0.3925
VG = σ2b	Shoot length	0.6916	0.5781	0.4136
	Root length	0.9413	0.4927	0.3455
h2B.S. = VG/VP	Shoot length	0.8300	0.8200	0.8000
	Root length	0.9300	0.8900	0.8800

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