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# ASSESSMENT OF VARIATION FOR SALINITY TOLERANCE IN *GOSSYPIUM HIRSUTUM* (L.)

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## ABSTRACT

The study was conducted to access the response of eighteen cotton varieties to four NaCl levels i.e., 100, 150, 200, 250 mM and one without added salt. Based upon six characters i.e. root, shoot length, fresh root, fresh shoot weight, dry weight and dry shoot weight examined for preliminary varietal comparison which significantly affected by salinity. Varieties were ranging from more tolerant to highly sensitive were identified base upon relative and absolute salt tolerant. Cultivars NlAB-78, B-821, MNH-93, BH-36, BH-74, CIM-434, S-12 and S-14 were categorized most tolerant to NaCl and cultivars CIM-1100, CIM-109, CIM-240 and FH-682 were proved to be moderately tolerant. The cultivars Karishma, Raishmi, SLS-1, and RH-1 were identified as the most sensitive to salinity. This data revealed differing tolerant of the cultivars and consequently existence of variation in salt tolerance in Gossypium hirsutum (L) .On the basis of high broad sense heritabilities, a potentially useful advance in NaCl tolerance seems possible to achieve by the selecting individual plant at the seedling stage.

**Key-words:** Salinity, cotton, varieties, assessment

## INTRODUCTION

There are many biotic and abiotic stresses in the plant environment, which limit crop productivity in the field. Among these stresses, the presence of salinity is the major stress, which affects growth and development of plants. According to the report of Soil Survey Staff about $5.7 \times 10^6$ hectares area has become salt-affected in Pakistan due to continuous use of canal irrigation (Khan, 1993). The presence of salts in root zone poses a great threat to the existence of crop husbandry in the country. There are numerous crops grown in the area affected by salinity and cotton is the most important from economic point of view; it fetches substantial amount of foreign exchange annually, through the export of raw fiber and fiber made-ups.

Although a galaxy of varieties had been released during the last two decades, but none of them had been able to withstand the adverse situation due to the presence of salinity. Lack of this potential in present day cotton cultivars were due to the "Unidirectional Approach" followed by the evolution of different genotypes. The major thrust of the breeders remained on improving seed cotton yield and fiber characteristics.

Keeping in view the magnitude of the problems, the government adopted "Engineering Approach" to tackle the menace of soil salinity but due to escalating cost of labour and energy, continued running of these projects like SCARP (Salinity Control and Reclamation Project) did not appear feasible in under-development countries like Pakistan. In recent years a more plausible solution to this problem has been suggested. In situations where it is not possible to modify the environment but genotypes may be modified to suit the adverse conditions, and this approach is called "Biological Approach" (Shannon, 1984).

The cotton crop is widely grown in the areas affected by salinity and clearly the development of salinity tolerance within species would be of great value. Therefore it was considered imperative to study the potential of cotton plants to grow under saline conditions. For effective and rapid progress in the development of such endeavour, availability of variation in salinity tolerance within *Gossypium hirsutum* (L.) is the prime requirement of a breeder and this was studied in a sample of eighteen varieties grown under four NaCl regimes at early growth stage.

## MATERIALS AND METHODS

The experiment was carried out in greenhouse of Plant Breeding and Genetics Department, University of Agriculture, Faisalabad to evaluate the response of eighteen cotton varieties to four NaCl levels i.e., 100, 150, 200, 250 mM and one without added salt. The genotype response was compared on the basis of their absolute and relative tolerance. These eighteen cotton cultivars were involved at different breeding research stations of Pakistan and differed from each other with respect to genetic make-up. The experiment was laid out using polythene-bags arranged in completely randomized design with three replications, and thus there were fifteen bags for each genotype. The seeds of all the genotypes were delineated with $H_2SO_4$ and soaked overnight prior to planting in polythene bags measuring $5^{//}\times10^{//}$. The bags were filled with soil known pH, ECe and saturation percentage. Anhydrous NaCl was used to develop the desired concentrations of NaCl in the bags and this was achieved in two doses, first half applied on the $9^{th}$ day after germination and the second half on the $4^{th}$ day of the first treatment. For making NaCl solutions, measured quantity of salt was added to tap water without nutrient solution. For uniform distribution of salt solution in the experimental unit, 3-4 holes were made at the bottom of each bag and were placed in plastic container accordingly 54 bags of each treatment. To start with first treatment all the bags in a container were watered with salinized water solution with desired concentration of NaCl, so that plants may be treated uniformly through the seepage and bags were kept for half an hour in the container. The same procedure was done in the case of second treatment. The ECe of control was 1.6 $dsm^{-1}$. For recording data five uniform plants of each genotype grown under each treatment were measured. After 14 days of growth, the data on shoot, root length, fresh shoot, root weight, dry root weight and dry shoot weight were recorded.

## DETAIL OF GENETIC MATERIAL USED

The following varieties were collected from breeders working at different Research Institutes of Pakistan.

| Name of Varieties | Place from where the genotype was collected |
|---|---|
| CIM-1100 | Central Cotton Research Institute, Multan. |
| CIM-240 | // |
| CIM-109 | // |
| CIM-434 | // |
| S-12 | Cotton Research Station, Multan. |
| S-14 | // |
| MNH-93 | // |
| MNH-329 | // |
| BH-36 | Cotton Research Institute, Bahawalpur. |
| BH-74 | // |
| FH-87 | Cotton Research Institute, Faisalabad. |
| FH-682 | // |
| SLS-1 | Cotton Research Institute, Sahiwal. |
| NIAB-78 | Nuclear Institute for Agriculture and Biology, Faisalabad. |
| Krishna | // |
| RH-1 | Cotton Research Institute, Rahim Yar Khan. |
| Raishmi | // |
| B-821 | University of agriculture, Faisalabad. |

## METHODOLOGY OF MEASURING THE CHARACTERS

The $14^{th}$ days old seedlings were used to measure the following traits. The methodology of collecting the data is as under:

**Shoot Length (cm)**
The length of fresh shoots of 5 seedling in each of 3 replicates were measured in centimeters and mean shoot length was obtained.

**Root Length (cm)**
The longest roots of plants were measure in the same manner as shoot length. This was also recorded in centimeters.

**Fresh Shoot Weight (g)**
Shoots of five seedlings were weighted collectively in grams by using an electronic balance CX-600.

**Dry Shoot Weight (g)**
The shoots of all the plants were air-dried and then placed in an oven at 70 $^{o}$C for 24 hours. Dry shoots were weighted in grams by using an electronic balance CX-600.

**Dry Root Weight (g)**

The same method was also followed to record dry root weighted data as was done in the case of dry shoot weight measurement.

**ASSESSMENT OF SALT TOLERANCE**

Choice of a method that measures the varied response of different cultivars to increasing NaCl concentration is important for varietal comparison. Salinity response of eighteen cultivars to increasing NaCl concentration was compared on the basis of their absolute performance as suggested by Dewelry (1960). The salinity response of variation was also examined as the reduction of in yield at a certain level of salinity expressed as percentage of growth or yield in non-salinized control condition, that is the relative yield of Maas (1986). The indices of salt tolerance was calculated according to the formula given below:

$$\text{Relative Salt Tolerance} = \frac{\text{Mean performance of character in NaCl solution}}{\text{Mean performance of character in control}} \times \mathbf{100}$$

**STATISTICAL ANALYSIS**

The data on salinity response of eighteen genotypes examined fewer than five NaCl treatments were subjected to analyze of variance following factorial design in order to find whether the genetic differences among NaCl treatments are significant of the effect of salinity treatment on root length, shoot length, fresh root weight, fresh shoot weight of eighteen genotypes.

**ESTIMATION OF BROAD SENSE HERITABILITY**

Estimates of broad sense heritability were made following Falconer (1981) based on variance data due to between accessions and within accessions variances in all the six characters assessed under each NaCl level. The formula followed to calculate the estimates of heritability ($h^2_B$) is given below :

$$h^2_B = \frac{\text{Between accessions Variance}}{\text{Between accession Variance + Within accession Variance}}$$

**Methodology in Laboratory**

Preparation of saturation soil paste is required for the determination of soil saturation percentage/water retention capacity of soil, which is used for the calculation of quantity of water required for irrigation.

Amount of total soluble salts (TSS) present in the soil were also calculated from the saturated soil paste on the basis of electrolytic conductivity of saturation paste extent (ECe) in $dsm^{-1}$ with the help of EC meter. Total soluble salts calculation is used for the development of salinity levels.

**Irrigation Water Requirement**

Following steps were involved in the determination of water requirement for irrigation.

**Saturation Paste**

Paste of soil (like dough) in which any drop of additional water will stand on the surface of the paste is termed as saturates.

**Preparation of Saturated Paste**

Some quantity of soil (Sand and Soil {3:1} mixture in this case) was taken in a beaker. Small quantity of distilled water was added in the soil to moisten it and continuously stirred with a spatula. This process was continued by adding water and stirring until the soil was just saturated.

The saturated paste so formed, glistens on the surface, slides easily and smoothly off the spatula for most of the soil and when a depression is made in the surface, no water accumulates in it and the depression slowly fills up the flow of paste under gravity. The soil filled beaker was covered and left at least for 30 minutes to reach equilibrium.

**Saturation Percentage**

Saturation percentage of soil is the weight of water in grams present in 100 grams of saturated paste on oven dry soil basis.

**Saturation Percentage Determination**

100 grams of soil saturated paste was transferred to a china dish and then placed in an oven at 105 $^{o}$C for the 24 hours. Then oven dry weight was observed on cooling in a desicator.

**Calculation**

Weight of dry china dish = A gram
Weight of china dish + saturated soil paste = B gram
Weight of china dish = saturated paste ( after drying) = C gram
Loss in weight ( water content of soil) = (B-C) gram
Weight of oven dry soil = (C-A) gram

$$\text{Saturation Percentage} = \frac{\text{Water Content of Soil}}{\text{Oven Dry weight of Soil}} \times 100$$

The saturation percentage calculated in this experiment was 24 % indicating that water retention capacity of the soil was 24 percent.

**Water Required for Irrigation**

Saturation percentage of soil (SP) was used for calculation of soil saturation point i.e., maximum quantity of water to be helped by soil. Application of irrigation water should be made in such a quantity that should not exceed the calculated saturation point of soil. The quantity of water required for irrigation was calculated by the formula:

$$\text{Irrigation Water Required for Seedling Stage} = \frac{\text{Weight of soil (gm)} \times \text{Soil Saturation Percentage (SP)}}{100}$$

$$= 100\ (24) / 100 \quad = 240 \text{ ml/1 Kg soil}$$

About half of the total quantity of water required for irrigation dissolved within calculated amount of salt (1/2 in quantity) for desired salinity level was used per polythene bag ($5^{//} \times 10^{//}$ ) in one application keeping in view that some moisture was already present in the soil and also to avoid water logging condition. First irrigation was applied on 9$^{th}$ day after sowing, when germination was completed, second application was applied on 12$^{th}$ day.

Saturation percentage was also used to calculate the amount of salts required to develop different salinity levels.

**Development of Salinity Levels**

The following steps are involved in the development of different salinity level.

**Electrolytic Conductivity of Soil**

The total soluble salts (TSS) present in the soil are expressed as electrical conductivity (EC) of soil in dsm$^{-1.}$

**Need of Electro-conductivity of Soil**

It is calculated to know the amount of total soluble salts present in the soil and also to develop different salinity levels.

**Saturation Extract**

It is the soil solution extracted from saturated soil paste by means of a suction pump.

**Methodology**

The saturated soil paste prepared was kept over weight and covered with a polythene sheet to avoid the loss of moisture and giving sufficient time to dissolve soluble salts. The saturated paste was transferred on a double sheet of filter paper that was placed in the perforated steel cups provided with the sunction pump. The sunction pump is a device used to suck the soil. Solution through filter paper by creating vacuum in the Buckner funnel, the extract was sucked out and collected in the plastic tubes placed beneath perforated steel cups in the Buckner funnel.

**Determination of Electrolytic Conductivity**

The saturation extract was used to determine ECe dsm$^{-1}$ by mean of conductivity meter (Model: 4070 Jenway Ltd. England. The ECe thus determined was 1.61 dsm$^{-1}$ of soil in to (control).

**Preparation of Different Salinity Levels**

The salinity development for assessment of variation in cotton genotypes are as follow:

| Salt Tolerance | Concentration (mM) | ECe $dsm^{-1}$ |
|---|---|---|
| $T_0$ | 10.60 | 1.6 |
| $T_1$ | 100.00 | 10.0 |
| $T_2$ | 150.00 | 15.00 |
| $T_3$ | 200.00 | 20.00 |
| $T_4$ | 250.00 | 25.00 |

The quantity of different salts required for different salinity levels was calculated by using the formula:

Respective Salt (RS) = Ratio of salt × 755 Eq.wt. × Sp × 100

Respective salts of calculated in terms of g /Kg of soil. TSS was observed from graphs using Handbook 60. Equivalent weight of salt used NaCl, was 58.5.

| Salinity Levels (mM) | Salt Required per Kg soil (g) for 1 bag | Salt required for 54 bags (g) | Half amount of salt used in each treatment (g) |
|---|---|---|---|
| 100 | 0.58 | 31.32 | 15.66 |
| 150 | 1.51 | 81.54 | 40.77 |
| 200 | 2.41 | 130.14 | 65.07 |
| 250 | 3.47 | 187.38 | 93.69 |

**RESULTS AND DISCUSSION**

The genotypic means of six characters of eighteen cotton cultivars at seedling stage using five test solutions were subjected to ordinary analysis of variance technique (Steel and Torrie, 1980. The analysis of variance of shoot, root length, fresh shoot, root weight, dry shoot weight and dry root weight revealed that 18 genotypes were significantly different for these characters ($P \leq 0.01$) and five salinity levels were also different from each other ($P \leq 0.01$). The significant genotypic- environment (G × S) interaction indicated that all the genotypes responded differently to increasing NaCl concentrations in the growing medium and five characters were affected significantly ($P \leq 0.01$). However, in case of root dry weight, the variance ratio of three components, i.e., genotypes, salinity levels and their interactions were reduced to non significantly level ($P \geq 0.05$) The detailed description of these comparisons is given as:

Table 1. Analysis of variance for Shoot Length of Eighteen *Gossypium hirsutum* (L.) genotypes in five NaCl levels.

| S.O.V | D.F | S.S | M.S | F-ratio |
|---|---|---|---|---|
| Genotypes (G) | 17 | 1355.825 | 6.149886 | 522.7151** |
| Salinity (S) | 4 | 24.59953 | 0.396185 | 40.30667** |
| G X S | 68 | 26.94064 | 0.152577 | 2.596624** |
| Error | 180 | 27.46391 | | |
| Total | 269 | 1434.830 | | |

**Shoot Length:**

The results of analysis of variance of shoot length are given in Table-1.The absolute and relative salt tolerance with respect of shoot length of 18 cultivars in each salinity level is presented in Table 2.

Data on absolute values showed differing responses of the genotypes different from each other even under non-stress conditions. In 100 mM NaCl the response of six cultivars BH-36. MNH-93, MNH-329, NIAB-78, B-821 and Raishmi were moderately different from other cultivars and produced longer shoot length (14.8 to17.5 cm). In contrast shoot length of the remaining cultivars ranged from 8.30-14.0 cm. Under increased concentrations of NaCl i.e., 200 mM and 250 mM, the same six cultivars responded appreciably and produced longer shoot lengths.

Table 2. Indices of absolute and Relative Salt Tolerance of eighteen genotypes of *Gossypium hirsutum* (L.) in five NaCl levels (mM) for shoot length (cm).

| **Accessions** | **Absolute Salt Tolerance** | | | | | | **Relative Salt Tolerance** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Karishma | Control | 100 Mm | 150 Mm | 200 Mm | 250 Mm | Mean | 100 Mm | 150 Mm | 200 Mm | 250 Mm | Means |
| | 12.9 | 11.3 | 10.5 | 9.1 | 7.9 | 9.7 | 87.5 | 81.3 | 70.5 | 61.2 | 75.1 |
| CIM-1100 | 11.3 | 11.0 | 10.3 | 9.9 | 9.1 | 10.1 | 97.3 | 91.1 | 87.6 | 80.5 | 89.1 |
| CIM-109 | 11.7 | 11.4 | 10.6 | 9.7 | 8.8 | 10.1 | 97.4 | 90.5 | 82.9 | 76.2 | 86.5 |
| CIM-434 | 11.9 | 11.15 | 10.7 | 9.6 | 8.3 | 10.0 | 96.6 | 89.9 | 80.6 | 69.7 | 84.2 |
| CIM-240 | 12.5 | 12.1 | 11.3 | 10.5 | 9.3 | 10.8 | 96.8 | 90.4 | 84.0 | 74.4 | 86.1 |
| S-12 | 13.1 | 12.6 | 12.0 | 11.3 | 10.4 | 11.6 | 96.1 | 91.6 | 86.2 | 79.3 | 88.3 |
| S-14 | 14.7 | 14.3 | 13.8 | 12.9 | 11.9 | 13.2 | 97.2 | 93.8 | 87.7 | 80.9 | 89.9 |
| BH-36 | 16.7 | 16.1 | 15.2 | 14.4 | 13.5 | 14.8 | 96.4 | 91.0 | 86.2 | 80.8 | 88.6 |
| BH-74 | 13.6 | 13.3 | 13.1 | 12.5 | 11.3 | 12.6 | 97.8 | 96.3 | 91.2 | 84.1 | 92.3 |
| MNH-93 | 15.1 | 14.8 | 14.1 | 13.6 | 12.9 | 13.9 | 98.0 | 93.3 | 90.0 | 85.4 | 91.7 |
| MNH-329 | 16.6 | 16.1 | 15.5 | 14.7 | 14.0 | 15.1 | 97.0 | 93.4 | 88.6 | 84.3 | 90.8 |
| FH-87 | 12.1 | 11.8 | 11.3 | 11.5 | 10.3 | 11.2 | 97.5 | 93.4 | 86.8 | 85.1 | 90.7 |
| FH-682 | 12.5 | 12.2 | 11.8 | 11.1 | 10.4 | 11.4 | 97.6 | 94.4 | 88.8 | 83.2 | 91.0 |
| RH-1 | 14.9 | 14.4 | 13.3 | 15.5 | 11.1 | 12.8 | 96.6 | 89.3 | 83.9 | 74.5 | 86.1 |
| SLS-1 | 9.1 | 8.3 | 7.1 | 6.4 | 5.5 | 6.8 | 91.9 | 78.0 | 70.3 | 60.5 | 74.9 |
| NIAB-78 | 17.7 | 17.5 | 17.0 | 16.3 | 15.6 | 16.6 | 98.9 | 96.0 | 92.1 | 88.1 | 93.7 |
| B-821 | 17.2 | 16.9 | 16.1 | 15.3 | 14.5 | 15.7 | 98.3 | 93.6 | 89.0 | 84.3 | 91.3 |
| Raishmi | 16.5 | 16.0 | 14.2 | 13.6 | 12.3 | 14.0 | 97.0 | 86.1 | 82.4 | 74.5 | 85.0 |

The remainder accessions and differences were again striking. The means of absolute values showed that BH-36, MNH-93, MNH-329, NIAB-78, B-821 and Raishmi produced longer shoots ranging from 14.00 to 16.6 cm as compared to 9 to 12 cm of the remaining cultivars.

Indices of salt tolerance given in Table 2 revealed that some of the varieties were less affected than the others and these differences were clear at concentrations as compared to those at lower concentrations. The effects of NaCl salinity were more pronounced on Karishma, SLS-1, CIM 434, CIM 240, CIM 109, RH-1 and Raishmi, which produced 75%, shoot length of the control. By contrast shoot length of CIM 1100, S-14, Bh-36, Bh-74, MNH-93, FH-87, FH-682, NIAB-78and B-821 were less affected and gave 80-88% indices of salt tolerance. The mean indices of the same cultivars were also higher than the others and ranged from 84-94%. Therefore, on basis of shoot length data cultivars CIM-1100, S-14, BH-36, BH-74, MNH-93, MNH-329, FH-87, FH-682, NIAB-78 and B-821 may be regarded as the most salt tolerant cultivars. The data suggest that there is some relationship between prior vigour in control solution and growth in salinized solutions is suggested by Shanon (1984).

The data in Table 3 showed that effects were high but in case of absolute responses within genotypes, the results were non significant. With the increase of salinity level, the mean squares of the shoot length decreased. The deviation from the mean square control (89.681) was more pronounced the highest salinity levels (75.836 and 74.487 for 200mM and 250 mM, respectively).

An increased in level of salinity adversely affected shoot length and consequently estimates of broad sense heritability. Approximately same haritability (0.85 and 0.84) was found in 150 and 200 mM levels (Table. 4)

Table 3. Mean Squares from Analysis of Variance of Shoot Length of eighteen *Gossypium hirsutum* (L.) genotypes in five NaCl levels.

| S.O.V | D.F | NaCl levels | | | | |
|---|---|---|---|---|---|---|
| | | Control | 100Mm | 150Mm | 200Mm | 250Mm |
| Between Genotypes | 17 | 89.681 | 84.296 | 82.396 | 75.836 | 74.487 |
| Within Genotypes | 252 | 8.046 | 10.844 | 11.733 | 11.690 | 12.949 |
| Total | 269 | | | | | |

Table 4. Components of variances and Broad Sense Heritabilities of Salt Tolerance of Eighteen *Gossypium hirsutum* (L.) in five NaCl levels.

| Components | Control | 100Mm | 150Mm | 200Mm | 250Mm |
|---|---|---|---|---|---|
| $\sigma^2_{b} = V_G$ | 81.63 | 73.45 | 70.66 | 64.14 | 61.53 |
| $\sigma^2_{b} + \sigma^2_{w} = V_D$ | 89.68 | 84.29 | 82.39 | 75.83 | 74.48 |

It was also observed that in control results were maximum (0.91) but gradually decreased as the NaCl level was increased and the lowest heritability was found at the highest salinity level 250mM (Table. 4).

**Root Length:**

The variance ratio for genotypes salinity level and G×S interaction highly significant. In Table 6, the results showed differing responses of the accessions to increasing NaCl salinity. The root length of some of the accessions was significantly reduced when exposed to the lowest NaCl concentration of 100 mM. However, genotypic differences appeared to be non-significant. The varietal differences were discernable under higher concentration of NaCl i.e. 250mM and cultivars SLS-1, BH-74, RH-1, Raishmi and FH-682, produced 7.1,9.3,5.5,4.2,and 8.7 cm root length respectively. By contrast, root length of MNH-329, BH-36 and MNH-93 were affected less and roots were 3.4, 3.4 ad 3.6 cm long in 250mM respectively. The response of remaining cultivars to salinity was intermediate.

Table 5. Analysis of Variance for root lengths of eighteen *Gossypium hirsutum* (L.) genotypes in five NaCl levels.

| **S.O.V** | **D.F** | **S .S** | **M .S** | **F-ratio** |
|---|---|---|---|---|
| Genotypes (G) | 17 | 1787.721 | 105.1601 | 52.08493** |
| Salinity levels (S) | 4 | 385.2899 | 96.32248 | 47.70773** |
| G x S | 68 | 466.4270 | 6.859221 | 3.397316** |
| Error | 180 | 363.4221 | 2.019011 | |
| Total | 269 | 3002.860 | | |

Differences of within-genotype mean squares were found non-significant. The heritability for the root length of eighteen cotton genotype was maximum in control (0.85) and it was gradually decreased as NaCl level was increased and the lowest heritability (0.72) was found in case of highest salinity level. The increased salinity level had adversely effect on root length and consequently estimates of broad sense heritability as showed in Table-8.

Table 6. Indices of absolute and Relative Salt Tolerance of eighteen genotypes of *Gossypium hirsutum* (L.) in five NaCl levels (mM) for root length (cm).

| **Accessions** | **Absolute Salt Tolerance** | | | | | | **Relative Salt Tolerance** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | 100 Mm | 150 Mm | 200 Mm | 250 Mm | Mean | 100 Mm | 150 Mm | 200 Mm | 250 Mm | Means |
| Karishma | 15.3 | 14.1 | 13.3 | 12.4 | 16.1 | 12.5 | 92.1 | 86.9 | 81.0 | 66.0 | 81.5 |
| CIM-1100 | 12.0 | 11.2 | 9.6 | 8.4 | 7.1 | 9.1 | 93.3 | 80.0 | 70.0 | 59.2 | 75.6 |
| CIM-109 | 13.1 | 12.3 | 10.1 | 9.1 | 8.2 | 9.9 | 94.0 | 70.1 | 69.5 | 63.0 | 75.9 |
| CIM-434 | 13.3 | 12.6 | 11.8 | 10.1 | 9.0 | 10.9 | 94.7 | 88.7 | 75.9 | 66.7 | 81.5 |
| CIM-240 | 14.8 | 13.5 | 12.0 | 10.9 | 9.7 | 11.5 | 91.2 | 81.1 | 73.6 | 65.5 | 77.8 |
| S-12 | 12.9 | 12.2 | 10.7 | 9.2 | 8.2 | 10.1 | 94.6 | 82.9 | 71.3 | 63.6 | 78.1 |
| S-14 | 12.2 | 11.3 | 10.2 | 9.7 | 8.8 | 10.0 | 92.6 | 83.6 | 76.5 | 72.1 | 81.9 |
| BH-36 | 16.2 | 14.9 | 13.9 | 12.6 | 11.2 | 13.2 | 92.0 | 85.8 | 77.7 | 69.1 | 81.1 |
| BH-74 | 15.1 | 13.7 | 11.9 | 10.2 | 9.3 | 11.3 | 90.7 | 78.8 | 67.5 | 61.6 | 73.6 |
| MNH-93 | 14.9 | 14.2 | 13.5 | 12.9 | 11.3 | 13.0 | 95.3 | 90.6 | 86.6 | 75.8 | 87.1 |
| MNH-329 | 17.1 | 16.0 | 15.1 | 14.4 | 13.7 | 14.8 | 94.6 | 88.3 | 84.2 | 80.1 | 86.5 |
| FH-87 | 13.3 | 10.9 | 9.9 | 7.7 | 7.0 | 8.9 | 88.6 | 80.5 | 62.6 | 56.9 | 72.1 |
| FH-682 | 14.3 | 12.3 | 11.1 | 10.0 | 8.7 | 10.5 | 86.6 | 78.2 | 70.4 | 61.3 | 74.1 |
| RH-1 | 11.1 | 10.0 | 9.2 | 7.9 | 5.5 | 8.2 | 90.1 | 82.9 | 7.02 | 49.5 | 73.4 |
| SLS-1 | 13.4 | 11.2 | 10.1 | 8.6 | 7.1 | 9.3 | 83.6 | 75.4 | 64.2 | 53.0 | 69.1 |
| NIAB-78 | 19.3 | 18.5 | 17.7 | 16.5 | 15.3 | 17.0 | 95.9 | 91.7 | 85.5 | 79.3 | 88.1 |
| B-821 | 17.5 | 16.3 | 15.2 | 14.4 | 13.2 | 15.0 | 94.1 | 86.9 | 82.3 | 75.4 | 84.4 |
| Raishmi | 9.8 | 8.5 | 7.0 | 6.2 | 4.2 | 6.5 | 86.7 | 71.4 | 63.3 | 42.9 | 66.1 |

Although the magnitudes of the mean squares from five salinity levels (Table-7) showed that increasing NaCl level had decreased root lengths differences between genotype mean squares were highly significant at ($P \leq 0.01$) and ($P \leq 0.05$).

The retarded growth of genotypes could be attributed to the toxic effects of NaCl and low water potential in the rooting medium. Some cultivars appeared to be the most tolerant due to sudden stress of NaCl salinity and the effect was found gradually increasing on manifestation of characters, as previously have been observed in cotton. During the experimentation and measurement of characters it was observed that growth of roots were more severely affected due to salinity stress as compared to shoots as had been observed in sorghum by Ratanadilok *et al.* (1978) Azhar and McNeilly, (1987) and Levitt (1980).

Table 7. Mean Squares from Analysis of Variance of Root Lengths of eighteen *Gossypium hirsutum* (L.) in five NaCl levels.

| S.O.V | D.F | NaCl levels | | | | |
|---|---|---|---|---|---|---|
| | | Control | 100Mm | 150Mm | 200Mm | 250Mm |
| Between Genotypes | 17 | 193.535** | 143.895** | 133.780** | 98.484** | 93.289** |
| Within Genotypes | 252 | 32.665 | 34.165 | 28.984 | 5.026 | 25.544 |
| Total | 269 | | | | | |

Table 8.Components of variances and Broad Sense Heritabilities of Salt Tolerance of Eighteen *Gossypium hirsutum* (L.) in five NaCl levels.

| Components | Control | 100Mm | 150Mm | 200Mm | 250Mm |
|---|---|---|---|---|---|
| $\sigma^2{}_{b} = V_G$ | 160.870 | 109.729 | 104.796 | 73.457 | 67.744 |
| $\sigma^2{}_{b} + \sigma^2{}_{w} = V_D$ | 193.535 | 143.895 | 133.780 | 98.484 | 93.289 |
| $h^2{}_{B} = V_G / V_D$ | 0.83 | 0.78 | 0.76 | 0.74 | 0.72 |

In addition there also appeared blackening of roots and their becoming brittle as has been reported in sorghum (Azhar and McNeilly, 1987). Root length inhibition and its blackening is likely to have been due to specific ion toxicity of Na+ as Cl- (Bernstein, 1975) and due to osmotic imbalance (Kingsbury *et al*., 1984). The former may have resulted in reduction of mitotic activity as previously observed in cotton (Strogonov, 1964) in barley (Avilov and Matukhin, 1967) and in rice (Akbar and Yabuno, 1975).

**Fresh Shoot Weight**

The results of the analysis of variance of fresh short weight are given in (Table-9). Indices of salt tolerance values of 18 cultivars on absolute and relative basis are presented in (Table-10).

Table 9. Analysis of variance for Fresh shoot weight of eighteen *Gossypium hirsutum* (L.) genotypes in five NaCl levels.

| **S.O.V** | **D.F** | **S .S** | **M .S** | **F-ratio** |
|---|---|---|---|---|
| Genotypes (G) | 17 | 6.624824 | 0.389695 | 109.2685** |
| Salinity levels (S) | 4 | 0.892275 | 0.223068 | 62.54731** |
| G x S | 68 | 1.043108 | 0.015339 | 4.301205** |
| Error | 180 | 0.641952 | 0.003566 | |
| Total | 269 | 9.202160 | | |

Data on absolute values showed differing responses of the genotypes to increasing NaCl levels the genotypes differed from each other even they were grown in un salinized condition. The response of NIAB-78, B-821, MNH-93, MNH-329, BH-36 and Raishmi were markedly different from other cultivars and produced higher fresh short weight (0.09 – 0.99 gm) under 100mM NaCl level. While the remainder produced fresh short weight ranging from 0.25 to 0.49 gm under 200 mM ad 250 mM levels and SLS-1 produced the lowest fresh shoot weight. The above mentioned accessions again gave the highest fresh short weight even at the highest salt concentrations and differences were also evident.

The means of absolute values of fresh short weight data showed that NIAB-78, B-821, MNH-93, MNH-329 ad BH-36 produced greater fresh shoot weight ranging from 0.79 to 0.90 and seem to be the most salt tolerant as compare to SLS-1, FH-87, S-12, CIM-240, CIM-109 and CIM-1100 while produced 0.55, 0.55, 0.48, 0.45,0.42 gram respectively. Mean indices of salt tolerance of the same cultivars were again higher & ranged from 80 to 85 %. On the basis of indices of fresh short weight S-14, BH-36, BH-74, MNH-93 and B-821 may be regarded as the most salt tolerant cultivars.

Table 10. Indices of absolute and Relative Salt Tolerance of eighteen genotypes of *Gossypium hirsutum* (L.) in five NaCl levels (Mm) for fresh shoot weight (gm).

| **Accessions** | **Absolute Salt Tolerance** | | | | | | **Relative Salt Tolerance** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | 100 | 150 | 200 | 250 | Mean | 100 | 150 | 200 | 250 | Means |
| Karishma | | Mm | Mm | Mm | Mm | | Mm | Mm | Mm | Mm | |
| | .72 | .67 | .61 | .53 | .44 | 0.56 | 93.06 | 84.7 | 73.6 | 61.1 | 78.1 |
| CIM-1100 | .58 | .54 | .51 | .44 | .34 | 0.46 | 93.1 | 87.9 | 75.9 | 58.6 | 78.9 |
| CIM-109 | .61 | .50 | .47 | .39 | .33 | 0.42 | 81.9 | 77.0 | 63.9 | 54.1 | 69.2 |
| CIM-434 | .57 | .53 | .50 | .42 | .30 | 0.43 | 92.9 | 87.7 | 73.7 | 52.6 | 76.7 |
| CIM-240 | .62 | .58 | .52 | .46 | .34 | 0.48 | 93.5 | 83.9 | 74.1 | 54.8 | 76.6 |
| S-12 | .71 | .65 | .57 | .49 | .41 | 0.53 | 91.5 | 80.3 | 69.0 | 57.7 | 74.6 |
| S-14 | .90 | .85 | .78 | .73 | .61 | 0.74 | 94.4 | 86.6 | 81.1 | 67.7 | 82.5 |
| BH-36 | .99 | .94 | .85 | .76 | .63 | 0.80 | 95.0 | 85.9 | 76.8 | 63.6 | 80.3 |
| BH-74 | .81 | .77 | .77 | .70 | .50 | 0.69 | 95.1 | 95.1 | 86.4 | 61.7 | 84.6 |
| MNH-93 | .93 | .90 | .83 | .76 | .67 | 0.79 | 96.8 | 89.2 | 81.7 | 72.0 | 84.9 |
| MNH-329 | 1.10 | .92 | .87 | .76 | .66 | 0.80 | 83.6 | 79.1 | 69.1 | 60.0 | 73.0 |
| FH-87 | .67 | .65 | .57 | .50 | .41 | 0.53 | 97.0 | 85.1 | 74.6 | 61.2 | 79.5 |
| FH-682 | .70 | .63 | .58 | .49 | .36 | 0.51 | 90.0 | 82.9 | 70.1 | 51.4 | 73.6 |
| RH-1 | .88 | .70 | .64 | .51 | .42 | 0.57 | 79.5 | 72.7 | 58.0 | 47.7 | 64.5 |
| SLS-1 | .61 | .52 | .43 | .31 | .23 | 0.37 | 85.2 | 70.5 | 50.8 | 37.7 | 61.1 |
| NIAB-78 | 1.06 | .99 | .92 | .88 | .79 | 0.90 | 93.4 | 86.8 | 83.0 | 74.5 | 84.4 |
| B-821 | 1.05 | .96 | .90 | .85 | .81 | 0.88 | 91.4 | 85.7 | 81.0 | 77.1 | 83.8 |
| Raishmi | 1.08 | .91 | .89 | .71 | .54 | 0.76 | 84.3 | 82.4 | 65.7 | 50.0 | 70.6 |

The relative response between genotypes against five NaCl levels based upon fresh shoot weight showed results highly significant at ($P \leq 0.01$) and ($P \leq 0.05$) level but in case of absolute response within genotype, the results were non-significant as indicated in table-II. The mean squares of the fresh shoot weight of all genotypes were decreased while the NaCl level was increased.

Table 11. Mean Squares from Analysis of Variance of Fresh Shoot weights of eighteen *Gossypium hirsutum* (L.) in five NaCl levels.

| S.O.V | D.F | NaCl levels | | | | |
|---|---|---|---|---|---|---|
| | | Control | 100Mm | 150Mm | 200Mm | 250Mm |
| Between Genotypes | 17 | 0.61160** | 0.4997** | 0.4227** | 0.3822** | 0.3389** |
| Within Genotypes | 252 | 0.615 | 0.0703 | 0.0843 | 0.0813 | 0.768 |
| Total | 269 | | | | | |

Table 12. Components of variances and Broad Sense Heritabilities of Salt Tolerance of Eighteen *Gossypium hirsutum* (L.) in five NaCl levels.

| Components | Control | 100Mm | 150Mm | 200Mm | 250Mm |
|---|---|---|---|---|---|
| $\sigma^2{}_{b} = V_G$ | 0.5500 | 0.4293 | 0.3384 | 0.3384 | 0.2620 |
| $\sigma^2{}_{b} + \sigma^2{}_{w} = V_D$ | 0.6116 | 0.4977 | 0.4227 | 0.3822 | 0.3389 |
| $h^2{}_{B} = V_G / V_D$ | 0.89 | 0.85 | 0.80 | 0.78 | 0.77 |

The deviation from the mean square of control (O.611gm) was more pronounced at the highest salinity levels (0.3822 and 0.3388 for 200 and 250 mM respectively.

The heritabilities for the fresh shoot weight of eighteen cotton accessions was minimum in control (o.89) but was increasingly decreased as the NaCl was increased ad the lowest heritability was found at the highest salinity level (250 mM). This increased salinity had adversely affected fresh shoot weight ad consequently estimates of broad sense heritability (Table-12)

**Fresh Root Weight**

Table-13 showed the results of analysis of variance of fresh root weight. All the varietal components are significant. Table 14 indicated the absolute root weigh in each salinity level and relative fresh root weight.

Table-13 Analysis of Variance for fresh root weights of eighteen *Gossypium hirsutum* (L.) genotypes in five NaCl levels.

| S.O.V | D.F | S .S | M .S | F-ratio |
|---|---|---|---|---|
| Genotypes (G) | 17 | 0.014275 | 0.000839 | 29.81514** |
| Salinity levels (S) | 4 | 0.001402 | 0.000350 | 12.44608** |
| G x S | 68 | 0.002321 | 0.000034 | 1.212075ns |
| Error | 180 | 0.005069 | 0.000028 | |
| Total | 269 | 0.023069 | | |

Table 14. Indices of absolute and Relative Salt Tolerance of eighteen genotypes of *Gossypium hirsutum* (L.) in five NaCl levels (mM) for fresh shoot weight (g).

| Accessions | Absolute Salt Tolerance | | | | | | Relative Salt Tolerance | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | 100 Mm | 150 Mm | 200 Mm | 250 Mm | Mean | 100 Mm | 150 Mm | 200 Mm | 250 Mm | Means |
| Karishma | .0155 | .0143 | .0136 | .0127 | .0108 | .0129 | 92.3 | 87.7 | 81.9 | 69.7 | 82.9 |
| CIM-1100 | .0161 | .0142 | .0128 | .0113 | .0107 | .0123 | 88.2 | 79.5 | 70.2 | 66.5 | 76.1 |
| CIM-109 | .0204 | .0155 | .0138 | .0131 | .0116 | .0135 | 76.0 | 67.6 | 64.2 | 56.9 | 66.2 |
| CIM-434 | .0182 | .0167 | .0150 | .0131 | .0122 | .0143 | 91.8 | 82.4 | 72.0 | 67.0 | 78.4 |
| CIM-240 | .0161 | .0148 | .0138 | .0125 | .0113 | .0131 | 91.9 | 85.7 | 77.6 | 70.2 | 81.4 |
| S-12 | .0174 | .0167 | .0156 | .0144 | .0136 | .0151 | 96.0 | 89.7 | 82.8 | 78.2 | 86.7 |
| S-14 | .0180 | .0174 | .0163 | .0151 | .0120 | .0152 | 96.7 | 90.6 | 83.9 | 66.7 | 84.5 |
| BH-36 | .0432 | .0286 | .0277 | .0235 | .0204 | .0251 | 66.2 | 64.1 | 54.4 | 47.2 | 57.9 |
| BH-74 | .0320 | .0257 | .0201 | .0146 | .0310 | .0179 | 80.3 | 62.8 | 45.6 | 34.4 | 55.8 |
| MNH-93 | .0208 | .0190 | .0184 | .0153 | .0144 | .0168 | 91.4 | 88.5 | 73.6 | 69.2 | 80.7 |
| MNH-329 | .0374 | .0352 | .0333 | .0319 | .0304 | .0327 | 94.1 | 89.0 | 85.3 | 81.3 | 87.4 |
| FH-87 | .0216 | .0127 | .0107 | .0100 | .0088 | .0106 | 58.8 | 49.5 | 46.3 | 40.7 | 48.8 |
| FH-682 | .0200 | .0135 | .0125 | .0103 | .0094 | .0114 | 67.5 | 62.5 | 51.5 | 47.0 | 57.1 |
| RH-1 | .0165 | .0152 | .0133 | .0112 | .0088 | .0121 | 92.1 | 80.6 | 67.9 | 53.3 | 73.5 |
| SLS-1 | .0132 | .0114 | .0108 | .0092 | .0074 | .0097 | 86.4 | 81.8 | 69.7 | 56.1 | 73.5 |
| NIAB-78 | .0455 | .0403 | .0361 | .0335 | .0396 | .0349 | 88.6 | 79.3 | 73.6 | 65.1 | 76.7 |
| B-821 | .0241 | .0218 | .0180 | .0165 | .0156 | .0180 | 90.5 | 74.9 | 68.5 | 64.7 | 74.7 |
| Raishmi | .0132 | .0113 | .0090 | .0069 | .0051 | .0081 | 85.6 | 68.2 | 52.3 | 38.6 | 61.2 |

The salinity effects were found to be more serious at higher concentration of NaCl i. e. 250 mM. On the basis of relative salt tolerance of 18 cultivars, genotype comparisons are again apparent. Reduction in fresh root weight of the genotypes at 100mM and 150mM levels were less as compared to that under 200mM and 250mM. On the basis of mean indices of salt tolerance, the response of Karishma, CIM-240, S-12, S-14, MNH-93, and MNH-329 was better than others ad therefore may be categorized under salt tolerant accessions. As indicated in Table-15, the magnitudes of the mean squares from five salinity level fresh root weight decreased with the increased of salinity levels, difference between genotype mean square were highly significant at ($P \leq 0.01$ ad ($P \leq 0.05$) level while differences within-genotypes mean squares were found non- significant.

Table 16 showed the heritability for the fresh root weight of 18 cotton genotypes. Control gained the maximum (0.85). The maximum effect was found in heritability at 100mM (0.77) and the heritabilitis at 150, 200 ad 250 mM were (0.81 to 0.82) ad it was non-significant as compared to each other and it was not so deviated from the control (0.85).

Table 15. Mean Squares from Analysis of Variance of Fresh root weights of eighteen *Gossypium hirsutum* (L.) in five NaCl levels.

| S.O.V | D.F | NaCl levels | | | | |
|---|---|---|---|---|---|---|
| | | Control | 100Mm | 150Mm | 200Mm | 250Mm |
| Between Genotypes | 17 | 0.00187** | 0.00062** | 0.00107** | 0.00072** | 0.00057** |
| Within Genotypes | 252 | 0.00027 | 0.00013 | 0.00019 | 0.00012 | 0.00010 |
| Total | 269 | | | | | |

Table 16. Components of variances and Broad Sense Heritabilities of Salt Tolerance in Eighteen *Gossypium hirsutum* (L.) genotypes in five NaCl levels.

| Components | Control | 100Mm | 150Mm | 200Mm | 250Mm |
|---|---|---|---|---|---|
| $\sigma^2{}_{b} = V_G$ | 0.00160 | 0.00048 | 0. 00087 | 0.00060 | 0.00047 |
| $\sigma^2{}_{b} + \sigma^2{}_{w} = V_D$ | 0.00187 | 0.00062 | 0.00107 | 0.00072 | 0.00057 |
| $h^2{}_{B} = V_G / V_D$ | 0.85 | 0.77 | 0.81 | 0. 82 | 0.81 |

**Dry Shoot Weight:**

Table 17 showed the analysis of variance results for dry shoot weight as absolute salt tolerance and relative salt tolerance of 18 cultivars is presented in Table-18. Data on absolute values showed differing responses of the genotypes to increasing NaCl levels and it was also showed that the genotypes responded differently to increasing NaCl levels even in control.

The response of all the cultivars was affected non-significantly at 100mM and 200mM and effect was same in RH-1 that was markedly decreased in dry short weight. Mean of the absolute values showed that all varieties except RH-1, MNH-93, Raishmi and Karishma. Means of absolute values showed that all varieties except these four varieties showed better response and produced dry shoot weight only 0.670gm at concentration of 250 mM. Means of absolute values showed that all varieties except these four varieties showed better response and produced dry shoot weight ranging from 0424 and 0852gm.

Table-17 Analysis of for root length of eighteen Gossypium hirsutum (L.) genotypes in five NaCl levels.

| **S.O.V** | **D.F** | **S .S** | **M .S** | **F-ratio** |
|---|---|---|---|---|
| Genotypes (G) | 17 | 0.047019 | 0.002765 | 79.53004** |
| Salinity levels (S) | 4 | 0.005818 | 0.001454 | 41.82611** |
| G x S | 68 | 0.007760 | 0.00114 | 3.281633** |
| Error | 180 | 0.006259 | 0.000034 | |
| Total | 269 | 0.066858 | | |

Some of the varieties were less affected than the others and difference at 250mM were more conspicuous as compared to those at lower concentration. The effects of NaCl salinity were more pronounced on RH-1 that produced only 73% dry shoot weight of the control.

The mean values of these cultivars were also higher ad ranged from 80 to 92% and therefore proved more salt tolerant.

In Table 19, the case of relative responses between genotypes against five NaCl levels based upon dry shoot weight was highly significant at ($P \leq 0.01$) and ($P \leq 0.05$) level but absolute value within genotype results was non-significant.

The deviation from the mean square of control (0.003480 was more pronounced of higher salinity level (0.00292 and 0.00289) for 200 and 250 mM respectively and it was same as compared to each other.

The heritabilities for the dry shoot weight results mentioned that control was maximum in all genotypes but it was gradually decreased as the NaCl level was increased in case of heritability at 150mM (0.83). The lowest heritability was found in the case of highest salinity level (250mM). This increased salinity had bad effect on dry shoot weight and consequently estimates of broad sense heritability.

Table 18. Indices of absolute and Relative Salt Tolerance of eighteen genotypes of *Gossypium hirsutum* (L.) in five NaCl levels (mM) for Dry Shoot Weight (gm).

| **Accessions** | **Absolute Salt Tolerance** | | | | | | **Relative Salt Tolerance** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | 100 Mm | 150 Mm | 200 Mm | 250 Mm | Mean | 100 Mm | 150 Mm | 200 Mm | 250 Mm | Means |
| Karishma | .0789 | .0666 | .0650 | .0646 | .0602 | .0641 | 84.4 | 82.4 | 81.9 | 76.3 | 81.3 |
| CIM-1100 | .0581 | .0529 | .0521 | .0502 | .0429 | .0495 | 91.0 | 89.7 | 86.4 | 73.8 | 85.2 |
| CIM-109 | .0587 | .0563 | .0509 | .0498 | .0462 | .0508 | 95.9 | 86.7 | 84.8 | 78.7 | 86.5 |
| CIM-434 | .0557 | .0525 | .0511 | .0492 | .0414 | .0486 | 94.3 | 91.7 | 88.3 | 74.3 | 87.2 |
| CIM-240 | .0618 | .0610 | .0572 | .0559 | .0521 | .0566 | 98.7 | 92.6 | 90.5 | 84.3 | 91.5 |
| S-12 | .0695 | .0650 | .0624 | .0622 | .0488 | .0596 | 93.5 | 89.9 | 89.5 | 70.2 | 85.8 |
| S-14 | .0840 | .0817 | .0795 | .0783 | .0602 | .0749 | 97.3 | 94.6 | 93.2 | 71.7 | 89.2 |
| BH-36 | .0879 | .0839 | .0793 | .0768 | .0701 | .0775 | 95.4 | 90.2 | 87.4 | 79.7 | 88.2 |
| BH-74 | .0749 | .0750 | .0745 | .0704 | .0493 | .0673 | 98.8 | 98.2 | 92.8 | 65.0 | 88.7 |
| MNH-93 | .0860 | .0837 | .0826 | .0802 | .0434 | .0775 | 97.3 | 96.0 | 93.3 | 73.7 | 90.1 |
| MNH-329 | .0891 | .0880 | .0854 | .0731 | .0625 | .0773 | 98.8 | 95.8 | 82.0 | 70.1 | 86.7 |
| FH-87 | .0672 | .0633 | .0622 | .0612 | .0568 | .0594 | 94.2 | 92.6 | 91.1 | 84.5 | 90.6 |
| FH-682 | .0692 | .0667 | .0611 | .0583 | .0479 | .0585 | 96.4 | 89.9 | 84.2 | 69.2 | 84.9 |
| RH-1 | .0817 | .0670 | .0635 | .0613 | .0498 | .0604 | 82.0 | 77.7 | 75.0 | 60.9 | 73.9 |
| SLS-1 | .0499 | .0490 | .0432 | .0421 | .0353 | .0424 | 98.2 | 86.6 | 84.4 | 70.8 | 85.0 |
| NIAB-78 | .0920 | .0907 | .0882 | .0881 | .0779 | .0862 | 98.9 | 95.9 | 96.9 | 84.7 | 94.1 |
| B-821 | .0929 | .0886 | .0871 | .0832 | .0819 | .0852 | 95.4 | 93.8 | 89.6 | 88.2 | 91.8 |
| Raishmi | .0919 | .0846 | .0892 | .0792 | .0593 | .0781 | 92.1 | 97.1 | 86.2 | 64.5 | 85.0 |

Table 19. Mean Squares from Analysis of Variance of Dry Shoot weights of eighteen *Gossypium hirsutum* (L.) in five NaCl levels.

| S.O.V | D.F | NaCl levels | | | | |
|---|---|---|---|---|---|---|
| | | Control | 100Mm | 150Mm | 200Mm | 250Mm |
| Between Genotypes | 17 | 0.00348** | 0.00319** | 0.00361** | 0.00292** | 0.00289** |
| Within Genotypes | 252 | 0.00043 | 0.00060 | 0.0061 | 0.00074 | 0.0068 |
| Total | 269 | | | | | |

Table 20. Components of variances and Broad Sense Heritabilities of Salt Tolerance of eighteen *Gossypium hirsutum* (L.) genotypes in five NaCl levels.

| Components | Control | 100Mm | 150Mm | 200Mm | 250Mm |
|---|---|---|---|---|---|
| $\sigma^2{}_{b} = V_G$ | 0.00305 | 0.00259 | 0.00030 | 0.00217 | 0.00220 |
| $\sigma^2{}_{b} + \sigma^2{}_{w} = V_D$ | 0.00348 | 0.00319 | 0.00361 | 0.00292 | 0.00289 |
| $H^2{}_{B} = V_G / V_D$ | 0.87 | 0.81 | 0.83 | 0.74 | 0.76 |

**Dry Root Weight**

Table 21 showed non-significant interaction components between genotypes and salinity levels (G X S). While Table-22 revealed varied response of the accessions to increasing NaCl salinity. The dry root weight of some of the accessions were non- significantly reduced when exposed to even to the lowest NaCl concentration of 100mM, however genetic differences appeared to be non significant. The varietal differences were discerned under higher concentration of NaCl 250mM.

Table 21. Analysis of Variance for dry root weight of eighteen *Gossypium hirsutum* (L.) genotypes in five NaCl levels.

| **S.O.V** | **D.F** | **S .S** | **M .S** | **F-ratio** |
|---|---|---|---|---|
| Genotypes (G) | 17 | 0.000899 | 0.000052 | 1.520862 NS |
| Salinity levels (S) | 4 | 0.000220 | 0.000055 | 1.586879 NS |
| G x S | 68 | 0.000619 | 0.000009 | 0.261993 NS |
| Error | 180 | 0.000765 | 0.000004 | |
| Total | 269 | 0.002504 | | |

Table 22. Indices of absolute and Relative Salt Tolerance of eighteen genotypes of *Gossypium hirsutum* (L.) in five NaCl levels (mM) for Dry Root Weight (g).

| **Accessions** | **Absolute Salt Tolerance** | | | | | | **Relative Salt Tolerance** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | 100 Mm | 150 Mm | 200 Mm | 250 Mm | Means | 100 Mm | 150 Mm | 200 Mm | 250 Mm | Means |
| Karishma | .0117 | .0051 | .0045 | .0041 | .0041 | .0045 | 43.6 | 38.5 | 35.0 | 35.0 | 38.0 |
| CIM-1100 | .0154 | .0141 | .0116 | .0110 | .0103 | .0118 | 91.6 | 75.3 | 71.4 | 66.9 | 76.3 |
| CIM-109 | .0083 | .0065 | .0051 | .0045 | .0037 | .0050 | 78.3 | 61.4 | 54.2 | 44.6 | 59.6 |
| CIM-434 | .0072 | .0059 | .0047 | .0039 | .0037 | .0046 | 81.9 | 65.3 | 54.2 | 51.4 | 63.2 |
| CIM-240 | .0088 | .0063 | .0051 | .0042 | .0031 | .0047 | 71.6 | 58.0 | 47.7 | 35.2 | 53.1 |
| S-12 | .0075 | .0063 | .0051 | .0049 | .0042 | .0051 | 84.0 | 68.0 | 65.3 | 56.0 | 68.3 |
| S-14 | .0079 | .0063 | .0051 | .0044 | .0037 | .0049 | 79.7 | 68.4 | 55.7 | 46.8 | 62.7 |
| BH-36 | .0118 | .0083 | .0077 | .0068 | .0051 | .0070 | 70.3 | 65.3 | 57.6 | 43.2 | 59.1 |
| BH-74 | .0065 | .0062 | .0047 | .0038 | .0033 | .0045 | 95.4 | 72.3 | 58.5 | 50.8 | 69.3 |
| MNH-93 | .0081 | .0069 | .0061 | .0051 | .0043 | .0056 | 85.2 | 76.5 | 63.0 | 53.1 | 69.5 |
| MNH-329 | .0122 | .0114 | .0100 | .0086 | .0047 | .0087 | 93.4 | 82.0 | 70.5 | 38.5 | 71.1 |
| FH-87 | .0093 | .0081 | .0069 | .0053 | .0041 | .0061 | 87.1 | 74.2 | 57.0 | 44.1 | 65.6 |
| FH-682 | .0061 | .0059 | .0048 | .0047 | .0044 | .0050 | 93.4 | 78.7 | 77.0 | 75.4 | 81.1 |
| RH-1 | .0089 | .0081 | .0071 | .0060 | .0050 | .0066 | 91.0 | 79.8 | 67.4 | 56.2 | 73.6 |
| SLS-1 | .0075 | .0061 | .0049 | .0045 | .0030 | .0046 | 81.3 | 65.3 | 60.0 | 40.0 | 61.7 |
| NIAB-78 | .0189 | .0175 | .0152 | .0146 | .0120 | .0148 | 92.6 | 80.4 | 77.2 | 63.5 | 78.4 |
| B-821 | .0101 | .0100 | .0098 | .0081 | .0074 | .0088 | 99.0 | 97.0 | 80.2 | 73.3 | 87.4 |
| Raishmi | .0069 | .0063 | .0049 | .0047 | .0042 | .0050 | 91.3 | 71.0 | 66.7 | 61.0 | 72.5 |

On the basis of relative salt tolerance, it was found that the genotypic responses differed from each other. Reduction of dry root weight of the genotypes under 100mM and 150mM were found to be less affected as compared to 200 and 250mM.

On the basis of indices of salt tolerance, the response of B-821, FH-682, NIAB-78, RH-1, Raishmi, MNH-93, MNH-329 and BH-74 was observed better than other cultivars and ranked as the most tolerant cultivars.

In Table 23 data showed that increasing level of NaCl had adversely effect on dry root weight but the differences between genotype mean squares were found non significant at ($P \leq 0.01$) and ($P \leq 0.05$) level.

The heritability for the dry root weight of 18 cotton genotypes was maximum at 150mM and 200mM level (0.69) that was even more as compare to control (0.60) and the lowest heritability (0.62 and 0.61) was found in case of 100 and 250 mM salinity levels.

Table 23. Mean Squares from Analysis of Variance of Dry Root weight of eighteen *Gossypium hirsutum* (L.) genotypes in five NaCl levels.

| S.O.V | D.F | NaCl levels | | | | |
|---|---|---|---|---|---|---|
| | | Control | 100Mm | 150Mm | 200Mm | 250Mm |
| Between Genotypes | 17 | 0.000103** | 0.000018** | 0.000136** | 0.000091** | 0.000096** |
| Within Genotypes | 252 | 0.000034 | 0.000006 | 0.000041 | 0.000028 | 0.000036 |
| Total | 269 | | | | | |

Table 24. Components of variances and Broad Sense Heritabilities of Salt Tolerance of eighteen *Gossypium hirsutum* (L.) in five NaCl levels.

| Components | Control | 100Mm | 150Mm | 200Mm | 250Mm |
|---|---|---|---|---|---|
| $\sigma^2_b = V_G$ | 0.000069 | 0.000011 | 0.000094 | 0.000063 | 0.000059 |
| $\sigma^2_b + \sigma^2_w = V_D$ | 0.000103 | 0.000018 | 0.000136 | 0.000091 | 0.000096 |
| $h^2_B = V_G / V_D$ | 0.66 | 0.62 | 0.69 | 0.69 | 0.61 |

The effect of this increased salinity was not found so adverse in case of dry root weight and this response can be used in breeding programme (Table 24)

Dry root and shoot weight and response of genotypes suggested that plant vigour and salt tolerance had some relationship as observed by Shanon (1984). There are several examples available in the literature both in plants and animals similar to the salinity tolerance in *Gossypium hirsutum* studied have explaining the phenomenon on correlated effects between tolerance to toxic effects and low adaptability. Warthurst and Kendrick (1967) observed a wild strain of rodent malaria, resistant to anti malarial drug, further atrazine resistant plants of *Amaranthus retroflexus* (L) grown in the absence of atrazine did not differ significantly in growth characteristics from susceptible plants (Weaver et al; 1982). From the result of the present investigation of salinity level in *G hirsutum* it would appear that tolerance and vigor are positively correlated.

## CONCLUSION AND RECOMMENDATIONS

- NIAB – 78 cotton cultivar recommended as the most salt- tolerant
- Assessment of variation for salinity tolerance is the best technique for selection a cultivar.
- By selecting suitable salt tolerant cotton cultivars, salt affected area can be used and more cotton produce could be gained.

## REFERENCES

Akbar, M. and T. Yabuno (1975). Breeding for saline-resistant varieties of rice. III: Response of F1 hybrids to salinity in reciprocal crosses between Jhona 349 and Mangoli. *Japan J. Breeding*, 25:215-220.

Avilov, L.D. and G.R. Matukhin (1967). Change of mitotic activity in plant roots under conditions of salinity. *Cytol*. 9: 215-220.

Azhar F.M.and McNeilly (1987). Variability for salt tolerance in *Sorghum bicolor* (L.) Moench under hydroponic conditions. *J. Agro. Cr. Sci*., 159: 269-277.

Bernstein, L. (1975). Effects of salinity and sodicity on plant growth. *Ann. Rev. Phytopathol*. 13: 295-312.

Dewelry, W.R. (1960). Salt tolerance of twenty-five strains of Agropyron. *Agron. J*., 52: 631-653.

Falconer, D.S. (1981). *Introduction to Quantitative Genetics*. 2nd Ed. London. Longman Group Ltd., New York USA.

Khan, G.S. (1993). *Characterization and genesis of saline sodic soils in Indus plains of Pakistan*. PhD Thesis. Deptt. Of Soil Sci. Univ. of Agri. Faisalabad.

Kingsbury, R.W., E. Epstein, and R. W. Peacy (1984). Physiological responses to salinity in selected lines of wheat. *Plant Physiol*., 74: 417-423.

Levitt, J. (1980). *Response of plant to environment stresses, water, radiation, salt, and other stresses*. Academic Press, New York.

Maas, E.V.(1986). Salt tolerance of plants. *Appl.Agri.Res*.,1: 12-26.

Mukhamedkhanova, F.S.M.P. Muminova and A.A. Abdukarimov (1991). Effect of salt stress on cultures of Cotton. In "IS ezd" fiziologov rstentii Uzbekistana Tashkent. P 16-18 dekbrya ( Pl. Br. Absts. 63 (11): 12403;1993).

Ratanadilok, N., V. Marcarian, and C. Schmilzel (1978). Salt tolerance in grain sorghum. *Agron. Absts*., 70: 160.

Shannon, M. C., 1984. Breeding, selection, and the genetics of salt tolerance. In: *Salinity Tolerance in plants -- Strategies for Crop Improvement* (Staples, R.C., and G.H. Toenissen Eds.), pp. 231-254. Wiley, New York, USA.

Steel, R.G.D. and J.H. Torrie (1980). *Principles and Procedures of Statistics*. McGraw Hill Book. Co., Inc; New York.

Strogonov, B.P. (1964). *Physiological basis of salt tolerance of plants* (Translated from Russian). I.P.S.I., Jerusalem.

Warhurst, D.C. and R.K. Kendrick (1967). Spontaneous resistance to chloroquinine in a strain of rodent malaria (*Plasmodium berghei yoelii*). *Nature*, 213: 1048-1049.

Weaver, S.E., S.I. Warwick and B.K. Thomson (1982). Comparative growth and atrazine response of resistant and susceptible populations of Amaranthus from Southern Ontario. *J. Appl. Ecol*., 19: 611-62.

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