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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 3 (12): 1991-1993, 2000

Variation and Heritability of Salinity Tolerance in Upland Cotton at Early Stage of Plant Development

F.M. Azhar and Raza Ahmad
Department of Plant Breeding and Genetics,
University of Agriculture, Faisalabad-38040, Pakistan

Abstract: The response of ten different genotypes of *Gossypium hirsutum* to five NaCl concentrations i.e., 0, 50, 75, 100 and 150 mM were compared. Increasing levels of salinity caused significant reduction in fresh shoot weight and fresh root weight. On the basis of relative salt tolerance, cultivars CIM 435, CIM 1100, CIM 443, B 630 and FH 882 were found to be the most tolerant to salinity and B 622 and FVH 57 were moderately tolerant and B 496 and NIAB Krishma were susceptible to salinity. The estimates of broad-sense heritability of two plant characters ranged 0.75 to 0.98. The data suggest that improvement in NaCl tolerance in Upland cotton is possible by exploiting variMility through conventional breeding methods.

Key words: Upland cotton, NaCl salinity, relative values, heritability

Introduction

The spread of soil salinity in arid and semi-arid areas is posing a serious threat to crop production. Depending upon a number of soil and climatic factors, the salt accumulation in soils vary which in turn affect plant growth to different degrees (Bernstein, 1975). The biggest cause of salt accumulation in root zone is the continuous supply of canal water to the fields and high evapo-transpiration rate. About 6.3×10^6 hectares of arable land is affected adversely by the problem of salinization (Malik and Shah, 1996) in Pakistan. Development of crop cultivars tolerant to salinity is a possible alternative to the expensive engineering approach to utilize the waste lands (Shannon, 1984). During the past two decades, there has been marked increase in the interests to tackle the problem of soil salinity through the development of salt tolerant lines/varieties of a number of crop species (Salim, 1991; Khan *et al.,* 1995; Malik and Shah, 1996; Azhar and Khan, 1997).

Upland cotton is an important crop of the area where soil salinity is of frequent occurrence. Therefore development of salinity tolerance within the species would be of great value. Synthesis of crop material capable of giving useful yields in saline conditions, through selection and breeding, requires the availability of genetic variation in salinity tolerance. Previous studies of salinity tolerance in cotton plant are relatively few, but they do suggest that variation exists within the species (Brugnoli and Lauteri, 1991; Henggeler and Moore, 1995; Khan *et al*., 1995; Ahmad *et al*., 1995; Zaidi, 1997). The present experiment examines variability for salinity tolerance in 10 Varieties of *G. hirsuturn* at early stages of plant development and the magnitude of heritability for the character.

Materials and Methods

In the present investigations, ten varieties namely BH 95, B 630, CIM 435, NIAB Krishma, CIM 443, FH 682, B 622, FVH 57, CIM 1100 and B 496 were used. The experiment involved five NaCl concentrations, 0, 50, 75, 100 and 150 mM. Seeds of all the entries were grown in polythene bags filled with approximately one Kg of sand and clay mixed in the ratio of 2:1. The ECe, pH and saturation percentage of the growing medium were determined prior to set the experiment so that salt requirement for each treatment level could be measured accurately. Fifty bags were arranged in a completely randomized design with three replicates, in glasshouse. The seeds of each genotype were dibbled in soil under proper moisture condition.

After ten days of germination (at two-leaf stage), first treatment of 25 mM NaCl solution was applied to all the treatment bags and the second treatment was applied one day after the first treatment. In this way, concentration of 50 mM was completed in first treatment bags. The NaCl concentration was progressively increased by adding 25 mM NaCl every other day until the desired levels of 75, 100 and 150 mM NaCl were achieved on 4th, 6th and 10th day after the application of the first treatment. After attaining 50, 75, 100 mM levels in the growing medium, the respective salinized solutions were applied every other day to each treatment bag. Three days after completing the highest treatment, 150 mM, the plants were harvested and data on fresh shoot weight and fresh root weight were collected.

Data were subjected to analysis of variance technique and the response of ten genotypes were compared in relative terms as suggested by Maas (1986). The indices of salt tolerance were computed according to the following formula:

Relative salt tolerance = 100 (Mean performance in stress/Mean performance in control)

Estimation of broad-sense heritability: Estimates of broad-sense heritability (h^2_{BS}) of two plant characters assessed under each NaCl treatment level were made following the formula given by Falconer (1981) based on the variance due to between-accessions and within-accessions. The formula used to calculate the estimates of broad-sense heritability (h^2_{BS}) is given below:

h^2_{BS} = variance between-accessions/variance between-accessions + variance within-accessions

Results and Discussion

The availability of genetically controlled variation in salinity tolerance is essential for the development of salt tolerant lines of *hirsutum* species, by using conventional breeding methods. In order to gain such information about variation, ten varieties of different pedigrees were evaluated using the method followed by Zaidi (1997). Assessment of the

Table 1: Mean squares of ten *G. hirsutum* L. genotypes in five NaCl levels

Source of Variance	df	Fresh Shoot Weight	Fresh Root Weight
Varieties (V)	9	269.36**	479.69* *
Treatments (T)	3	8007.63**	2E164.85**
V x T	27	265.94**	129.07**
Error	80	45.76	42.40

Table 2: Relative salt tolerance of ten varieties of *Gossypium hirsutum* L. against five NaCl levels

Genotypes	Fresh shoot weight NaCl levels (mM)					Fresh root weight NaCl levels (mM)				
	50	75	100	150	Mean	50	75	100	150	Mean
BH 95	95.81	96.51	50.41	46.47	72.50	87.70	82.35	81.02	78.08	82.29
8 630	99.87	98.67	76.95	74.62	88.78	92.11	90.79	74,47	58.16	78.88
CIM 435	99.81	97.03	63.95	61.64	80.61	96.89	95.64	85.68	68.47	86.67
NIAB Krishma	97.95	87.96	63.08	56.02	76.25	95.92	64.89	57.68	53.29	67.95
CIM 443	99.50	86.82	84.92	69.04	85.16	86.14	84.82	79.87	74.92	81.44
FH 682	95.30	80.82	73.06	63.02	78.05	91.99	88.50	85.71	84.32	87.63
B 622	96.70	90,80	78.72	42.48	77.22	97.55	90.21	74.40	69.73	85.47
FVH 57	81.96	80.93	79.30	75.04	79.31	80.48	76.47	73.00	63.37	73.33
CIM 1100	93.62	86.59	86.34	62.15	82.17	96.21	93.77	80.76	77.51	87.06
B 496	95.47	94.16	74.47	46.51	77.66	89.52	86.97	83.85	59.21	79.89

Table 3: Components of variances and broad-sense heritabilities of salt tolerance in 10 *Gossypium hirsutum* L. genotypes for fresh shoot and root weights in 5 NaCl levels

Components	NaCl levels (mM)					
	Character	Control	50	75	100	150
$V_p = \delta^2_b + \delta^2_w$	Shoot weight	0.5698	0.5256	0,4534	0.3752	0.3128
	Root weight	0.0070	0.0062	0.0053	0.0049	0.0041
$V_G = \delta^2_b$	Shoot weight	0.5171	0.4659	0.3845	0.2876	0.2346
	Root weight	0.0068	0.0060	0.0051	0.0045	0.0037
$h^2_{BS} = V_G/V_P$	Shoot weight	0.91	0.89	0.85	0.77	0.75
	Root weight	0.98	0.97	0.95	0.93	0.89

accession response to increasing NaCl concentrations was carried out following the method suggested by Maas (1986) as used previously for assessing salt tolerance in sorghum (Azhar and McNeilly, 1987; Azhar and Khan, 1997). Significant mean squares for fresh shoot weight and fresh root weight showed significant differences in the two characters measured between varieties and NaCl treatments (Table 1). The significant interactions, varieties × NaCl treatments indicated that two plant characters of different varieties responded differently to increasing NaCl concentrations in the growing medium.

The indices of salt tolerance given in Table 2 clearly show the adverse effect of increasing salinity on fresh shoot weight and fresh root weight of all the varieties and also indicate differences in responses between varieties. The comparison of indices of tolerance based upon fresh shoot weight reveals that some of the varieties are more tolerant than the others even at 50 mM NaCl. The variety CIM 435 gave 99.81 fresh shoot weight of the control treatment and in contrast it is 82 of FVH 57. With each increase in NaCl concentration in the rooting medium, fresh shoot weight of all the varieties was affected but to varying degrees. At higher concentration, 150 mM NaCl differences among the responses of varieties became more apparent. The varieties B 622, B4 96 and BH 95 gave only 42, 46 and 50 respectively relative values in comparison with 74 and 75 of B 630 and FVH 57 respectively. However from overall assessment of the varieties, B 630, CIM 443 and CIM 1100 appeared to be the most tolerant to salinity.

Indices of tolerance based upon fresh root weight provide further estimates of the salinity tolerance of varieties. The root weight of some varieties was markedly reduced when exposed to the lowest level of NaCl salinity. Thus the variety FVH 57 was affected the most at 50 mM NaCl with a tolerance index 80. By contrast B 622, CIM 435, NIAB Krishma and CIM 1100 had the greatest index of tolerance i.e., 97, 97, 96 and 96 respectively. The data show that with each increase in NaCl concentrations, the relative behaviour of the varieties also changed. Although fresh root weight decreased markedly at high NaCl concentration of 150 mM NaCl, pronounced differences between varieties are still evident. The variety NIAB Krishma which was tolerant at 50 mM NaCl, appeared to be susceptible at 150 mM NaCl. However, from the overall assessment of varietal responses, the varieties, CIM 435, FH 682 and CIM 1100 with mean values of about 87, 88 and 87 respectively appeared to be tolerant whereas NIAB Krishma and FVH 57 with an overall tolerance index 68 and 73 respectively seemed to be sensitive cultivars. Although size of the sample of genotypes tested is small, yet the data reveal considerable variation in the responses of the germplasm assessed here at early growth stages.

The estimates of broad-sense heritability of fresh shoot weight under four NaCl levels and control are given in Table 3. The estimate was maximum (0.91) in control and these decreased as the salinity level increased in the rooting medium and it was lowest i.e. 0.75 at 150 mM NaCl level. The estimates of heritability based upon root length data were 0.97, 0.95, 0.93 and 0.89 under 50, 75, 100, 150 mM NaCl levels respectively.

Previous information on broad-sense heritability for salinity tolerance in Upland cotton had not been reported in the literature. However, these estimates in other crop species showed that salinity tolerance was a heritable character (Noble *et al*., 1984; Allen *et al*., 1985) and significant improvement was made by making selection of tolerant individuals. Although the estimates of broad-sense heritability reported here seem to be inflated, these

generally agree with, those observed in other species.
According to Falconer (1981) the heritability estimates are subject to considerable environmental conditions and therefore must be interpreted and used with great care in plant improvement exercise. Nonetheless information derived from the present study using diverse germplasm is encouraging. The estimates of broad-sense heritability suggest that prospects of improving salinity tolerance in *G. hirsutum* L. through selection and breeding are present, provided the genetic system controlling the variation in the character is predominantly affected by additive genetic effects.

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