Asian Journal of Biochemistry, Genetics and Molecular Biology

9(4): 10-22, 2021; Article no.AJBGMB.75945
ISSN: 2582-3698

Study of Genetic Analysis of Physiological Attributes under Normal and Drought Conditions in *Gossypium hirsutum* L.

Muhammad Akbar [a], Syed Bilal Hussain [b*], Farzana Ashraf [c] and Muhammad Zubair [d]

[a] Plant Breeding and Genetics Section, Central Cotton Research Institute, Multan, Pakistan.
[b] Institute of Molecular Biology and Biotechnology, Bahuddin Zakariya University Multan, Pakistan.
[c] Department of Cytogenetics, Central Cotton Research Institute, Multan, Pakistan.
[d] Department of Forestry and Range Management FAS&T, Bahuddin Zakariya University, Multan, Pakistan.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJBGMB/2021/v9i430224
Editor(s):
(1) Dr. S. Prabhu, Sri Venkateswara College of Engineering, India.
Reviewers:
(1) Shaik Sameera, Acharya NG Ranga Agricultural University, India.
(2) Endang Dwi Purbajanti, Diponegoro University, Indonesia.
Complete Peer review History: https://www.sdiarticle4.com/review-history/75945

Original Research Article

Received 06 September 2021
Accepted 12 November 2021
Published 17 November 2021

ABSTRACT

The aim of this study was to identify the suprior cotton genotypes with improved physiological characteristics under drought conditions. On the bais of root-shoot charcteristics, five genoypes of *G. hirsutum* were identified as drought tolerant and three genotypes screened out as drought susceptible. The field screening experiment were carried out to validate the findigs of root-shoot screening sudy on the basis of physiological as well as agronomical chracteristics. Both drought tolerant and susceptible genotypes were grown in glass house in pots and followed line x tester mating desighn to cross these genotyps. Parents with their fiftenn offsprings were grown in field conditions in very next cotton season for further analysis. Analysis of variance showed the existence of significant variations among the accessions for all the physiological parameters i.e, osmotic potential, relative water content, cell injury, leaf water potential, excised leaf water loss, stomatal

**Corresponding author: E-mail: drsyedbilal@hotmail.com;*

conductance, photosynthesis rate and transpiration rate. Further, among parents line, MS-64 and tester, BH-176 showed superior performance under water scarce conditions. Among the crosses COOKER-315 x Cyto-62 and GS-444 x MPS-11 were better perfomed for high yielding parametrs. The results showed that these two combinations might be helpful to develop drought resistant germplasm on large scale.

Keywords: Drought; Gossypium hirsutum L.; Genetic analysis; Line × Tester; Normal.

1. INTRODUCTION

Upland cotton (*Gossypium hirsutum* L.) is famous all over the world by virtue of its economic importance. The cotton crop is cultivated in tropical and sub-tropical zones and approximately cultivated in 80 countries across the globe including America, China, Brazil India and Pakistan [1]. Its shares in value addition about 5.2% and 1.0% in gross domestic production (GDP) in Pakistani agriculture [2]. In subject to cotton crop, various phases like seed germination, seedling emergence and flowering are sensitive to a great extent than that of vegetative stages to drought [3]. Cotton is not well-known as drought tolerant crop as compared to sorghum and not disciplined in case of water exploit [4]. Cotton plant has extensive deep root system due to which it is well modified to semi-arid regions [5]. Different stages of growth in cotton plant due to drought stress were also investigated [6].

The above explained findings plays vital job for cotton breeding scientists in starting their hyberdization scheme. The major area of focusing for the methods in cotton breeding is for bright germplasm expansion having drought resistance physiological traits along with superior yield performance equipped with fiber quality traits in accordance as textile industry demand. The knowledge of gene expression and combining ability is very essential to select the suitable parents for effective hybridization program. Therefore; this study was done for perceptive of gene function/expression and inheritance of combining ability in the existing cotton germplasm physiological parameters under drought condition.

2. MATERIALS AND METHODS

The current research work was conducted in the field at Central Cotton Research Institute, Multan. Strains/genotypes for this experiment was collected from Central Cotton Research Institute, Multan. Five drought tolerant G.hirsutum strains (BH-176, MPS-11, DPL-45, Tree Cotton and CYTO-62) and three droughts susceptible (GS-444, MS-64 and COOKER-315) were sown in glasshouse condition during outseason 2014-15. When the flowering appeared on the plants, few flowers were self-fertilized to maintain genetic purity.

Line x Tester mating design was used for crossing the screened material. Parents with their fiftenn offsprings were grown in field conditions in very next cotton sason under two water level i.e, well watered condistions (control) and water stress (drought) in three repeats in randomized complete block design (RCBD) in the field during 2015-16. Ten plants of each genotype were planted in one row keeping plant to plant distance of 30cm while row to row 75cm. All the practices like irrigation, fertilization and plant protection measures were done as per requirement. Data on physiological attributes in both the conditions i.e, field and laboratory were collected from each family. The detailed protocol of each physiological trais are as below.

2.1 Relative Water Content (RWC)

Under both well-watered and water stress conditions, three fresh leaf samples were collected from the selected plants. Fresh weight was calculated from the samples enclosed in polythene bags by using electronic balance. For turgid leaf weight recording, leaves were dipped in water for overnight. After turgid weight recording, the leaves were kept under room temperature for one hour for drying. For dry weight calculation, the samples were kept in oven at 70°C for 72 hours to have finally dry weight. By following Barrs and Weatherly formula used in [7], RWC was calculated.

RWC = [(Fresh weight–Dry weight) / (Turgid weight–Dry weight)] x 100.

2.2 Excised Leaf Water Loss (ELWL)

Under both conditions i.e. well-watered and water stress, three leaf samples were taken from selected plants. Fresh weight was recorded from the sample enclosed in polythene bags by using electronic balance. For wilting purpose, leaves were kept at room temperature for about twenty four hours. The weight of the wilted leaf was noted. For dry weight calculation, the samples were kept in oven at 70°C for 72 hours to have finally dry weight. By following Clarke and McCaig [8] formula ELWL was noted.

ELWL = (Fresh weight – wilted weight) / Dry weight.

2.3 Cell Injury

Cell injury both under normal and water stress conditions was determined following the procedure described by Sullivan, [9]. The uppermost fully expanded cotton leaves were collected from all plots and brought into the laboratory. The leaves were cut with sharp punch machine having diameter of 0.75 cm. Two sets of 10 leaf discs were taken into 50 ml glass tubes and surface adhered electrolytes were removed by three times washing with de-ionized distilled water. After washing, leaf discs were submerged in distilled water (10 ml) in glass tubes. One set of tubes was placed at 450C in water bath for one hour and after that both the sets were optimized in air-conditioned room (22°C) for overnight. On the next day, electrical conductivity from each tube was noted by EC meter (EUTECH Con 700). The samples were then autoclaved for 15 minutes at pressure of 15 lbs and temperature setting at 121°C, the leaf tissues were killed and then allowed to cool down for overnight by placing in air-conditioned room at 22°C. The electrical conductivity was again noted. The degree of membrane integrity reflects stability of membrane and the electrolyte leakage through membrane reflects cell damage caused by stress conditions. Using the EC values of both sets before and after autoclaving, cell injury both under normal and water stressed conditions was calculated by the formula given below:

Percent Cell injury = [1- {1- (T1 / T2)}/ {l-(C1 / C2)}] × l00

T1= EC of samples at 45oC before autoclave,
T2 = EC of samples at 45oC after autoclave.
C1= EC of sample at room temperature (22oC) before auto clave.
C2 = EC of sample at room temperature (22oC) after auto clave

2.4 Leaf Water Potential

Leaf water potential (ψl) was measured with the help of pressure chamber ARIMAD2 using N2 gas [10] by taking fully expanded leaves sample with petiole excised from each plant.

2.5 Osmotic Potential

The leaf samples used for determination of leaf water potential measurement were used for determination of osmotic potential. The leaf samples after freezing in polyvinyl bag for a period of one week were thawed, and finally by pressing leaf samples sap were extracted with garlic squeezer. The sap was used for measuring of osmotic potential in an osmometer.

2.6 Gas Exchange Parameters

Gas exchange parameters like net photosynthetic rate, (PN, mmol CO2/m-2s-1), transpiration rate (E, µmol H2O/m-2s-1) and stomatal conductance (C, mmol CO2/m-2s-1) were measured at fully expanded top 4th leaf from the control and stressed plots by using handheld portable photosynthesis system (CI-340, CID Inc, USA).
The data for the traits mentioned earlier from each treatment (normal and drought) were analysed by the method as describe by Steel et al, [11]. Further, data were also analysid to Line × Tester method as devised by Kempthorne, [12] to evaluate the genetic variances.

3. RESULTS

3.1 Genetic Analysis of Variance under Normal Condition

Table 1 revealed that in case of treatment, all parameters were highly significant. While all traits were found highly significant in parent. In hybrids, concerning to parents all traits was highly significant except relative water content being non-significant. In parent × hybrids all chracters were greatly significant excluding stomatal conductance which exhibited non-significant differences. For lines, all chaterters were highly significant while the excised leaf water loss (ELWL) was significant. In case of testers, all parameters were greatly significant. On the other hand, the relations between lines × testers, all chracters were greatly significant except leaf water potential which was significant.

Table 1. Mean squares of physiological parameters of fifteen hybrids and eight parents under normal condition

S.O.V	***d.f***	**Relative water contents**	**Excised leaf water loss**	**Cell injury**	**Leaf water potential**	**Osmotic potential**	**Photosynthesis**	**Transpiration rate**	**Stomatal conductance**
Replications	2	10.565**	0.001ns	1.221ns	0.406ns	0.006ns	0.003ns	0.004ns	0.227ns
Treatments	22	202.511**	0.468**	81.054**	8.000**	0.006**	1.349**	0.866**	22.832**
Parent	7	480.548**	1.286**	129.668**	12.851**	0.012**	1.547**	1.378**	59.929**
P x C	1	314.613**	0.039**	449.261**	10.797**	0.003**	1.862**	2.317**	0.313ns
Crosses	14	35.467ns	0.026*	34.579**	23.022**	0.006**	1.143**	0.199**	0.634**
Lines	4	55.486ns	0.090**	30.447**	5.375**	0.004**	1.215**	0.505**	5.892**
Testers	2	19.256**	0.115**	18.241**	2.478**	0.004**	1.381**	0.070**	1.174**
L x T	8	78.606	0.094	35.516	2.411	0.003	1.149	0.799	9.565
Error	44	12.717	0.009	2.789	0.830	0.005	0.011	0.013	0.159

*NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = highly significant (P<0.01)*

Table 2. Mean squares of physiological parameters of fifteen and eight parents under drought condition

S.O.V	***d.f***	**Relative water contents**	**Excised leaf water loss**	**Cell injury**	**Leaf water potential**	**Osmotic potential**	**Photosynthesis**	**Transpiration rate**	**Stomatal conductance**
Replications	2	3.754ns	0.008ns	6.259ns	0.232ns	0.006ns	0.033ns	0.002ns	0.044ns
Treatments	22	187.265**	0.231**	413.607**	6.105**	0.001**	1.268**	0.476**	4.203**
Parent	7	400.262**	0.651**	778.571**	7.405**	0.001**	2.499**	1.133**	8.077**
P x C	1	358.126**	0.110**	367.293**	44.352**	0.002**	2.725**	0.302**	0.082ns
Crosses	14	68.562**	0.029**	234.433**	2.724**	0.001**	**0.549****	**0.160****	2.560**
Lines	4	191.022ns	0.030**	96.520**	3.589**	0.003**	0.152**	0.130**	3.385**
Testers	2	56.267**	0.009**	90.795**	1.400ns	0.002**	0.034ns	0.243**	5.828***
L x T	8	10.406	0.035	339.299	2.622**	0.005	0.876	0.154	1.331
Error	44	11.314	0.003	6.941	0.641	0.003	0.022	0.005	0.131

3.2 Genetic Analysis of Variance under Drought Condition

Table 2 revealed that in case of treatment, all parameters were highly significant. All traits were highly significant for parents. In case of hybrids, all traits were greatly significant. On the other hand, parent × hybrids, all charters were greatly significant excluding stomatal conductance showed non-significant variations. For lines, all parameters were greatly significant excluding leaf water potential, photosynthesis which showed non-significant differences. In case of tester, all chracters were greatly significant excluding relative water content had non-significance. For relations between lines x testers, all chracters were greatly significant except relative water content which was significant.

3.3 Genetic Variance for Physiological Parameters

3.3.1 Under normal condition

The results for combining ability of variances and gene action for physiological traits are given in (Table 3). All the physiological traits including relative water content (RWC), excised leaf water lose (ELWL), cell injury, leaf water potential, osmotic potential, stomatal conductance, transpiration rate and photosynthesis showed higher values for specific combining ability than general combining ability that indicated dominance variances for all these characters under normal condition. The highest specific combining ability variance was shown by relative water content (21.963) followed by cell injury (10.909) under normal condition. The GCA/SCA values for the all the traits were less than 1 while the SCA/GCA was greater than 1 for excised leaf water lose (152.000), photosynthesis (65.414) and leaf water potential (4.748) revealed more dominant type of gene action. Leaf water potential has maximum additive variance (0.222) from rest of the physiological traits. The relative water content indicated maximum dominance type of gene action (21.963) followed by cell injury (10.909). The physiological traits i.e. ELWL, LWP, photosynthesis and osmotic potential for σ^2D/σ^2A were greater than 1 which showed over dominances type of gene action. The values for σ^2A/σ^2D variance ratio for all chraters excluding photosynthesis were less than 1 showing non-additive behavior of gene function while photosynthesis value was greater than 1 showing additive gene action.

3.3.2 Under drought conditions

The results for combining ability of variances and gene actions for physiological traits are shown in (Table 4). All the physiological traits including excised leaf water lose, cell injury, leaf water potential, osmotic potential, stomatal conductance, transpiration rate and photosynthesis except relative water content showed high values of specific combining ability than general combining ability which indicated dominance variances for all these characters under drought condition. The highest specific combining ability variance under drought condition was shown by cell injury (110.786). The GCA/SCA values for the all the traits were less than 1 while the SCA/GCA is greater than 1 for transpiration (99.200), leaf water potential (52.000) and stomatal conductance (7.692) exhibited more dominant type of gene action. The relative water content has maximum additive variance (5.077) from rest of the physiological traits under drought condition. The cell injury indicated maximum dominance type of gene action (110.786) under drought condition. The physiological traits i.e. leaf water potential, stomatal conductance and transpiration rate for σ^2D/σ^2A were greater than 1 which showed over dominances type of gene action. The values for $A\sigma^2/\sigma^2D$ variance ratio for all the traits were less than 1 revealing non-additive behavior of gene action

3.4 General Combining Ability under Normal Water Conditions

3.4.1 GCA effects of lines

The values of general combining ability for physiological traits under normal and drought conditions given in (Table 5 & 6). The line Cyto-62 indicated positive GCA effects for ELWL, cell injury, leaf water potential and stomatal conductance under normal condition while negative GCA effects for relative water content, transpiration rate, photosynthesis rate and osmotic potential as in Table 5. Under drought condition, positive GCA was observed in relative water content, ELWL, cell injury, transpiration rate and photosynthesis. While negative for leaf water potential, stomatal conductance and osmotic potential as in Table 6.

Table 3. Genetic Variances for physiological traits under normal condition

Description	Relative water content	Excised leaf water loss	Cell injury	Leaf water potential	Osmotic potential	Photo-synthesis	Transpiration rate	Stomatal conductance
σ^2GCA	-0.769	0.000	-0.133	0.111	0.000	0.006	-0.010	-0.127
σ^2SCA	21.963	0.030	10.909	0.527	0.001	0.379	0.262	3.135
σ^2GCA/σ^2SCA	-0.035	0.007	-0.012	0.211	0.000	0.015	-0.039	-0.040
σ^2SCA/σ^2GCA	-28.571	152.000	-81.899	4.748	0.000	65.414	-25.706	-24.708
σ^2A(F=1)	-1.538	0.003	-0.266	0.222	0.000	0.012	-0.020	-0.254
σ^2D(F=1)	21.963	0.030	10.909	0.527	0.001	0.379	0.262	3.135
σ^2D/σ^2A(F=1)	-14.285	10.133	-40.950	2.373	9.000	32.707	-12.853	-12.354
σ^2A/σ^2D (F=1)	-50.576	0.000	-0.506	0.071	0.000	12.889	-0.054	-0.968

σ^2gca = estimate of gca variance, σ^2sca = estimate of sca variance, σ^2A = Additive variance, σ^2D= Dominance variance, σ^2gca/σ^2sca = Variance ratio

Table 4. Genetic variances for physiological traits under drought condition

Description	Relative water content	Excised leaf water loss	Cell injury	Leaf water potential	Osmotic potential	Photo-synthesis	Transpiration rate	Stomatal conductance
σ^2GCA	2.538	0.000	-3.464	0.013	0.000	-0.011	0.001	0.052
σ^2SCA	-0.303	0.011	110.786	0.660	0.000	0.285	0.050	0.400
σ^2GCA/σ^2SCA	-8.380	-0.009	-0.031	0.019	0.000	-0.039	0.010	0.130
σ^2SCA/σ^2GCA	-0.119	-107.000	-31.982	52.000	-0.119	-25.402	99.200	7.692
σ^2A(F=1)	5.077	0.000	-6.927	0.025	0.000	-0.022	0.001	0.104
σ^2D(F=1)	-0.303	0.011	110.786	0.660	0.000	0.285	0.050	0.400
σ^2D/σ^2A(F=1)	-0.060	-53.500	-15.993	26.103	2.000	-12.701	45.091	3.846
σ^2A/σ^2D (F=1)	-16.761	-0.019	-0.063	0.038	0.500	-0.079	0.022	0.260

The line tree cotton indicated a positive GCA for cell injury and photosynthesis under normal condition while rest of the traits showed negative GCA effects. A positive GCA effect was noticed in ELWL, cell injury and leaf water potential under drought condition.

The line, DPL-45, showed a positive GCA for relative water content, leaf water potential, stomatal conductance, transpiration rate and photosynthesis rate and negative for rest of the traits under normal condition. Under stress, positive GCA effect for photosynthesis and osmotic potential was noticed and rest of the traits had negative effects.

In line, BH-176, positive GCA was observed for relative water content, ELWL, cell injury, leaf water potential, transpiration rate and osmotic potential under normal condition. While under drought condition, positive GCA effects were found for relative water content, leaf water potential, stomatal conductance, transpiration rate and osmotic potential and other traits had negative effects for GCA.

For line, MPS-11 all the characters showed positive GCA effects for leaf water potential, stomatal conductance and osmotic potential under normal condition. Under drought condition positive GCA effects observed for relative water conductance, ELWL, leaf water potential, stomatal conductance, transpiration rate and osmotic potential.

3.4.2 GCA effects of testers

The values of general combining ability for physiological traits under normal and drought conditions given in (Table 5 & 6). The tester GS-444 showed a positive GCA effects for ELWL, leaf water potential, transpiration rate and osmotic potential under normal condition while relative water content, cell injury, stomatal conductance and photosynthesis rate showed a negative GCA effects under normal condition. The positive GCA effects were observed for relative water content and transpiration rate under drought condition while negative GCA effects were noticed in ELWL, cell injury, leaf water potential stomatal conductance, photosynthesis and osmotic potential.

The tester MS-64 showed positive GCA effects for ELWL and osmotic potential while had negative for other traits under normal condition. But under drought condition positive GCA effects were found for relative water content, ELWL, cell injury, leaf water potential and photosynthesis rate under drought condition.

The tester Cooker-315 had a positive GCA effects for relative water content, cell injury, stomatal conductance, transpiration rate and photosynthesis rate while negative GCA for rest of the traits under normal condition. Positive GCA effects for stomatal conductance, transpiration rate and osmotic potential under drought stress while rest of the traits had negative GCA effect.

3.4.3 Estimation of Specific combining ability under normal and drought conditions

Specific combining ability under normal and drought conditions as given in (Table 7 & 8). The F_1 cross Cyto-62 x GS-444 showed a positive SCA for cell injury, leaf water potential, transpiration rate and photosynthesis under normal condition. Under drought condition, positive SCA was observed in relative water content, ELWL, leaf water potential, stomatal conductance and photosynthesis rate while other traits had negative SCA effects.

The cross Cyto-62 x MS-64 showed positive SCA for ELWL, leaf water potential and osmotic potential while other traits had negative SCA under normal condition. Under drought stress positive SCA effects were found for relative water content, ELWL and cell injury while for all other traits SCA estimates were negative.

The cross Cyto-62 x Cooker-315 showed positive SCA for relative water content, cell injury, stomatal conductance, transpiration rate and photosynthesis rate under normal condition. Under drought condition, positive SCA effects found for ELWL, stomatal conductance, transpiration rate and photosynthesis rate SCA effects were positive while in all other traits SCA was negative.

In cross Tree Cotton x MS-64 had a positive SCA value for cell injury and osmotic potential under normal condition while all other traits had negative SCA effects under normal condition. Under drought condition SCA effect were positive for ELWL, cell injury, leaf water potential and photosynthesis and rest had negative SCA.

The cross Tree Cotton x GS-444 had positive SCA for transpiration rate and photosynthesis rate while for rest of the traits, it had negative SCA effects under normal condition. In case of drought, positive SCA effects for leaf water potential, stomatal conductance,

Table 5. Estimation of GCA effects for physiological parameters in lines and testers under normal conditions

Hybrids	Genotypes	Relative water content	Excised leaf water loss	Cell injury	Leaf water potential	Osmotic potential	Photo-synthesis	Transpiration rate	Stomatal conductance
GCA for Lines	Cyto-62	-0.844	0.033	0.902	-0.628	-0.209	-0.286	-0.080	0.242
	Tree Cotton	-1.178	-0.109	1.724	2.603	-0.015	0.347	-0.074	-0.470
	DPL-45	0.044	-0.069	-1.042	-0.738	-0.021	0.495	0.074	0.426
	BH-176	2.489	0.180	0.202	-0.653	0.024	-0.352	0.113	-0.240
	MPS-11	-0.511	-0.034	-1.787	-0.6 28	0.031	-0.204	-0.032	0.043
SE (GCA for Lines)		1.178	0.019	0.568	2039	0.004	0.035	0.031	0.133
SE (gi ji Lines		1.666	0.027	0.804	2.884	0.006	0.039	0.044	0.146
GCA for Testers	GS-444	-1.200	0.036	-1.240	0.512	-0.003	-0.002	0.109	-0.199
	MS-64	-0.533	0.009	-0.453	-1.418	0.017	-0.275	-0.120	-0.013
	Cooker-315	1.733	-0.046	1.693	0.914	-0.021	0.277	0.010	0.212
SE (GCA for tester)		0.921	0.014	0.431	0.235	0.002	0.027	0.029	0.103
SE (gi ji tester		1.681	0.025	0.787	0.430	0.003	0.050	0.054	0.188

Table 6. Estimation of GCA effects for physiological parameters in lines and testers under drought conditions

Hybrids	Genotypes	Relative water content	Excised leaf water loss	Cell injury	Leaf water potential	Osmotic potential	Photo-synthesis	Transpiration rate	Stomatal conductance
GCA for Lines	Cyto-62	2.244	0.080	3.316	-0.733	-0.023	0.112	0.080	-0.364
	Tree Cotton	-7.088	0.0115	3.638	0.600	-0.017	-0.068	-0.012	-0.632
	DPL-45	-2.089	-0.060	-2.784	-0.622	0.009	0.099	-0.202	-0.226
	BH-176	4.244	-0.052	-3.140	0.266	0.023	-0.194	0.095	0.904
	MPS-11	2.689	0.020	-1.028	0.488	0.007	0.051	0.039	0.320
SE (GCA for Lines)		1.121	0.018	0.878	0.267	0.001	0.050	0.024	0.120
SE (gi ji Lines		1.228	0.020	0.962	0.292	0.002	0.054	0.027	0.132
GCA for Tester	GS-444	0.133	-0.014	-1.920	-0.066	-0.001	-0.020	0.121	-0.119
	MS-64	1.867	0.028	2.773	0.333	-0.033	0.054	-0.132	-0.555
	Cooker-315	-2.000	-0.014	-0.853	-0.266	0.004	-0.033	0.010	0.674
SE (GCA for tester)		1.869	0.014	0.680	0.206	0.001	0.038	0.018	0.093
SE (gi ji tester		1.586	0.025	1.242	0.377	0.002	0.070	0.034	0.171

Table 7. Estimation of SCA effects for physiological parameters in lines and testers under drought conditions

Hybrids	Genotypes	Relative water content	Excised leaf water loss	Cell injury	Leaf water potential	Osmotic potential	Photo-synthesis	Transpiration rate	Stomatal conductance
SCA	Cyto-62 x GS-444	1.089	0.032	-4.235	0.066	-0.003	0.195	-0.195	0.177
	Cyto-62 x MS-64	-11.978	-0.181	-11.596	1.000	0.013	-0.543	0.422	0.659
	Cyto-62x Cooker-315	-3.778	-0.204	4.131	-1.067	0.036	0.281	-0.257	-0.576
	Tree Cotton x GS-444	12.088	0.021	-9.157	0.066	0.046	-0.030	0.023	0.368
	Tree Cotton x MS-64	8.689	-0.018	-6.818	0.333	0.011	-0.239	0.411	1.807
	Tree Cotton x Cooker-315	14.222	0.107	12.742	-0.066	-0.005	-0.411	-0.084	-1.376
	DPL-45 x GS-444	-3.911	0.116	16.364	0.955	-0.029	0.405	-0.113	-0.960
	DPL-45 x MS-64	2.022	-0.063	-7.095	1.222	-0.006	0.367	0.241	-0.398
	DPL-45 x Cooker-315	10.222	0.160	-9.502	1.155	0.003	-0.085	-0.004	0.809
	BH-176 x GS-444	-2.244	0.074	11.987	-0.266	-0.029	0.015	-0.307	-0.995
	BH-176 x MS-64	-7.977	0.061	-2.373	-2.333	-0.043	0.704	0.356	0.197
	BH-176 x Cooker-315	-9.778	0.131	8.753	0.933	-0.045	-0.085	-0.319	-1.908
	MPS-11 x GS-444	-7.356	0.045	-4.891	-1.155	-0.007	-0.614	-0.508	0.566
	MPS-11xMS-64	-3.089	-0.307	9.416	-0.888	0.021	-0.548	0.442	2.074
	MPS-11 x Cooker-315	1.778	0.025	-7.724	0.044	0.025	0.589	-0.107	-0.444
SE for SCA effect		1.942	0.031	1.521	0.462	0.003	0.086	0.042	0.209

Table 8. Estimation of SCA effects for physiological parameters in lines and testers under normal conditions

Hybrids	Genotypes	Relative water content	Excised leaf water loss	Cell injury	Leaf water potential	Osmotic potential	Photo-synthesis	Transpir ation rate	Stomatal conductance
SCA	Cyto-62 x GS-444	-3.022	-0.073	5.351	0.022	-0.028	0.444	0.222	-0.861
	Cyto-62 x MS-64	-2.022	-0.123	-2.169	-0.311	-0.013	0.907	0.618	-2.283
	Cyto-62x Cooker-315	-4.956	-0.164	-7.316	2.956	0.035	-0.338	-0.490	1.168
	Tree Cotton x GS-444	9.644	0.313	-1.938	1.467	0.030	-0.689	0.323	-0.561
	Tree Cotton x MS-64	0.977	0.303	-4.591	3.467	0.031	0.107	0.276	1.970
	Tree Cotton x Cooker-315	-5.955	0.085	-8.504	1.067	0.078	-1.165	-0.485	-1.042
	DPL-45 x GS-444	-2.578	-0.044	3.496	-2.978	0.037	-1.034	-0.206	-0.388
	DPL-45 x MS-64	5.756	0.126	1.342	-0.977	-0.033	0.128	0.627	-0.563
	DPL-45 x Cooker-315	-1.511	0.178	1.729	0.955	0.039	-1.030	-0.637	1.048
	BH-176 x GS-444	-0.356	-0.150	0.417	-1.422	0.047	-0.030	-0.278	0.299
	BH-176 x MS-64	5.978	-0.016	3.031	-0.089	-0.067	0.153	0.064	3.100
	BH-176 x Cooker-315	-0.622	-0.304	3.784	-0.155	-0.052	1.311	-0.743	0.831
	MPS-11 x GS-444	0.644	-0.099	4.773	-2.089	-0.065	1.692	0.123	-0.038
	MPS-11xMS-64	0.978	0.260	1.920	-1.088	-0.024	0.024	0.685	-1.207
	MPS-11 x Cooker-315	-2.956	-0.291	-1.327	-0.822	-0.014	-0.480	-0.018	-1.472
SE for SCA effect		2.059	0.030	0.964	0.526	0.04	0.061	0.065	0.230

transpiration rate and osmotic potential were noticed while other have negative effects.

The cross Tree Cotton x Cooker-315 showed positive SCA for cell injury, stomatal conductance and photosynthesis under normal condition. Under drought stress SCA has positive effects for ELWL, cell injury and leaf water potential.

The cross DPL-45 x GS-444 showed a positive SCA for leaf water potential, stomatal conductance and osmotic potential in normal condition and other traits had negative SCA effects. A positive SCA for cell injury, photosynthesis and osmotic potential were observed under drought condition.

The cross DPL-45 x MS-64 had a positive SCA value for relative water content, ELWL, cell injury, transpiration rate and photosynthesis rate under normal condition. Under drought condition positive SCA for relative water content, transpiration rate and photosynthesis rate were noticed and rest traits had negative SCA.

The cross DPL-45 x Cooker-315 indicated a positive SCA for relative water content, cell injury, transpiration rate and photosynthesis rate and rest of traits had negative SCA under normal condition. In drought condition, SCA had positive effects for ELWL and stomatal conductance.

The cross BH-176 x GS-444 had positive SCA for relative water content, ELWL, leaf water potential, transpiration rate and osmotic potential under normal condition while other traits had negative SCA effects. Under drought condition, positive SCA effects observed for relative water content, ELWL, leaf water potential, stomatal conductance, transpiration and osmotic potential were noticed. The cross BH-176 x MS-64 indicated positive SCA for ELWL, cell injury, leaf water potential, stomatal conductance and osmotic potential. Under drought a positive SCA effects were observed for relative water content, ELWL, leaf water potential, stomatal conductance and osmotic potential.

The cross BH-176 x MS-64 indicated positive SCA for ELWL, cell injury, leaf water potential, stomatal conductance and osmotic potential. Under drought a positive SCA effects were observed for relative water content, ELWL, leaf water potential, stomatal conductance and osmotic potential.

The cross BH-176 x Cooker-315 positive SCA for relative water content, ELWL, cell injury, transpiration rate ad photosynthesis rate under normal condition. Under drought SCA had positive effects for cell injury, stomatal conductance, transpiration rate and osmotic potential.

The cross MPS-11 x GS-444 showed positive SCA effects for all the traits under study except for cell injury which showed positive estimates. A positive SCA for relative water content, leaf water potential, stomatal conductance, transpiration rate and osmotic potential were noticed while all other traits had negative SCA effects under drought condition.

The cross MPS-11 x MS-64 showed positive SCA for cell injury, stomatal conductance and osmotic potential while rest of the traits had negative SCA values. A positive SCA values were observed for ELWL, cell injury and photosynthesis and other traits were negative.

In cross MPS-11 x Cooker-315 showed negative SCA effects for all the physiological traits under study in normal condition. While under drought condition positive SCA effects were found for relative water content, ELWL, leaf water potential, photosynthesis and osmotic potential.

4. DISCUSSION

Two types of selection such as natural or induced are the pre-requisites for cotton variety improvement alongside water stress. First, the genetic variations existence for definite traits and second, there would be genetic control for these variations. Now, there is a need for hard work to develop genetic population until the plants maturity. Complete data for plant against drought in the earlier studies are not existing in G. hirsutum [13]. Keeping in view, five G.hirsutum strains (Tree Cotton, BH-176, Cyto-62, DPL-45 and MPS-11) were identified as drought tolerant, on the other hand, three strains (GS-444, COOKER-315 and MS-64) were screened as drought suseptible. As the data were evaluated against different genetic chracters revealed the role of genetic mechanisms in control and stress conditions.

All the physiological traits including relative water content, ELWL, cell injury, photosynthesis rate, leaf water potential, osmotic potential, transpiration rate and stomatal conductance exhibited greater values of SCA than GCA under control condition. The highest specific combining ability variance under control condition was shown by relative water content, cell injury, leaf water potential, transpiration rate photosynthesis and stomatal conductance. The result was same for all the traits except relative water content under drought condition which exhibited non-additive gene action. The conclusion of Javid et al, [14] coincides with present results.

Additionally, cotton breeders essentially have the knowledge about genetic variations of parents and hybrids to develop drought tolerant varieties in their varital development programme through hyberdization as enlightened by Singh et al, [15]. Previous reports indicated non-additive gene action in cotton for certain parameters under drought tolerance [16; 17]. Comparison of GCA for eight parents exhibited that (lines named as GS-444, COOKER-315 and MS-64 and testers named as Tree Cotton, BH-176, MPS-11, DPL-45 and Cyto-62) were the suprior general combiners for different physiological chracters under study. These strains can be used for drought tolerance improvement in G.hirsutum. Amongst the different combinations, the positive GCA effects were observed for relative water content and transpiration rate under drought condition while negative GCA effects were noticed in ELWL, cell injury, leaf water potential stomatal conductance, photosynthesis and osmotic potential. Tree Cotton x GS-444 showed best results for relative water content, excised leaf water lose, leaf water potential, osmotic potential and transpiration rate (Roy et al, {18] under normal condition. While Tree Cotton x GS-444 showed best results for relative water content, excised leaf water lose, leaf water potential, stomatal conductance, osmotic potential and transpiration rate under drought condition.

SCA displayed gene action that is dominant and are limited effects for best parent's selection for definite traits [19]. Therefore, both SCA and GCA effects are very significant. The participation of one of parent with high GCA would increase satisfactory existence of allele. Most of the combination with good SCA properties is due to virtuous GCA of the parents, displayed additive genetic effects occurrence [20]. Parents with higher SCA properties crossing with low GCA indicated non-additive genetic effects that are the petition for the researcher to delay early generation selection [21]. Reverse the case with having significant SCA because it appeals for early generation selection [18].

The variations in genetic makeup and environmental factors highly impact the performance of genotypes and differences in strains performance is due to these factores [22]. The non-additive gene action incidence make the observable performance of this plant material for progenies growth [23].

5. CONCLUSION

The valuable information achieved from the data analyzing by the application of various biometrical techniques. By these studies, it is the missive for plant scietist for the assortment of favorite chracters must not be implemented up to far ahead generations. Such types of these discoveries are delimited for plant physical under test and hence, may not be all-inclusive major area under cotton cultivation suffer stark water scarcity. So, this knowledge would be verified by performing another experiment which may include reasonable cotton accessions, piloted under different ecological situations in order to enhance the flexibility of our existing viable cotton cultivars under stress and form up better drought acceptance plant material.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Singh P. Cotton breeding. 2nd ed. Kalyani Publishers, New Delhi India; 2004.
2. Anonymous. Economic survey of Pakistan (20162017). Government of Pakistan, Finance Division. Economic Advisor's Wing. Islamabad; 2017.

3. Loka DA, Oosterhuis DM. Water stress and reproductive development in cotton. Flowering and Fruiting in Cotton. Cordova: The Cotton Foundation. 2012;51-58.
4. Allen Jr, LH, VG. Kakani JC. Vu, Boote KJ. Elevated CO2 increases water use efficiency by sustaining photosynthesis of water-limited maize and sorghum. J. Plant Physio. 2011;168: 1909-1918.
5. Bruner E, Román FJ, de la Cuétara JM, Martin-Loeches M, Colom R. Cortical surface area and cortical thickness in the precuneus of adult humans. Neuroscience. 2015;286:345-352.
6. Zhang D, Luo Z, Liu S, Li W, Dong H. Effects of deficit irrigation and plant density on the growth, yield and fiber quality of irrigated cotton. Field Crops Res. 2016;197: 1-9.
7. Barrs HD, Weatherley PE. A re-examination of the relative turgidity technique for estimating water deficits in leaves. Australian journal of Biological Sciences. 1962;15(3):413-428.
8. Clarke JM, McCaig TN. Excised-leaf water retention capability as an indicator of drought resistance of Triticum genotypes. Canadian Journal of Plant Science. 1982;62(3):571-578.
9. Sullivan CY. Mechanism of heat and drought resistance in grain sorghum and methods of measurement. Sorghum in the Seventies; 1972.
10. Hsiao TC. Measurements of plant water status. Agronomy. 1990;30:243-279.
11. Steel RGD, Torrie JH, Dickey DA. Principles and procedures of statistics: A biometrical approach. (3rd ed.) McGraw Hill, New York; 1997.
12. Kempthorne O. An introduction to genetic statistics. New York, John Wiley and Sons, Inc, New York; 1957.
13. Iqbal K, Azhar FM, Khan IA, Ullah E. Assessment of cotton (*G. hirsutum* L.) germplasm under water stress condition. Int. J. Agric. Biol. 2010;12: 251-255.
14. Javid A, Azhar FM, Khan IA, Rana SA. Genetic basis of some yield components in *G. hirsutum* L. Pakistan J. Agric. Sci. 2014;51:143-146.
15. Singh P, Narayanan SS. Biometrical Techniques in Plant Breeding. Kalyani Publishers, New Delhi, India; 2000.
16. Shakoor MS, Malik TA, Azhar FM, Saleem MF. Genetics of agronomic and fiber traits in upland cotton under drought stress. Int. J. Agric. Biol. 2010;12:495-500.
17. Sarwar MKS, Ashraf MY, Rahman M, Zafar Y. Genetic variability in different biochemical traits and their relationship with yield and yield parameters of cotton cultivars grown under water stress conditions. Pakistan J. Bot. 2012;44:515-520.
18. Roy N, Jettopujov V, Solanik N. Combining ability for some agronomic characters in alfalfa (*Medicago sativa* L.). Pakistan J. Agric. Res. 2002;17:346-350.
19. Caixeta FM, Tulio Cassini S, Rodrigues Oliveira V, Vieira C, Mui Tsai S, Damiao Cruz C. Combining ability for nodulation in common bean (*Phaseolus vulgaris* L.) genotypes from Andean and Middle American gene pools. Euphytica. 2001;118:265-270.
20. Kenga RS, Alabi, Gupta S. Combining ability studies in tropical sorghum (*Sorghum bicolor* L. Moench). Field Crop Res. 2004;88:251260.
21. Saidaiah P, Kumar SS, Ramesha MS. Combining ability studies for development of new hybrids in rice over environments. Journal of Agricultural Science. 2010;2(2):225.
22. Pettersen RI, Mortensen LM, Moe R, Gislerod HR. Air humidity control essential for rose production under continuous lighting. Acta Horticulturae. 2006;711:323.
23. Vaghela PO, Thakkar DA, Bhadauria HS, Sutariya DA, Parmar SK, Prajapati DV. Heterosis and combining ability for yield and its component traits in Indian mustard [*Brassica juncea* (L.)]. Journal of Oilseed Brassica. 2016;1(1):39-43.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/75945