Research Article

Assessment of drought tolerant cotton genotypes based on seedling & physiological attributes at different moisture levels

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Citation

Muhammad Akbar and Sayed Bilal Hussain. Assessment of drought tolerant cotton genotypes based on seedling & physiological attributes at different moisture levels. Pure and Applied Biology. Vol. 8, Issue 1, pp93-107.

<http://dx.doi.org/10.19045/bspab.2018.700167>

Received: 07/07/2018

Revised: 28/09/2018

Accepted: 04/09/2018

Online First: 12/10/2018

Abstract

The potential of any crop variety is subjected to various environmental conditions and a large fraction of the potential yield cannot be attained. For this study, fifty cotton genotypes of different origin were collected from gene pool of Central Cotton Research Institute, Multan and screened in the glass house. These genotypes were also evaluated under the field condition to obtain parents that possess better tolerance against drought. Initial screening of these genotypes was conducted in the glass house under three moisture levels 100, 70 and 40% at field water capacity. Data were recorded for root length, fresh root weight, dry root weight, root shoot length ratio, shoot length; fresh shoot weight, dry shoot weight, fresh root shoot weight ratio and dry root shoot weight ratio in glass house. Five drought tolerant genotypes (BH-176, MPS-11, DPL-45, Tree cotton and Cyto-62) and three susceptible genotypes (GS-444, Cooker-315, MS-64) were identified. Highly significant differences found among genotypes for all seedling characters. Further evaluation was done in field on the basis of various physiological parameters i.e. relative water content, excised leaf water loss, cell injury, leaf water potential, osmotic potential, net photosynthesis rate, transpiration rate and stomatal conductance under normal and water stress conditions. Same genotypes were confirmed under field studies. Highly significant genotypic variation existed among genotypes for all the physiological traits. The predicting genotypes may be selected and exploited to improve drought tolerance for the cotton crop.

Keywords: Cotton; Drought; Physiological traits; Pakistan; Seedling traits; Tolerance

Introduction

Cotton being a miraculous fibre that has a variety of uses, from fashion to home stuff to medical products. Cotton is noted for its versatility, appearance and performance. Cotton moved from field to fabrics as it provides thousands of useful products and supports millions of jobs. It is the key source of lint along with its by-products i.e. cotton

seed oil, cake, hulls, and linters. In the international cotton set-up, Pakistan has the peculiarity in terms of cotton production and area. Cotton is the second most significant crop of our country after wheat, in terms of area, production and value added. Pakistan is the fifth largest producer of cotton all over the globe by producing 2170,000 million tons, the third leading exporter of raw cotton, the

fourth major consumer of cotton (2467,000 million tons), and the prime exporter of cotton yarn [1].

The potential of any crop variety is subjected to various environmental conditions and a large fraction of the potential yield cannot be attained. It is speculated that crop attains less than 25 % of the potential yield due to the adverse environmental conditions, and low water availability affected crop productivity nearly as much as all the other environmental factors combined [2, 3]. Amongst the abiotic stresses, deficiency of soil water constitutes a primary limitation to crop productivity in many regions of the world [4, 5]. Water deficit is not only the cause of differences between actual yield and the potential yield, but it also results in yield instability of crops. Both surface and ground water resources in Pakistan are inadequate to meet the growing requirements for irrigation of agricultural crops. Drought has a very critical effect on growth, yield and quality characters [6]. Limited water supply and high-energy costs can also decrease the yield of irrigated cotton. [7, 8] have focused on root systems to enlarge water use efficiency. Root characteristics can be significant in predicting the response of plants to drought. Drought effect not only decreases plant height, shoot growth rate, and yield but also diminishes root growth. [9] have exhibited that root growth is less sensitive than shoot growth. Development of such genotypes which appears to be practicable, cost-effective and to tackle the problem of water shortage is an alternate way by genetic variation.

It has been found from earlier studies that varieties/cultivars in each species vary from one another in their actions under drought conditions, signifying that drought tolerance in these groups can be improved through breeding. Physiological traits linked with drought tolerance in cotton have strong relationship with yield parameters. For example, photosynthetic rate; which

significantly decreases with the imposition of water stress, can be effectively used for germplasm screening under drought conditions [10, 11]. Since, the response of germplasm with genetic variability may exhibit differential response under normal and water deficit conditions, regular screening of emerging germplasm need to be carried out for better adaptability and sustainable production.

This study will help to understand the relationship of different seedling and physiological traits of cotton and their direct and indirect effects. The following studies were, therefore, to evaluate advanced cotton genotypes for drought tolerance characteristics under field conditions.

Materials and methods

Screening of cotton genotypes in glass house

Initial screening was conducted in glasshouse under three moisture levels 100%, 70% and 40% at field water capacity. Seeds of all 50 accessions were collected from the available stock at Central Cotton Research Institute, Multan. Seeds of accessions were planted during November, 2012 in polythene bags. Four hundred and fifty polythene bags with three repeats using completely randomized design were divided into three sets. One set was treated as control (T_0) 100% and the other two as water stressed conditions 70% (T_1) and 40% field capacity (T_2).

Seedlings grown under control condition with 100% water level (T_0) were watered daily to keep the soil at field capacity. Water stress condition was developed by withholding water supply to the seedlings grown under water stress condition at two water level of 70% (T_1) & 40% (T_2), and the effect of water stress was monitored visually and with soil moisture meter (HH2 Theta Probe Type, Delta-T device, Cambridge, England).

The data for each accession were recorded after 45 days of emergence. Plants were

removed from the pots and gently washed to remove all sand. The plants were spread on paper for the measurement of fresh root length (g) and shoot length (cm). Plants were cut into roots and shoots, and fresh root weight (g) and fresh shoot weight (g) were calculated. Then roots and shoots dried for 72h at 60°C. Genotypes were evaluated for root length, fresh root weight, dry root weight, root shoot length ratio, shoot length, fresh shoot weight, dry shoot weight, fresh root weight, fresh shoot weight ratio and dry root shoot weight ratio.

Screening of cotton genotypes in field condition

Fifty cotton genotypes were screened under two irrigation levels i.e., well watered (T_0) and water-limited (T_1) in the field. The experimental design was Randomized Complete Block (RCBD) with three replications. Seeds of the genotypes were planted by maintaining 75 x 30cm row to row and plant to plant distance respectively. In order to avoid the rainfall effect, soil between the rows was covered with polythene sheet during the rainy period i.e. July-August as done by [12]. Data of relative water content, excised leaf water loss, cell injury, leaf water potential, osmotic potential, net photosynthesis rate, transpiration rate and stomatal conductance were recorded.

Statistical analysis

The average data of all the seedling traits were subjected to statistical analysis. The least significance difference (LSD) was calculated at probability of 0.05%. Software packages of SPSS version 19 was used for data analysis [13].

Results and discussion

Response of cotton genotypes in glass house

Variations were significant among all parameters for 50 genotypes (Table 1) under both stress levels suggested that root and shoot parameters as reliable traits for screening cotton germplasm for moisture

stress. Genetic variation in 50 genotypes under drought and controlled conditions suggested the importance of root and shoot parameters in breeding programs [14, 15].

Highly significant differences were also noted in respect of genotypes (G), replication (R) as well as interaction of genotypes with replications ($G \times R$). Stress produced a range of responses on the seedling traits measured. The presence of variability among genotypes for different traits under water stressed conditions has been reported [16, 17]. It is evident from the findings that the mean squares between all the accessions for all the seedling traits were highly significant under normal and moisture stress conditions ($P \leq 0.01$).

Root parameters

Results exhibited from (Table 2) that mean for all the root parameters under controlled were ranged from 6.77cm for (MS-64) to 13.97 cm for DPL-45. On the average basis DPL-45 had maximum root length (11.56cm) followed by BH-176 (11.42cm), Tree cotton (11.33cm) and MPS-11 (10.72cm). These genotypes performed better in all the conditions and these are considered as drought tolerant genotypes while entries GS-444 showed minimum root length following MS-64, Coker-315 and CIM-84 with root length of 4.8, 4.99, 5.4 and 5.6cm respectively. Due to drastic reduction in root length in stressed condition, these accessions may be rated as susceptible to water stress. [18] reported in his findings that in cotton, root length was increased in mild and initial-stage drought stress, but long-time reduced the root length as compared to control plants. On overall mean performance for fresh root weight, Tree cotton, F-14, GH-11-9-75 and MPS-11 had maximum mean values of 0.394, 0.387, 0.380 and 0.374g respectively while minimum fresh root weight was predicted by VS-212 (0.222g), Cooker-315 (0.224g), CIM-608 (0.226g) and GS-444 (0.230g). Root length-shoot length ratio

under controlled and stressed conditions was maximum in F-14 followed by DPL-45, Cyto-62 and BH-176 with 0.910, 0.810, 0.794 and 0.778 respectively. These findings were very similar to [19]. [20] Reported that accessions may be rated as susceptible due to reduction in root lengths in stressed condition. Minimum ratio was exhibited by CRIS-533 (0.404), Stoneville-603 (0.436), CIM-84 (0.444) and VS-212 (0.457). [21, 22] also reported that root related parameters in cotton are directly associated with drought tolerance.

Shoot parameters

For drought tolerance, shoot length has been used as a selection parameter [23, 24]. Under 100% moisture levels (Table 3) shoot length ranged from 12.07cm (MS-64) to 19.67 cm (VS-212) similarly at 70% and 40% moisture levels its range was 9.6-15.8 and 4.07-11.50cm respectively. Data on mean performance of shoot length exhibited that maximum shoot length was found in MPS-11, Tree cotton, BH-176 and VS-212, with values of 15.0, 14.9 and 14.9cm respectively and these entries were less affected by moisture stress revealing that these are tolerant as compared to remaining entries. Minimum shoot length was shown by MS-64 (7.87cm), GS-444(8.0cm), F-14 (9.29cm) and Cooker-315 (9.66cm). [25] Exhibited that shoot length can be used as selection criteria for drought tolerance.

On overall performance under normal and stress conditions, shoot weight mean values showed that Cyto-62 and BH-176 were the most tolerant entries showing better performance with maximum shoot weight of 1.91 and 1.82g respectively. The genotypes GS-444, L-229-29-71 and Cooker-315 had minimum fresh shoot weight of 0.93, 0.97 and 1.03g respectively.

In cotton, shoot dry weight is commonly used as a parameter for screening cotton genotypes against drought stress. Under normal condition; minimum dry shoot weight was

exhibited by GS-444, Coker-315 and MS-64 with an average value of 0.28, 0.27 and 0.27g respectively. Minimum values for shoot weight at both stress levels were shown by the genotypes Cooker-315(0.19), MS-64(0.189) and GS-444(0.151g) respectively at 70% moisture level. While under 40% moisture level it was found as 0.109, 0.107, 0.103g and at mean of three levels it was observed as 0.192, 0.189, 0.178g respectively (Table 3).

Based on root and shoot weight ratio; all accessions again appeared to respond differently both under normal and stressed conditions. On average based performance, under controlled and stress conditions maximum ratio was exhibited by the genotype L-229-29-71 followed by CRIS-9, F-14 and BP-52 with mean ratio of 0.91, 0.338, 0.327, 0.297 and 0.296 respectively. Minimum ratio was exhibited by NIAB-112, VS-212, CIM-84 and CIM-608 with values of 0.155 0.139, 0.145, 0.151 respectively.

Entries performed better under stress condition exhibited low dry root dry shoot weight ratio as the stress level increased. Under 40% moisture level; entries i.e. Cooker-315 (0.322) and MS-64 (0.300) with poor performance under maximum stress showed maximum ratio while minimum ratio was observed for BH-176 followed by Cyto-62, DPL-45, MPS-11 and Tree cotton with ratios of 0.123, 0.132, 0.133, 0.134 and 0.141 respectively. It was concluded that diminution in performance for root and shoot parameters is due to the shortage of water supply and was also reported in the study of [20, 26].

Response of cotton genotypes under field condition

Drought stress causes a wide range of adverse effects on physiological traits as well as productivity of cotton crop. Under drought conditions specifically in cotton leaves, net photosynthetic rate, transpiration rate, stomatal conductance, carboxylation

efficiency and water potential decreased significantly [27].

The data obtained for all physiological traits under normal and stress conditions were subjected to pooled analysis of variance. Analysis of variance showed highly significant differences ($P \leq 0.01$) among cotton genotypes (Table 4). Genotype x environment interaction was also found highly significant for all the traits.

Relative water content (RWC).

In cotton plants reduction of water loss through leaves is an important phenomenon under drought stress. Wilting and rolling of leaves result in water loss [28] Relative Water Content was reduced remarkably under stress condition. Maximum RWC was found in CIM-591 followed by BH-176, MPS-11, Cyto-62 and DPL-45 with average values of 83.00, 81.00, 80.67, 80.33 and 80.33 respectively under controlled condition (Table 5). While, minimum RWC was exhibited by MS-64 (44.0), Cooker-315 (45.3) and GS-444 (63.3). Maximum value was shown by MPS-11 (59.33), BH-176 (58.67), Karishma (54.67) and DPL-45 (54.33) while entries with lowest values of relative water content were GS-444, CRIS-510 and Cooker-315 with average value of 32.33, 34.67 and 40.08 respectively in drought. On basis of grand mean obtained from normal and drought condition RWC was 42.33 to 70.00. Our results were very similar to [29, 30] who reported that relative water content and water potential reduction occur when leaves are subjected to drought condition

Excised leaf water loss (ELWL).

Excised leaf water loss had been widely used in various crops plants as a selection parameter under drought condition [31, 32]. Minimum excised leaf water loss was exhibited by GS-444 (0.53) and B-452, Cooker-315 (0.57). Maximum value was found in BH-176 (1.47), Cyto-62, Tree cotton, MPS-11 (1.20), and Stoneville (1.10)

while entries with lowest values of excised leaf water loss were MS-64, Cooker-315, Cooker-312, and GS-444 with average value of 0.23, 0.33, 0.37, and 0.43 respectively under drought condition. While at controlled condition, maximum excised leaf water loss was observed in BH-176 followed by Cyto-62, Tree cotton, MPS-11, and DPL-45 with average value of 2.03, 2.00, 1.97, 1.93 and 1.87 respectively. On the basis of grand mean obtained from normal and drought conditions, excised leaf water loss range was 0.43-1.75 (Table 5).

Cell injury

Relative cell injury has been considered as a reliable parameter for screening against abiotic stress tolerance [33, 34]. Cell injury was also reduced remarkably in stress condition. Minimum cell injury was exhibited by BH-176, DPL-45 Tree cotton, CIM-608 and Cyto-62 with an average values of 21.1, 21.47, 22.03, 22.07 and 22.27 respectively. Under drought condition; maximum value was shown by MS-64 (67.10), GS-444 (66.07), and Cooker-315(65.5) while entries with lowest values of cell injury were Tree cotton (31.60), Cyto-62(36.57). DPL-45 (36.63), MPS-11 (38.07) and BH-176 (39.30). Under controlled condition, maximum cell injury was shown by MS-64 followed by Sun-02, and GS-444 with an average values of 42.57, 38.87 and 38.37 respectively (Table 5). On the basis of grand mean obtained from normal and conditions cell injury range was 26.82 to 54.83.

Leaf water potential

Under controlled condition, maximum leaf water potential was found in Tree cotton (-17.00), Stoneville-603(-17.00), BH-176 (-20), DNH-105 (-20.33), Cyto-62(-18.00) and GS-444 with value of (-21.00) (Table 5). Similarly, minimum leaf water potential was exhibited by Cooker-315 (-29.33), MS-64 (-27.33) and GS-444, (-27.00). Under drought condition, maximum value was

shown by Tree cotton (-21.00), BH-176(-22.00), Cyto-62 (-22.33), Stoneville-603 (-22.33) and MPS-11 (-22.67). While Cooker-315, MS-64, NIAB-78 and GS-444 had lowest values of leaf water potential (-31.67), (-30.33), (-30.33), (-31.00). On the basis of grand mean, leaf water potential range was -30.5 -20.50.

Osmotic potential

Under drought condition, negative effects have been observed on osmotic balance therefore, plants tend to accumulate different organic and inorganic molecules to reduce the osmotic potential [29]. Osmotic potential was also markedly reduced in stress condition. Under controlled condition; maximum value was shown by BH-176(-0.141), DPL-45 (-0.141), Tree cotton (-0.144), MPS-11 (-0.145) and Cyto-62(-0.153), while entries with lowest values of osmotic potential included PB-38 (-0.270), MS-64(-0.269) and IUB-2011(-0.269) (Table 6). Under drought condition, maximum osmotic potential was shown by BH-176 followed by Cyto-62, MPS-11, DPL-45 and BP-52 with average value of -0.188, -0.242, -0.254, -0.254, and -0.256 respectively. Similarly, minimum osmotic potential was exhibited by cooker-315 (-0.380), MS-64(-0.365) and CIM-43 (-0.355). On the basis of grand mean obtained from normal and drought condition osmotic potential range was -0.324 to -0.165.

Gas exchange parameters

Net photosynthetic rate (P_N), stomatal conductance (g_s) and transpiration rate (E) of 50 cotton genotypes were measured under normal (Table 6) and stress conditions (Table 6). Water deficit induced substantial reduction in (P_N) compared to the normal condition [35]. Reduction in P_N was apparent in genotypes GS-44 (11.10 m mol CO₂ m⁻²s⁻¹) and Cooker-315 (11.13 m mol CO₂ m⁻²s⁻¹) under drought. However, water deficit caused less reduction for P_N in DPL-45, MPS-11, Cyto-62 and Tree cotton with average value

of 13.02, 13.00, 12.96 and 12.94 m mol CO₂ m⁻²s⁻¹ respectively. On the basis of grand mean obtained from normal and drought conditions, P_N range was 13.08-14.9 μ mol/m²/s. Photosynthesis was affected under drought condition which is predicted in findings of [36, 37]. These studies revealed that under drought condition photo synthesis was reduced in cotton which in turn affects growth and yield.

Ninety per cent of water losses (transpiration) from plants occur through stomata openings under drought; stomatal conductance (g_s) was maximum in the entries (MPS-11 (25.61 mmol CO₂ m⁻²s⁻¹), BH-176 (25.52 mmol CO₂ m⁻²s⁻¹), DPL-45 (25.05 mmol CO₂ m⁻²s⁻¹) and Tree cotton (25.36 mmol CO₂ m⁻²s⁻¹) revealing that under stress condition these entries were performing better while minimum g_s was exhibited by GS-444 and MS-64 with g_s of 21.63 mmol CO₂ m⁻²s⁻¹ and 21.69 μ mol/m²s revealing that these were badly affected by stress [29]. The genotypes BH-176, Cyto-62, MPS-11, Tree cotton and DPL-45 had the highest stomatal conductance where as g_s was lowest in CIM-84 (30.61 mmol CO₂ m⁻²s⁻¹), MS-64 (31.28 mmol CO₂ m⁻²s⁻¹), GS-444 (31.45 mmol CO₂ m⁻²s⁻¹) and cooker-315 (32.07 mmol CO₂ m⁻²s⁻¹) in controlled condition.

Drought stress caused drastic reduction in transpiration rate, genotypes with an average decline of 45%. Again, genotype BH-176, MPS-11, DPL-45 and Tree cotton also showed higher values for E under controlled condition while entries GS-444, MS-64 and Cooker-315 exhibited minimum E under normal condition. When stress was applied, same entries DPL-45, BH-176, Tree cotton, MPS-11 and Cyto-62 performed better in spite of stress revealing their tolerance to drought while entries with minimum value were MS-64, Cooker-315 and GS-444 revealing their susceptible behavior for drought.

Table 1. Mean square for seedling traits of 50 *Gossypium hirsutum* L. accessions measured under control and water stressed conditions

SOV	DF	RL	FRW	DRW	SL	SW	DSW	RL:SL	FRW:FSW	DRW:DSW
REP	2	867.602	1.22450	0.01156	2743.20	29.1753	1.81619	0.094410	0.031554	0.1434173
GENO	49	21.953	0.01856	1.215E-04	26.79	0.4460	0.02758	0.106597	0.017796	0.0048114
ERROR	300	0.106	0.00033	2.142E-06	0.20	0.0040	0.00066	0.001370	0.000321	0.0003783

SOV, Source of variation; Df, degree of freedom; SL, shoot length; RL, root length; SL/RL ratio, ratio of shoot to root length; RW, root weight; SW, shoot weight; SW/RW ratio, ratio between shoot and root weight; DRW/DSW ratio, dry root weight dry shoot weight ratio

Table 2. Mean values of 50 *Gossypium hirsutum* L. accessions for Root parameters grown in control and water stress conditions

Genotypes	RL				FRW				Root Shoot Length ratio			
	100	70	40	M. Value	100	70	40	M. Value	100	70	40	M. Value
GS-444	7.30	4.40	2.80	4.83	0.333	0.203	0.155	0.230	0.591	0.589	0.675	0.618
Cyto-124	8.43	6.20	4.93	6.52	0.386	0.275	0.241	0.301	0.548	0.511	0.617	0.558
DNH-105	9.00	6.43	4.13	6.52	0.377	0.285	0.241	0.301	0.518	0.481	0.399	0.466
CRIS-533	7.87	5.47	4.07	5.8	0.373	0.262	0.213	0.283	0.432	0.381	0.399	0.404
MPS-27	8.70	6.53	5.17	6.8	0.389	0.287	0.208	0.295	0.575	0.567	0.587	0.576
CIM-506	8.53	5.80	4.70	6.34	0.347	0.275	0.215	0.279	0.586	0.537	0.553	0.559
TH-112/05	9.43	6.47	3.87	6.59	0.401	0.311	0.219	0.310	0.536	0.510	0.455	0.500
PB-896	10.50	7.40	4.73	7.54	0.409	0.301	0.266	0.325	0.575	0.600	0.585	0.586
Sun-02	10.13	7.20	3.93	7.09	0.425	0.319	0.268	0.338	0.519	0.492	0.409	0.474
CIM-573	11.47	8.17	5.40	8.34	0.452	0.295	0.175	0.307	0.666	0.646	0.724	0.679
BH-176	13.70	11.63	8.93	11.42	0.465	0.320	0.271	0.352	0.731	0.742	0.860	0.778
CIM-591	9.40	6.50	4.37	6.76	0.315	0.222	0.205	0.247	0.556	0.551	0.555	0.554
NIA-80	10.30	6.80	4.80	7.3	0.359	0.283	0.242	0.295	0.634	0.665	0.735	0.678
CRIS-510	9.50	5.97	4.23	6.57	0.345	0.260	0.208	0.271	0.576	0.487	0.510	0.524
VH-300	8.90	6.80	5.00	6.9	0.318	0.245	0.214	0.259	0.476	0.457	0.531	0.488
VS-212	8.63	6.20	5.10	6.64	0.279	0.219	0.169	0.222	0.439	0.407	0.524	0.457

MPS-11	12.87	10.70	8.60	10.72	0.489	0.350	0.282	0.374	0.682	0.677	0.820	0.726
DPL-45	13.97	11.70	9.00	11.56	0.469	0.325	0.244	0.346	0.760	0.786	0.882	0.810
NIAB-112	10.37	7.90	5.50	7.92	0.289	0.219	0.189	0.232	0.597	0.738	0.764	0.700
CIM-608	8.17	6.10	4.27	6.18	0.295	0.221	0.163	0.226	0.498	0.519	0.615	0.544
IUB-2011	8.70	6.70	4.00	6.47	0.367	0.236	0.218	0.274	0.557	0.691	0.586	0.611
PB-38	10.27	7.40	4.87	7.51	0.443	0.268	0.217	0.309	0.613	0.714	0.669	0.665
CIM-534	9.60	6.10	5.10	6.93	0.318	0.248	0.190	0.252	0.586	0.528	0.680	0.598
CIM-612	10.13	6.37	4.30	6.93	0.439	0.264	0.253	0.319	0.649	0.601	0.580	0.610
CIM-473	10.40	6.70	4.20	7.1	0.418	0.302	0.228	0.316	0.672	0.679	0.577	0.643
L-229-29-71	9.50	7.47	5.93	7.63	0.416	0.337	0.211	0.322	0.625	0.728	0.886	0.746
B-452	7.80	6.00	4.40	6.07	0.468	0.318	0.250	0.346	0.487	0.489	0.564	0.513
Stone ville-603	8.57	5.93	3.43	5.98	0.404	0.301	0.220	0.308	0.456	0.459	0.392	0.436
Tree Cotton	13.40	11.40	9.20	11.33	0.536	0.347	0.299	0.394	0.727	0.764	0.800	0.764
BP-52	9.67	6.70	4.80	7.06	0.465	0.307	0.289	0.353	0.684	0.705	0.663	0.684
Cooker-312	9.87	7.47	5.37	7.57	0.337	0.255	0.195	0.262	0.599	0.719	0.661	0.660
RA-31-21	10.13	7.43	4.57	7.38	0.434	0.302	0.260	0.332	0.703	0.849	0.703	0.751
MS-64	6.77	5.03	3.17	4.99	0.364	0.250	0.177	0.264	0.561	0.674	0.781	0.672
CIM-84	7.43	5.43	3.93	5.6	0.294	0.227	0.205	0.242	0.424	0.437	0.472	0.444
AC-307	12.43	9.70	6.50	9.54	0.465	0.322	0.271	0.353	0.679	0.659	0.753	0.697
NIAB-78	10.10	6.80	5.90	7.6	0.351	0.278	0.228	0.286	0.650	0.619	0.820	0.696
GH-11-9-75	9.80	7.43	5.80	7.68	0.516	0.358	0.267	0.380	0.632	0.713	0.777	0.708
CIM-86	9.00	6.20	4.50	6.57	0.488	0.356	0.219	0.354	0.552	0.518	0.538	0.536
CIM-43	11.23	8.50	5.80	8.51	0.435	0.316	0.183	0.311	0.723	0.753	0.746	0.741
Karishma	9.03	6.70	5.03	6.92	0.355	0.264	0.219	0.279	0.597	0.698	0.694	0.663

Cooker-315	8.10	5.10	3.07	5.42	0.300	0.219	0.152	0.224	0.538	0.574	0.615	0.576
SLH-41	10.77	6.77	4.87	7.47	0.454	0.350	0.266	0.357	0.648	0.577	0.569	0.598
Cyto-62	13.07	10.80	7.90	10.59	0.476	0.360	0.231	0.356	0.766	0.748	0.868	0.794
CRIS-134	9.77	6.17	4.23	6.72	0.322	0.283	0.197	0.268	0.662	0.642	0.538	0.614
CRIS-9	10.43	7.87	6.00	8.1	0.400	0.310	0.278	0.329	0.591	0.587	0.657	0.612
ME15	11.37	8.70	7.27	9.11	0.468	0.275	0.178	0.307	0.601	0.596	0.982	0.726
CIM-57	10.40	7.20	4.27	7.29	0.447	0.232	0.160	0.280	0.720	0.683	0.569	0.657
F-14	10.17	7.40	6.33	7.97	0.521	0.348	0.293	0.387	0.738	0.884	1.106	0.910
S-71	11.20	8.20	5.00	8.13	0.439	0.250	0.170	0.286	0.627	0.712	0.656	0.665
CIM-496	12.40	8.50	5.63	8.84	0.431	0.329	0.272	0.344	0.6946	0.642	0.600	0.645

Table 3. Mean values of 50 *Gossypium hirsutum* L. accessions for shoot parameters grown in control and water stress conditions

Genotypes	SL				SW				DSW				RW:SW				DRW:DSW			
	100	70	40	M. Value	100	70	40	M. Value	100	70	40	M. Value	100	70	40	M. Value	100	70	40	M. Value
GS-444	12.37	7.47	4.17	8.00	1.37	0.85	0.57	0.93	0.280	0.151	0.103	0.178	0.243	0.238	0.273	0.251	0.168	0.211	0.222	0.201
Cyto-124	15.40	12.13	8.00	11.84	1.81	1.62	1.22	1.55	0.394	0.299	0.175	0.289	0.213	0.169	0.222	0.202	0.148	0.148	0.202	0.166
DNH-105	17.37	13.40	10.37	13.71	2.24	1.73	1.35	1.77	0.493	0.320	0.183	0.332	0.168	0.165	0.179	0.171	0.116	0.138	0.249	0.168
CRIS-533	18.23	14.37	10.20	14.27	1.84	1.43	1.22	1.50	0.484	0.314	0.193	0.330	0.203	0.183	0.175	0.187	0.117	0.134	0.209	0.154
MPS-27	15.13	11.53	8.80	11.82	1.74	1.26	1.15	1.38	0.382	0.225	0.189	0.265	0.224	0.228	0.180	0.211	0.150	0.191	0.174	0.172
CIM-506	14.57	10.80	8.50	11.29	1.91	1.45	0.91	1.42	0.455	0.298	0.202	0.318	0.182	0.190	0.237	0.203	0.126	0.140	0.186	0.151
TH-112/05	17.63	12.67	8.50	12.93	1.82	1.35	0.99	1.39	0.489	0.295	0.181	0.322	0.221	0.231	0.221	0.224	0.113	0.136	0.201	0.150
PB-896	18.27	12.37	8.10	12.91	1.65	1.13	0.99	1.26	0.391	0.214	0.165	0.257	0.248	0.266	0.272	0.262	0.137	0.195	0.206	0.179
Sun-02	19.57	14.63	9.63	14.61	2.13	1.39	0.86	1.46	0.454	0.306	0.198	0.319	0.199	0.230	0.314	0.248	0.130	0.154	0.202	0.162
CIM-573	17.23	12.67	7.47	12.46	1.76	1.43	1.16	1.45	0.425	0.291	0.215	0.310	0.257	0.206	0.151	0.205	0.120	0.141	0.160	0.140
BH-176	18.73	15.70	10.40	14.94	2.24	1.72	1.48	1.82	0.574	0.398	0.332	0.435	0.207	0.186	0.183	0.192	0.104	0.126	0.123	0.118
CIM-591	16.93	11.80	7.83	12.20	1.44	1.02	0.80	1.09	0.375	0.250	0.203	0.276	0.219	0.219	0.257	0.232	0.151	0.189	0.198	0.179
NIA-80	16.23	10.23	6.53	11.00	1.66	1.25	0.88	1.26	0.370	0.250	0.200	0.273	0.216	0.227	0.275	0.240	0.136	0.169	0.183	0.163
CRIS-510	16.50	12.27	8.30	12.36	1.73	1.39	0.91	1.34	0.437	0.306	0.170	0.304	0.199	0.187	0.230	0.205	0.135	0.148	0.239	0.174
VH-300	18.70	14.93	9.43	14.36	2.04	1.46	0.85	1.45	0.453	0.284	0.208	0.315	0.156	0.168	0.253	0.192	0.124	0.158	0.194	0.159
VS-212	19.67	15.27	9.73	14.89	2.11	1.65	0.99	1.58	0.472	0.310	0.240	0.341	0.132	0.133	0.171	0.145	0.115	0.139	0.168	0.141
MPS-11	18.90	15.80	10.50	15.07	1.75	1.83	1.28	1.62	0.562	0.391	0.328	0.427	0.279	0.192	0.220	0.230	0.105	0.123	0.134	0.121
DPL-45	18.37	14.90	10.20	14.49	2.24	1.77	1.27	1.76	0.562	0.383	0.338	0.427	0.209	0.184	0.192	0.195	0.113	0.127	0.133	0.124
NIAB-112	17.37	10.70	7.20	11.76	2.24	1.75	1.17	1.72	0.474	0.315	0.250	0.346	0.129	0.125	0.162	0.139	0.115	0.141	0.155	0.137
CIM-608	16.40	11.77	6.97	11.71	2.12	1.67	0.85	1.54	0.420	0.310	0.207	0.312	0.139	0.133	0.194	0.155	0.119	0.137	0.158	0.138
IUB-2011	15.67	9.70	6.83	10.73	1.85	1.23	0.79	1.29	0.438	0.320	0.212	0.323	0.199	0.192	0.277	0.223	0.131	0.146	0.190	0.155

PB-38	16.77	10.37	7.30	11.48	1.57	1.15	0.82	1.18	0.388	0.206	0.168	0.254	0.281	0.233	0.264	0.260	0.127	0.195	0.203	0.175
CIM-534	16.40	11.60	7.50	11.83	2.04	1.35	0.86	1.42	0.447	0.233	0.198	0.293	0.156	0.183	0.222	0.187	0.117	0.169	0.182	0.156
CIM-612	15.60	10.60	7.43	11.21	1.77	1.14	0.86	1.25	0.334	0.251	0.196	0.260	0.249	0.232	0.296	0.259	0.153	0.155	0.183	0.163
CIM-473	15.50	9.87	7.30	10.89	1.54	1.07	0.75	1.12	0.322	0.260	0.170	0.251	0.272	0.283	0.306	0.287	0.158	0.154	0.225	0.179
L-229-29-71	15.20	10.27	6.70	10.72	1.34	0.92	0.63	0.97	0.347	0.210	0.175	0.244	0.310	0.370	0.334	0.338	0.159	0.202	0.189	0.183
B-452	16.07	12.27	7.80	12.04	1.83	1.70	0.93	1.49	0.459	0.292	0.194	0.315	0.256	0.187	0.270	0.238	0.127	0.159	0.164	0.150
Stone ville-603	18.80	12.93	8.77	13.50	1.93	1.23	0.62	1.26	0.444	0.245	0.190	0.293	0.209	0.244	0.358	0.271	0.127	0.186	0.226	0.180
Tree Cotton	18.43	14.93	11.50	14.96	2.24	1.64	1.13	1.67	0.553	0.376	0.351	0.426	0.240	0.212	0.266	0.239	0.113	0.132	0.141	0.128
BP-52	14.13	9.53	7.23	10.30	1.66	1.16	0.84	1.22	0.387	0.250	0.204	0.280	0.280	0.266	0.343	0.296	0.144	0.188	0.214	0.182
Cooker-312	16.47	10.40	8.13	11.67	1.68	1.17	0.85	1.24	0.395	0.257	0.182	0.278	0.200	0.218	0.229	0.216	0.147	0.186	0.234	0.189
RA-31-21	14.43	8.77	6.50	9.90	1.76	1.22	0.84	1.28	0.346	0.250	0.213	0.269	0.247	0.249	0.309	0.268	0.173	0.191	0.200	0.188
MS-64	12.07	7.47	4.07	7.87	1.46	1.13	0.85	1.14	0.273	0.189	0.107	0.189	0.250	0.222	0.210	0.227	0.177	0.205	0.300	0.227
CIM-84	17.57	12.47	8.33	12.79	2.14	1.66	1.15	1.65	0.416	0.287	0.170	0.291	0.137	0.137	0.178	0.151	0.117	0.138	0.240	0.165
AC-307	18.30	14.73	8.63	13.89	2.26	1.78	1.23	1.76	0.460	0.270	0.195	0.308	0.206	0.181	0.221	0.203	0.126	0.153	0.193	0.157
NIAB-78	15.53	11.00	7.20	11.24	1.94	1.35	0.96	1.42	0.405	0.260	0.166	0.277	0.181	0.206	0.237	0.208	0.141	0.162	0.233	0.179
GH-11-9-75	15.50	10.43	7.50	11.14	1.74	1.25	0.96	1.32	0.374	0.235	0.193	0.268	0.296	0.287	0.280	0.288	0.152	0.179	0.186	0.172
CIM-86	16.30	11.97	8.37	12.21	1.94	1.39	0.85	1.39	0.445	0.281	0.211	0.312	0.252	0.257	0.258	0.256	0.132	0.164	0.194	0.163
CIM-43	15.53	11.30	7.80	11.54	1.78	1.34	1.18	1.43	0.348	0.290	0.193	0.277	0.245	0.237	0.156	0.213	0.153	0.145	0.179	0.159
Karishma	15.13	9.60	7.27	10.67	1.74	1.15	0.95	1.28	0.342	0.262	0.214	0.273	0.204	0.230	0.230	0.221	0.147	0.163	0.171	0.160
Cooker-315	15.07	8.90	5.00	9.66	1.52	0.92	0.66	1.03	0.277	0.190	0.109	0.192	0.197	0.239	0.230	0.222	0.175	0.205	0.322	0.234
SLH-41	16.63	11.73	8.57	12.31	1.84	1.35	0.75	1.31	0.358	0.325	0.175	0.286	0.247	0.259	0.357	0.288	0.158	0.135	0.236	0.177
Cyto-62	17.10	14.43	9.10	13.54	2.22	1.86	1.65	1.91	0.552	0.390	0.350	0.431	0.214	0.194	0.140	0.183	0.113	0.126	0.132	0.124
CRIS-134	14.77	9.60	7.87	10.74	1.62	1.24	0.84	1.23	0.405	0.292	0.206	0.301	0.199	0.233	0.235	0.222	0.126	0.141	0.190	0.152
CRIS-9	17.67	13.40	9.13	13.40	1.83	0.93	0.64	1.14	0.420	0.263	0.192	0.292	0.219	0.332	0.432	0.327	0.128	0.164	0.212	0.168
ME15	18.90	14.60	7.40	13.63	2.24	1.64	1.07	1.65	0.460	0.223	0.185	0.289	0.209	0.168	0.166	0.181	0.115	0.195	0.190	0.167
CIM-57	14.47	10.53	7.50	10.83	1.62	1.35	0.95	1.31	0.367	0.253	0.261	0.294	0.277	0.172	0.169	0.206	0.152	0.182	0.161	0.165
F-14	13.77	8.37	5.73	9.29	1.76	1.46	0.83	1.35	0.443	0.276	0.181	0.300	0.296	0.239	0.355	0.297	0.134	0.170	0.238	0.181
S-71	17.90	11.53	7.63	12.36	1.75	1.23	1.04	1.34	0.431	0.232	0.186	0.283	0.252	0.204	0.164	0.207	0.134	0.189	0.170	0.164
CIM-496	18.03	13.27	9.40	13.57	1.91	1.34	0.94	1.40	0.452	0.274	0.196	0.307	0.226	0.245	0.291	0.254	0.128	0.168	0.215	0.170

Table 4. Analysis of variance (Mean squares) for physiological attributes

Source of variation	Degrees of freedom	Mean squares							
		RWC	Exceed leaf water loss	Cell injury	Leaf water potential	Stomatal conductance	Transpiration rate	Photo-synthesis	Osmotic potential
Replication	2								
Treatment (T)	1	3.88 ^{NS}	0.00510 ^{NS}	1.11 ^{NS}	0.813	0.28 ^{NS}	0.0046 ^{NS}	0.043 ^{NS}	0.000012
Genotype (G)	49	58688.05**	14.24412**	35154.19**	1600.830**	11149.28**	263.3345**	1240.073**	0.570462**
T x G	49	167.44**	0.57059**	202.18**	8.637**	19.62**	0.6015**	1.442**	0.006871**
Error	198	69.18**	0.17472**	101.46**	5.442**	10.96**	0.1895**	0.473**	0.001818**
Total	299	5.02	0.00821	2.69	0.948	0.21	0.0120	0.028	0.000096

NS = Non-significant (P>0.05); * = significant (P<0.05); ** = highly significant (P<0.01), RWC: Relative water content

Table 5. Means of Physiological parameters of 50 *Gossypium hirsutum* L. accessions grown in normal and drought conditions

Genotypes	Relative water contents			Exceed leaf water loss			Cell injury			Leaf water potential		
	Normal	Drought	Mean	Normal	Drought	Mean	Normal	Drought	Mean	Normal	Drought	Mean
GS-444	63.33	32.33	47.83	0.53	0.43	0.48	38.37	66.07	52.22	-22.00	-27.00	-24.50
Cyto-124	76.33	46.00	61.17	0.93	0.53	0.73	32.97	55.73	44.35	-19.33	-24.67	-22.00
DNH-105	73.67	41.00	57.33	1.17	1.00	1.08	33.73	61.50	47.62	-17.33	-25.33	-21.33
CRIS-533	74.33	43.00	58.67	0.82	0.57	0.70	23.47	65.50	44.48	-22.33	-26.33	-24.33
MPS-27	77.00	47.67	62.33	0.77	0.53	0.65	28.80	55.27	42.03	-20.67	-24.67	-22.67
CIM-506	72.67	48.67	60.67	1.10	0.70	0.90	29.13	56.53	42.83	-19.00	-25.33	-22.17
TH-112/05	75.33	52.00	63.67	1.30	0.77	1.03	35.40	63.67	49.53	-22.00	-25.67	-23.84
PB-896	76.33	45.33	60.83	0.83	0.50	0.67	25.77	58.00	41.88	-22.33	-24.00	-23.17
Sun-02	74.33	46.00	60.17	1.27	1.00	1.13	38.87	56.83	47.85	-20.00	-25.33	-22.67
CIM-573	76.33	48.33	62.33	1.87	0.83	1.35	32.87	61.07	46.97	-18.00	-26.00	-22.00
BH-176	81.00	58.67	69.83	2.03	1.47	1.75	21.10	39.30	30.20	-17.00	-23.00	-20.00
CIM-591	83.00	51.00	67.00	1.10	0.73	0.92	36.87	61.73	49.30	-22.00	-24.00	-23.00
NIA-80	75.33	49.33	62.33	0.83	0.60	0.72	31.57	48.13	39.85	-22.00	-24.67	-23.34
CRIS-510	74.67	34.67	54.67	0.84	0.60	0.72	34.97	49.30	42.13	-22.00	-25.00	-23.50
VH-300	76.00	41.00	58.50	0.87	0.73	0.80	29.10	51.67	40.38	-21.00	-26.00	-23.50
VS-212	76.00	52.00	64.00	1.10	0.90	1.00	25.83	61.43	43.63	-20.67	-25.00	-22.84
MPS-11	80.67	59.33	70.00	1.93	1.20	1.57	25.93	38.07	32.00	-18.00	-23.00	-20.50
DPL-45	80.33	54.33	67.33	1.87	1.00	1.43	21.47	36.63	29.05	-19.33	-22.33	-20.83
NIAB-112	78.33	52.33	65.33	1.00	0.43	0.72	38.23	48.97	43.60	-22.67	-24.33	-23.50
CIM-608	77.33	50.00	63.67	1.33	0.80	1.07	22.07	53.67	37.87	-19.00	-25.33	-22.17
IUB-2011	78.00	41.33	59.67	0.83	0.67	0.75	27.53	55.03	41.28	-20.00	-26.00	-23.00
PB-38	72.33	40.33	56.33	0.90	0.70	0.80	33.27	47.97	40.62	-20.67	-26.33	-23.50
CIM-534	77.33	41.33	59.33	0.73	0.70	0.72	27.87	60.20	44.03	-21.67	-23.67	-22.67
CIM-612	76.00	48.33	62.17	1.37	0.63	1.00	30.13	49.13	39.63	-22.33	-23.33	-22.83
CIM-473	77.00	53.00	65.00	0.83	0.50	0.67	29.17	54.87	42.02	-22.67	-23.67	-23.17
L-229-29-71	71.67	48.00	59.83	0.90	0.67	0.78	32.47	50.97	41.72	-22.00	-25.00	-23.50
B-452	73.00	49.67	61.33	0.57	0.90	0.73	32.20	41.07	36.63	-19.00	-26.33	-22.67
Stone ville-603	71.67	47.33	59.50	0.97	1.10	1.03	31.03	52.20	41.62	-17.00	-25.33	-21.17
Tree Cotton	79.00	52.67	65.83	1.97	1.20	1.58	22.03	31.60	26.82	-17.00	-22.00	-19.50
BP-52	71.33	48.33	59.83	0.87	0.67	0.77	29.80	47.73	38.77	-19.67	-25.67	-22.67
Cooker-312	74.67	51.67	63.17	1.03	0.37	0.70	35.27	55.47	45.37	-22.00	-26.00	-24.00
RA-31-21	72.33	40.67	56.50	1.30	0.47	0.88	26.17	55.20	40.68	-20.00	-24.33	-22.17
MS-64	44.00	40.67	42.33	0.63	0.23	0.43	42.57	67.10	54.83	-22.33	-27.00	-24.67
CIM-84	73.67	42.33	58.00	0.83	0.43	0.63	27.67	51.30	39.48	-22.33	-24.33	-23.33
AC-307	75.33	42.00	58.67	0.93	0.53	0.73	37.03	45.60	41.32	-22.67	-25.00	-23.84
NIAB-78	72.67	50.33	61.50	0.90	0.67	0.78	32.70	60.37	46.53	-22.00	-26.33	-24.17
GH-11-9-75	77.67	44.33	61.00	1.70	0.53	1.12	31.60	60.00	45.80	-19.33	-26.33	-22.83
CIM-86	73.67	40.67	57.17	0.80	0.47	0.63	26.07	42.83	34.45	-22.00	-26.67	-24.34
CIM-43	79.00	41.33	60.17	0.80	0.53	0.67	36.60	41.87	39.23	-21.00	-25.33	-23.17

Karishma	76.00	54.67	65.33	0.73	0.73	0.73	35.77	42.07	38.92	-19.33	-25.67	-22.50
Cooker-315	45.33	40.00	42.67	0.57	0.33	0.45	35.40	65.53	50.47	-22.00	-27.67	-24.84
SLH-41	77.67	46.67	62.17	1.53	0.80	1.17	30.10	56.17	43.13	-18.67	-25.00	-21.84
Cyto-62	80.33	47.00	63.67	2.00	1.20	1.60	22.27	36.57	29.42	-18.00	-22.00	-20.00
CRIS-134	79.33	42.33	60.83	1.63	0.50	1.07	34.17	52.60	43.38	-20.00	-25.67	-22.84
CRIS-9	70.67	42.33	56.50	1.70	0.53	1.12	37.07	49.70	43.38	-19.00	-25.33	-22.17
ME-115	73.33	47.00	60.17	0.93	0.60	0.77	27.70	62.67	45.18	-18.33	-26.00	-22.17
CIM-57	78.00	43.33	60.67	0.70	0.43	0.57	30.07	52.17	41.12	-20.67	-26.67	-23.67
F-14	71.67	45.00	58.33	0.87	0.47	0.67	30.07	51.13	40.60	-21.00	-25.33	-23.17
S-71	74.67	45.33	60.00	0.87	0.43	0.65	31.97	44.20	38.08	-22.00	-24.67	-23.34
CIM-496	74.67	44.67	59.67	1.77	0.53	1.15	22.47	44.83	33.65	-22.00	-24.67	-23.34

Table 6. Means of Physiological parameters of 50 *Gossypium hirsutum* L. accessions grown in normal and drought conditions

Genotypes	Osmotic Potential			Photosynthesis rate			Transpiration rate			Stomatal Conductance		
	Normal	Drought	Mean	Normal	Drought	Mean	Normal	Drought	Mean	Normal	Drought	Mean
GS-444	-0.254	-0.350	0.302	15.05	11.10	13.08	4.04	2.18	3.11	31.45	21.63	26.54
Cyto-124	-0.209	-0.331	0.270	15.34	11.62	13.48	4.45	2.70	3.58	36.34	23.58	29.96
DNH-105	-0.186	-0.287	0.236	15.15	11.23	13.19	4.81	2.86	3.84	39.22	23.01	31.12
CRIS-533	-0.187	-0.333	0.260	15.48	11.35	13.42	4.29	2.92	3.61	34.40	24.25	29.33
MPS-27	-0.171	-0.283	0.227	15.21	11.98	13.60	4.35	3.06	3.70	32.28	25.06	28.67
CIM-506	-0.205	-0.342	0.273	15.24	11.42	13.33	4.92	2.38	3.65	36.40	22.62	29.51
TH-112/05	-0.205	-0.268	0.237	15.19	11.35	13.27	4.21	2.77	3.49	37.34	23.66	30.50
PB-896	-0.198	-0.277	0.237	15.34	11.39	13.37	4.95	2.87	3.91	34.41	22.37	28.39
Sun-02	-0.192	-0.269	0.231	15.14	11.45	13.30	4.52	2.33	3.43	39.38	24.78	32.08
CIM-573	-0.170	-0.328	0.249	15.21	11.40	13.31	4.98	2.54	3.76	34.39	22.76	28.58
BH-176	-0.141	-0.188	0.165	17.15	12.53	14.84	5.49	3.38	4.44	40.48	25.52	33.00
CIM-591	-0.213	-0.324	0.268	15.23	11.92	13.58	4.48	2.68	3.58	35.37	22.96	29.17
NIA-80	-0.207	-0.325	0.266	16.48	11.32	13.90	4.47	2.50	3.49	35.40	23.73	29.57
CRIS-510	-0.206	-0.267	0.237	15.64	11.46	13.55	4.94	3.21	4.08	36.49	25.00	30.75
VH-300	-0.191	-0.280	0.236	15.22	12.44	13.83	4.15	2.47	3.31	34.35	24.32	29.34
VS-212	-0.217	-0.260	0.238	15.85	11.24	13.55	4.48	2.97	3.72	32.10	24.01	28.06
MPS-11	-0.145	-0.254	0.200	16.98	13.00	14.99	5.37	3.32	4.34	39.84	25.61	32.73
DPL-45	-0.141	-0.254	0.197	16.59	13.02	14.81	5.26	3.41	4.34	39.60	25.50	32.55
NIAB-112	-0.237	-0.319	0.278	15.27	11.77	13.52	4.94	3.08	4.01	38.54	23.14	30.84
CIM-608	-0.242	-0.264	0.253	16.24	11.28	13.76	4.28	3.03	3.66	36.47	21.71	29.09

IUB-2011	-0.269	-0.263	0.266	15.13	11.49	13.31	4.45	2.76	3.61	32.20	22.63	27.42
PB-38	-0.270	-0.332	0.301	16.01	12.09	14.05	4.96	2.96	3.96	38.61	22.04	30.33
CIM-534	-0.191	-0.338	0.264	15.74	11.15	13.45	4.45	2.89	3.67	32.43	22.60	27.52
CIM-612	-0.192	-0.265	0.228	15.11	11.16	13.14	4.63	2.26\	3.44	35.30	24.44	29.87
CIM-473	-0.182	-0.268	0.225	16.33	11.18	13.76	4.18	3.14	3.66	37.24	24.51	30.88
L-229-29-71	-0.215	-0.274	0.245	15.85	11.26	13.56	5.05	2.93	3.99	32.37	24.61	28.49
B-452	-0.225	-0.266	0.245	16.26	11.55	13.91	4.20	2.73	3.47	32.44	22.04	27.24
Stone ville-603	-0.190	-0.321	0.256	15.11	11.22	13.17	4.43	2.53	3.48	32.25	21.84	27.05
Tree Cotton	-0.144	-0.258	0.201	16.71	12.94	14.83	5.18	3.34	4.26	39.61	25.36	32.49
BP-52	-0.183	-0.256	0.220	15.13	11.47	13.30	4.30	2.35	3.33	33.42	21.90	27.66
Cooker-312	-0.206	-0.332	0.269	15.96	11.44	13.70	4.95	2.44	3.70	33.75	22.11	27.93
RA-31-21	-0.245	-0.351	0.298	15.22	11.54	13.38	4.75	2.51	3.63	38.47	22.00	30.24
MS-64	-0.269	-0.365	0.317	15.06	11.15	13.11	4.08	2.06	3.07	31.28	21.69	26.49
CIM-84	-0.244	-0.260	0.252	15.52	11.36	13.44	4.56	2.53	3.54	30.61	24.75	27.68
AC-307	-0.252	-0.325	0.288	16.46	11.23	13.85	5.08	2.87	3.98	35.51	22.17	28.84
NIAB-78	-0.262	-0.321	0.291	15.79	11.64	13.72	4.92	2.93	3.92	37.38	23.07	30.23
GH-11-9-75	-0.245	-0.322	0.284	15.48	11.34	13.41	4.20	2.45	3.33	32.45	21.79	27.12
CIM-86	-0.215	-0.336	0.276	15.48	11.80	13.64	4.55	2.54	3.55	35.44	21.95	28.70
CIM-43	-0.237	-0.355	0.296	15.90	11.18	13.54	4.68	2.66	3.67	38.56	22.83	30.70
Karishma	-0.190	-0.263	0.227	16.02	12.07	14.05	4.19	3.05	3.62	39.45	24.59	32.02
Cooker-315	-0.268	-0.380	0.324	15.02	11.13	13.08	4.10	2.12	3.11	32.07	21.76	26.92
SLH-41	-0.264	-0.334	0.299	15.65	12.53	14.09	4.96	2.54	3.75	32.54	22.79	27.67
Cyto-62	-0.153	-0.242	0.198	17.00	12.96	14.98	5.10	3.24	4.17	39.84	24.91	32.38
CRIS-134	-0.239	-0.331	0.285	15.36	11.22	13.29	4.36	2.24	3.30	32.28	21.98	27.13
CRIS-9	-0.215	-0.263	0.239	16.16	12.16	14.16	4.26	2.58	3.42	36.49	24.60	30.55
ME-115	-0.241	-0.322	0.282	15.35	12.21	13.78	4.39	2.44	3.41	32.35	24.03	28.19
CIM-57	-0.204	-0.270	0.237	16.01	11.21	13.61	4.17	2.95	3.56	33.21	24.44	28.83
F-14	-0.247	-0.320	0.284	16.19	11.48	13.84	4.40	2.93	3.66	37.45	22.11	29.78
S-71	-0.187	-0.314	0.251	16.48	11.44	13.96	5.12	2.95	4.04	38.31	21.73	30.02
CIM-496	-0.255	-0.323	0.289	15.72	12.01	13.87	4.94	2.73	3.83	39.47	24.90	32.19

Conclusion

Currently, drought stress is the main cause of severe yield losses and would be threat in future; thus, it is need of the day to develop drought-tolerant varieties on global level. We evaluated parameters that can fully differentiate between tolerant and susceptible cotton genotypes. Considerable genotypic variation found for morphological and physiological traits in response to water stress, implying that selection for drought tolerance is possible. Using our results and those of the studies cited herein, we concluded that five genotypes (BH-176, MPS-11, DPL-45, Tree cotton and Cyto-62) had high genetic potential for excellent performance under water stress condition.

Authors' contributions

Conceived and designed the experiments: M Akbar, Performed the experiments: M Akbar, Analyzed the data: M Akbar & SB Hussain, Contributed materials/ analysis/ tools: M Akbar & SB Hussain, Wrote the paper: M Akbar & SB Hussain.

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