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**Full Length Article**

# Assessment of Cotton (*Gossypium hirsutum*) Germplasm under Water Stress Condition

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## ABSTRACT

The responses of 80 *Gossypium hirsutum* L. accessions to normal and limited water supply were examined under glasshouse conditions. The assessments was made on the basis of shoot and root length of 45 days old seedlings at 3rd true leaf stage. A sample of 34 elite accessions was initially examined on the basis of absolute shoot and root length. Under water stress, some accessions showed better shoot length, while others produced good root length. However few accessions were found more or less consistent in their response to water stress. The Genotypes DPL-26, 149F, B-557, BOU-1724 and BH-124 were identified as tolerant. FH-1000, CIM-446, NF 801-2, H 499-3 and MNH-129 were susceptible to water stress. The existence of variability in the cotton germplasm suggest that genetic improvement may be made in this species through selection and breeding, provided that the variability is effected by significant genetic components. 

**Key Words:** Water deficit; Cotton; Root length; Variability; Tolerant

## INTRODUCTION

The economic development of an agricultural country like Pakistan depends largely on the harvest of good crop yields resulting from the successful interaction of the genotype and the environment. Water deficit is not only the cause of difference between the actual yield and the potential yield but it also results in yield instability of crops.

The water resources of Pakistan, both surface and ground water are limiting to meet the demand of water for irrigated areas. It has been shown that irrigation skipped at any critical growth stage results in significant reduction in yield (Yaseen & Rao, 2002). This situation demands the government to take immediate action to develop new water resources. The changing circumstances around the world indicate that due to increasing demand and competition due to environmental, industrial and domestic sectors, supply of irrigation water will be reduced during the coming years. Clearly the major challenge for the agriculture sector during the 21st century is to raise crops with low water supply. Various planting techniques have been suggested by agronomists to utilize the available water more judiously. For example, bed planting has shown even distribution of water and resulted in increased fertilizer use efficiency, reduced weed infestation and lodging (Hobbs & Gupta, 2004).

In Pakistan, cotton (*Gossypium hirsutum* L.) is an important agricultural commodity. The adverse effects of water stress on the cotton plant has been reported by various researchers, for example Ball *et al*. (1994) reported that root growth of 55 days old seedlings of cotton reduced after with holding water, but Pace *et al*. (1999) observed that stressed plants had greater tap root length than control. This suggested that increase in tap root at the expense of root thickening may be a common response of cotton plant and permits to survive under stress by accessing water from deeper in the soil profile. The study of Malik *et al*. (1979) showed that water stress reduced growth, development and distribution of cotton roots. Quisenberry *et al*. (1981) found significant genetic variation in shoot and root growth. From these studies, it seems that root morphology and root growth appeared to be an important plant character for the adaptation of cotton to conditions, where limited water availability is a major constraint to growth.

Previous reports on drought tolerance in crops are not extensive, but few studies which exist in literature show that variability in the genotypic responses to water stress does occur, for example in wheat (Sadiq *et al*., 1994; Trethowan *et al*., 2002; Moinuddin *et al*., 2005), maize (Kamara *et al*., 2003), triticale (Ozkan *et al*., 1999), common beans (Teran & Singh, 2002), barley (Rizza *et al*., 2004), peanut (Upadhyaya, 2005) and soybean (Hufsteler *et al*., 2007). These studies revealed that varieties/cultivars in each species differed from each other for their responses to water stressed conditions, suggesting drought tolerance in these species may be improved through breeding.

## MATERIALS AND METHODS

In the present studies, responses of 80 cotton accessions to water stress and non-stress conditions were examined in glasshouse. Seeds of all accessions were obtained from the available stock in the department. Seeds of accessions were planted during October, 2004 in polythene bags measuring 25×15 cm, filled with about 1.15 kg of silt mixed with 100 g farm yard manure. All the bags were saturated to field capacity before planting seeds. Seeds were soaked overnight before seeding in the bags. Four holes of 2.5 cm deep were made in each bag and four seeds were sown in one hole. After germination, seedlings were thinned to one plant per hole and thus there were four seedlings per bag. Eighteen polythene bags of each accession were divided into two sets. One set was treated as control ($T_0$) and the other as water stressed ($T_1$). Bags were arranged following the completely randomized design with three replications.

Seedlings grown under stressed and non-stressed conditions were watered and fertilized till the development of the first true leaf and thereafter, seedlings under non-stressed condition were watered daily to keep the soil at field capacity. The stress condition was developed by withholding water supply and the effect of water stress was monitored visually and with soil moisture meter ($HH_2$ Theta Probe Type, Delta-T device, Cambridge, England). At initial wilting stage (observed visually), when soil had 14 to 16% soil moisture contents, the stressed plants were watered to relieve the sign of wilting but not enough to reach the soil at field capacity. The experiment was continued till the 3$^{rd}$ main stem leaf was fully expanded. Plants grown under normal water supply and stressed conditions were measured for shoot and root length.

For the measurement of shoot and root length, eight plants of each accession in each replication from each treatment were uprooted gently avoiding breakage and the shoot was separated by cutting at the junction of root and shoot. Shoot and root lengths were measured with a measuring tape. Mean shoot and root lengths for each accession were computed.

## RESULTS

The means of shoot and root length of 80 cotton accessions under control and water stressed conditions were measured. Analyses of variance showed that accessions differed significantly from each other (Table I). The results indicated that all the accessions differed significantly ($P \leq 0.01$) for the two traits measured in control and water stressed conditions. The difference between the two water treatments was also significant ($P \leq 0.01$). The highly significant interaction ($P \leq 0.01$), accessions (A) × treatment (T), indicated that the accessions responded differently to the two moisture conditions.

In order to examine the responses of the accessions to water stress conditions, a sample of 34 accessions that performed better than others under stress was taken for detailed description. Absolute water stress tolerances of 34 accessions are presented in Table II. Comparison of accessions based upon the measurements of the two characters is presented here:

It is evident from Table II that shoot lengths of 34 accessions measured in control differed from each other, and ranged from 14.2 cm of CIM-473 (No. 1) to 22.9 cm of BH-162 (No. 24). Under water stressed conditions, shoot lengths were markedly reduced and these ranged from 7.9 cm of CIM 446 (No. 4) to 15.4 cm of DPL-26 (No. 30). Data on absolute shoot length revealed that accessions had differing responses to the two moisture conditions. Accessions BH-162 (No. 24) and 199F (No. 26) had the tallest shoot length under control measuring 22.9 and 22.8

**Table I: Mean squares of shoot and root length measured under normal and water stressed conditions**

| Source of variation | Df | Shoot length | Root length |
|---|---|---|---|
| Accessions(A) | 79 | 20.10** | 21.40** |
| Treatments(T) | 1 | 4079.37** | 1096.93** |
| A x T | 79 | 4.38** | 4.35** |
| Error | 320 | 0.10 | 0.06 |

**, Denotes differences significant at 1% probability level

**Table II: Absolute data of water stress tolerance of 34 accessions of *Gossypium hirsutum***

| Accession No. | Accession name | Shoot length | | Root length | |
|---|---|---|---|---|---|
| | | Control | Stress | Control | Stress |
| 1 | CIM473 | 14.2 | 10.6 | 8.0 | 5.4 |
| 2 | CIM1100 | 16.8 | 12.5 | 8.1 | 5.6 |
| 3 | CIM70 | 15.2 | 11.7 | 8.6 | 6.4 |
| 4 | CIM-446 | 16.3 | 7.9 | 7.7 | 3.7 |
| 5 | BOU-1724 | 14.5 | 12.0 | 8.2 | 7.9 |
| 6 | CIM497 | 16.3 | 12.2 | 8.3 | 8.0 |
| 7 | NF801-2 | 14.9 | 8.3 | 7.4 | 2.9 |
| 8 | VH57 | 16.9 | 11.8 | 9.2 | 8.9 |
| 9 | VH37 | 16.9 | 13.2 | 10.1 | 6.5 |
| 10 | FH679 | 17.3 | 9.6 | 9.4 | 4.9 |
| 11 | FH-1000 | 16.8 | 8.6 | 9.2 | 3.5 |
| 12 | FH950 | 16.9 | 12.2 | 9.1 | 5.0 |
| 13 | FH925 | 18.6 | 13.5 | 9.1 | 5.3 |
| 14 | MNH-147 | 20.5 | 13.1 | 10.0 | 7.5 |
| 15 | MNH93 | 19.8 | 14.1 | 9.0 | 6.3 |
| 16 | MNH-129 | 19.4 | 11.4 | 11.8 | 8.8 |
| 17 | MNH554 | 19.2 | 13.2 | 9.5 | 7.5 |
| 18 | NIAB228 | 19.7 | 15.3 | 11.6 | 8.5 |
| 19 | BH121 | 21.0 | 14.5 | 13.0 | 7.3 |
| 20 | 149F | 15.7 | 14.0 | 8.0 | 7.7 |
| 21 | COKER 4601 | 14.6 | 9.1 | 10.5 | 7.6 |
| 22 | BH-124 | 16.0 | 12.7 | 12.7 | 12.1 |
| 23 | BH36 | 21.7 | 12.9 | 14.0 | 7.5 |
| 24 | BH162 | 22.9 | 13.5 | 12.7 | 6.6 |
| 25 | H499-3 | 16.0 | 8.7 | 10.6 | 5.1 |
| 26 | 199F | 22.8 | 14.8 | 13.0 | 11.1 |
| 27 | 268F | 21.0 | 14.1 | 13.1 | 11.8 |
| 28 | BH-125 | 21.8 | 14.2 | 6.4 | 5.7 |
| 29 | B557 | 17.2 | 14.5 | 14.0 | 13.7 |
| 30 | DPL 26 | 18.0 | 15.4 | 14.0 | 13.7 |
| 31 | SLH257 | 16.3 | 10.9 | 10.9 | 9.7 |
| 32 | 1118 | 18.7 | 9.9 | 10.0 | 7.9 |
| 33 | DIXI-KING | 17.5 | 11.5 | 10.9 | 5.2 |
| 34 | VH-53 | 16.4 | 12.0 | 7.9 | 7.0 |

cm, respectively while DPL-26 (No. 30) and NIAB-228 (No. 18) gave maximum shoot length under water stress. In contrast, accessions CIM-473 (No. 1), BOU-1724 (No. 5) and Coker-4601 (No. 21) had shorter shoot lengths under control, measuring 14.2, 14.5 and 14.6 cm, respectively while under stressed condition, CIM-446 (No. 4) developed shortest shoot length. It is further evident that some accessions like 149F (No. 20), DPL-26 (No. 30), B-557 (No. 29) and BOU-1724 (No. 5) appeared to have similar shoot length under the two moisture conditions, showing better tolerance against moisture stress.

In contrast, CIM-446 (No. 4), FH-1000 (No. 11), 1118 (No. 32) and H499-3 (No. 25) showed varied responses to the two moisture conditions e.g., shoot length of these accessions were 16.3, 16.8, 18.7 and 16.0 cm, respectively under non-stress, while under stress these measured 7.9, 8.6, 9.9 and 8.7 cm, respectively. Due to drastic reduction in shoot lengths in water stressed condition, these accessions may be rated as susceptible.

Based upon root length data in (Table II), 34 accessions again appeared to respond differently to non-stressed and stressed conditions. The root length under control ranged from 6.4 cm of BH-125 (No. 28) to 14.0 cm of each BH-36 (No. 23), DPL-26 (No. 30) and B-557 (No. 29). Root lengths under water stress were markedly reduced and varied from 2.9 cm of NF801-2 (No. 7) to 4.9 cm for FH-679 (No. 10) and similar differences were recorded among other accessions. Accessions B-557 (No. 29), DPL-26 (No. 30) and BH-36 (No. 23) have the longest root length under control, each measuring 14.0 cm, against root length of BH-36, which produced only 7.5 cm. Under water stress, DPL-26 (No. 30) and B-557 (No. 29) with longest root length i.e., 13.7 cm appeared to show high tolerance. Similarly accession BOU-1724 (No. 5) and VH-57 (No. 8) with little reduction in root length due to water stress revealed better tolerance, these measured 8.2 and 9.2 cm under control and 7.9 and 8.9 cm under stress, respectively.

In contrast, root lengths of NF801-2 (No. 7), FH-1000 (No. 11), H499-3 (No. 25) and CIM-446 (No. 4) were drastically reduced under water stress and yet the differences among these accessions were discernible, these were 2.9, 3.5, 5.1 and 3.7 cm, respectively under stress against 7.4, 9.2, 10.6 and 7.8 cm, respectively under control and thus exhibited their susceptibility to water stress condition.

## DISCUSSION

When a large number of germplasm is available for screening against any stress condition, availability of a technique, which could rapidly and efficiently identify the variation is important. In the present investigations, 45-days old seedlings of 80 accessions, grown under water stress and watered conditions in the glasshouse, were examined for shoot and root length. This method distinguished tolerant and non-tolerant accessions and provided data to study the growth pattern of accessions with least environmental influences. The previous workers had studied growth and physiological response of cotton to moisture stress under greenhouse conditions (Radin & Ackerson, 1981; Loffroy *et al.,* 1983; Ball *et al.,* 1994; Pace *et al*., 1999). The response of accessions to water stress conditions have been compared with those measured under non-stress conditions based upon shoot and root length. Water stress tolerance cannot be attributed to a genotype, because of its superiority for a single trait; therefore two different parameters were examined as suggested by Al-Hamdani and Barger (2003). Root growth is an important and reliable indicator of the response of drought tolerant varieties (Pace *et al.,* 1999) and therefore this character was also examined at the seedling stage. However at plant maturity, roots and its characteristics are complex to measure and screening method is destructive, thus making their use limited in breeding programs.

The absolute data showed differing responses of accessions under the two moisture conditions. Although shoot and root length were markedly reduced by water stress, the differences between accessions are still evident. Similar adverse affect of water stress on cotton seedling traits have been noted in previous studies (Pace *et al.,* 1999; Pettigrew, 2004a, b). The data in Table II provide a clear identification of differing responses of the accessions to the adverse affect of moisture stress and further suggest that over all, there is no clear relationship between plant vigor in control and growth in stress conditions. Accessions MNH-47 (No. 14), BH-121 (No. 19), 199F (No. 26), 268F (No. 27) and BH-125(No. 28) have high shoot length in watered conditions, but also have greater than the average shoot length in water stress conditions. The similar pattern is shown by 199 F (No. 26), 268F (No. 27), B-557 (No. 29) and DPL-26 (No. 30) for root length. It is thus not necessarily always the case that high tolerance to environmental stress and high yield in non-stress conditions are mutually exclusive as suggested by Rosielle and Hamblin (1981). Although some accessions, for example MNH-147 (No. 14), BH-121 (No. 19), BH-36 (No. 23) and BH-162 (No. 24) for shoot length do show such a negative relationship and these accessions illustrated low tolerance. By contrast, some slow growing accessions namely BOU-1724 (No. 5) and NIAB-228 (No. 18) are relatively much less affected by moisture stress conditions. Similarly the accessions BOU-1724 (No. 5), CIM-97 (No. 6), VH-57 (No. 28), BH-124 (No. 22) and SLH-257 (No. 31) have low root length in non-stress (Table II). The differing responses of accessions to water stress have been reported by Ball *et al.* (1994) who studied the different growth responses of root and shoot to water stress and depicted those for better description of root growth within the soil for purpose of modeling plant growth and assessment of drought resistance trait.

The results revealed the existence of significant variability for water stress tolerance in the material examined. Comparison of 34 accessions reveals some useful information about potential of accessions to water stress conditions and allows the identification of some tolerant accessions, which grew well under water stress and they may be nonetheless useful source of genes for enhancing the tolerance of more vigorous lines through breeding. In previous work on water stress tolerance on cotton (McMichael & Quisenberry, 1991; Ullah *et al.,* 2008) indicated significant variation in material tested under control and water stress conditions.

In previous studies, root length has been used to successfully distinguish salt tolerant and normal population of a number of grass species in saline and non-saline habituates (Hannon & Bradshaw, 1968; Ahmad & Wainwright, 1977; Leim *et al*., 1985; Ashraf *et al*., 1986a). Nguyen *et al.* (1997) suggested root characteristics to be associated with water stress tolerance in rice. Bhatti and Azhar (2002) studied the responses of cotton to salt stress at seedling stage using shoot and root length data. They found that root length was more sensitive to salt stress than shoot length and suggested as a reliable indicator of stress tolerance. Mambani and Lal (1983) reported that an extended root system in rice enabled the plants to extract available soil moisture and resulted in increase yield under drought. Root characteristics of drought tolerant bread wheat genotypes were also studied by Gesimba *et al*. (2004). It was reported that root length of tolerant genotypes were longer than the susceptible ones. Azhar and McNeilly (1987) studied the response of *Sorghum bicolor* (L.) Moench seedling to salt stress using traits like root and shoot length and found that salt stress resulted in reduction in the traits. Cowpea genotypes varying in drought tolerance were evaluated for root: shoot ratio (Ogbonnaya *et al*., 2003). Root growth response to water stress was studied for screening upland cotton for drought tolerance (Basal *et al.,* 2003, 2005). Kinyua *et al.* (2003) screened wheat cultivars for drought tolerance and studied rooting pattern for screening the cultivars.

## CONCLUSION

It is quite clear from the results that genotypes responded differently to the water stress for the two traits studied. Therefore inferences cannot be drawn on the basis of only one parameter. The performance of the genotype need to be assessed on the basis of its performance for different traits. It is evident from the results that few genotypes remained more or less consistent in their response. The accessions DPL-26.149F, B-557, BOU-1724 and BH-124 performed better for the two traits studied and hence may be called as tolerant genotypes. FH-1000, CIM-446, NF 801-2, H 499-3 and MNH-129 with poor response to water stress condition, may be called as susceptible genotypes.

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