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BIPLOT AND CLUSTER ANALYSIS OF SOME WATER STRESS TOLERANCE RELATED TRAITS IN UPLAND COTTON

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ABSTRACT

Background The scarcity of water is a critical threat to world food security. It warns the plant researchers to identify and develop water stress tolerant germplasm of field crops. The extent of water stress tolerance depends on many soil and plant related factors such as capacity of soil to store moisture, distribution of rainfall, evapotranspiration rate and root characteristics.

Methodology The present experiment was conducted to screen the available germplasm of cotton against water stress by irrigating the plants at four different levels of pot capacity at seedling stage i.e. 80, 60, 40 and 20% of the pot capacity. The plants were grown for 45 days after exposing to water stress. The data on fresh root weight, fresh shoot weight, dry root weight, dry shoot weight and root: shoot ratio were collected.

Results Mean values of seedling traits exhibited genotypic differences for water stress tolerance. Same data from each treatment were used to develop cluster tree by software Statistic 6.0 and biplot by software SPSS. Three groups (I, II and III) comprised of various accessions of cotton were observed at various levels of water stress. Group I indicated the genotypes having tolerance to water stress due to high mean values, group III was consisted of susceptible genotypes due to poor performance in water stress conditions while group II exhibited intermediate values between group I and group III. In Biplot analysis, quadrant I indicated the water stress tolerant genotypes whereas water stress susceptible genotypes were present in quadrant III.

Conclusion The divergence of genotypes in various groups indicated the presence of potential for water stress tolerance which could be used for the development and induction of water stress tolerant genotypes.

INTRODUCTION

Water stress is one of the most devastating environmental threats damaging the productivity of several field crops throughout the world, particularly in arid and semi-arid regions. It is a state of dry weather which causes severe hydrological shortage in a specified region to adversely affect the plant growth and development. It have many definitions based on the potential evapotranspiration, moisture content of soil, precipitation profile or their combinations (Wilhite et al. 2000; Heim 2002; Burke et al. 2006). According to Demirevska et al. (2009), it is more damaging factor for plant growth and productivity than any other biotic and abiotic stress, with major effects in arid and semi-arid regions. But cotton (*Gossypium hirsutum* L.) is a major cash crop in Pakistan with an area of 7.86 million acres (Rehman et al. 2017). Cotton and cotton related products constitute an integral component of national economy by contributing around 60% to total foreign exchange earnings and 10% to gross domestic products in Pakistan (Anonymous 2016). However, seed cotton yield per unit area is far below in Pakistan compared to some other cotton producing countries. Among many factors, water stress poses severe threat to its yield and quality (Luo et al. 2016). Water stress also reduces the uptake and distribution of nutrients within the plant body, leading to growth and yield decline (Zhang et al. 2017). Furthermore, chlorophyll damage, reduced photosynthesis, altered plant metabolism, hormonal imbalance and oxidative stress are the major

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mechanisms of growth reduction under water stress (Iqbal et al. 2010). Plants have adopted different strategies to overcome water stress. Among these, development of drought tolerant varieties is more viable and cost-effective to sustain cotton growth under drought conditions (Christiansen and Lewis 1982). In cotton, diploid species have high degree of drought tolerance by virtue of their deep root system (Bhatt and Andal 1979). Generally, deep-rooted plants exhibit greater drought tolerance than shallow rooted genotypes. Therefore, first irrigation is usually delayed in cotton up to forty days, so that roots may become longer in search of soil water. Therefore, root related parameters might be important criteria for screening against drought stress. Many studies have demonstrated that root related characteristics can be used for assessing drought tolerance in several field crops including maize (Avramova et al. 2016), cowpea (Matsui and Singh 2003) and wheat (Manschadi et al. 2008). In addition, there are many physiological parameters that could be used for screening of cotton genotypes in drought stress conditions namely fresh and dry biomass, boll diameter, boll number and boll weight (Riaz et al. 2013).

Availability of soil moisture during plant growth ensures plant growth and seed cotton yield in ample quantity (Quisenberry et al. 1981; Schuppler et al. 1998; Siddique et al. 2000). Acquisition of water from soil is accomplished through roots. So, modifications in root growth, density, size and proliferation are strategic responses to drought stress (Kavar et al. 2008). Burke and Mahony (2001) showed that drought negatively affected the shoot growth of cotton cultivars more than root. Fernandez et al. (1996) also found that drought affected the shoot growth prior to root growth in young cotton plants. Ball et al. (1994) studied the response of differential growth of roots and shoots to water stress and found that increase in root length was less sensitive to water stress than shoot. Pace et al. (1999) studied the performance of root and shoot growth of upland cotton genotypes under drought period after 36 days of planting with subsequent recovery period. Reduction in various parameters were found in water stress conditions as compared to control. While, increase in root growth was more prominent in water deficit conditions than control. It was also observed that length of tap roots increased under water stress than control, indicating that length of tap roots of cotton may not be affected in water deficit conditions. The present investigation was aimed to study the differential growth behavior of 30 genotypes of upland cotton against drought stress conditions at seedling stage. The information derived from this study might be helpful for the plant breeders to assess the genetic potential of genotypes for the development of water stress tolerant germplasm for drought stress area.

MATERIALS AND METHODS

The response of 30 genotypes of upland cotton to four water stress treatments was evaluated in glasshouse with day and night temperature of 35°C and 28°C, respectively in the Department of Plant Breeding and Genetics, University of Agriculture (latitude 31°25´N, longitude 73°09´E and altitude 184.4 m from sea level), Faisalabad, Punjab, Pakistan (Table 1). The experimental plan was comprised of four levels of water stress, irrigation at 20, 40, 60 and 80% of pot capacity. Cotton plants were grown in polythene bags (7″×4″) and all the polythene bags were saturated to pot capacity before planting seeds. Seeds were soaked overnight before sowing. Experiment was planned according to split plot design with three replications. Bags were filled with soil + sand at the ratio of 1:1 of known water holding capacity. Pot capacity was calculated by following gravimetric and volumetric direct measurement of soil water content method (Reynolds 1970). Three cotton seeds per polythene bag were sown in each replication, and later on two seedlings were thinned out at third leaf stage to maintain one healthy and uniform seedling bag^{-1}. Recommended agronomic and plant protection measures were adopted uniformly for all treatments. Pot capacity was maintained on alternate days, and this experiment was completed in 45 days. At the time of harvesting (45 days after water stress imposition), heavy irrigation was made to all pots before uprooting to avoid root damage. After uprooting, plants were cut into roots and shoots for measuring fresh root and shoot weight. The roots (tap and lateral roots) and shoots were dried for 72 h at 65±5˚C and the dry weight was recorded. Root: shoot ratios were calculated by dividing fresh root weight on fresh shoot weight. The mean values of all the parameters of each treatment grown under four water stress levels were compared to study the genotypic differences. While, grouping of genotypes on the basis of their mean performance was conducted by Statistic 6.0 and the biplot graphs were formulated by software SPSS.

RESULTS

Mean values of all the seedling traits i.e. fresh root weight, fresh shoot weight, dry root weight, dry shoot weight and root: shoot ratio are shown in Table 2 and 3. Results revealed that NIAB-111 exhibited highest values of fresh shoot weight 1.42, 1.34, 1.27 and 0.88 mg at 80, 60, 40 and 20% water stress levels, respectively and identified as superior performer for

Table 1 List of cotton accessions used to screen for water stress tolerance

Sr. #	Accessions	Sr. #	Accessions	Sr. #	Accessions
1	FH-1000	11	CIM-1100	21	CIM-707
2	S-12	12	CRSM-58	22	BH-118
3	Acala-1517-C	13	CRIS-134	23	CIM-482
4	CIM-496	14	FH-4243	24	RH-510
5	NIAB-111	15	CIM-446	25	CIM-506
6	MSK-12	16	NIAB-78	26	FH-942
7	CP-15/2	17	FH-900	27	NIAB Karishma
8	MSK-15	18	PB-899	28	FH-114
9	BH-160	19	MNH-93	29	MNH-129
10	MNH-886	20	FH-941	30	CIM-473

Table 2 Mean values of seedling traits of cotton accessions grown under water stress (irrigated at 80 and 60% of pot capacity)

Cotton accessions	Water stress (80%)					Water stress (60%)				
	FSW	FRW	DRW	DSW	R/S	FSW	FRW	DRW	DSW	R/S
FH-1000	0.77	0.08	0.05	0.10	0.10	0.79	0.09	0.05	0.10	0.11
S-12	0.84	0.09	0.05	0.11	0.11	0.80	0.07	0.04	0.10	0.09
Acala-1517-C	0.81	0.09	0.05	0.10	0.11	0.79	0.07	0.04	0.10	0.09
CIM-496	1.04	0.10	0.06	0.13	0.10	1.11	0.12	0.07	0.14	0.11
NIAB-111	1.42	0.21	0.12	0.18	0.15	1.34	0.17	0.10	0.17	0.13
MSK-12	1.04	0.11	0.06	0.13	0.11	1.09	0.12	0.07	0.14	0.11
CP-15/2	1.26	0.18	0.10	0.16	0.14	1.21	0.15	0.08	0.15	0.12
MSK-15	1.05	0.12	0.07	0.13	0.12	0.96	0.12	0.07	0.12	0.13
BH-160	1.28	0.19	0.11	0.16	0.15	1.21	0.16	0.09	0.15	0.13
MNH-886	0.97	0.13	0.07	0.12	0.13	0.92	0.12	0.07	0.11	0.13
CIM-1100	1.23	0.18	0.10	0.15	0.15	1.20	0.15	0.09	0.15	0.13
CRSM-58	0.97	0.11	0.06	0.12	0.12	0.90	0.11	0.06	0.11	0.12
CRIS-134	1.33	0.15	0.08	0.17	0.11	1.28	0.13	0.08	0.16	0.11
FH-4243	0.93	0.11	0.06	0.12	0.12	0.92	0.11	0.06	0.11	0.12
CIM-446	1.38	0.17	0.10	0.17	0.13	1.17	0.14	0.08	0.15	0.12
NIAB-78	0.94	0.11	0.06	0.12	0.12	0.98	0.10	0.06	0.12	0.10
FH-900	1.33	0.15	0.08	0.17	0.11	1.19	0.17	0.10	0.15	0.14
PB-899	0.92	0.11	0.06	0.12	0.12	1.08	0.11	0.06	0.14	0.10
MNH-93	1.27	0.16	0.09	0.16	0.13	1.17	0.17	0.09	0.15	0.14
FH-941	0.91	0.12	0.07	0.11	0.13	1.08	0.13	0.07	0.13	0.12
CIM-707	1.33	0.18	0.10	0.17	0.13	1.16	0.16	0.09	0.15	0.14
BH-160	0.91	0.13	0.07	0.11	0.14	1.03	0.10	0.06	0.13	0.10
CIM-482	1.36	0.20	0.11	0.17	0.14	1.14	0.15	0.09	0.14	0.14
RH-510	0.99	0.13	0.08	0.12	0.14	1.08	0.10	0.05	0.13	0.09
CIM-506	0.88	0.09	0.05	0.11	0.11	0.87	0.09	0.05	0.11	0.11
FH-942	0.99	0.13	0.07	0.12	0.13	1.02	0.11	0.06	0.13	0.11
NIAB Karishma	0.90	0.08	0.05	0.11	0.09	0.85	0.08	0.04	0.11	0.09
FH-114	1.03	0.13	0.07	0.13	0.13	0.97	0.11	0.06	0.12	0.11
MNH-129	0.82	0.08	0.04	0.10	0.10	0.82	0.08	0.04	0.10	0.09
CIM-473	0.83	0.12	0.07	0.10	0.15	0.92	0.10	0.06	0.12	0.11

FSW- fresh shoot weight; FRW- fresh root weight; DRW- dry root weight; DSW- dry shoot weight; R/S- root: shoot ratio

fresh shoot weight (Table 2 and 3). Cotton genotypes also differed for fresh root weight and ranged from 0.08 mg (FH-1000) to 0.21 mg (NIAB-111) at 80% of pot capacity (Table 2 and 3). At 60% of pot capacity water stress level, highest value of 0.17 mg was observed for FH-900, NIAB-111 and MNH-93 while, lowest value of 0.07 mg was found in Acala-1517-C and S-12. NIAB-111 and BH-160 were identified as drought tolerant on the basis of fresh root weight at 40 and 20% of pot capacity water stress levels.

Table 3 Mean values of seedling traits of cotton accessions grown under water stress (irrigated at 40 and 20% of pot capacity)

Cotton accessions	Water stress (40%)					Water stress (20%)				
	SFW	RFW	RDW	SDW	R/S	SFW	RFW	RDW	SDW	R/S
FH-1000	0.79	0.08	0.04	0.10	0.10	0.44	0.05	0.03	0.06	0.10
S-12	0.72	0.07	0.04	0.09	0.10	0.38	0.05	0.03	0.05	0.14
Acala-1517-C	0.65	0.08	0.05	0.08	0.13	0.38	0.03	0.02	0.05	0.11
CIM-496	1.01	0.12	0.07	0.13	0.12	0.68	0.07	0.04	0.09	0.10
NIAB-111	1.27	0.16	0.09	0.16	0.12	0.88	0.11	0.06	0.11	0.12
MSK-12	0.98	0.11	0.06	0.12	0.11	0.73	0.08	0.05	0.09	0.11
CP-15/2	1.22	0.15	0.09	0.15	0.13	0.80	0.10	0.06	0.10	0.13
MSK-15	1.02	0.11	0.06	0.13	0.11	0.74	0.08	0.05	0.09	0.11
BH-160	1.20	0.16	0.09	0.15	0.13	0.79	0.11	0.06	0.10	0.14
MNH-886	0.97	0.10	0.06	0.12	0.10	0.75	0.08	0.05	0.09	0.11
CIM-1100	1.19	0.14	0.08	0.15	0.11	0.86	0.10	0.06	0.11	0.12
CRSM-58	1.02	0.10	0.06	0.13	0.10	0.73	0.06	0.04	0.09	0.09
CRIS-134	1.20	0.14	0.08	0.15	0.12	0.87	0.10	0.06	0.11	0.12
FH-4243	0.94	0.11	0.06	0.12	0.11	0.74	0.06	0.04	0.09	0.09
CIM-446	1.14	0.16	0.09	0.14	0.14	0.87	0.10	0.05	0.11	0.11
NIAB-78	0.96	0.11	0.06	0.12	0.11	0.61	0.06	0.04	0.08	0.11
FH-900	1.14	0.15	0.08	0.14	0.13	0.81	0.10	0.05	0.10	0.12
PB-899	0.89	0.11	0.06	0.11	0.13	0.63	0.07	0.04	0.08	0.10
MNH-93	1.07	0.13	0.07	0.13	0.12	0.79	0.10	0.05	0.10	0.12
FH-941	1.02	0.10	0.06	0.13	0.10	0.63	0.07	0.04	0.08	0.10
CIM-707	1.21	0.14	0.08	0.15	0.12	0.82	0.10	0.05	0.10	0.12
BH-160	0.96	0.12	0.07	0.12	0.12	0.64	0.06	0.04	0.08	0.10
CIM-482	1.23	0.14	0.08	0.15	0.11	0.87	0.10	0.06	0.11	0.11
RH-510	1.04	0.12	0.07	0.13	0.11	0.63	0.06	0.04	0.08	0.10
CIM-506	0.83	0.09	0.05	0.10	0.10	0.49	0.05	0.03	0.06	0.11
FH-942	1.01	0.10	0.06	0.13	0.10	0.56	0.07	0.04	0.07	0.12
NIAB Karishma	0.84	0.09	0.05	0.11	0.10	0.51	0.05	0.03	0.06	0.10
FH-114	0.94	0.10	0.06	0.12	0.11	0.57	0.07	0.04	0.07	0.11
MNH-129	0.54	0.07	0.04	0.07	0.13	0.44	0.05	0.03	0.06	0.11
CIM-473	0.96	0.11	0.06	0.12	0.11	0.55	0.07	0.04	0.07	0.12

FSW- fresh shoot weight; FRW- fresh root weight; DRW- dry root weight; DSW- dry shoot weight; R/S- root: shoot ratio

Maximum dry root weight of 0.12 mg was observed for NIAB-111 while minimum in MNH-129 (0.04 mg) at 80% of pot capacity water stress level (Table 2 and 3). At 60% of field capacity, NIAB-111 and FH-900 showed highest value of dry root weight (0.10 mg) while Acala-1517-C, S-12 and MNH-129 exhibited the minimum value of 0.04 mg. Likewise, at 40% of pot capacity water stress level, NIAB-111, CP-15/2, BH-160 and CIM-446 showed maximum value of 0.09 mg while FH-1000, S-12 and MNH-12 produced the minimum value of 0.04 mg. At 20% of pot capacity water stress level, NIAB-111, BH-160, CIM-1100, CP-15/2, CRIS-134 and CIM-482 showed the highest value of 0.06 mg while, Acala-1517-C gave the minimum value of 0.02 mg.

In case of dry shoot weight, NIAB-111 attained highest value of 0.18 while FH-1000, Acala-1517-C, MNH-129 and CIM-473 showed the minimum value of 0.10 mg. At 60% of pot capacity, NIAB-111 again gave the maximum value of 0.17 mg while FH-1000, S-12, Acala-1517-C and MNH-129 showed the minimum value of 0.10 mg. At 40% of pot capacity water stress level, NIAB-111 gave the maximum value of 0.16 mg while, MNH-129 showed the minimum value of 0.07 mg. At 20% of pot capacity water stress level, NIAB-111, CIM-1100, CRIS-134, CIM-446 and CIM-482 produced maximum dry shoot weight of 0.11 mg while, S-12 and Acala-1517-C produced minimum value of 0.05 mg (Table 2 and 3).

Highest root : shoot ratio was observed in NIAB-111, BH-160 and CIM-1100 (0.15) at 80%, FH-900, MNH-93, CIM-482 and CIM-707 (0.14) at 60%, CIM-446 (0.14) at 40%, BH-160 and S-12 (0.14) at 20% while, minimum value of root shoot ratio of 0.09 by NIAB Karishma at 80%, 0.09 by S-12, Acala-1517-C, RH-510, MNH-129 and NIAB Karishma at 60%, 0.10 by FH-1000, S-12, MNH-886, CRSM-58, FH-941, CIM-506, FH-942 and NIAB Karishma at 40% while, 0.09 by CRSM-58 and FH-4243 at 20% of pot capacity water stress level (Table 2 and 3).

The present experiment was conducted for grouping of cotton genotypes by means of multivariate analysis which facilitated to classify the available germplasm into various clusters on the basis of their genetic potential. Thirty cotton genotypes were screened at seedling stage to assess genetic variability for water stress conditions. Multivariate analysis was used to analyze various variables and divided into various clusters based on similarities and dissimilarities among them grown under water stress conditions. Phonograms were constructed for grouping of thirty cotton genotypes grown in water stressed environment. So, ten tolerant genotypes were identified as lines whereas six susceptible genotypes were selected as testers. The cluster analysis revealed the presence of considerable phenotypical diversity among thirty cotton genotypes (Figure 1 to 4). Phonograms were constructed based on seven seedling traits which were significantly affected due to water stress. Phonograms were divided into three clusters and closely related genotypes fell in the same cluster. In cluster I, 33% of total genotypes were placed. It was observed that group I performed best for all of the parameters including fresh root weight, fresh shoot weight, dry root weight, dry shoot weight and root: shoot ratio. This cluster was designated as tolerant group, suggesting that group could be used as lines in crossing program for the development of water stress tolerant germplasm. In cluster II, sixteen genotypes were placed which were 48% of the total genotypes. It was observed that genotypes in cluster II performed intermediate for water stress for fresh root weight, fresh shoot weight, dry root weight, dry shoot weight and root: shoot ratio. This cluster was considered as moderately tolerant/intermediate group. About 19% of the total genotypes were grouped in cluster III. It was observed that genotypes in group III performed poorly for fresh root weight, fresh shoot weight, dry root weight, dry shoot weight and root: shoot ratio. Due to poor performance, these genotypes were considered as water stress susceptible which were used as testers in current study.

The data from screening were also confirmed by principal component analysis (PCA) which exploited genotypic variation. The objective of this analysis was to identify most divergent parents i.e. the tolerant and susceptible for hybridization program. Each stress level scattered the genotypes around the biplot origin represented the genetic diversity (Figure 5 to 8). The statistical analysis showed the presence of potential variations. Biplot analysis of quantitative traits at 80% of pot capacity water stress level represented the significant differences among 30 cotton genotypes (Figure 5). Maximum tolerance was shown by NIAB-111 for traits in quadrant I because it was located away from the origin than other genotypes. Other genotypes which showed genetic potential for drought tolerance across various traits were CP-15/2, BH-160, CIM-1100, MNH-93, CIM-707 and CIM-482. While, in quadrant III, CIM-506, NIAB Karishma, MNH-129, FH-1000, S-12 and Acala-1517-C were identified as water stress susceptible genotypes. While, genotypes CIM-446, CRIS-134 and FH-900 showed intermediate response to stress conditions. Biplot generated for 60% of the pot capacity water stress highlighted the presence of NIAB-111, BH-160, CIM-1100, FH-900, MNH-93, CIM-707 and CIM-482 at extreme upper right side of the graph (Figure 6). The genotypes CIM-446, CIM-496, CRIS-134, and CP-15/2 indicated their response towards water stress, whereas CIM-506, NIAB Karishma, MNH-129, FH-1000, S-12 and Acala-1517-C were considered as sensitive to water stress. Significant variations were also found in thirty genotypes at 40% of the pot capacity water stress (Figure 7). The tolerant genotypes that showed the positive results were BH-160, CIM-1100, CRIS-134, CIM-446, FH-900 and MNH-93 while, the genotypes NIAB-111, CIM-707 and CIM-482 had shown intermediate response to water stress conditions. The genotypes on negative side of graph were MNH-129, FH-1000, CIM-506, NIAB Karishma, S-12, and Acala-1517-C. Biplot generated at 20% of the pot capacity water stress (Figure 8) revealed that genotypes CIM-506, NIAB Karishma, MNH-129, FH-1000, S-12 and Acala-1517-C showed maximum divergence from origin towards negative vector indicating susceptibility towards stress. While genotypes NIAB-111, CP-15/2, BH-160, CIM-1100, CRIS-134, CIM-446, FH-900, MNH-93, CIM-707 and CIM-482 may be regarded as less affected by the drought due to the presence near the origin. From the analyzed data of cluster and biplot analysis, ten tolerant cotton genotypes (NIAB-111, CP-15/2, BH-160, CIM-1100, CRIS-134, CIM-446, FH-900, MNH-93, CIM-707 and CIM-482) and six susceptible testers (CIM-506, NIAB Karishma, MNH-129, FH-1000, S-12 and Acala-1517-C) were selected for breeding program.

DISCUSSION

In the present study, data on shoot and root related traits at 45 days seedling stage were used to assess variability for these traits under four water stress levels. In the present investigation, it was observed that effect of water stress on shoot related traits was more prominent than root related traits. Previous researchers, for example, Kar et al. (2005), Shakoor et al. (2010), Iqbal et al. (2011) and Riaz et al. (2013) have used these traits to screen out large germplasm

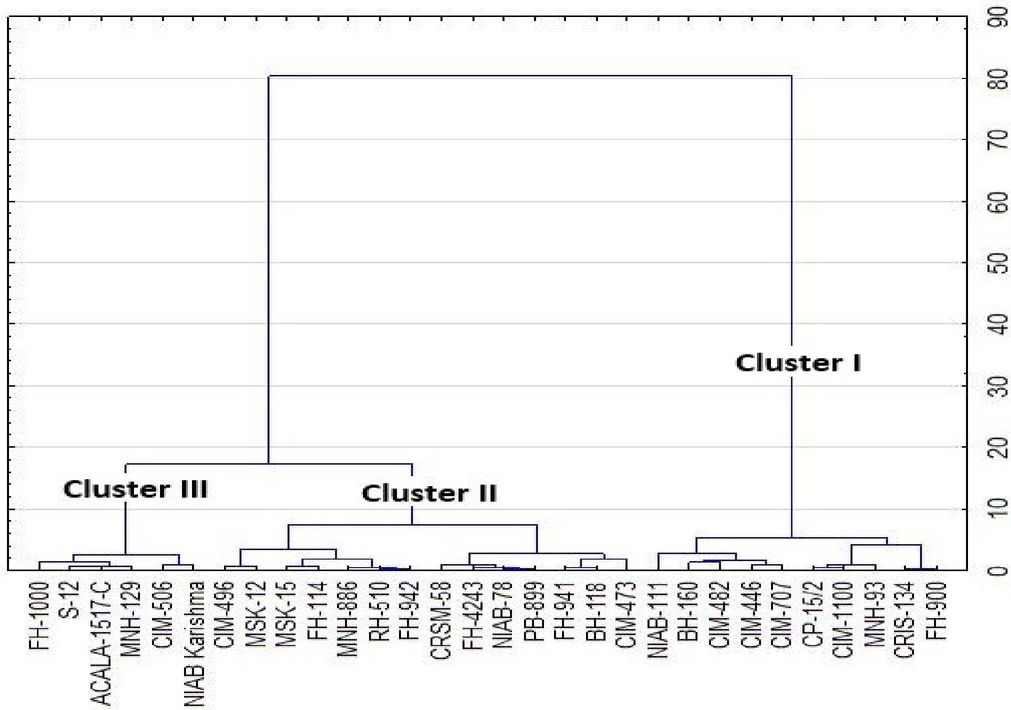

Figure 1 Cluster analysis of various seedling traits of cotton accessions grown under water stress (irrigated at 80% of pot capacity)

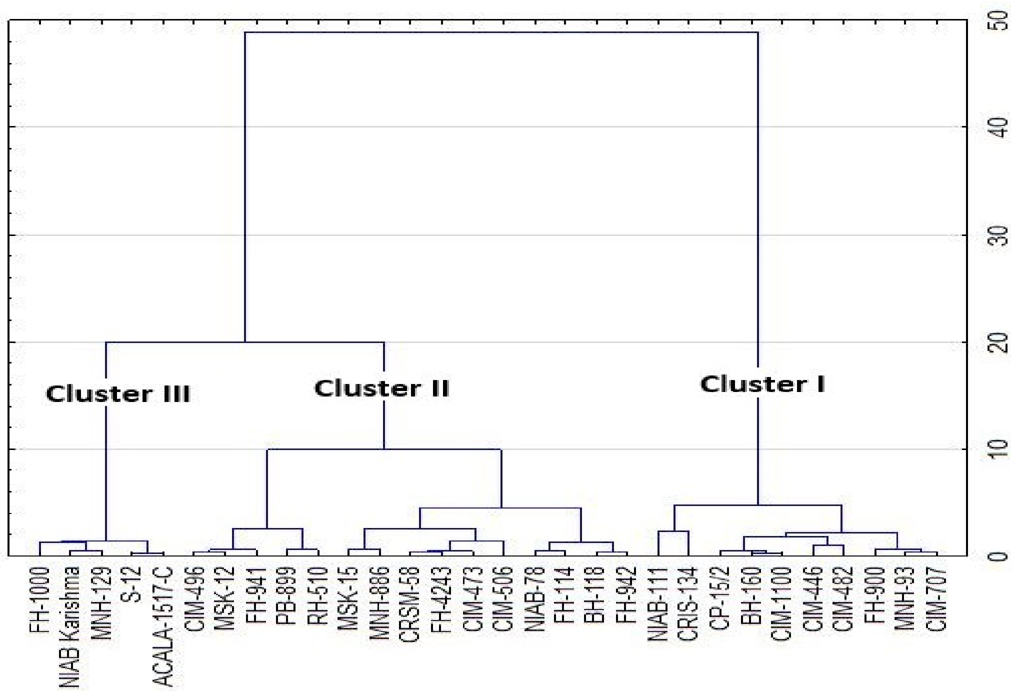

Figure 2 Cluster analysis of various seedling traits of cotton accessions grown under water stress (irrigated at 60% of pot capacity)

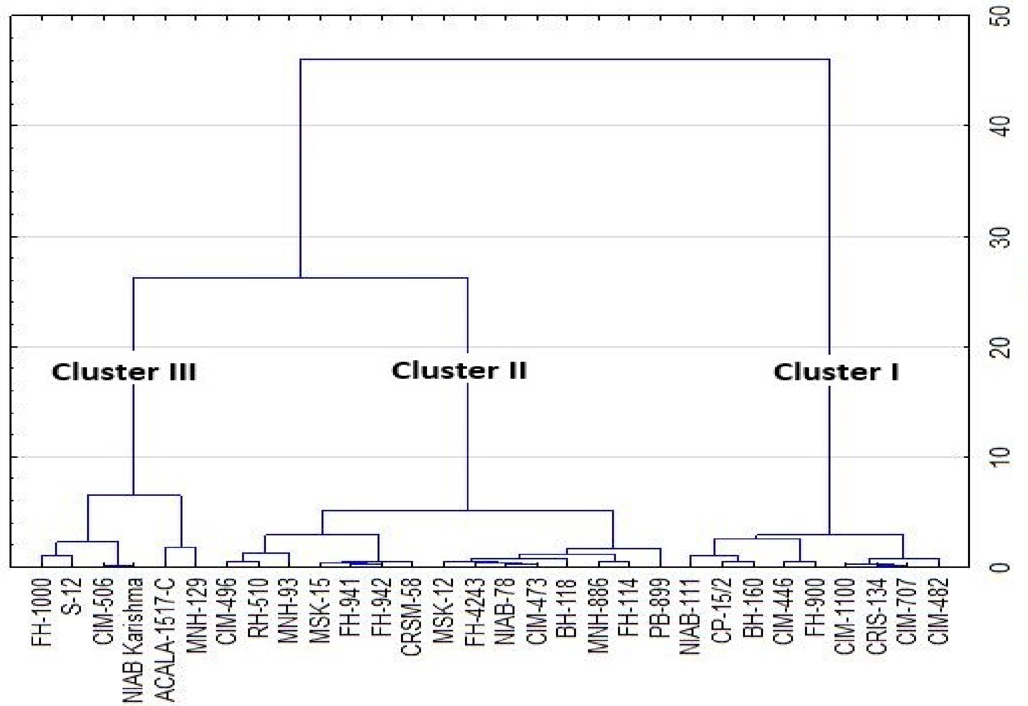

Figure 3 Cluster analysis of various seedling traits of cotton accessions grown under water stress (irrigated at 40% of pot capacity)

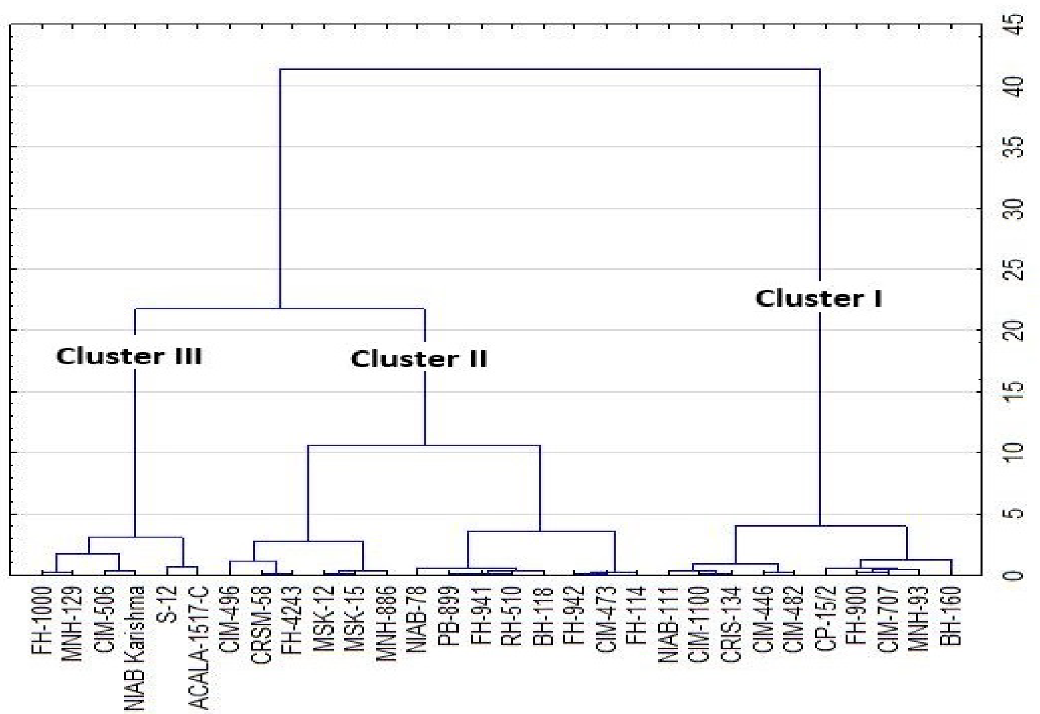

Figure 4 Cluster analysis of various seedling traits of cotton accessions grown under water stress (irrigated at 20% of field pot)

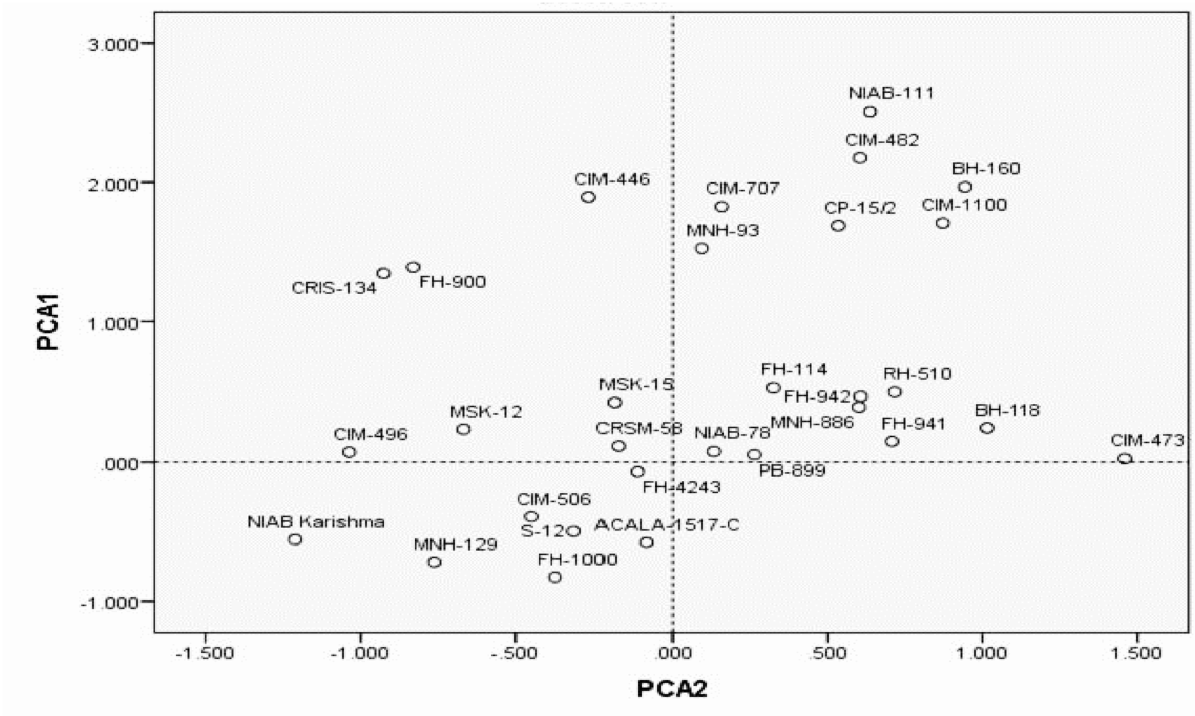

Figure 5 Biplot analysis of various seedling traits of cotton accessions grown under water stress (irrigated at 80% of pot capacity)

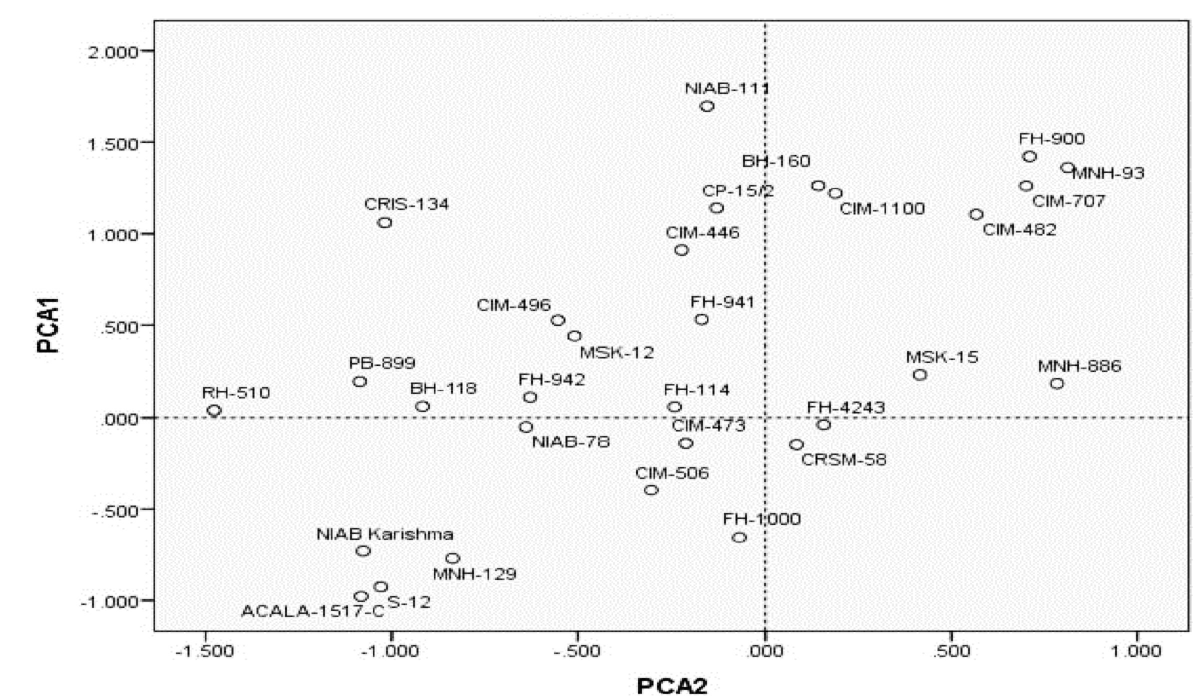

Figure 6 Biplot analysis of various seedling traits of cotton accessions grown under water stress (irrigated at 60% of pot capacity)

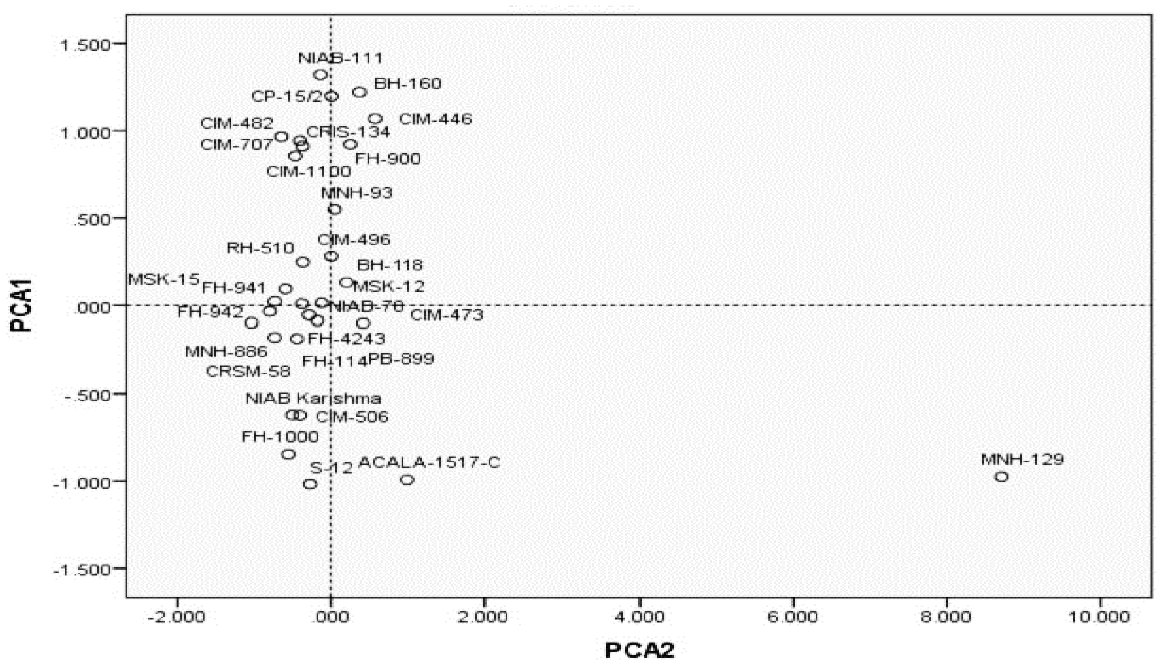

Figure 7 Biplot analysis of various seedling traits of cotton accessions grown under water stress (irrigated at 40% of pot capacity)

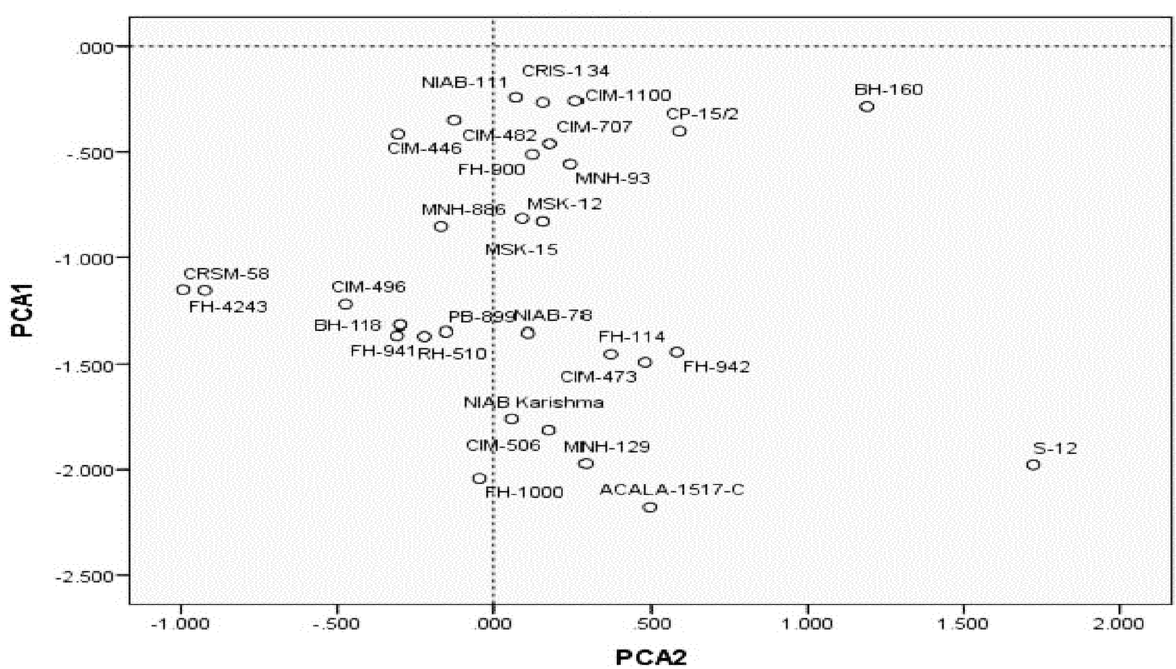

Figure 8 Biplot analysis of various seedling traits of cotton accessions grown under water stress (irrigated at 20% of pot capacity)

for the identification of drought tolerant and drought susceptible genotypes. In the present research work, 30 genotypes of upland cotton were tested at seedling stage to assess the presence of variability in five morphological parameters i.e. fresh root weight, fresh shoot weight, dry root weight, dry shoot weight and root: shoot ratio at 80, 60, 40 and 20% of pot capacity. Because these traits are adversely affected by water stress (Pace et al. 1999; Benjamin et al. 2014). Mean of these parameters were compared through cluster and biplot analysis.

Significant reduction was found in these parameters namely fresh root weight, fresh shoot weight, dry root weight, dry shoot weight and root: shoot ratio. It was observed that effect of water stress on shoot growth was higher than root growth. Previously, similar results were reported about the effect of water stress on shoot length of *Pennisetum galucum* and *Gossypium hirsutum* L. (Govindaraj et al. 2010; Iqbal et al. 2011) whilst, Huang and Gao (2000) reported adverse effect of water shortage on root growth in tall fescue. Bhatti and Azhar (2002) also reported that roots are more affected organs than shoot due to water stress conditions. Roots related traits are important in plant water relations and being considered an important criterion in the screening of several crop species against water stress. From these experiments, it has been reported that all of root related traits are genetically controlled (McMichael and Quisenberry 1991; Pace et al. 1999; Klueva et al. 2000; Basal and Turgut 2003; Iqbal et al. 2010; Riaz et al. 2013) but differential response in these traits have been noted due to environmental factors (De Dorlodot et al. 2007; Cooper et al. 2009). Existence of significant genetic variability among 30 genotypes under various waters stress levels recommended the utilization of these information of root and shoot related traits in cotton breeding program to develop drought tolerant germplasm (Al-Hamdani and Barger 2003). Water stress significantly affected the performance of cotton genotypes except NIAB-111, CP-15/2 and BH-160 that showed consistency for seedling traits at different water stress levels (Pace et al. 1999; Pettigrew 2004). Root related parameters are directly correlated with drought tolerance in rice (Nguyen et al. 1997) and cotton (Iqbal et al. 2010). Cluster and biplot analysis were used effectively for screening of germplasm against water stress conditions (Malik et al. 2011; Noorifarjam et al. 2013; Rahimi et al. 2013). After analyzing by using the statistical approaches, 10 genotypes i.e. NIAB-111, CP-15/2, BH-160, CIM-1100, CRIS-134, CIM-446, FH-900, MNH-93, CIM-707 and CIM-482 found to be treatment specific response, and declared as water stress tolerant genotypes. In contrast, CIM-506, NIAB Karishma, MNH-129, FH-1000, S-12 and Acala-1517-C revealed to be water stress sensitive.

CONCLUSION

The accessions of upland cotton were diverged from susceptible to tolerant in different groups based on the data on various traits related to water stress conditions. In addition, divergence of the upland cotton give clue that genetic variability is existed within the germplasm and is a valuable source for use in breeding program after another assessment on large area affected with water stress.

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