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Characterization of Cotton Genotypes for Agronomic and Fibre Traits Under Water Deficit Conditions

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Abstract: Drought stress an important yield reduction factors and heading toward severity due to shortage of fresh water availability. The fifty cotton genotypes in field condition were screened out for drought tolerance on the basis of various yield, fiber quality profile and stress resistance indicator. The treatments were arranged according to Randomized Complete Block Design (RCBD) split plot with three replications. The irrigation treatments (normal and drought) were kept in main plots and genotypes in sub-plots. The great genotypic diversity was observed among tested entries and response to stress tolerance was not similar for all observed characters even within variety. The ginning out turn (GOT), staple strength and micronaire values were improved with drought stress and remaining tested traits were adversely affected with drought. The highest seed cotton yield in normal and stress condition was recorded from CIM-608 and MPS-11, respectively. The highest (42.3) and lowest (9.4) TOL based on seed cotton yield was noted for CIM-608 and MS-64, respectively which showed their relatively susceptible and tolerant for drought. The yield of genotypes in normal is positively and in stress is negatively associated with TOL and SSI. Twenty genotypes were characterized with YI greater than one which exhibited better performance under drought conditions. The results suggested that intra-specific morphological diversity can further be exploited to have genetic information about parameters which signify drought resistance using molecular markers.

Keywords: Drought, Seed Cotton Yield, Lint Quality, Resistance Indicators

1. INTRODUCTION

Cotton is a miraculous fiber that has a variety of uses, from fashion to home stuff to medical products. Cotton, all around the world is known as very most valuable and abundant produced agricultural as well as industrial crop. Cotton is cultivated in more than 100 countries, covering about 2.5% arable land of the world, assembling it one of the most important crops with respect to land use after food grains and soybeans. In 2017, cotton was sown on an area of 29.27 million hectare with production of 105.34 million bales all over the globe while India, China, United States of America, Pakistan and Brazil were the top growers. (USDA, 2017). Cotton is sown in tropical and subtropical areas; the temperature for cotton crop is required (21° C to 30ºC) and rainfall of (50-100) cm in Pakistan. (Azam *et al.*, Bakhsh *et al.*, 2009; Sial *et al.*, 2014).

Shortage of irrigation water is major limiting factor for crop production in arid and semi-arid regions. It is the second important factor of yield reduction followed by diseases (Khatri *et al.*, 2004). The fresh water availability is declining with time due to competition with industries, domestic use and climate changing scenario. The major cotton production area lies in Punjab and Sindh, categorized arid and semi-arid regions with average annual rainfall about 250 mm. Although cotton has been classified drought tolerant but its impacts on lint mass and quality are quite serious. The most common and obvious effects of drought appear in form of decreased cell turgor pressure leading to reduced cell and plant growth. The decreased in photosynthesis due to stomatal closure and reduced leaf area, accelerated shedding of fruiting bodies from competition between vegetative and reproductive parts for carbohydrates are next drought effects following reduced turgor pressure. The nutrient uptake by plant root in drought is decreased which reduced the growth and development. The proportion of yield losses depends on genotypes ability to withstand low water availability, stage and duration of drought. The deep knowledge of plant water relation and consequences of drought is indispensable for improving crop productivity in stressful environment. Some of the physiological processes are affected with onset, while others suffer with projection of drought, however, the end result is reduced yield. The yield losses from limited water supply can be reduced by maintain soil moisture supply through conservation practices and cultivating promising genotypes for drought (Alishah and Ahmadikhah, 2009).

An efficient and effectiveness strategy which clearly shows completely practical and cost-effective to minimize the problem of drought is the development of crop cultivars with the induction of genetic modification

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through breeding and appropriate selection for developing their adopting capability to the drought conditions. Genetic approaches may expedite the breeding of genotypes to survive better in adverse environment. The genotype performance in various environment is of primary importance to breed for desirable traits. The expression of drought tolerance varied among genotypes and phenotypic variations are important tools to identify the promising genotypes for water stressed areas (Bray, 1997). Moreover, characterization can be exploited to have genetic information about agronomic and fibre traits that identify drought resistance using molecular markers. Different stress indices including stress susceptibility index (Fischer and Mourer (1978), stress tolerance index and geometric mean productivity (Rosielle and Hamblin (1981). Therefore, the planned study was conducted to screen out potential drought tolerance varieties through various yield and fibre attributes.

2. <u>MATERIAL AND METHODS</u>

The field study was conducted in central cotton research institute under arid environmental conditions during crop season 2013. The soil was clay loam with alkaline in chemical properties and moderately fertile. The experiment was comprised of 50 genotypes, collected from respective breeding station (Table 1). The genotypes performance was evaluated at two moisture levels. The first treatment was stress free and irrigation was applied at planting and five post planting irrigations with 750 mm. While drought was imposed in second treatment, by applying irrigation at planting and three supplemental irrigations with 300 mm). The treatments were arranged according to Randomized Complete Block in split plot in three replications. The irrigation was kept in main plots and genotypes in sub-plots. The crop was sown on 27th May 2013 by dibbling the seeds on moist beds with 30 cm space in 75 cm apart beds. The plant population was maintained (4.5 m^{-2}) by uprooting weak and disease seedlings at 28 days after planting. The intra-row spaces were covered with polythene sheet in peak rainy season (July-August) to protect soil from expected rains as proposed by Pettigrew (2004). The recommended plant population (57406 ha^{-1}) was maintained by uprooting diseased and weak plant at 30 days after sowing. The crop was fertilized with recommended doses of $N_{150}P_{60}K_{60}$ ha^{-1}. The plant height and number of bolls were averaged across ten randomly selected plants and boll weight was estimated from hundred bolls. The seed cotton yield was recorded at maturity by manual picking of whole plot. The relative reduction in yield (RYR), stress susceptibility index (SSI), stress tolerance (TOL), geometric mean productivity (GMP), yield index (YI) and harmonic mean (HM) was recorded according to following equations

$$\text{RYR (\%)} = 1 - \frac{\text{Ys}}{\text{Yp}}$$

where Ys and Yp represents mean yields in water deficit and well-watered conditions

Stress tolerance (TOL) was equated as

$TOL = Yp - Ys$------------------------Hossain *et al.* (1990)

$SSI = \{1 - Ys/Yns\}/SI$---------------Fischer and Maurer (1978)

While SI is stress intensity, calculated as

$SI = 1 - \bar{Y}_s/\bar{Y}_{ns}$

$YI = {Y_s}/{\bar{Y}_s}$ ----------------------------Gavuzzi *et al.* (1997)

Where Ys is the mean yield of genotypes in stress and $\bar{Y}_s$ is mean yield of all genotypes under stress

$HM = 2(Y_p * Y_s)/(Y_p + Y_s)$------------------------------ Chakherchaman *et al.* (2009)

Where Ys and Yp are means of total yield in stress and non-stress conditions

$GMP = [Y_{ns} * Y_s]^{0.5}$------------------------------------- (Fernández, 1992)

Yns and Ys represents the mean yield of genotype in non-stress and stress condition, respectively.

The lint samples were submitted to fiber testing lab to determine the fiber traits by High Volume Instruments (HVI-900-A) following procedures prescribed by ASTM Committeen (1997). The statistical software MSTAT-C was used to perform ANOVA and LSD test to evaluate the significance of various treatments at 5% probability level.

List of Genotypes and their origin

Sr. No	Genotype	Country
1.	GS-444	Pakistan
2.	Cyto-124	Pakistan
3.	DNH-105	Pakistan
4.	CRIS-533	Pakistan
5.	MPS-27	Pakistan
6.	CIM-506	Pakistan
7.	TH-112/05	Pakistan
8.	PB-896	Pakistan
9.	Sun-02	Pakistan
10.	CIM-573	Pakistan
11.	BH-176	Pakistan
12.	CIM-591	Pakistan
13.	NIA-80	Pakistan
14.	CRIS-510	Pakistan
15.	VH-300	Pakistan
16.	VS-212	Pakistan
17.	MPS-11	Pakistan
18.	DPL-45	USA
19.	NIAB-112	Pakistan
20.	CIM-608	Pakistan
21.	IUB-2011	Pakistan

22.	PB-38	Pakistan
23.	CIM-534	Pakistan
24.	CIM-612	Pakistan
25.	CIM-473	Pakistan
26.	L-229-29-71	USA
27.	B-452	Syria
28.	Stone ville-603	USA
29.	Tree Cotton	USA
30.	BP-52	Pakistan
31.	Cooker-312	USA
32.	RA-31-21	Zaire
33.	MS-64	Pakistan
34.	CIM-84	Pakistan
35.	AC-307	USA
36.	NIAB-78	Pakistan
37.	GH-11-9-75	Pakistan
38.	CIM-86	Pakistan
39.	CIM-43	Pakistan
40.	Karishma	Pakistan
41.	Coker-315	USA
42.	SLH-41	Pakistan
43.	Cyto-62	Pakistan
44.	CRIS-134	Pakistan
45.	CRIS-9	Pakistan
46.	ME-115	Syria
47.	CIM-57	Pakistan
48.	F-14	Pakistan
49.	S-71	Pakistan
50.	CIM-496	Pakistan

3. RESULTS AND DISCUSSION

Morphological traits

The tested genotypes differed significantly for plant height, yield components and seed index in both normal and stressed conditions **(Table 1).** The genotypes ranged 71.7 to 113.7 cm, 10.0 to 28.0, 2.63 to 3.13 (g), 5.2 to 7.8 (g), 22.8 to 75.9 g plant^{-1}, plant height, number of bolls, boll weight, seed index and seed cotton yield, respectively under normal irrigation. While in drought conditions, the plant height, number of bolls, boll weight, seed index and seed cotton yield ranged from 62.0 to 84.3 (cm), 5.3 to 20.0, 2.23 to 2.77 (g), 4.5 to 6.9 (g) and 11.7 to 52.2 g plant^{-1}, respectively. In normal irrigated plots, the maximum plant height was recorded from Cooker-315 and BH-176 with 113.7 and 113.3 cm, respectively. Similarly, the minimum plant height (71.7 cm) was obtained from MPS-27 followed by CIM-506 (73.3 cm), GS-444 (73.67 cm) and Cooker-315 (74.00 cm). The genotypes like B-452 (84.3 cm), ME-15 (84.3 cm) and B-45 (84.3 cm) produced the highest and similar plant height in stress. The genotype MPS-11 and CIM-608 produced highest (28.00) in normal, while BH-176, DPL-45 and Tree cotton produced similar number of bolls (28.00) in stress. The GS-444 (10.00) and MS-64 (10.00) gave the lowest and MPS-11 and CIM-608 produced the highest (28.0) number of bolls in normal. Under drought condition maximum boll numbers were showed by BH-176, DPL-45, Tree cotton, MPS-11 and Cyto-62 with average boll no of 20.00, 20.00, 20.00, 19.67 and 18.67 respectively and the minimum numbers of bolls per plants were recorded for Cooker-315 (5.00), GS-444 (5.00) and MS-64 (5.33). the highest boll weight (3.03 g) in normal irrigated plots was obtained from CIM-573 and MPS-11 produced the maximum (2.77 g) boll weight in stress. The seed index also varied significantly among genotypes being maximum in Cyto-62 (7.8 g) and Karishma (6.9 g) in normal and drought conditions, respectively. The genotype CIM-608 and MPS-11 was the best yield performer for normal and drought conditions. It is clear from results that no single genotype can be regraded best for all recorded observations for both normal and stress conditions which indicates great diversity in yield attributes to be further use for object oriented breeding. The adequate moisture supply is critical for normal growth and development of plants. The plant height was low in moisture deficit conditions because of critical role of water in meristematic activities (Chaves *et al.*2004 and Parolin, 2001). Less number of bolls and boll weight in drought translated to reduced yield in drought. The findings are in agreement with Pettigrew (2004) where less number of bolls have been identified as major cause of low yield in moisture stress.

Qualitative traits

The highest GOT was recorded in CRIS-533 in both normal and drought treatment **(Table 1-3).** the highest staple length in normal (29.4) and stress (28.6) was obtained in Cyto-124. Under normal condition, maximum fibre strength was exhibited by GS-444 (35.2 g tex^{-1}) and NIAB-78 (34.3 g tex^{-1}) and minimum fibre strength was showed by SLH-41 and Tree cotton with average fibre strength of 28.7 g tex^{-1}. In moisture deficient treatment, maximum strength was given by GS-444 (34.2 g tex^{-1}) and minimum strength (27.2g tex^{-1}) was exhibited by SLH-41. In previous work on drought of cotton, McMichael and Quisenberry (1991) and Ullah *et al.*, (2008) exhibited great genetic variation in tested genotypes under control and water stress conditions and thus similar with the present work. In general, GOT, staple strength and micronaire values were positively associated with drought **(Fig 1).** Water stress caused a trend of increased fibre fineness and production of shorter and weaker fiber with reduced micronaire values. Water-deficit stress during secondary wall synthesis or fiber elongation leads to decreased fiber length and maturity, respectively. Fibre strength is most affected during boll development in 25 to 30 days and 3-4 days prior to boll opening (McWilliams, 2004).

Table 1. Genotypes mean values ± SE for agronomic traits of in normal and stress condition

Genotypes	Plant height		No of Bolls		Boll weight		Seed index	
	Normal	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**
GS-444	73.7	62.3±1.45	10.0±0.58	5.0±0.58	2.63±0.07	2.27±0.03	5.4±0.26	4.7±0.09
Cyto-124	91.7±1.67	71.3±0.88	17.3±0.33	12.3±0.33	2.83±0.03	2.27±0.07	6.7±0.03	4.6±0.20
DNH-105	83.3±1.67	72.0±1.15	21.0±1.53	13.0±1.00	2.93±0.03	2.33±0.03	7.3±0.27	4.7±0.12
CRIS-533	81.7±4.41	66.7±0.88	16.0±0.58	9.0±0.58	2.63±0.07	2.23±0.03	6.7±0.09	5.5±0.15
MPS-27	71.7±1.67	65.0±2.52	17.0±0.58	10.0±0.58	2.70±0.06	2.30±0.06	6.2±0.10	5.1±0.18
CIM-506	73.3±0.88	64.0±0.58	16.0±0.58	12.0±1.00	2.77±0.03	2.37±0.03	5.9±0.36	5.5±0.12
TH-112/05	97.0±1.15	62.0±0.58	16.3±0.88	11.0±0.58	2.80±0.15	2.23±0.03	6.4±0.19	5.4±0.22
PB-896	98.3±0.88	65.3±0.88	18.0±1.15	10.3±0.33	2.83±0.12	2.27±0.03	6.8±0.06	5.6±0.13
Sun-02	107.3±1.4	70.3±0.88	16.3±1.45	11.0±0.58	2.67±0.13	2.33±0.03	5.5±0.01	4.6±0.22
CIM-573	106.0±0.5	70.7±1.20	27.0±0.58	15.3±0.88	3.13±0.03	2.40±0.06	5.7±0.10	5.1±0.11
BH-176	113.3±0.8	79.0±0.58	24.7±2.85	20.0±0.58	3.03±0.03	2.63±0.03	5.6±0.10	4.6±0.09
CIM-591	104.3±0.6	75.0±1.15	17.7±1.20	10.0±0.58	2.77±0.03	2.33±0.03	5.4±0.06	4.9±0.04
NIA-80	109.3±1.4	72.3±0.88	21.0±0.58	8.0±0.58	3.00±0.06	2.30±0.00	7.3±0.12	6.3±0.09
CRIS-510	107.3±0.8	69.0±0.58	16.0±0.58	9.7±0.67	2.73±0.07	2.30±0.00	5.2±0.37	4.5±0.14
VH-300	82.7±1.45	67.7±0.67	18.3±0.88	14.3±0.88	2.83±0.03	2.43±0.03	6.0±0.20	5.2±0.16
VS-212	92.0±1.15	65.7±0.67	16.0±0.58	11.0±0.58	2.80±0.06	2.33±0.03	6.0±0.03	5.5±0.10
MPS-11	111.3±0.8	71.7±1.45	28.0±1.15	19.7±0.88	2.80±0.06	2.77±0.03	6.2±0.02	5.4±0.14
DPL-45	112.3±1.4	74.0±2.08	27.0±0.58	20.0±0.58	3.00±0.06	2.70±0.06	6.6±0.01	5.6±0.06
NIAB-112	95.00±1.1	73.3±2.40	11.0±1.53	9.0±0.58	2.67±0.07	2.43±0.13	5.4±0.06	4.8±0.20
CIM-608	93.3±0.88	62.0±0.58	28.0±0.58	13.7±0.33	3.03±0.07	2.37±0.09	7.3±0.33	6.4±0.16
IUB-2011	87.7±1.20	63.0±0.58	20.7±0.33	13.0±0.58	3.00±0.00	2.30±0.10	5.7±0.06	4.7±0.20
PB-38	93.3±0.88	69.3±1.20	24.0±0.58	13.0±0.58	2.97±0.03	2.40±0.06	6.3±0.06	6.0±0.02
CIM-534	89.7±2.40	63.3±0.88	14.0±0.58	10.3±0.88	2.63±0.03	2.33±0.07	7.2±0.03	6.2±0.08
CIM-612	80.7±4.70	62.0±1.15	21.0±1.15	14.3±0.67	2.97±0.03	2.47±0.09	5.3±0.01	4.4±0.17
CIM-473	81.7±0.88	71.0±1.15	25.0±0.58	13.0±0.58	3.03±0.03	2.47±0.03	7.1±0.03	6.4±0.11
L-229-29-71	81.3±0.88	73.3±0.88	16.3±0.88	9.0±0.58	2.87±0.07	2.40±0.06	6.1±0.01	5.2±0.17
B-452	94.7±0.88	84.3±0.88	14.7±0.33	8.0±0.58	2.77±0.03	2.27±0.07	6.6±0.17	4.8±0.06
Stone ville-603	91.3±0.88	83.0±0.58	14.3±0.88	10.0±0.58	2.80±0.06	2.33±0.03	7.6±0.09	6.3±0.05
Tree Cotton	93.7±0.88	83.3±2.03	21.0±0.58	20.0±0.58	3.00±0.06	2.73±0.03	5.2±0.15	4.6±0.04
BP-52	88.7±0.88	77.3±2.19	18.7±0.88	11.0±0.58	2.93±0.03	2.47±0.03	6.6±0.05	5.3±0.03
Cooker-312	113.7±0.8	78.3±0.67	15.0±0.58	10.0±0.58	2.77±0.03	2.37±0.03	6.2±0.05	5.2±0.04
RA-31-21	78.7±0.88	68.3±0.33	14.0±0.58	10.0±0.58	2.73±0.03	2.30±0.12	6.1±0.04	5.7±0.09
MS-64	84.7±0.88	71.7±0.88	10.0±0.58	5.3±0.88	2.80±0.06	2.23±0.03	5.8±0.06	5.3±0.20
CIM-84	108.7±0.8	73.3±0.88	19.0±0.58	11.7±0.33	2.90±0.00	2.27±0.07	6.4±0.04	5.3±0.12
AC-307	94.0±0.58	72.0±0.58	17.7±0.88	9.0±0.58	2.83±0.03	2.30±0.06	5.2±0.28	4.5±0.07
NIAB-78	113.3±0.8	77.0±1.53	13.0±0.58	9.0±0.58	2.77±0.03	2.30±0.06	6.3±0.32	5.0±0.06
GH-11-9-75	109.0±0.5	79.0±0.58	19.0±0.58	12.0±0.58	2.90±0.06	2.50±0.10	4.9±0.01	3.9±0.12
CIM-86	104.0±0.5	79.0±0.58	17.0±1.00	11.3±0.88	2.77±0.03	2.40±0.06	5.8±0.64	4.6±0.25
CIM-43	98.7±0.88	73.7±1.45	18.3±0.33	9.7±1.20	2.93±0.03	2.33±0.03	5.2±0.03	4.9±0.11
Karishma	104.3±0.6	73.3±0.88	15.3±1.76	12.3±0.33	2.70±0.06	2.40±0.06	7.6±0.06	6.9±0.06
Cooker-315	74.0±0.58	64.7±2.33	11.7±0.88	5.0±0.58	2.83±0.03	2.23±0.07	5.7±0.30	5.4±0.23
SLH-41	112.7±1.4	67.0±2.00	18.0±0.58	13.3±0.67	2.90±0.00	2.50±0.06	7.2±0.17	5.1±0.10
Cyto-62	110.0±1.1	71.7±0.88	21.3±2.40	18.7±0.67	2.90±0.06	2.53±0.07	7.8±0.21	6.9±0.09
CRIS-134	91.3±0.88	74.7±0.33	24.7±1.45	18.7±0.88	3.03±0.03	2.70±0.06	6.6±0.33	4.8±0.26
CRIS-9	83.7±0.88	76.7±0.33	21.3±0.88	12.3±1.45	2.93±0.03	2.40±0.06	6.6±0.03	6.0±0.05
ME15	80.0±2.89	84.3±2.85	22.0±0.58	13.0±0.58	3.00±0.06	2.43±0.03	6.5±0.18	6.1±0.08
CIM-57	77.0±6.51	61.7±3.71	21.3±0.88	11.0±0.58	2.97±0.03	2.40±0.10	5.9±0.03	5.1±0.31
F-14	85.0±1.15	70.7±1.20	22.3±1.20	12.0±1.15	2.93±0.07	2.50±0.06	6.1±0.10	5.6±0.07
S-71	82.7±1.45	70.7±0.88	19.0±0.58	12.0±0.58	2.83±0.03	2.33±0.07	6.8±0.04	6.3±0.03
CIM-496	92.3±1.20	77.0±1.73	21.3±0.88	13.0±0.58	2.97±0.03	2.30±0.10	7.3±0.27	6.1±0.07
LSD at 5%	9.4109		5.2032		0.3526		0.9924	

Table 2. Genotypes mean values ± SE for agronomic traits of in normal and stress condition

Genotypes	GOT		Staple length		Staple strength		MIC	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
GS-444	38.0±0.54	40.2±0.35	28.7±0.34	27.7±0.44	35.2±0.23	34.2±0.35	4.1±0.07	4.3±0.09
Cyto-124	38.7±0.56	41.1±0.64	29.4±0.28	28.6±0.15	31.2±0.40	30.7±0.40	3.8±0.06	4.1±0.07
DNH-105	39.±0.19	40.9±0.15	25.6±0.43	24.7±0.24	32.5±0.12	31.6±0.12	4.0±0.12	4.2±0.12
CRIS-533	43.2±0.09	44.3±0.28	25.8±0.51	25.2±0.57	29.2±0.15	28.2±0.20	4.5±0.12	4.8±0.03
MPS-27	39.3±0.18	41.2±0.38	26.4±0.15	25.8±0.03	30.4±0.88	28.1±0.12	4.0±0.09	4.4±0.17
CIM-506	38.6±0.36	40.5±0.42	26.3±0.15	25.8±0.52	29.9±0.98	29.3±0.15	4.8±0.24	5.0±0.15
TH-112/05	40.3±0.10	41.1±0.69	26.1±0.86	25.8±0.21	31.0±1.04	27.7±0.17	4.6±0.15	4.8±0.09
PB-896	38.2±0.12	40.9±0.50	26.6±0.75	26.2±0.07	32.1±0.19	31.1±0.57	4.7±0.12	4.9±0.09
Sun-02	40.3±0.15	41.8±1.03	27.3±0.78	25.5±0.73	31.9±0.35	31.0±0.12	3.7±0.15	4.3±0.15
CIM-573	39.2±0.12	40.0±0.28	28.0±0.12	27.8±0.44	34.2±0.27	32.7±0.32	3.4±0.12	3.8±0.12
BH-176	38.7±0.24	41.0±0.72	26.1±0.20	25.0±0.12	28.7±0.15	28.3±0.83	3.7±0.06	4.2±0.15
CIM-591	40.9±0.44	42.3±0.23	27.2±0.06	26.5±0.75	31.9±0.33	30.8±0.13	3.7±0.15	4.0±0.19
NIA-80	37.5±0.09	38.9±0.32	25.5±0.19	24.4±0.15	28.9±0.06	27.7±0.17	3.8±0.18	4.3±0.17
CRIS-510	39.2±0.09	40.8±0.47	27.2±0.80	25.9±0.43	32.9±0.12	32.5±0.13	4.1±0.09	4.3±0.20
VH-300	37.3±0.15	39.2±0.18	26.9±0.52	25.2±0.57	29.7±0.17	28.3±0.10	4.0±0.12	4.4±0.15
VS-212	40.1±0.17	41.6±0.29	24.9±0.12	24.6±0.21	30.3±0.79	28.4±0.23	4.8±0.12	5.2±0.12
MPS-11	41.5±0.12	41.9±1.72	27.5±0.21	26.7±0.12	32.3±0.20	31.8±0.30	4.0±0.17	5.2±0.19
DPL-45	40.7±0.15	41.8±0.18	26.7±0.19	25.4±0.26	32.7±0.39	31.4±0.75	3.6±0.12	4.2±0.17
NIAB-112	37.4±0.09	38.6±0.10	27.8±0.48	26.3±0.35	31.1±0.32	29.9±0.47	4.0±0.06	4.5±0.12
CIM-608	36.7±0.17	38.1±0.26	25.5±0.13	24.5±0.12	32.6±0.30	29.8±0.39	4.1±0.20	4.6±0.06
IUB-2011	40.6±0.09	42.2±0.34	27.9±0.09	26.3±0.27	30.1±0.32	29.7±0.48	4.5±0.15	5.2±0.15
PB-38	38.4±0.15	41.6±0.64	26.3±0.10	25.2±0.09	30.7±0.79	28.8±0.15	4.0±0.06	4.7±0.15
CIM-534	41.3±0.12	41.7±0.34	25.5±0.19	23.6±0.15	29.1±0.19	28.8±0.56	4.1±0.06	4.3±0.15
CIM-612	40.5±0.12	42.2±0.13	26.3±0.71	26.1±0.20	29.3±0.23	28.8±0.54	4.1±0.06	4.6±0.17
CIM-473	35.3±0.23	39.7±0.53	27.0±0.85	24.6±0.15	32.1±0.35	31.1±0.37	3.8±0.06	4.3±0.17
L-229-29-71	37.7±0.15	39.3±0.19	26.2±0.18	25.0±0.57	32.4±0.35	29.7±0.47	3.5±0.17	4.2±0.12
B-452	36.3±0.17	39.8±0.18	25.4±0.38	23.5±0.30	32.4±0.09	30.0±0.39	3.8±0.12	4.0±0.19
Stone ville-603	36.7±0.00	39.9±0.23	27.1±0.12	25.7±0.27	30.6±0.47	28.0±0.12	4.2±0.15	4.5±0.15
Tree Cotton	35.7±0.20	37.3±0.23	26.4±0.32	25.1±0.24	28.7±0.12	27.7±0.12	3.5±0.07	4.0±0.06
BP-52	35.9±0.36	38.0±0.29	25.7±0.07	24.4±0.20	32.5±0.52	31.2±0.12	3.7±0.09	4.7±0.09
Cooker-312	37.2±0.12	38.8±0.21	26.7±0.15	25.0±0.15	33.2±0.18	32.2±0.17	3.7±0.12	4.1±0.24
RA-31-21	37.8±0.07	39.0±0.28	25.8±0.21	24.4±0.12	29.7±0.09	28.2±0.34	3.6±0.18	4.6±0.10
MS-64	39.0±0.34	40.5±1.07	27.1±0.13	25.8±0.10	30.0±0.29	28.4±0.26	4.4±0.12	4.8±0.06
CIM-84	39.6±0.15	41.2±0.67	27.1±0.15	26.2±0.23	31.7±0.15	30.6±0.45	4.6±0.15	4.8±0.17
AC-307	35.7±0.15	36.7±0.56	26.6±0.17	25.0±0.07	30.8±0.48	29.8±0.19	3.7±0.15	4.0±0.12
NIAB-78	39.8±0.15	41.3±0.61	25.5±0.70	24.7±0.45	34.3±0.50	32.7±0.18	4.2±0.26	4.8±0.20
GH-11-9-75	35.9±0.64	37.4±0.55	27.7±0.30	25.9±0.20	31.3±0.19	30.3±0.18	3.6±0.06	4.2±0.12
CIM-86	39.2±0.09	41.3±0.56	27.0±0.56	25.9±0.42	28.9±0.26	27.7±0.25	3.9±0.15	4.1±0.15
CIM-43	36.5±0.10	38.0±0.32	26.1±0.60	25.0±0.15	31.8±0.15	30.4±0.20	3.5±0.12	4.0±0.12
Karishma	35.±0.24	36.8±0.38	27.8±0.21	26.8±0.18	32.5±0.12	31.5±0.18	3.5±0.09	3.7±0.12
Cooker-315	39.±0.13	41.2±0.18	26.0±0.62	24.9±0.20	29.8±0.37	27.8±0.41	4.1±0.18	4.3±0.13
SLH-41	35.5±0.23	39.5±0.35	26.1±0.17	24.5±0.35	28.7±0.46	27.2±0.17	3.5±0.12	3.8±0.24
Cyto-62	39.8±0.06	41.0±0.77	26.8±0.26	25.8±0.48	31.8±0.15	31.1±0.44	4.1±0.06	4.5±0.12
CRIS-134	37.5±0.06	38.7±0.92	25.8±0.26	24.9±0.58	30.5±0.09	29.3±0.18	4.0±0.19	4.6±0.18
CRIS-9	36.6±0.15	38.6±0.46	25.8±0.24	24.3±0.20	29.1±0.43	29.2±1.14	4.0±0.06	4.8±0.09
ME15	39.±0.12	41.8±0.17	26.9±0.27	24.7±0.32	31.8±0.15	30.7±0.17	4.1±0.13	4.7±0.12
CIM-57	37.3±0.21	38.4±0.75	26.1±0.15	25.1±0.53	31.7±0.28	30.4±0.22	4.2±0.12	4.5±0.15
F-14	37.3±1.29	40.7±0.90	26.3±0.12	25.0±0.22	32.2±0.18	31.1±0.21	4.2±0.12	4.4±0.15
S-71	35.4±0.37	37.3±0.50	26.9±0.33	25.3±0.38	32.4±0.06	30.4±1.29	4.1±0.12	4.6±0.12
CIM-496	36.5±0.30	37.8±0.56	28.0±0.26	26.8±0.09	30.6±0.12	29.0±0.45	4.1±0.15	4.8±0.07
LSD at 5%	2.6668		NS		2.4133		0.8277	

Table 3: Resistance indicators for seed cotton yield of various genotypes in normal and stress conditions

Genotypes	Seed cotton yield		RRY (%)	TOL	STI	HM	YI	GMP	SSI
	Normal	Stress							
GS-444	23.6	11.7	50.4	11.9	0.12	15.6	0.40	16.62	1.27
Cyto-124	45.9	28.5	37.9	17.4	0.56	35.2	0.98	36.17	0.95
DNH-105	57.6	34.6	39.9	23	0.85	43.2	1.19	44.64	1.00
CRIS-533	35.2	22.1	37.2	13.1	0.33	27.2	0.76	27.89	0.94
MPS-27	37.2	22.4	39.8	14.8	0.36	28.0	0.77	28.87	1.00
CIM-506	41	25.5	37.8	15.5	0.45	31.4	0.88	32.33	0.95
TH-112/05	37.7	22.6	40.1	15.1	0.36	28.3	0.78	29.19	1.01
PB-896	37.2	22.1	40.6	15.1	0.35	27.7	0.76	28.67	1.02
Sun-02	42.2	25.2	40.3	17	0.46	31.6	0.87	32.61	1.01
CIM-573	64	37.6	41.3	26.4	1.03	47.4	1.29	49.06	1.04
BH-176	69.6	49.8	28.4	19.8	1.48	58.1	1.71	58.87	0.71
CIM-591	52.4	25.4	51.5	27	0.57	34.2	0.87	36.48	1.29
NIA-80	53.7	21.3	60.3	32.4	0.49	30.5	0.73	33.82	1.52
CRIS-510	44.2	27.3	38.2	16.9	0.52	33.8	0.94	34.74	0.96
VH-300	55.8	32.9	41.0	22.9	0.79	41.4	1.13	42.85	1.03
VS-212	45.9	28.8	37.3	17.1	0.57	35.4	0.99	36.36	0.94
MPS-11	70.3	52.2	25.7	18.1	1.57	59.9	1.79	60.58	0.65
DPL-45	71	51.3	27.7	19.7	1.56	59.6	1.76	60.35	0.70
NIAB-112	32.6	20.8	36.2	11.8	0.29	25.4	0.71	26.04	0.91
CIM-608	75.9	33.6	55.7	42.3	1.09	46.6	1.15	50.50	1.40
IUB-2011	57.7	32.9	43.0	24.8	0.81	41.9	1.13	43.57	1.08
PB-38	44.1	30.2	31.5	13.9	0.57	35.8	1.04	36.49	0.79
CIM-534	37.2	22.6	39.2	14.6	0.36	28.1	0.78	29.00	0.99
CIM-612	57	34.4	39.6	22.6	0.84	42.9	1.18	44.28	1.00
CIM-473	70.6	30.9	56.2	39.7	0.93	43.0	1.06	46.71	1.41
L-229-29-71	42.2	19.9	52.8	22.3	0.36	27.0	0.68	28.98	1.33
B-452	32.4	18.6	42.6	13.8	0.26	23.6	0.64	24.55	1.07
Stone ville-603	35.2	22.1	37.2	13.1	0.33	27.2	0.76	27.89	0.94
Tree Cotton	62.7	49.3	21.4	13.4	1.32	55.2	1.69	55.60	0.54
BP-52	46.8	29.6	36.8	17.2	0.59	36.3	1.02	37.22	0.92
Cooker-312	40.7	24.4	40.0	16.3	0.42	30.5	0.84	31.51	1.01
RA-31-21	37.2	23.1	37.9	14.1	0.37	28.5	0.79	29.31	0.95
MS-64	22.8	13.4	41.2	9.4	0.13	16.9	0.46	17.48	1.04
CIM-84	50.4	30.8	38.9	19.6	0.66	38.2	1.06	39.40	0.98
AC-307	45.9	25.8	43.8	20.1	0.51	33.0	0.89	34.41	1.10
NIAB-78	38.9	25.6	34.2	13.3	0.43	30.9	0.88	31.56	0.86
GH-11-9-75	48.4	26.3	45.7	22.1	0.54	34.1	0.90	35.68	1.15
CIM-86	52.5	29.4	44.0	23.1	0.66	37.7	1.01	39.29	1.11
CIM-43	40.7	25.6	37.1	15.1	0.45	31.4	0.88	32.28	0.93
Karishma	39	28.8	26.2	10.2	0.48	33.1	0.99	33.51	0.66
Cooker-315	25.8	12.3	52.3	13.5	0.14	16.7	0.42	17.81	1.31
SLH-41	48.1	28	41.8	20.1	0.58	35.4	0.96	36.70	1.05
Cyto-62	61.1	44.4	27.3	16.7	1.16	51.4	1.53	52.08	0.69
CRIS-134	68.7	41.9	39.0	26.8	1.23	52.1	1.44	53.65	0.98
CRIS-9	52.9	30.3	42.7	22.6	0.69	38.5	1.04	40.04	1.07
ME15	57.1	33.4	41.5	23.7	0.82	42.1	1.15	43.67	1.04
CIM-57	54.2	33.8	37.6	20.4	0.78	41.6	1.16	42.80	0.95
F-14	55.8	34.3	38.5	21.5	0.82	42.5	1.18	43.75	0.97
S-71	46.5	29.2	37.2	17.3	0.58	35.9	1.00	36.85	0.93
CIM-496	51.5	27.9	45.8	23.6	0.61	36.2	0.96	37.91	1.15

Drought resistance indicators:

The genotypes with high yield in non-stress conditions does not necessarily translate into high yielder under drought. The CIM-608 was high yielder in normal and MPS-11 was the highest yield producers in drought. This indicates that selection under optimum conditions is not efficient. Different stress tolerance indices were used on basis of seed cotton yield in normal and stressed conditions. The highest (42.3) and lowest (9.4) TOL of CIM-608 and MS-64 respectively indicated that CIM-608 is relatively susceptible and MS-64 is tolerant for drought. However, it does not mean that genotype with low TOL is good yield producer under non-stress conditions and it came true for MS-64. SSI is also important for screening for stress and genotypes having SSI value lower than unit are taken as drought resistant (Fischer and Maurer, 1978). Therefore, genotypes characterized with high TOL and SSI would produce higher yield in normal conditions and conversely, the genotypes with smaller TOL and SSI values would produce greater yield under stress conditions (Table 3). The SSI value blew one indicates the stress high tolerance (Choukan *et al.*, 2006) and twenty genotypes were identified with SSI value below unit which actually showed that yield reduction in these twenty-four genotypes is lower than mean yield losses of genotypes in drought. Different researchers (Khalilzade and Karbalai-Khiavi, 2002 and Yarnia *et al.*, 2011) suggested that STI is the most reliable tool to evaluate the tolerance and is valuable to distinguish high yielding genotypes in both stress and stress free environment. The maximum stress tolerance capability was observed for MPS-11 which showed that the genotype can be used for breeding for drought stress. The STI has been better option to evaluate the drought tolerance than SSI and TOL (Behmaram *et al.*, 2006). However, some researchers also suggested that correlation must be development between stress indices and yield of crop for both stress and non-stress conditions to identify the most effective indices for selection (Khalilzade and Karbalai-Khiavi, 2002). The highest yield index (1.79) was achieved from MPS-11 and minimum (0.4) was recorded for GS-444. On overall basis, twenty genotypes exhibited yield index greater than one and others were characterized with low yield index. Normally genotypes with high value of YI are supposed to be better performer under drought (Gavuzzi *et al.*, 1997). The Yp and Ys were negatively association with RRY and SSI and positively associated with GMP, HM and STI **(Table 4).** The results confirmed the findings of (Taghizade *et al.* 2002 and Siahsar *et al.*, 2010) for lentil. STI has been documented as most reliable tool to estimate the stress tolerance but negatively associated with RRY (r=-0.3962) and SSI (r=-0.3965).

Table 4: Correlation coefficient for seed cotton yield and stress tolerance indices in stress and non-stress conditions

	GMP	HM	RRY	SSI	STI	TOL	YI
HM	0.9976						
RRY	-0.3731	-0.4340					
SSI	-0.3738	-0.4348	0.9999				
STI	0.9848	0.9857	-0.3962	-0.3965			
TOL	0.5054	0.4446	0.5823	0.5813	0.4472		
YI	0.9733	0.9866	-0.5680	-0.5685	0.9725	0.2941	
Yp	0.9586	0.9365	-0.1031	-0.1040	0.9282	0.7301	0.8678
Ys	0.9737	0.9868	-0.5660	-0.5666	0.9734	0.2959	1.0000

4 CONCLUSION

The results indicated significant variations for recorded traits and resistance indicators among cotton genotypes in normal and drought conditions. There were strong associations between seed cotton yield in stress and GMP, HM, STI, TOL and YI which supports the hypothesis that such indicators can be used to screen out promising drought tolerance entries.

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