Pak. J. Agri. Sci., Vol. 52(2), 301-307; 2015
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
http://www.pakjas.com.pk

ASSESSMENT OF VARIABILITY FOR DROUGHT TOLERANCE IN *GOSSYPIUM HIRSUTUM* L. AT SEEDLING STAGE

Saba Zafar and Muhammad Tehseen Azhar*

Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan
***Corresponding author's e-mail: tehseenazhar@gmail.com**

Response of 49 accessions of cotton (*Gossypium hirsutum* L.) was examined at seedling stage in normal and limited water supply. The experiment was conducted in glasshouse conditions using three moisture levels i.e. normal water supply and two stress conditions. After fifteen days root length, shoot length, root weight, shoot weight, excised leaf water loss and relative water content were measured. Analysis of variance indicated significant differences among accessions for all the traits. Differences among cotton accessions were assessed using least significant difference test. Accession Shaheen showed appreciable response for the six traits, whilst Ali Akbar 802 showed maximum performance for the traits i.e. root length, shoot length, root weight, and shoot weight. IR-3701 performed better for relative water content and excised leaf water loss under normal conditions, whereas, TADLA-32 showed better performance for four traits namely, root length, shoot length, root weight, and shoot weight under stress condition. Existence of variability in the cotton germplasm suggests that further genetic improvement may be made through selection and breeding.
Keywords: Drought tolerance, seedling traits, upland cotton, variation
Abbreviations: SOV= Source of variance, DF= Degree of freedom, RL= Root length, SL= Shoot length, RW= Root weight, SW= Shoot weight, RWC= Relative water content, ELWL= Excised leaf water loss.

INTRODUCTION

Amongst abiotic stresses, acute shortage of water is the most important factor for the production of field crops in many areas of the developing countries. In fact, water stress at critical stages increases the significant difference between actual and potential yield of field crops (Iqbal *et al*., 2010). Climate changes occurring in the universe enhances the magnitude of irregular rainfall pattern, dry winters, prolonged dry spells and elevated temperature due to global warming, are expected to result in shortage of fresh water (Jeswani *et al*., 2008; Mir *et al*., 2012). Thus keeping in the view the low water level in canals and rivers, it has become important to develop such varieties of crops through selection and breeding which could withstand the stress due to water in canal irrigated areas.

Although upland cotton is characterized as drought tolerant plant, substantial amount of variation exists within the species in response to water stress (Naidu *et al*., 1998; Loka *et al*., 2011). Several adverse effects on plant character due to drought has been reported e.g. plant height (Ball *et al*., 1994; Pace *et al*., 1999), and in some cases root elongation is reduced due to shortage of water (Prior *et al.*, 1995). Water shortage not only effect the vegetative growth but had been seen to reduce flowering, reproductive, seed development stage, and finally yield (Pettigrew, 2004a; Prasad *et al.*,2008; Sarvestani*et al*., 2008).

Availability of significant variation must be present in the germplasm in response to water stress, and this variation must be controlled genetically (Mitra, 2001). Keeping in view these requisites of breeding, previous information indicated the presence of genetic variation for drought tolerance in cotton (Saba *et al*., 2001; Ye *et al*., 2003; Kar *et al*., 2005; Ullah *et al.*, 2006; Iqbal *et al*., 2011; Taheri *et al*., 2011).

Several physiological and morphological parameters of upland cotton had been widely used for the assessment of variation for water stress. These parameters includes number of lateral roots, seedling vigor, root-to-shoot ratio (Cook, 1985); longer tap root length (Pace *et al*., 1999); photosynthetic rate and stomatal conductance (Nepomuceno *et al*., 1998); reduced transpiration (Quisenberry *et al*., 1982), leaf water content (Leidi *et al*., 1999), and opening and closing of stomata for short time is also one of the important trait that could be exploited for the development of drought tolerant cultivars (Fambrini *et al*., 1995; Franca *et al*., 2000). Rate of excised leaf water loss had been exploited in *Triticum aestivum* L. (McCaig and Romagosa, 1989; Sadiq *et al*., 1994; Trethowan *et al*., 2002; Moinuddin *et al*., 2005), *Zea mays* L. (Kamara *et al*., 2003), *Hordeum vulgare* L. (Rizza *et al*., 2004), brassica species (Kumar and Singh, 1998) and *Glycine max* (Hufsteler *et al*., 2007). It is likely to use these traits for the identification of potential genotypes of cotton but limited information is reported in the literature on the response of root related traits of cotton to water stress. The present study examines the variation in 49 varieties of cotton against water stress at seedling stage. The information from this study may facilitate the breeders for the identification of potential germplasm for development of drought tolerant plant material for water limiting areas.

MATERIALS AND METHODS

In the present studies, response of 49 varieties of upland cotton to two water stress, under controlled conditions was examined in the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan (Table 1).

Cotton seeds of the material were pre-soaked overnight, and 3-4 seeds were sown in polythene bags (5 × 2.5 cm). The polythene bags were filled with sand. It took 3-4 days to complete germination, and one seedling was kept in each bag. There were three moisture levels i.e. normal water supply and the other two were 25% and 50% of the normal moisture level. Five polythene bags for each genotype in one treatment were maintained in greenhouse according to factorial complete randomized design. Seedlings were irrigated routinely for their establishment. Water stress was applied on the appearance of 2nd leaf. After 15 days seedlings of each variety were uprooted, and rinsed 4-5 times with distilled water and swapped with paper towel. These seedlings were dissected into two portions i.e. shoot and root, and measures for their length, fresh root and shoot weight were also recorded. Means of each genotype were used for statistical analysis. For the determination of relative water content (RWC),fully developed leaves were excised from each of plant in each treatment. These excised leaves were immediately taken to the laboratory and fresh weight was recorded immediately. The leaf samples were kept in 30 ml of distilled water for overnight to record turgid leaf weight. Then leaf samples were oven dried at 70°C for six hours. The relative water content was measured as,

RWC = Fresh weight – Dry weight / Turgid weight – Dry weight

Excised leaf water loss (ELWL) was also determined from fully developed leaves of each genotype. Excised leaves from selected plants were packed in polythene bags to avoid water loss. Fresh weight of leaves was recorded and samples were left on laboratory benches for six hours. Then weight of wilted leaves was recorded and finally samples were oven dried at 70°C to determine dry weight. The ELWL was calculated using the following formula,

ELWL = Fresh weight – Wilted weight / Dry weight

Statistical analysis: Means of each trait were analyzed by using Statix-8.1 to see whether genotypic differences are significant for all the traits.

RESULTS

Analysis of variance revealed highly significant differences ($P \leq 0.01$) among the genotypes for all traits (G) (Table 2). The differences between the three water treatments (T) were also highly significant ($P \leq 0.01$), and highly significant interaction (G × T) indicated the differential response of the genotypes to three moisture levels ($P \leq 0.01$).

Table 1. Names of 49 genotypes of *Gossypium hirsutum* L. examined for drought tolerance

Sr. No.	Genotypes	Sr. No.	Genotypes	Sr. No.	Genotypes	Sr. No.	Genotypes
1	ALDL-18	13	Hg-2	25	Z-293	37	Coker-3113
2	CP 15/2	14	UKAB-2	26	GH-2-1-75	38	Ali Akbar 802
3	KZ-189	15	Hg-HN-134	27	FH-941	39	IR-3701
4	Shaheen	16	XL-1	28	VH-282	40	C-26
5	LB-391	17	AC-134	29	VH-259	41	Ali Akbar 703
6	Royal Smooth	18	KZ-181	30	Brycot	42	Hg-142
7	Menufi	19	FH-113	31	UCD-581	43	TH-41-83
8	PB-900	20	Qualandri	32	Linea-100	44	Gland less (Rex)
9	Alseemi-151	21	LH-72	33	289 F/1	45	Alrasham
10	H-469	22	TADLA-32	34	Cedix-1176	46	SB-149
11	E-288	23	Coscot-B-2	35	NS-131	47	KZ-191
12	Die-Xie-King	24	SA-100	36	L-S-S	48	Lasani-15
						49	A-619

Table 2. Mean squares of various seedling traits in *G. hirsutum* L.

SOV	DF	RL	SL	RW	SW	RWC	ELWL
Genotypes(G)	48	31.23**	33.295**	0.00898**	0.01789**	2536.8**	9.0356**
Treatments(T)	2	1060.54**	563.312**	0.35251**	0.82486**	52260.9**	97.8406**
G×T	96	4.80**	1.429*	0.00170*	0.01243**	1663.8**	1.9824**
Error	588	2.21	1.260	0.00161	0.00199	448.3	0.0099

* = Significant, **= highly significant

Table 3. Root and shoot length of upland cotton under control and water stress conditions

Genotypes	Root length (cm)			Shoot length (cm)		
	Cont-rol	25% Stress	50% Stress	Cont-rol	25% Stress	50% Stress
ALDL-18	10.7	8.8	7.9	15.3	13.7	12.1
CP 15/2	10.8	8.6	7.3	15.6	13.8	11.1
KZ-189	9.7	8.2	7.2	14.0	12.7	11.6
Shaheen	17.9	13.8	10.9	17.8	15.5	13.3
LB-391	8.9	8.1	7.1	15.4	13.9	11.8
Royal Smooth	9.3	7.7	6.9	15.2	13.2	12.1
Menufi	9.2	8.5	6.7	14.5	13.2	10.9
PB-900	9.3	9.2	9.1	13.3	13.2	13.1
Alseemi 151	10.4	7.8	6.9	13.8	12.9	11.6
H-469	10.9	8.6	7.8	15.4	14.1	12.9
E-288	15.4	8.0	6.8	16.4	12.4	10.8
Die-Xie-King	10.6	7.7	6.6	15.4	13.5	12.1
Hg-2	10.8	7.9	6.6	14.3	13.1	11.9
UKAB-2	9.7	8.7	7.9	13.2	12.3	11.9
Hg-HN-134	8.3	7.5	6.3	15.8	11.4	8.7
XL-1	11.9	8.9	7.0	15.6	13.9	12.1
AC-134	10.8	9.3	7.1	14.5	12.4	9.7
KZ-181	9.2	9.2	8.4	14.6	12.7	10.6
FH-113	11.6	9.2	7.6	13.9	12.5	10.8
Qualandri	10.8	9.7	8.3	13.8	11.7	10.6
LH-72	13.8	8.8	7.2	11.7	9.3	10.5
TADLA-32	13.2	13.4	9.7	15.2	14.7	13.3
Coscot-B-2	13.7	11.2	8.7	16.1	14.2	11.8
SA-100	14.7	10.8	6.8	11.9	13.6	12.7
Z-293	11.3	9.6	7.9	14.5	13.2	12.3
GH-2-1-75	11.0	10.4	8.9	15.7	13.6	11.4
FH-941	13.7	10.6	7.2	13.5	12.5	10.9
VH-282	11.2	9.0	8.0	15.1	13.3	11.9
VH-259	11.9	10.1	7.9	14.5	13.1	12.0
Brycot	10.9	9.5	8.1	14.5	13.5	12.7
UCD-581	12.8	9.5	6.9	13.5	11.8	10.6
Linea-100	11.2	9.0	7.8	13.9	12.7	10.6
289 F/1	11.8	8.4	6.9	11.9	10.9	9.2
Cedix-1176	12.5	7.9	6.8	12.9	11.1	7.9
NS-131	9.0	8.4	7.5	10.8	10.1	8.9
L-S-S	11.4	8.6	7.5	13.5	12.5	10.5
Coker 3113	12.3	9.4	7.9	14.3	12.5	11.8
Ali Akbar 802	16.3	11.1	8.9	17.3	13.3	12.1
IR-3701	15.8	10.9	8.4	16.6	12.3	10.9
C-26	10.8	10.5	7.7	12.9	11.1	9.9
Ali Akbar 703	10.9	9.2	7.2	10.6	9.4	8.9
Hg-142	12.6	8.8	7.9	13.7	12.5	11.4
TH-41-83	11.9	10.7	8.5	12.0	10.9	9.6
Glandless(Rex)	12.8	10.8	7.2	14.3	12.7	11.1
Alrasham	14.2	7.9	8.9	12.5	10.8	9.9
SB-149	12.1	10.8	9.1	11.2	8.9	7.2
KZ-191	10.8	9.5	5.8	11.9	10.7	9.6
Lasani-15	13.1	13.3	9.5	13.7	13.5	13.2
A-619	9.7	7.9	7.9	13.0	11.2	10.5
Means	11.70	9.41	7.73	14.10	12.49	11.08
SE	0.29	0.21	0.14	0.23	0.19	0.19
CV	0.17	0.15	0.13	0.11	0.11	0.12

Root length: Root lengths of 49 genotypes measured in control condition differed from each other, and ranged from 8.3 cm (Hg-HN-134) to 17.9 cm (Shaheen) (Table 3). Under water 25% stress conditions, root length of all the genotypes markedly reduced and ranged from 7.5-13.8 cm for Hg-HN-134 and Shaheen respectively whilst 5.8-10.9 for KZ-191and Shaheen respectively under 50% of water stress.

Table 4. Root and shoot weight of upland cotton under control and water stress conditions

Genotypes	Root weight (mg)			Shoot weight (mg)		
	Cont-rol	25% Stress	50% Stress	Cont-rol	25% Stress	50% Stress
ALDL-18	56.3	37.5	26.3	103.7	83.8	60.0
CP 15/2	78.8	37.5	22.5	122.5	83.8	48.8
KZ-189	70.0	38.8	27.5	163.8	123.8	86.3
Shaheen	205.0	135.0	71.2	752.5	193.7	132.5
LB-391	148.7	33.8	16.3	171.3	126.3	78.8
Royal Smooth	66.2	33.8	20.0	155.0	122.5	87.5
Menufi	78.8	51.3	26.3	165.0	128.8	92.5
PB-900	58.8	112.5	63.8	170.0	167.5	116.2
Alseemi 151	91.2	52.5	32.5	222.5	130.0	80.0
H-469	86.2	46.3	31.3	182.5	133.8	90.0
E-288	161.2	36.3	23.8	247.5	115.0	87.5
Die-Xie-King	91.3	57.5	37.5	180.0	140.0	102.5
Hg-2	65.0	46.3	30.0	198.8	116.3	78.8
UKAB-2	112.5	63.8	42.5	185.0	123.8	78.8
Hg-HN-134	85.0	52.5	30.0	175.0	130.0	71.3
XL-1	122.5	55.0	32.5	207.5	165.0	68.8
AC-134	135.0	43.8	25.0	167.5	128.8	96.3
KZ-181	113.7	62.5	42.5	245.0	147.5	105.0
FH-113	117.5	50.0	33.8	196.3	165.0	113.7
Qualandri	85.0	48.8	27.5	201.3	133.8	102.5
LH-72	91.3	40.0	20.0	176.3	108.8	82.5
TADLA-32	111.2	120.0	65.0	222.5	172.5	125.0
Coscot-B-2	150.0	65.0	41.3	215.0	127.5	73.8
SA-100	117.5	71.2	46.3	216.3	141.2	107.5
Z-293	120.0	71.3	33.8	201.2	142.5	101.2
GH-2-1-75	62.5	90.0	53.8	201.2	165.0	86.3
FH-941	156.3	57.5	35.0	216.3	146.2	95.0
VH-282	153.7	82.5	45.0	238.8	122.5	108.8
VH-259	111.2	70.0	48.8	231.3	117.5	85.0
Brycot	131.3	75.0	47.5	196.3	125.0	92.5
UCD-581	93.8	70.0	37.5	201.3	100.0	58.8
Linea-100	80.0	57.5	43.8	202.5	96.3	71.3
289 F/1	97.5	73.8	51.3	193.8	113.8	80.0
Cedix-1176	156.3	95.0	58.8	123.8	101.3	83.7
NS-131	86.2	68.8	50.0	143.8	122.5	82.5
L-S-S	88.7	76.3	35.0	156.3	115.0	88.8
Coker 3113	133.8	85.0	35.0	237.5	135.0	100.0
Ali Akbar 802	186.3	75.0	62.5	261.3	165.0	108.8
IR-3701	166.2	72.5	51.3	260.0	112.5	88.8
C-26	97.5	70.0	50.0	160.0	127.5	103.8
Ali Akbar 703	130.0	90.0	63.8	216.2	96.3	112.5
Hg-142	142.5	45.0	30.0	192.5	151.3	96.3
TH-41-83	137.5	91.3	58.8	186.2	106.3	90.0
Glandless(Rex)	100.0	57.5	35.0	188.7	127.5	80.0
Alrasham	110.0	82.5	56.3	152.5	113.7	88.8
SB-149	128.8	87.5	52.5	136.3	115.0	87.5
KZ-191	47.5	36.3	25.0	202.5	123.8	101.2
Lasani-15	103.7	116.3	65.0	192.5	170.0	120.0
A-619	96.2	80.0	47.5	171.2	102.5	77.5
Means	110.5	66.7	40.9	202.2	129.0	90.9
SE	5.02	3.39	2.02	12.50	3.41	2.43
CV	0.32	0.35	0.34	0.43	0.18	0.18

Data on root length revealed that cotton genotypes exhibited variability to three moisture conditions. Genotypes namely, Shaheen, Ali Akbar 802 and IR-3701 had the longest root length i.e. 17.9, 16.3 and 15.8 cm respectively under control, whilst Shaheen, TADLA-32 and Lasani-15 had root length of 13.8, 13.4 and 13.1 cm respectively in 25% stress but same genotypes reduced root length to 10.9, 9.7 and 9.5 cm respectively in 50% water stress level. Hg-HN-134, LB-391, NS-131 had shorter root length i.e. 8.3, 8.9 and 9 cm respectively under control, and 25% stress conditions. The cotton varieties namely, Hg-HN-134, Di-Xie-King and Royal Smooth developed shortest root length of 7.5, 7.7 and 7.7 cm respectively in 25% water stress. Under 50% stress of stress root length of KZ-191, Hg-HN-134 and Hg-2 is greatly reduced to 5.8, 6.3 and 6.6 cm respectively (Table 3).

Shoot length: The selected genotypes of cotton were also differed for shoot length and ranged from 10.6 to 17.8 cm. Ali Akbar 802, IR-3701, E-288 and Coscot-B-2 were found to be drought tolerant genotypes. The shoot length 49 genotypes were remarkably reduced under 25% of stress, and ranged from 8.9 (SB-149) to 15.5 cm (Shaheen) whilst 7.2 to 13.3 cm for SB-149 and Shaheen, respectively, under 50% stress level. The varieties namely Shaheen, TADLA-32, Lasani 15, PB-900 and Coscot-B-2 were identified to be drought tolerant but SB-149, LH-72, Ali Akbar 703, NS-131 and KZ-191 were found to be susceptible genotypes under 25% stress conditions (Table 3).

Root weight: Maximum root weight of 205 mg was observed for Shaheen in normal as compared to 135 and 71.2 mg in 25% and 50% stress conditions respectively. KZ-191 exhibited minimum weight of 47.5 mg under normal moisture while 33.8 and 16.3 mg were noted for LB-391 in both stress conditions (Table 4).

Shoot weight:Shaheen attained maximum shoot weight of 752.5, 193.7 and 132.5 mg under normal and both the stress conditions but CP 15/2 produced minimum shoot weights of 103.7 mg in control conditions. The genotype, ALDL-18 gained 83.8 and 48.8 mg under 25% and 50% stress conditions respectively (Table 4).

Relative water content (RWC): Significant decline inRWC among 49 varieties of cotton was observed under water stress conditions in this study. There were highly significant differences ($P \leq 0.01$) among the genotypes in moisture levels. In control conditions, Shaheen exhibited highest RWC while H-469 contained lowest RWC. Highest RWC was found in Shaheen and lowest RWC in LB-391 in 25% stress condition. Ali Akbar 802 and C-26 contained lowest RWC in 50% stress level (Table 5).

Excised leaf water loss (ELWL): Highly significant differences were found between treatments as well as genotypes for ELWL. The highest ELWL was found in Shaheen under normal moisture level in contrast SA-100 and TADLA-32 had lowest ELWL. Again Shaheen showed highest ELWL in 25% and 50% water stress condition whilst lowest value of ELWL was found in LB-391 in both the stress levels (Table 5).

Table 5. Relative water content and excised leaf water loss of upland cotton under control and water stress conditions

Genotypes	RWC			ELWL		
	Cont-rol	25% Stress	50% Stress	Cont-rol	25% Stress	50% Stress
ALDL-18	0.49	0.43	0.14	0.024	0.0140	0.0068
CP 15/2	0.51	0.27	0.17	0.026	0.0062	0.0040
KZ-189	0.48	0.39	0.25	0.021	0.0180	0.0120
Shaheen	1.19	0.63	0.50	0.075	0.0570	0.0270
LB-391	0.64	0.10	0.07	0.014	0.0009	0.0001
Royal Smooth	0.53	0.23	0.09	0.014	0.0039	0.0001
Menufi	0.51	0.28	0.18	0.011	0.0064	0.0054
PB-900	0.40	0.62	0.45	0.021	0.0290	0.0150
Alseemi 151	0.44	0.32	0.24	0.015	0.0100	0.0055
H-469	0.30	0.29	0.21	0.011	0.0026	0.0022
E-288	1.17	0.38	0.26	0.067	0.0160	0.0110
Die-Xie-King	0.48	0.40	0.23	0.019	0.0120	0.0055
Hg-2	0.36	0.29	0.22	0.016	0.0110	0.0077
UKAB-2	0.61	0.51	0.36	0.016	0.0130	0.0100
Hg-HN-134	0.46	0.41	0.39	0.014	0.0130	0.0110
XL-1	0.47	0.47	0.34	0.018	0.0130	0.0100
AC-134	0.50	0.48	0.38	0.022	0.0180	0.0018
KZ-181	0.54	0.41	0.29	0.018	0.0130	0.0110
FH-113	0.47	0.43	0.25	0.012	0.0100	0.0049
Qualandri	0.45	0.45	0.32	0.014	0.0140	0.0093
LH-72	0.43	0.29	0.23	0.027	0.0150	0.0039
TADLA-32	0.48	0.55	0.45	0.009	0.0240	0.0150
Coscot-B-2	0.42	0.34	0.23	0.013	0.0062	0.0043
SA-100	0.62	0.37	0.26	0.008	0.0051	0.0032
Z-293	0.49	0.26	0.22	0.015	0.0059	0.0052
GH-2-1-75	0.43	0.38	0.28	0.017	0.0096	0.0065
FH-941	0.47	0.45	0.32	0.013	0.0110	0.0078
VH-282	0.54	0.38	0.21	0.010	0.0056	0.0032
VH-259	0.48	0.38	0.31	0.011	0.0100	0.0058
Brycot	0.57	0.14	0.11	0.018	0.0035	0.0012
UCD-581	0.34	0.20	0.13	0.011	0.0033	0.0029
Linea-100	0.40	0.32	0.27	0.014	0.0082	0.0070
289 F/1	0.40	0.22	0.13	0.013	0.0042	0.0029
Cedix-1176	0.61	0.45	0.36	0.018	0.0150	0.0110
NS-131	0.71	0.31	0.25	0.030	0.0078	0.0026
L-S-S	0.44	0.38	0.27	0.026	0.0066	0.0055
Coker 3113	0.41	0.40	0.27	0.020	0.0180	0.0068
Ali Akbar 802	0.74	0.31	0.20	0.039	0.0011	0.0004
IR-3701	0.72	0.34	0.27	0.035	0.0057	0.0048
C-26	0.43	0.36	0.20	0.012	0.0083	0.0075
Ali Akbar 703	0.44	0.39	0.29	0.011	0.0076	0.0044
Hg-142	0.39	0.30	0.16	0.015	0.0057	0.0049
TH-41-83	0.36	0.34	0.23	0.013	0.0120	0.0110
Glandless(Rex)	0.40	0.38	0.25	0.012	0.0081	0.0038
Alrasham	0.37	0.30	0.24	0.024	0.0120	0.0088
SB-149	0.53	0.43	0.42	0.019	0.0150	0.0140
KZ-191	0.62	0.39	0.34	0.026	0.0088	0.0056
Lasani-15	0.39	0.52	0.42	0.013	0.0220	0.0140
A-619	0.62	0.45	0.31	0.019	0.0120	0.0049
Means	0.51	0.36	0.26	0.020	0.0140	0.0069
SE	0.02	0.01	0.09	0.001	0.0010	0.0006
CV	0.33	0.28	0.03	0.640	0.7700	0.7000

DISCUSSION

Firstly, efficient screening is pre-requisite for the identification of tolerant genotypes against biotic and abiotic stress, and these genotypes are used as basis of breeding program. Secondly, the presence of genetic variability in plant material is necessary for effective selection, and finally the identification of traits which are directly related to yield in stress conditions. In the present experiment 49 varieties of cotton are grown under watered (control) and stress conditions in glasshouse for the assessment of root and shoot length, and other drought related traits. Previous researchers like Loffroy *et al.* (1983), Ball *et al*. (1994), Pace *et al*. (1999) and Iqbal *et al*. (2010) screened cotton germplasm at seedling stage for drought tolerance.

The presence of significant genetic variation in 49 genotypes in water stress condition suggests the utilization of information of root and shoots related traits in breeding program (Al- Hamdani and Barger, 2003). Although shoot and root length was remarkably reduced due to water stress but differences between accessions were amenable. Performance of most of the cotton varieties is significantly affected due to water stress except Shaheen and PB-900 that showed consistency for root and shoot length in control and both the stress conditions. The reduction in performance/response for root and shoot traits is due to limited supply of water (Pace *et al*., 1999; Pettigrew, 2004b). It is also observed that root length of tolerant genotypes were longer than the susceptible ones (Basal *et al*., 2005), root related traits are directly associated with water stress tolerance, as studied in rice (Nguyen *et al*., 1997) and cotton (Iqbal *et al*., 2010). The same trend was seen in our study i.e. IR-3701(Dr Mehboob-ur-Rahman, personal communication) Shaheen, and Ali Akbar- 802 are found to be stress tolerant genotypes (Anonymous, 2014), and these varieties exhibited better root traits under water stress environments, which explains the reason of their stress bearing capability (Mambani and Lal, 1983). Root related traits are also used for the development of salt tolerance in grasses by Leim *etal*. (1985) and Ashraf *etal*. (1986). Although roots are more sensitive than shoot traits even then it is reliable indicator for tolerance against salt and water stress (Bhatti and Azhar, 2002). Mean values of RWC and ELWL under control and stress conditions indicated the reduction in response with the increase of stress. Genotypes having high RWC are desirable because they are better adapted in dry environments (Malik *et al*., 2006; Parida *et al*., 2008). For instance, sorghum exhibited a smaller decrease in RWC per unit change in leaf water potential than cotton and maize (Ackerson and Krieg, 1977; Levitte, 1980). Earlier studies support our finding that maintenance of higher RWC is a strong and dependable screening criterion for the identification of drought tolerant genotypes (Matin *et al*., 1989; Ritchie *et al*., 1990). For ELWL, Shaheen is found to be potential genotype among the 49 varieties, and this parameters is utilized by several plant researchers as amenable trait for drought resistance (Clarke and Townley-Smith 1986; Clarke, 1987; Clarke *et al*., 1992). One of reason for difference of ELWL in cotton varieties is due to variation in thickness of cuticle layer (Haque *et al*., 1992). The present study reveals the presence of genetic variation in root related traits grown under water stress conditions, and there identified tolerant lines could be used in breeding program. In addition, it is suggested that cotton researcher should conduct another study on vast area in water deficit areas of Punjab province to assess the potential of identified varieties for yield of seed cotton and other related traits.

REFERENCES

Ackerson, R.C. and D.R. Krieg. 1977. Stomatal and non stomatal regulation of water use in cotton, corn and sorghum. Plant Physiol. 60: 850-853.

Anonymous. 2014. Website of Extension and Adaptive Research, Directorate of Agricultural Research. Available online at http://www.ext.agripunjab.gov.pk/crops_related_faqs

Ashraf, M., T. McNeilly and A.D. Bradshaw. 1986. Heritability of NaCl tolerance at the seedling stage in the seven grass species. Euphytica 35: 935-940.

Ball, R.A., M.O. Derrick and A. Mauromoustakos. 1994. Growth dynamics of the cotton plant during water deficit stress. Agron. J. 86: 788-795.

Basal, H., C.W. Smith, P.S. Thaxton and J.K. Hemphill. 2005. Seedling drought tolerance in upland cotton. Crop Sci.45: 766-771.

Bhatti, M.A. and F.M. Azhar. 2002. Salt tolerance of nine (*Gossypium hirsutum* L.) varieties to NaCl salinity at early stage of plant development. Int. J. Agric. Biol. 4: 544-546.

Clarke, J.M. and T.F. Townley-Smith. 1986. Heritability and relationship to yield of excised leaf water retention in durum wheat. Crop Sci. 26: 289-292.

Clarke, J.M. 1987. Use of physiological and morphological traits in breeding programs to improve drought resistance of cereals. In: J.P. Srivastiva, E. Proceddu, E. Acevedo and S. Verma (eds.), Drought tolerance in Winter Cereals, pp.171-189. Wiley Interscience, New York.

Clarke, J.M., R.M. Depauw and T.F. Townley-Smith. 1992. Evaluation of methods for quantification of drought tolerance in wheat. Crop Sci. 32: 723-728.

Cook, C.G. 1985. Identifying root traits among MAR and non-MAR cotton, *Gossypium hirsutum* L. cultivars that relate to performance under limited moisture conditions. Master Thesis. Texas A&M University, USA.

Fambrini, M., P. Vernieri, M.L. Toncelli, V.D. Rossi and C. Pugliesi. 1995. Characterization of a wilty sunflower (*Helianthus annus* L.) mutant. III. Phenotypic interaction in reciprocal grafts from wilty mutant and wild-type plants. J. Exp. Bot. 46: 525-530.

Franca, M.G.C., A.T.P. Thi, C. Pimental, R.O.P. Rossiello, Y.Z. Fodil and D. Laffary. 2000. Differences growth and water relations among *Phaseolus vulgaris* cultivars in response to induced drought stress. Environ. Exp. Bot. 43: 227-237.

Haque, M.M., D.J. Mackill and K.T. Ingram. 1992. Inheritance of leaf epicuticular wax content in rice. Crop Sci. 32: 865-868.

Hufsteler, E.V., H.R. Boerma, T.E. Carter and H.J. Earl. 2007. Genotypic variation for three physiological traits affecting drought tolerance in soybean. Crop Sci.47: 25-35.

Iqbal, K., F.M. Azhar, I.A. Khan and E. Ullah. 2010. Assessment of cotton (*Gossypium hirsutum*) germplasm under water stress condition. Int. J. Agric. Biol. 12: 251-255.

Iqbal, K., F.M. Azhar, I.A. Khan and E. Ullah. 2011. Variability for drought tolerance in cotton (*Gossypium hirsutum*) and its genetic basis. Int. J. Agric. Biol. 13: 61-66.

Jeswani, H., W. Wehrmeyer and Y. Mulugetta. 2008. How warm is the corporate response toclimate change? Evidence from Pakistan and the UK. Business Strategy and the Environment 18: 46-60.

Kar, M., B. Patro, C. Sahoo and B. Hota. 2005. Traits related to drought resistance in cotton hybrids. Indian J. Plant Physiol. 10: 377-380.

Kamara, A.Y., A. Munkir, B. Apraku and O. Ibikunle. 2003. The influence of drought stress on growth, yield and yield components of stressed maize genotypes. J. Agric. Sci.141: 43-50.

Kumar, A. and D.P. Singh. 1998. Use of physiological indices as a screening technique for drought tolerance in oilseed *Brassica* species. Ann. Bot. 81: 413-420.

Leidi, E.O., M. Lopez, J. Gorham and J.C. Gutierrez. 1999. Variation in carbon isotope discrimination and other traits to drought tolerance in upland cotton cultivars under dryland conditions. Field Crops Res. 61: 109-123.

Leim, A.S.N., A. Hendriks, H. Kraal and M. Loenen. 1985. Effects of deicing salt on roadside grasses and herbs.Plant Soil 84: 299-310.

Levitte, J. 1980. Water stress. In: J. Levitt (ed.), Responses of plants to environmental stresses, 2nd Ed., 2: 25-205. Academic press, New York.

Loffroy, O., C. Hubac and J.B. Vieira Da Silva. 1983. Effect of temperature on drought resistance and growth of cotton plants. Physiol. Plant. 59: 297-301.

Loka, D.A., D.M. Oosterhuis and G.L. Ritchie. 2011. Water-Deficit Stress in Cotton. pp. 37-72. *In*: D.M. Oosterhuis (ed.). Stress Physiology in Cotton. The Cotton Foundation, Memphis, Tenn.

McCaig, T.N. and I. Romagosa. 1989. Measurement and use of excised-leaf water status in wheat. Crop Sci. 29: 1140-1145.

Malik, T.A., S. Ullah and S. Malik. 2006. Genetic linkage studies of drought tolerant and agronomic traits in cotton. Pak. J. Bot. 38: 1613-1619.

Mambani, B. and R. Lal. 1983. Response of upland rice cultivars to drought stress. III. Screening rice varieties by means of variable moisture regimes along a topo sequence. Plant Soil 73: 73-94.

Matin, M.A., J.H. Brown and H. Ferguson. 1989. Leaf water potential, relative water content and diffusive resistance as screening techniques for drought resistance in barley. Agron. J. 81: 100-105.

Mir, R.R., M. Zaman-Allah, N. Sreenivasulu, R. Trethowan and R.K. Varshney. 2012. Integrated genomics, physiology and breeding approaches for improving drought tolerance in crops. Theor. Appl. Genet., 125: 625-645.

Mitra, J. 2001. Genetics and genetic improvement of drought resistance in crop plants. Curr. Sci. 80: 758-763.

Moinuddin, R.A. Fischer, K.D. Sayre and M.P. Reynolds. 2005. Osmotic adjustment in wheat in relation to grain yield under water deficit environments. Agron. J. 97: 1062-1071.

Naidu, B.P., D.E. Cameron and S.V. Konduri. 1998. Improving drought tolerance of cotton byglycine betain application and selection. In: Proc. 9th Australian Agronomy Conference, Wagga Wagga

Nepomuceno, A.L., D.M. Oosterhuis and J.M. Stewart. 1998. Physiological response of cotton leaves and roots to water deficit induced by polyethylene glycol. Env. Exp. Bot. 40: 29-41.

Nguyen, H.T., R.C. Babu and A. Blum. 1997. Breeding for drought resistance in rice physiology and molecular genetics considerations. Crop Sci. 37: 1426-1434.

Pace, P.F., H.T. Cralle, S.H.M. El-Halawany, J.T. Cothren and S.A. Senseman. 1999. Drought induced changes in shoot and root growth of young cotton plants. J. CottonSci. 3: 183-187.

Parida, A.K., V.S. Dagaonka, M.S. Phalak and L.P. Aurangabadkar. 2008. Differential responses of the enzymes involved in proline biosynthesis and degradation in drought tolerant and sensitive cotton genotypes during drought stress and recovery. Acta Physiol. Plant. 30: 619-627.

Pettigrew, W.T. 2004a. Moisture deficit effects on cotton lint yield, yield components and boll distribution. Agron. J. 96: 377-383.

Pettigrew, W.T. 2004b. Physiological consequences of moisture deficit stress in cotton. Crop Sci. 44: 1265-1272.

Prasad, P.V.V., S. A. Staggenborg and Z. Ristic. 2008. Impacts of drought and/or heat stress on physiological, developmental, growth, and yield processes of crop plants. In: Response of crops to limited water: understanding and modeling water stress effects on plant growth processes. In: Advances in Agricultural Systems Modeling Series. (Eds LR Ahuja, VR Reddy,SA Saseendran, Q Yu) pp. 301-355. (ASA, CSSA, SSSA: Madison, WI, USA)

Quisenberry, J.E., B. Roark and B.L. McMichael. 1982. Use of transpiration decline curves to identify drought-tolerant cotton germplasm. Crop Sci. 22: 918-922.

Ritchie, S.W., H.T. Nguyen and A.S. Hholaday. 1990. Leaf water content and gas exchange parameters of two wheat genotypes differing in drought resistance. Crop Sci. 30: 105-111.

Rizza, F., W. Badeck, L. Cattivelli, O. Lidestri, N. Di Fonzo and A.M. Stanca. 2004. Use of a water stress index to Identify barley genotypes adapted to rainfed and irrigated conditions. Crop Sci.44: 2127-2137.

Prior, S.A., H. H. Rogers, G. B. Runion, B.A. Kimball, J.R. Mauney, K.F. Lewin, J. Nagy and G.R. Hendry. 1995. Free-air carbon dioxide enrichment of cotton: root morphological characteristics. J. Environ. Qual. 24:678-683.

Saba, J., M. Moghaddam, K. Ghassemi and M.R. Nishabouri. 2001. Genetic properties of drought resistance indices. J. Agri. Sci. Tech. 3: 43-49.

Sadiq, I.S., K.A. Siddiqui, C.R. Arain and A.R. Azmi. 1994. Wheat breeding in water stressed environment. I. Delineation of drought tolerance and susceptibility. Plant Breed.113: 36-46.

Sarvestani, Z.T., H, Pirdashti, S.A. Sanavy and H. Balouchi. 2008. Study of water stress effects in different growth stages on yield and yield components of different rice (*Oryzasativa* L.) cultivars. Pak. J. Biol. Sci. 11: 1303-1309.

Taheri, S, J. Saba, F. Shekari and T.L. Abdullah. 2011. Effects of drought stress condition on the yield of spring wheat (*Triticumaestivum* L.) lines. Afr. J. Biotechnol. 10:18339-18348.

Trethowan, R.M., M.V. Ginkel and S. Rajaram. 2002. Progress in breeding wheat for yield and adaptation in global drought affected environment. Crop Sci. 42: 1441-1446.

Ullah, I., M. Rahman and Y. Zafar. 2006. Genotypic variation for drought tolerance in cotton (*Gossypium hirsutum* L.): seed cotton yield responses. Pak. J. Botany 38: 1679-1687.

Ye, Z.H., Z.Z. Lu and J. Zhu. 2003. Genetic analysis for developmental behavior of some seed quality traits in Upland cotton (*Gossypium hirsutum* L.). Euphytica 129: 183-191.