Pak. J. Bot., 44(1): 383-388, 2011.

SCREENING PAKISTANI COTTON FOR DROUGHT TOLERANCE

MUHAMMAD HUSSAIN SOOMRO, GHULAM SARWAR MARKHAND[*] AND BARKAT A. SOOMRO[1]

Department of Botany, Shah Abdul Latif University, Khairpur, Sindh, Pakistan
[1]Central Cotton Committee of Pakistan, M.T. Khan Road Karachi, Pakistan.
[*]Corresponding author:gsmarkhand@gmail.com

Abstract

The drought is one of the biggest abiotic stresses for crop production in arid and semi-arid agriculture. Thus it is a challenge for plant scientists to screen and develop the drought tolerant cotton lines. In this study, 31 cotton genotypes/cultivars were evaluated under two irrigation regimes i.e., seven irrigations (Control) and two irrigations (Stress), using split plot design with four replications. The crop growth, yield and some physiological parameters were studied. There were high inter-varietal differences for all the parameters under control as well as drought stress. Although all the varieties for all parameters were significantly affected by drought but however, CRIS-9, MARVI, CRIS-134, CRIS-126, CRIS-337, CRIS-355 and CRIS-377 maintained highest performance for all the parameters studied under high drought conditions.

Introduction

Cotton (*Gossypium hirsutum* L.) is considered as world's leading oil and fiber producing crop (Fryxell, 1992) and is most important cash crop for smallholders in many of the Asian and Latin American countries including Pakistan (Fortucci, 2002). About 47% of total world cotton acreage comes from rainfed cotton but it contributes only 27% to total production, while irrigated cotton grown in arid and semi-arid regions stretching from Spain to central Asia and Australia (Gilham *et al.,* 1995), contributes rest to world cotton production. The availability of suitable irrigation water to such regions is limited thus limiting the growth and yield of cotton crop. Under such conditions the only practical solution is to develop drought tolerant cotton genotypes for high yields in order to meet world demand.

The drought stress significantly reduces crop production by affecting many agronomic traits like reduction in size and number of bolls per plant, plant height, above ground fresh weight, seed cotton yield etc (Malik *et al.,* 2006). The time between 45 to 65 days after planting is most critical for plant growth which coincides the time from first square to first flower formation (Oosterhuis, 1990). During last two decades significant efforts have been taken to develop drought tolerant cotton lines. Majority of techniques however, use laboratory experiments for selection of tolerant lines which can not be translated well under variable field environments. These approaches generally suggest testing of germplasm under stress and non-stress conditions and ranking genotypes for drought tolerance or susceptibility on the basis of reduction in yield (Blum, 1988).

Identification of stress tolerant lines is a challenge but plant stress tolerance can be developed by identifying and characterizing traits which contribute stress tolerance and determine their relative importance. Difficulties in the past have included the identification of physiological characteristics that are correlated with drought stress that could be used as indicators of drought tolerance. Many physiological parameters can be potentially identified as indicators for drought tolerance, for example inhibition of photosynthesis and stomatal conductance (Pettigrew, 2004; Athar & Ashraf, 2005), osmotic adjustment (Saranga *et al.,* 2001) cell membrane stability (Ashraf *et al.,* 1992) accumulation of proline concentrations (Kocsya *et al.,* 2005) and leaf water potential, O_2 evolution and stomatal conductance (Pimentel *et al.,* 1999). According to Blum (1997) water availability mostly affects the growth of leaves and roots, stomatal conductance, photosynthesis and dry matter accumulation. One of the important aspects of drought tolerance may be the plant's ability to reduce water loss by early stomatal closure (stomatal conductance) or leaf morphological structures (Levitt, 1980, Fernandez & McCree, 1991; Fambrini *et al*., 1995; Franca *et al*., 2000). Leaf chlorophyll content has also been reported as reliable indicator for the selection of genotypes for drought tolerance in canola (Kauser *et al.,* 2006). On other hand lower excised leaf water loss, lower transpiration rate along with higher leaf water content has also been reported as selection criteria to breed plants against drought stress (Clark & McCaig, 1982; Malik *et al*., 1999; Rahman *et al.*, 2000). In the most of the breeding programmes agronomic traits are considered as indicators of drought tolerance which are directly related to yield or yield improving components of the crops. Erb (1993) described a breeding scheme that would allow blueberry (*Vaccinium* section *Cyanococcus*) breeders to efficiently access existing variability for mineral soil adaptation, based on an initial screening for drought tolerance, followed by selection for root development and shoot growth on mineral soil.

Due to large scale genotypic variability for drought tolerant characteristics in cotton it has become necessary to evaluate more and newly developed genotypes. Therefore majority of germplasm used in the present study has no drought tolerance history and are evaluated for agronomic traits and some physiological parameters like transpiration rate, stomatal conductance, excised leaf water loss and leaf chlorophyll contents to select the cotton genotypes with potential drought tolerance.

Materials and Methods

Plant material: Healthy seed of 31 cotton genotypes/cultivars (Table 1) was collected from the Cotton Research Institute, Sakrand (CRIS), Sindh, Pakistan during 2003. Most of the genotypes are developed in CRIS by breeding high yielding inland and exotic cultivars. Only three out of 31 genotypes are released commercial varieties while rest are ready to be released soon. The seeds were treated in concentrated sulfuric acid for 20 minutes to remove the extra lint from surface. The seeds were washed thoroughly and soaked for 12 hours in tap water and surface dried in shade to remove extra moisture.

Table 1. The 31 genotypes/Cultivars and their parentage.

	Genotypes/ cultivars	Parentage		Genotypes/ cultivars	Parentage
1.	CRIS-9	Rajhans x R.A-33-47	17.	CRIS-120	B-909 x Rajhans
2.	Marvi	Qalandri x 9L 34Icc	18.	CRIS-121	-do-
3.	CRIS-134	Acala SJ1 x CRIS-9	19.	CRIS-126	NIAB-78 x B-909
4.	CRIS-7A	NIAB-78 x Rajhans	20.	CRIS-337	CRIS-52 x CRIS-121
5.	CRIS-19	NIAb-78 x ST1	21.	CRIS-342	-do-
6.	CRIS-52	PD-4548 x Rajhans	22.	CRIS-355	-do-
7.	CRIS-54	Coker-310 x Rajhans	23.	CRIS-377	-do-
8.	CRIS-56	CIM-70 x Coker 100 staple	24.	CRIS-402	S12 x Alseeml-515
9.	CRIS-78	PD-4548 x Rajhans	25.	CRIS-465	Cedix x CRIS-379
10.	CRIS-79	Coa-6 x PD-4548	26.	CRIS-466	(LRA-5166 x CRIS-278) x LRA-5166
11.	CRIS-82	Acala 1517 Br2 x PD-4548	27.	CRIS-467	LRA-5166 x CRIS-9
12.	CRIS-83	DPL-16 x MNH-53	28.	CRIS-468	CP-15/2 x CRIS-9
13.	CRIS-85	PD-4548 x Rajhans	29.	CRIS-129	CIM-70 x B-909
14.	CRIS-107	Coker 310 x Rajhans	30.	CRIS-133	Acala-SJ1 x CRIS-18
15.	CRIS-110	PD-4548 x Rajhans	31.	CRIS-154	Sx941L-GOL-7C-78-3 x NIAB-78
16.	CRIS-117	B-557 x NIAB-78	32.	------	----------

Soil preparation: The experiments were conducted on clay-loam textured soil with 74.95% water holding capacity, pH 8.2 and ECe 0.13-018 dSm^{-1}, irrigated at its 100% field capacity 15 days before sowing (soaking dose). The soil was ploughed thrice to remove weed seedlings emerged after irrigation. Chemical fertilizer DAP (Di-Ammoniumphosphate), as source of nitrogen and phosphate, at the rate of 50 Kg per acre was applied at sowing time.

Experimental design: The two field experiments were conducted to evaluate the drought tolerance in 31 cotton genotypes/cultivars during Kharif 2004 at experimental field station Shah Abdul Latif University, Khairpur, Sindh, Pakistan. The experiments were carried out in Split Plot Design, net plot size 80x100 square feet, with irrigations in main plots and genotypes/cultivars in sub-plots. There were two irrigation treatments with four replications. The treatments were;

T1= Seven irrigations (Control No stress) one sowing and six other irrigations applied at various stages of crop development.

T2= Two irrigations (Severe stress) one sowing and other after 45 days of sowing.

Irrigations started after 35 days of sowing and were continuously applied at the interval of 15 days up to 125 days after sowing in control. The seeds were sown by drill method on 12th May 2004, with a row to row space of 2 feet. After emergence the plants were thinned and finally 1 foot plant to plant space was maintained. The following parameters were determined:

a. Yield & Yield components: At maturity about 10 plants per treatment per replication were randomly selected to collect data for growth and yield parameters like Plant height (cm), number of total fruiting branches, number of bolls $plant^{-1}$, boll weight (g), and seed cotton yield (g p^{-1}).

b. Stomatal conductance: The four randomly selected plants per plot were selected for measurements. The stomatal conductance measurements were carried out using AP4 Porometer (Delta-T devices Ltd) between 10.00 to 13.00hrs daily after 70-75 days of planting on fully expanded leaves. The instrument was carefully calibrated each day and used with the limits specified for this instrument. Both adaxial and abaxial surfaces were measured. Leaf temperatures were measured with Raytec infra-red thermometer.

c. Transpiration rate: The fully expanded six leaves were selected for the measurement of transpiration rate. The transpiration rate was measured using Li-Cor LI-6000 portable photosynthesis system on cloudless days between 12.00-15.00 hrs with the interval of 45 minutes.

d. Relative water content (RWC): At the middle of plant canopy, six fully developed leaf samples were taken from each of the selected plants from each plot, when drought appeared. After excision each sample was carefully taken to laboratory in polythene bag and fresh weight was recorded immediately. The leaf samples were kept in water for over night to record turgid leaf weight. On next day the samples were oven dried at 70^{o}C for six hours. The relative water content was measured using the following formula:

$$RWC = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}}$$

e. Excised leaf water loss (ELWL): Three fully developed leaves were excised from selected plants and carefully packed in polythene bags. The samples were brought into laboratory avoiding any water loss. Immediately at laboratory fresh weight of leaves was recorded and samples were left on laboratory benches for six hours. After six hours the weight of wilted leaves was recorded and samples were then dried in oven at 70^{o}C. The ELWL was calculated using the following formula:

$$ELWL = \frac{\text{Fresh weight} - \text{Wilted weight}}{\text{Dry weight}}$$

f. Chlorophyll content: For chlorophyll contents three fresh mid-canopy leaves were selected from each treatment. The leaves were brought to laboratory and 1.0 g leaf material was ground in 80% acetone and centrifuged at 14,000rpm for 5 minutes. The supernatant was used to determine chlorophyll contents µg/g at 645, 665 and 480 nm wavelength, according to method of Williams (1984) using spectrophotometer (model UV-160A Shimadzu, Japan).

Statistical analysis: The data was statistically analyzed for mean and mean variance of all genotypes/cultivars. The LSD was calculated at probability of 0.05%.

Results

a. Growth, yield and yield components: The plant height, total number of fruiting branches plant^{-1}, bolls plant^{-1}, bolls weight plant^{-1} and seed cotton yield (g) plant^{-1} of all the varieties reduced significantly at stress conditions but however varieties like CRIS-9, MARVI, CRIS-134, CRIS-126, CRIS-337, CRIS -355 and CRIS-377 maintained highest plant height, total number of fruiting branches plant^{-1}, bolls plant^{-1}, bolls weight plant^{-1} and seed cotton yield (g) plant^{-1}. The differences between these varieties, although were found significant but however they maintained highest performance at high stress conditions. The inter-treatmental differences were highly significant which show high reductions in all parameters under high stress conditions (Table 2).

b. Stomatal conductance: Stomatal conductance (gs mmol m^{-2} s^{-1}) measured through AP4 Porometer remained highly affected by water stress. The analysis of variance suggests that there were highly significant differences between control and water stress treatments. LSD $_{(0.05)}$ confirmed that there were significant mean differences between two treatments. Similarly, inter-genotype/cultivar differences were also highly significant (Table 2). The highest stomatal conductance under control was of CRIS-19 followed by CRIS- 337 and lowest was those of CRIS-324 followed by CRIS-377. Under drought conditions lowest stomatal conductance was of CRIS-129 followed by CRIS-468 and CRIS-466, while CRIS-107 maintained highest stomatal conductance followed by CRIS-9 (Table 3).

Table 2. Mean plant height (cm), Mean number of fruiting branches, Number of bolls plant^{-1}, Boll weight (g) plant^{-1} and seed cotton yield (g) of various cotton varieties as affected by water stress.

Varieties	Plant height (cm)		Number of fruiting branches		Bolls per plant		Boll weight (g) plant^{-1}		Seed cotton yield	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress
CRIS 9	114.68	104.50**	18.23	14.25**	32.25	24.25**	4.36	3.52**	140.61	105.36**
MARVI	124.80	110.25**	17.25	14.25**	31.25	21.23**	5.36	3.99**	167.50	133.47**
CRIS 134	122.83	102.36**	16.26	13.25**	34.25	20.12**	4.25	2.95**	145.56	129.35**
CRIS 7A	113.08	97.87	11.75	7.56	22.56	13.25	2.36	1.26	53.24	25.35
CRIS 19	106.85	85.72	13.50	7.69	25.00	14.25	2.36	1.25	59.00	26.73
CRIS 52	138.60	95.75	12.50	6.25	20.25	11.25	2.2	1.00	44.55	17.50
CRIS 54	135.75	91.12	14.50	5.65	23.25	12.25	3.02	2.07	70.21	25.35
CRIS 56	127.95	91.05	12.11	6.89	23.69	11.65	3.86	1.86	67.75	25.38
CRIS 78	104.35	75.25	13.20	6.75	25.50	11.75	2.01	1.93	51.25	20.67
CRIS 79	134.93	78.80	14.25	8.56	22.25	11.00	2.02	1.44	44.94	15.22
CRIS 82	125.50	94.50	11.25	6.58	25.56	12.56	2.00	1.00	51.12	23.65
CRIS 83	117.30	94.22	12.36	5.55	24.00	13.25	1.98	0.56	47.52	21.21
CRIS 85	148.02	90.45	12.50	8.69	25.75	14.48	2.01	1.14	51.75	16.50
CRIS 110	125.00	85.48	14.25	6.58	21.14	11.56	2.86	1.96	60.46	26.57
CRIS 107	93.05	71.56	10.50	4.56	20.25	11.25	2.77	1.55	56.09	21.93
CRIS 117	139.90	79.20	14.50	6.25	21.58	12.75	2.07	1.23	44.67	17.60
CRIS 120	97.70	90.40	12.36	9.65	21.50	13.56	2.01	1.16	43.21	25.22
CRIS 121	98.75	85.58	11.25	8.50	18.00	13.25	1.99	1.03	45.82	13.64
CRIS 126	133.30	110.25**	19.56	14.56**	33.75	22.25**	4.78	3.01**	161.32	66.97**
CRIS 337	138.30	107.28**	17.45	12.28**	32.00	23.36**	5.69	3.85**	182.08	89.93**
CRIS 342	145.25	95.56	13.25	6.52	23.58	16.25	2.36	0.96	55.64	21.85
CRIS 355	114.75	101.23**	11.23	6.52	32.75	25.75	4.56	3.71	149.34	95.53**
CRIS 377	154.60	121.40**	17.25	13.56**	30.00	23.50**	4.23	2.74**	126.90	64.39**
CRIS 402	133.10	108.70	18.25	15.25**	23.56	12.56**	2.18	1.74**	51.36	17.07
CRIS 465	106.05	90.70	13.25	7.69	24.00	12.23	2.06	0.95	49.44	15.41
CRIS 466	101.95	91.60	12.25	5.65	24.00	12.56	2.01	0.54	48.24	6.78
CRIS 467	103.25	85.23	11.25	6.58	22.50	11.25	3.08	1.33	46.80	14.96
CRIS 468	130.35	77.40	11.75	6.58	24.58	11.45	3.15	1.62	52.84	18.54
CRIS 129	97.55	91.35	12.56	7.63	23.75	13.25	2.19	0.96	52.01	12.72
CRIS 133	99.95	93.38	12.25	6.35	22.00	12.56	3.24	1.99	49.28	14.99
CRIS 154	97.57	94.87	11.25	5.56	20.50	13.50	2.01	0.56	41.20	7.56
Mean	120.16	93.32	13.68	8.46	25.00	14.97	2.94	1.77	74.57	37.33
LSD $_{(0.05)}$ for varieties	3.92		0.90		1.41		0.39		2.29	
LSD $_{(0.05)}$ for treatments	0.38		0.06		0.09		0.10		0.19	

Table 3. Mean stomatal conductance (gs mmol m^{-2} s^{-1}) and Transpiration rate (mmol m^{-2} s^{-1}) of 31 cotton genotypes/cultivars under control (7 times Irrigated) and Stress (2 times irrigated) conditions.

Genotype/Cultivar	Stomatal conductance			Transpiration rate		
	Control	Stress	Mean	Control	Stress	Mean
CRIS-9	264.75	213.75	239.25	10.00	5.29	7.64
MARVI	251.00	203.25	227.13	9.54	5.08	7.31
CRIS-134	269.00	193.50	231.25	9.07	5.08	7.07
CRIS-7A	249.00	181.50	215.25	8.79	5.17	6.98
CRIS-19	351.50	156.50	254.00	8.47	5.08	6.77
CRIS-52	332.25	192.50	262.38	9.42	5.10	7.26
CRIS-54	302.75	188.00	245.38	9.45	5.16	7.30
CRIS-56	273.75	171.00	222.38	8.56	5.07	6.81
CRIS-78	318.00	160.50	239.25	8.83	5.03	6.93
CRIS-79	275.50	150.50	213.00	8.60	5.17	6.88
CRIS-82	258.00	141.25	199.63	8.55	5.03	6.79
CRIS-83	248.00	153.25	200.63	8.73	5.03	6.88
CRIS-85	241.00	191.50	216.25	10.20	5.21	7.70
CRIS-107	248.50	215.50	232.00	10.30	5.39	7.84
CRIS-110	259.50	186.00	222.75	8.55	5.11	6.83
CRIS-117	272.00	165.00	218.50	8.56	5.00	6.78
CRIS-120	235.50	193.25	214.38	9.68	5.17	7.42
CRIS-121	224.50	120.00	172.25	8.52	5.11	6.81
CRIS-126	246.50	138.00	192.25	8.84	5.11	6.97
CRIS-337	338.00	109.25	223.63	8.41	4.93	6.67
CRIS-342	204.00	112.50	158.25	8.46	4.96	6.71
CRIS-355	256.00	110.25	183.13	9.25	5.11	7.18
CRIS-377	222.00	147.50	184.75	9.28	5.21	7.24
CRIS-402	286.75	140.00	213.38	9.05	5.01	7.03
CRIS-465	299.75	120.00	209.88	8.48	4.75	6.61
CRIS-466	285.00	108.25	196.63	8.33	4.97	6.65
CRIS-467	265.00	148.50	206.75	9.16	4.80	7.00
CRIS-468	243.00	107.50	175.25	10.68	5.16	7.92
CRIS-129	307.00	101.75	204.38	8.08	4.82	6.45
CRIS-133	292.50	139.00	215.75	9.33	4.84	7.08
CRIS-154	241.50	123.75	182.63	9.34	4.88	7.11
Mean	282.04	154.29		9.05	5.06	
$LSD_{(0.05)}$ for treatments = 0.337				0.008638		
$LSD_{(0.05)}$ for varieties = 5.227				0.133894		

c. Transpiration rate: Transpiration rate (mmol $m^{-1}s^{-1}$) declined significantly under drought conditions. Analysis of variance showed highly significant inter-treatment differences. CRIS-468 was found with highest transpiration rates under control followed by CRIS-107 and CRIS-85, however later two were statistically non-significant. Under stress conditions highest transpiration was found in CRIS- 107 followed by CRIS-9 but however both were non-significant (Table 3).

d. Relative water content (RWC): Relative water content (RWC) measured from the excised leaf samples declined significantly by water stress. Inter-treatment differences were significant. There were also significant differences among genotype/cultivars under both treatments. Under control the highest RWC was maintained by CRIS-355 followed by CRIS-468 while CRIS-467 followed by CRIS-342 was found with lowest RWC under control. Under stress conditions however, the highest RWC was found in CRIS-79 followed by CRIS-129. The lowest RWC was found in CRIS-7A followed by CRIS-120 (Table 4).

e. Excised leaf water loss (ELWL): Excised leaf water loss (*ELWL)*, measured directly on the basis of leaf fresh, wilted and dry weight was adversely affected by water deficit stress. There were highly significant differences between treatments as well as genotypes/cultivars. The highest ELWL was found in CRIS-465 followed by CRIS-83 under normal irrigations, while CRIS-78 and CRIS-468 had lowest ELWL. CRIS-52 showed highest ELWL followed by CRIS-121 under stress conditions. The lowest ELWL was found in CRIS-7A under stress followed by CRIS-126, but statistically the both were non-significant (Table 4).

f. Chlorophyll content: The chlorophyll content (µg g^{-1}) remained slightly affected by the water stress. The overall analysis of variance shows no differences between treatments but however, few genotypes/cultivars showed significant reduction in chlorophyll content in response to drought stress. The genotypes/cultivars, however were found with high significant differences under both control and water deficit stress. The CRIS-110 was found with highest chlorophyll content under both control and stress conditions followed by CRIS-377. CRIS-342 was found with lowest chlorophyll rate under both control and stress conditions followed by CRIS-337 (Fig. 1).

Table 4. Mean excised leaf water loss *ELWL* (g) and relative water content *RWC* of 31 cotton genotypes/cultivars under control (7 times Irrigated) and Stress (2 times irrigated) conditions.

Genotype/Cultivar	ELWL			RWC		
	Control	Stress	Mean	Control	Stress	Mean
CRIS-9	0.53	0.52	0.52	0.96	0.92	0.94
MARVI	0.75	0.23	0.49	0.96	0.90	0.93
CRIS-134	0.86	0.17	0.51	1.36	0.87	1.11
CRIS-7A	0.86	0.02	0.44	1.55	0.25	0.90
CRIS-19	0.35	1.22	0.78	0.94	0.97	0.96
CRIS-52	1.63	1.97	1.80	0.97	0.85	0.91
CRIS-54	0.71	0.46	0.58	1.44	0.74	1.09
CRIS-56	0.91	0.10	0.51	0.97	0.99	0.98
CRIS-78	0.25	0.44	0.34	0.94	0.86	0.90
CRIS-79	0.97	0.62	0.80	0.94	1.42	1.68
CRIS-82	1.18	1.13	1.15	0.96	0.97	0.96
CRIS-83	1.19	0.37	0.78	0.99	0.88	0.94
CRIS-85	0.61	0.10	0.35	0.90	0.88	0.89
CRIS-107	0.65	0.92	0.78	0.96	0.92	0.94
CRIS-110	0.44	0.80	0.62	0.99	1.06	1.03
CRIS-117	0.43	0.12	0.27	0.98	1.10	1.04
CRIS-120	0.83	0.22	0.53	0.97	0.32	0.65
CRIS-121	0.58	1.45	1.01	0.95	0.93	0.94
CRIS-126	0.51	0.04	0.28	2.08	0.48	1.28
CRIS-337	0.68	0.20	0.44	0.93	0.90	0.91
CRIS-342	0.79	0.28	0.53	0.55	0.97	0.76
CRIS-355	0.77	0.15	0.46	3.07	0.91	1.99
CRIS-377	0.64	0.28	0.46	0.57	0.94	0.76
CRIS-402	0.67	0.94	0.80	0.74	0.94	0.84
CRIS-465	1.38	0.36	0.87	1.29	0.73	1.01
CRIS-466	0.59	0.22	0.40	0.98	0.34	0.66
CRIS-467	0.30	0.95	0.63	0.30	0.93	0.61
CRIS-468	0.71	1.01	0.86	2.36	0.92	1.64
CRIS-129	0.42	0.12	0.27	1.03	1.13	1.08
CRIS-133	0.55	0.46	0.51	0.78	0.86	0.82
CRIS-154	0.54	0.49	0.52	0.85	0.57	0.71
Mean	1.11	0.89		0.72	0.53	
LSD $_{(0.05)}$ for treatments = 0.00138			0.337		0.013	
LSD $_{(0.05)}$ for varieties = 0.24			5.227		0.214	

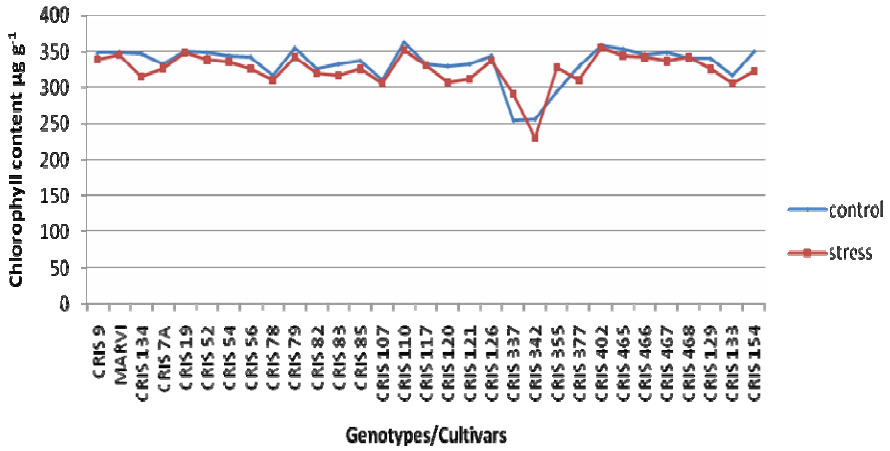

Fig. 1. The total chlorophyll content (µg g^{-1}) of cotton genotypes/cultivars as affected by water stress.

Discussion

The effect of water stress upon leaf water status, growth and yield of 31 cotton varieties, developed under the tropical conditions of central Sindh province Pakistan, was evaluated in the field. The results suggest that the effect of water deficit was severe on the all varieties in general but however, varieties such as CRIS-09, Marvi, CRIS-134, CRIS-126, CRIS 337, CRIS, 335 and CRIS 377 maintained the high plant height, number of fruiting

branches, boll weight, seed cotton yield and seed index. Although the decrease in these varieties for growth and yield parameters was significant but however, they showed a little difference when compared to control. The ANOVA individual and combined revealed that there were significant differences in the varieties as well as treatments. It was observed that water deficit stress significantly decreased the growth, yield and water content of leaves. The LSD at (0.05) probability was computed to bring the mean differences more clear. Since most of the cotton varieties showed sensitive responses to water stress thus it can be predicted that cotton as overall is a drought sensitive plant, which was also predicted through a careful field study on two cotton strains by Wilson *et al.,* 1987 that the water deficit has severe adverse effects on the developmental factors of cotton plant. However the appearance of some varieties produced high growth and yield as well as maintained high rate of leaf water relations and photosynthetic activities is a hope for the breeders to utilize these sources for the development of future tolerant varieties. It has been found that water deficit is an important factor contributing to low growth, yield and water relations as well as photosynthetic activity in cotton. Thus, it was considered important to evaluate a high number of varieties particularly those with no or very rare water stress tolerance history. The field observation also confirmed that the growth and development of tolerant varieties was quite rapid so they maintained a growth quite earlier than most of other varieties and this can be due to the absorption of much moisture from soil earlier and leaving the soil little drier for others thus maintained the avoidance mechanisms showing increased phonological development. This can be another important trait of plant adoptability to utilize maximum amount of available moisture. It has been found by the studies that rapid phenological development, increased stomatal and cuticular resistance, changes in leaf area, orientation and anatomy are some of the avoidance mechanisms in plants (Jones & Corlett, 1992 and Morgan, 1984).

References

Ashraf, M., M.H. Bokhari and S.N. Chishti, 1992. Variation in somatic adjustment of accessions of lentil (*Lens culinaris* Medic.) in response to drought stress. *Acta Bot. Neerl.,* 41: 51-62.

Athar, H.R. and M. Ashraf. 2005. Photosynthesis under drought stress. In: *hand book photosynthesis*, 2nd edition, (Ed.): M. Pessarakli. CRC Press, New York, USA, pp. 795-810.

Blum, A. 1988. *Plant breeding for stress environments.* CRC press Florida, USA.

Blum, A. 1997. Crop responses to drought and the interpretation of adaptation. In: *Drought Tolerance in Higher Plants: Genetical, Physiological, and Molecular Biological Analysis*. (Ed.): I. Belhassen. Kluwer Academic Publ., Dordrecht, pp. 57-70. ISBN 0- 7923-4123-6.

Clark, J.M. and T.M. McCaig. 1982. Evaluation of techniques for screening for drought resistance in wheat. *Crop Sci*., 22: 1036-1040.

Erb, W.A. 1993. Improved drought tolerance and root development as components of a scheme to breed blueberries for mineral soil adaptability. *Euphytica*, 70: 9-16.

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

Fernandez, C.J. and K.J. McCree. 1991. Visualizing differences in plant water dynmics with a simulation model. *Crop Sci*., 31:399-404.

Fortucci, P. 2002. The contribution of cotton to economy and food security in developing countries. *UN food and Agriculture organization FAO*.

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

Fryxell, P.A. 1992. A revised taxonomic interpretation of *Gossypium* L. (Malvaceae). *Rheedea*, 2: 108-165.

Gilham, F.E.M., T.M. Bell, T. Arin, T.A Matthews, C.L. Rumeur and A.B. Hearn. 1995. Cotton production prospects for the next decade. *World bank technical paper*, No. 287. World Bank, Washington DC.

Jones, H.G. and J.E. Corlett. 1992. Current topics in drought physiology. *J. Agr. Sci*., 119: 291-296.

Kauser, R., H.R. Athar and M. Ashraf. 2006. Chlorophyll fluorescence a: a potential indicator for rapid assessment of water stress tolerance in canola (*Brassica napus* L.) *Pak. J. Bot*., 38(5): 1501-1509.

Kocsya Ga´bor, R. Laurieb, G. Szalaia, V.S. gyia, L. Simon-Sarkadic, G. Galibaa and J.A. de Ronde. 2005. Genetic manipulation of proline levels affects antioxidants in soybean subjected to simultaneous drought and heat stresses. *Physiologia Plantarum*, 124: 227-235.

Levitt, J. 1980. *Responses of plants to environmental stress.* Vol. II. Water, Radiation, Salt and Others. Academic Press, New York.

Malik T. A., Sanaullah and S. Malik. 2006. Genetic linkage studies of drought tolerant and agronomic traits in cotton. *Pak. J. Bot.,* 38(5): 1613-1619.

Malik, T.A., D. Wright and D.H. Virk. 1999. Inheritance of net photosynthesis and transpiration efficiency in spring wheat, *Triticum aestivum* L., under drought. *Plant Breed.* 118: 93-95.

Morgan, J.M. 1984. Osmoregulation and water stress in higher plants. *Annu. Rev. Plant Physiol*., 35: 299-319.

Oosterhuis, D.M. 1990. *Growth and development of cotton. In nitrogen nutrition of cotton: practical issues*, 1-24 (Ed.): W.N. Miley and D.M. Ooserhuis, ASA Madison, WI.

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

Pimentel, C.G. He´bert b and J.V. da Silva. 1999. Effects of drought on O_2 evolution and stomatal conductance of beans at the pollination stage. *Envir. and Exp. Bot*., 42: 155-162.

Rahman, S., M.S. Shaheen, M. Rahman and T.A. Malik. 2000. Evaluation of excised leaf water loss and relative water content as screening techniques for breeding drought resistant wheat. *Pak. J. Biol. Sci*., 3: 663-665.

Saranga, Y., M. Menz, C. Jiang, R. Wright, D. Yakir and A.H. Paterson. 2001. Genomic dissection of genotype x environment adaptation conferring adaptation of cotton arid conditions. *Genome Res*., 11: 1988-1995.

Williams, S. 1984. *Official methods of analysis of the association of analytical chemist. Published by the Association of official analytical chemist Inc.* Virginia, USA., 22-209, 40: 59-60.

Wilson R.F., J.J. Burke and J.E. Quisenberry. 1987. Plant Morphological and Biochemical Responses to Field Water Deficits II. Responses of leaf glycerolipid composition in cotton. *Plant Physiol*., 84: 251-254.

(Received for publication 3 August 2009)