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Assessment of Variation for Salinity Tolerance in Some Hybrids of Cotton (*Gossypium hirsutum* L.)

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ABSTRACT

A solution culture experiment was conducted to examine the influence of salinity on 35 cotton hybrids at two different levels i.e. 0 and 250 mm NaCl in the root medium. Indices of salt tolerance were estimated in absolute and relative terms. All the hybrids showed a wide degree of responses for all the characters under study at maximum salinity level ranging from more tolerance to susceptible. Estimation of broad-sense heritabilities for salt tolerance would be very useful in the early segregating generations for further strengthening the cotton breeding programme for salinity tolerance.

Key Words: Seedling traits; NaCl; Salinity; Heritabilities

INTRODUCTION

Salinity problems are especially prevalent and serious in irrigated lands in many parts of world. Reclamation of saline lands has proved to be successful, but it is not economical for developing countries just like Pakistan. Therefore, a genetic dimension is essential to overcome such soil problems. The plant breeders are seeking to modify plants to suit such adverse soil conditions while maintaining reliable yield. Salinity tolerance is considered to be a polygenic trait, its expression affected by various genetic, developmental and physiological interactions within the plant and interactions between plant and external environment (Bernstein & Hayward, 1958; Shannon, 1984). Information derived from various species examined for salt tolerance suggests that different genetic architectures may be able to control the character from single major dominant/recessive gene to polygenic control with mainly additive effects, but with some degree of dominance toward tolerance (Moeljopawiro & Ikehashri, 1981; Azhar & McNeilly, 1989; Gregrio & Sendhira, 1993; Ahsan *et al*., 1996).

According to several workers, (Christiansen & Lewis, 1982; Shannon, 1985) different species have developed polymorphisms for adaptation to saline and other problem soils. A polymorphism is a major category of discontinuous variation within a species, which is controlled by supper genes, where allelic substitutions tend to bring about marked differences in phenotype. However, mechanism in importing resistance to salinity and other soil stresses are yet to be properly understood and reliable markers need to be made available (Rana, 1986). Greenway and Munns (1980) reported many examples in which the mechanism of salt tolerance varied from cultivar to cultivar within species.

It is well documented that improving salt tolerance to increase economic yield can be accompanied by genetic manipulations, which are normally accomplished through hybridization and selection. Genetic diversity is the foundation of all plant breeding programs. Systemic work to examine genetic variability within crops is still in its infancy, but it is evident from previous work that inter-specific (Maas & Hoffman, 1977) and intra-specific variations for salt tolerance (Rashid, 1986; Ashraf & McNeilly, 1988; Singh *et al*., 1988). The estimation of heritability has a great value in prediction of the effect in selection (Johnson *et al*., 1955). Teran *et al*. (1990) reported high heritability and genetic advance in germination percentage of sorghum genotypes treated with NaCl. Heritability estimates in forage and wheat grasses (Ashraf *et al*., 1986a,b; 1987) and *Sorghum bicolor* L. munch (Azhar, 1988) also indicated that salt tolerance is a heritable trait and there is potential for progress through selection.

This study was conducted to (i) assess the tolerance of cotton hybrids at seedling stage, and (ii) detect the heritability for salinity tolerance in *Gossypium hirsutum* L.

MATERIALS AND METHODS

The experimental material comprised of seven male parents viz., SLH-41, MS-84, SLS-1, CIM-109, SLH-1, TH-14/83 and LA-17801 and five female parents viz. Express, Allepo-45, AUH, H-2918-2 and HG-142. The parents were field planted during the year 1998. The recommended agronomic practices were constantly employed for optimum growth. At flowering, the parents were crossed to get 35 hybrids. During crossing, necessary precautions were made to avoid the chances of contamination. Seeds were collected separately for each cross and grown in the polythene bags of measuring 6" x 8" filled with a mixture of sand and clay in the ratio 2:1. The electrical conductivity (0.92 ds m^{-1}) and pH (9) were determined prior to the start of experiment so that salt requirement for each of the treatment level could be measured accurately. The experiment was laid out following CRD with three replications for the treatment as well as control. One week after germination (at cotyledonary leaves stage) 50 mM NaCl solution was applied as a first increment to all the bags. Another dose of 50 mM NaCl solution was applied next day. In this way, the required level of 250 mM was achieved by applying 50 mM NaCl solution daily to the treatment bags. After 15 days of germination, data were recorded using 10 plants in each replication for fresh shoot length (cm), fresh root length (cm), fresh shoot weight (g) and root weight (g).

Salinity response of all the hybrids to increasing NaCl concentration was compared on the basis of their absolute and relative performance as suggested by Dewey (1960) and Maas (1986). The recorded data were subjected to analysis of variance technique (Steel & Torrie, 1980) to obtain level of significance among the genotypes. These genotypes were further analyzed for broad sense heritability illustrated by Falconer (1981).

RESULTS AND DISCUSSION

Analysis of variance indicating significant differences among parents and F_1 progenies for different characters is given in Table I. Indices of absolute and relative salt tolerance of all the hybrids for these seedling traits is presented in Tables IIa and b. An examination of Table IIIa and b showed that results for all the traits under study in both the salinity levels were highly significant among all the hybrids. Table IV indicates the components of variance and broad sense heritability of salt tolerance at two salinity levels.

Fresh shoot length. Data on absolute and relative values (Table IIa,b) showed differing responses of hybrids to

Table I. Mean square values of the characters

SOV	d.f.	Fresh shoot length	Fresh root length	Fresh shoot weight	Fresh root weight
Hybrid	34	16.109	24.696	0.1490	0.00043
Treatment	1	283.040	93.867	4.9439	0.00270
Hybrid x treatment	34	1.874	0.621	0.0364	0.00010
Error	140	0.110	0.102	0.0003	0.00005

Table III a: Mean squares values for control

SOV	d.f.	Fresh shoot length	Fresh root length	Fresh shoot weight	Fresh root weight
Hybrid	34	8.196	13.9138	0.1020	0.00028
Error	70	0.106	0.0585	0.0004	0.00001

Table III b. Mean squares values for treatment

SOV	d.f.	Fresh shoot length	Fresh root length	Fresh shoot weight	Fresh root weight
Hybrid	34	9.787	11.403	0.0834	0.00025
Error	70	0.114	0.146	0.0002	0.00001

Table II a. Indices of absolute tolerance for control and treatment

Sr. No.	Hybrids	FSL		FRL		FSW		FRW	
		AT T	ATC	AT T	ATC	AT T	ATC	AT T	ATC
1.	Express x SLH-41	11.133	13.067	10.900	12.100	0.440	0.726	0.0111	0.0157
2.	Express x MS-84	11.833	13.067	12.000	12.900	0.343	0.600	0.0106	0.0159
3.	Express x SLS-1	10.400	13.700	9.467	10.967	0.330	0.553	0.0119	0.0204
4.	Express x CIM-109	11.633	12.700	11.267	12.267	0.310	0.626	0.0124	0.0184
5.	Express x SLH-1	8.500	11.733	8.500	10.133	0.340	0.706	0.0119	0.0160
6.	Express x TH-14/83	10.933	14.367	11.267	12.633	0.410	0.910	0.0138	0.0173
7.	Express x LA-17801	9.900	13.067	10.133	11.267	0.606	0.993	0.0147	0.0181
8.	Allepo-45 x SLH-41	12.100	15.433	12.033	13.067	0.623	0.800	0.0180	0.0434
9.	Allepo-45 x MS-84	16.600	17.367	15.100	17.533	0.494	0.913	0.0310	0.0321
10.	Allepo-45 x SLS-1	12.767	15.033	13.333	14.133	0.666	1.123	0.0144	0.0207
11.	Allepo-45 x CIM-109	11.300	11.700	11.900	13.633	0.656	0.666	0.0320	0.0374
12.	Allepo-45 x SLH-1	9.067	14.733	8.967	10.300	0.604	0.690	0.0087	0.0214
13.	Allepo-45 x TH-14/83	11.967	13.367	12.900	13.900	0.360	0.856	0.0097	0.0201
14.	Allepo-45 x LA-17801	11.067	15.200	10.833	12.267	0.423	0.606	0.0088	0.0165
15.	AUH x SLH-41	12.933	15.867	12.300	15.067	0.240	1.043	0.0074	1.0130
16.	AUH x MS-84	13.233	13.900	13.567	15.300	0.783	1.030	0.0396	1.0448
17.	AUH x SLS-1	10.933	13.300	10.567	12.467	0.806	1.070	0.0166	0.0241
18.	AUH x CIM-109	10.067	12.033	11.367	11.433	0.540	1.433	0.0061	0.0132
19.	AUH x SLH-1	11.833	14.033	9.267	10.733	0.436	0.703	0.0108	0.0152
20.	AUH x TH-14/83	10.867	13.067	10.000	12.067	0.336	0.580	0.0108	0.0160
21.	AUH x LA-17801	11.467	12.767	12.133	13.200	0.326	0.613	0.0120	0.0204
22.	H-2918-2 x SLH-41	9.933	11.867	9.333	11.100	0.340	0.573	0.0128	0.0180
23.	H-2918-2 x MS-84	10.100	13.467	6.900	4.433	0.410	0.636	0.0116	0.0161
24.	H-2918-2 x SLS-1	8.867	10.733	8.933	9.500	0.610	0.706	0.0136	0.0172
25.	H-2918-2 x CIM-109	11.100	14.233	12.000	12.467	0.626	0.900	0.0152	0.0180
26.	H-2918-2 x SLH-1	10.133	12.633	10.233	11.233	0.500	0.986	0.0205	0.0430
27.	H-2918-2 x TH-14/83	13.033	15.400	13.900	15.267	0.666	0.806	0.0308	0.0320
28.	H-2918-2 x LA-17801	14.200	16.800	14.267	16.333	0.660	0.950	0.0146	0.0206
29.	HG-142 x SLH-41	15.900	17.933	15.533	17.433	0.410	1.123	0.0345	0.0373
30.	HG-142 x MS-84	12.900	14.600	9.233	11.100	0.360	0.653	0.0086	0.0215
31.	HG-142 x SLS-1	11.200	13.400	11.533	12.300	0.700	0.700	0.0093	0.0201
32.	HG-142 x CIM-109	12.200	15.467	13.333	14.500	0.876	0.876	0.0078	0.0164
33.	HG-142 x SLH-1	13.067	14.867	11.700	14.167	0.603	0.703	0.0098	0.0134
34.	HG-142 x TH-14/83	13.933	16.000	11.900	13.133	1.026	1.026	0.0164	0.0451
35.	HG-142 x LA-17801	10.933	13.533	12.900	13.120	1.050	1.050	0.0061	0.0240

FSL=Fresh shoot length; FRL= Fresh root length; FSW= Fresh shoot weight; FRW= Fresh root weight; ATT = Absolute Tolerance Treatment; ATC= Absolute Tolerance Control

Table II b. Indices of relative salt tolerance for seedling traits

Sr. No.	Hybrids	FSL	FRL	FSW	FRW
1.	Express x SLH-41	85.204	90.08	60.550	70.763
2.	Express x MS-84	90.561	93.03	59.195	66.876
3.	Express x SLS-1	75.912	86.32	55.000	58.401
4.	Express x CIM-109	91.601	91.84	56.024	67.450
5.	Express x SLH-1	72.443	83.88	54.255	74.375
6.	Express x TH-14/83	76.102	89.15	58.019	79.769
7.	Express x LA-17801	75.765	89.93	66.667	80.917
8.	Allepo-45 x SLH-41	78.402	92.08	62.752	41.596
9.	Allepo-45 x MS-84	95.585	86.12	61.667	96.473
10.	Allepo-45 x SLS-1	84.922	94.33	72.993	69.565
11.	Allepo-45 x CIM-109	96.581	87.28	58.457	85.740
12.	Allepo-45 x SLH-1	61.538	87.07	61.000	40.583
13.	Allepo-45 x TH-14/83	89.526	92.80	52.174	48.425
14.	Allepo-45 x LA-17801	72.807	87.59	49.416	53.333
15.	AUH x SLH-41	81.513	81.63	39.560	56.777
16.	AUH x MS-84	103.474	88.67	75.080	88.262
17.	AUH x SLS-1	82.206	84.75	78.317	68.690
18.	AUH x CIM-109	83.657	99.42	50.467	46.096
19.	AUH x SLH-1	84.323	86.34	62.085	71.116
20.	AUH x TH-14/83	83.163	82.87	58.046	67.200
21.	AUH x LA-17801	89.817	91.91	53.261	59.054
22.	H-2918-2 x SLH-41	83.708	84.08	59.302	70.980
23.	H-2918-2 x MS-84	75.000	92.82	64.398	72.464
24.	H-2918-2 x SLS-1	82.609	94.03	86.321	78.916
25.	H-2918-2 x CIM-109	77.986	96.30	69.630	84.288
26.	H-2918-2 x SLH-1	80.211	91.09	50.676	47.792
27.	H-2918-2x TH-14/83	84.632	91.04	82.645	96.250
28.	H-2918-2 x LA-17801	84.524	81.35	69.474	71.197
29.	HG-142 x SLH-41	88.662	89.10	36.499	92.500
30.	HG-142 x MS-84	88.356	83.18	55.102	40.000
31.	HG-142 x SLS-1	83.582	93.76	60.000	46.192
32.	HG-142 x CIM-109	78.879	91.95	26.236	47.368
33.	HG-142 x SLH-1	89.892	82.58	85.780	73.260
34.	HG-142 x TH-14/83	87.083	90.68	78.896	36.384
35.	HG-142 x LA-17801	80.788	99.243	50.794	25.417

FSL=Fresh shoot length; FRL= Fresh root length; FSW= Fresh shoot weight; FRW= Fresh root weight

increasing NaCl levels and hybrids differed from each others even under non stress condition and under highest NaCl concentration i.e. 250 mM. The response of some hybrids were longer shoot lengths ranging from 12.100 to 16.600 cm (Allepo-45 x SLH-41 and Allepo-45 x MS-84) in contrast to the response of remaining hybrids ranging from 8.500 to 11.967 cm (Express x SLH-1 and Appepo-45 x TH-14/83). The response of all the hybrids were compared in relative terms (Table IIb). The data revealed that most of the hybrids showed high degree of tolerance ranging from 80.211 to 96.581 (H-2918-2 x SLH-1 and Allepo-45 x CIM-109) while the other hybrids were less tolerant ranging from 61.538 to 78.879 (Allepo-45 x SLH-1 and HG-142 x CIM-109). Table IV showed the estimation of broad sense heritability ($h^2_{B.S}$), which was greater in control (0.9781) than treatment (0.9658).

Fresh root length. The value of absolute salt tolerance for this trait (Table IIa) revealed differing responses of the hybrids to increasing NaCl salinity. The hybrids Express x MS-84 and HG-142 x SLH-41 were less affected by the given salinity ranging from 12.000 to 15.333 while the hybrids which were more sensitive to salinity level for this trait ranged from 6.900 to 11.900 (H-2918-2 x MS-84 and Allepo-45 x CIM-109). On the basis of relative salt tolerance, the hybrid HG-142 x LA-17801 (99.742) showed maximum degree of tolerance while the hybrid AUH-50 x TH-14/83 (82.870) was less tolerant. The components of variance and broad sense heritability ($h^2_{B.S}$) for two salinity levels (Table IV) showed that heritability for the root length was less in saline condition (0.962) than the control (0.987).

Fresh shoot weight. Table IIa, b showed for fresh shoot weight that the responses of some of the hybrids were markedly different from each other and produced high fresh shoot weight ranging from 0.500 to 1.050 (H-2918-2 x SLH-1 and HG-142 x 17801) while remainder produced low fresh shoot weight ranging from 0.240 to 0.493 (AUH x SLH-41 and Allepo-45 x MS-84). On the basis of indices of relative salt tolerance, some of the crosses appeared to be more tolerant as compared to others ranging from 26.236 to 86.321 (HG-142 x CIM-109 and H-2918-2). The broad sense heritability ($h^2_{B.S}$) for the fresh shoot weight was lower in treatment (0.7307) than the control (0.9872).

Fresh root weight. The data revealed differing responses of all cotton hybrids to maximum NaCl salinity level presented to Table IIa, b. The salinity effects were found to be less serious to some of the hybrids at higher concentration of 250 mM NaCl and produced fresh root weight ranging from 0.010 to 0.039 (Express x MS-84 and AUH x MS-84) in contrast to the hybrids which were more affected and gave fresh root weight ranging from 0.0061 to 0.0097 (HG-142 x LA-17801 and Express x SLS-1). On the basis of relative salt tolerance, some of the hybrids showed high degree of tolerance in comparison to the others ranging from 25.41 to 96.47 (HG-142 x LA-17801 and Allepo-45 x MS-84). The broad sense heritability ($h^2_{B.S}$) for fresh root weight was greater in control (0.998) than salinity at 250 mM NaCl (0.882). It is evident from these results that all the hybrids showed a wide degree of responses at maximum salinity level ranging from more tolerance to susceptible. On the basis of absolute salt tolerance with increase salinity level, a retarded growth of all the characters was examined. This retarded growth of hybrids could be attributed to the toxic effect of NaCl and low water potential in the shooting medium. However, the differences among hybrids were greater, which suggested that each hybrid had different potential to respond to toxic effect of NaCl in soil culture. Differences among all the cotton hybrids based upon relative salt tolerance appeared to be significant, which is due to growth of shoot while exposing to salinity stress as

Table IV. Broad sense heritability for two salinity levels

Components of variance	Fresh shoot length	Fresh root length	Fresh shoot weight	Fresh root weight
V_g	2.69	4.61	0.033	0.000096
	3.22	3.75	0.028	0.000082
V_P	2.80	4.67	0.034	0.000098
	3.44	3.89	0.038	0.000093
$h^2_{B.S}$	0.96	0.98	0.98	0.96
	0.93	0.96	0.73	0.88

Light = $h^2_{B.S}$ for treatment; Bold = $h^2_{B.S}$ for control reported by Geenway and Rogers (1963). The heritability of any given character refers only to the offspring examined under the particular experimental conditions (Falconer & Mackay, 1996) and therefore, variability is estimation of heritability is to be expected. Such variation would seem likely to occur with increased stress, because different genes may contribute to the same trait in different environments (Richards, 1978; Rumbaugh *et al*., 1984). The broad sense heritabilities, which were estimated ranged from moderate to very high. Based upon this data, it is suggested that significant advance in salinity tolerance may be possible using high selection pressure.

The results revealed differing tolerance of the hybrids and consequently existence of variation in salt tolerance in *Gossypium hirsutum* L. Estimation of broad sense heritability ($h^2_{B.S}$) for salt tolerance is appreciably high suggesting that selection would be very useful in the early segregating generations for further strengthening the cotton breeding programme for salinity tolerance.

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