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BREEDING DROUGHT TOLERANT COTTON; WITH AN EMPHASIS ON WITHIN BOLL YIELD COMPONENTS

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Abstract
Evolution of low moisture stress tolerant genotypes of cotton is a dire need of the time for sustainable/increased production of cotton in Pakistan. A study was conducted to estimate the varietal differences and genetic control of various within boll yield components and fiber quality traits under normal and moisture stress conditions. Five parents viz; PB-39, MNH-886, MNH-147, CIM-598, BH-95 and their ten direct crosses were grown in field in split plot arrangement under randomized complete block design with two replications. Analysis of variance revealed significant differences between the two treatments (normal and moisture deficit) and among the fifteen genotypes for all the recorded traits including bolls number per plant, weight per boll, seed cotton yield per plant, GOT, seeds number per boll, seeds mass per boll, lint mass per boll, fiber length, fiber strength and fiber fineness. Treatment × genotype interaction was also significant for all the traits except fiber fineness. Variance due to GCA and SCA were significant for most of the traits; however, magnitude of dominance variance was higher than additive variance indicating prevalence of non-additive genetic control for all the traits under both the conditions. The phenotypic expression of all the genotypes varied greatly under the two growing conditions.
Keywords: *Cotton, Genetics, Moisture stress, Within boll yield components*

INTRODUCTION

Cotton, often called white gold, is an important cash crop belonging to the family Malvaceae of genus, *Gossypium*. It is an important cash crop for smallholders in many countries of the world including Pakistan (1-3) Pakistan ranks 4th in term of cotton production and it is the main stay of agricultural economy of the country ((4, 5). The crop faces many biotic and abiotic stresses that limit the growth and ultimately yield and quality (6). Most of the crops are subtle to low moisture stress, principally during sexual phase (7). Although cotton is considered as tolerant to low moisture stress to some extent yet its sensitivity/tolerance differs greatly among genotypes and growth stage (8-10). In many crops, reproductive development is the most sensitive period to drought stress following seed germination and seedling establishment (11) , and cotton appears to follow this pattern, as well (12) . Cotton is sensitive to water deficit during both flowering and boll development (13-16). Recent research has shown that the developing pollen (17) and pollen tube growth (18) are highly sensitive to environmental stress.

About 47% of total world cotton acreage comes from rain fed cotton but it contributes only 27% to total production, (19). The availability of irrigation water to such regions is limited thus limiting the growth and yield of cotton crop. Water stress affects the cotton plant by limiting fiber yield and lint quality. The drought stress significantly reduces crop production by affecting many agronomic traits like reduction in plant height, lower size and number of bolls per plant and seed cotton yield etc (20-22).

For successful breeding of cotton cultivars tolerant to drought through conventional approach, basic information about the breeding material must be available to the breeders (23-25). Firstly, there must be significant variability in genotypic responses to water stress and secondly, this variation must be genetically controlled. Thus, an understanding of the knowledge of these two components about the breeding material under consideration is necessary (26-28).

Previous works on drought tolerance provide sufficient evidence on the occurrence of variation within the *G. hirsutum* (29-34). Evolution of stress tolerant genotypes is a challenge but stress tolerance can be developed after identification, selection and incorporation of potential traits which could confer drought tolerance or minimize the economic losses due to the stress.

Difficulties in the past included the identification of physiological characteristics that are correlated with drought stress that could be used as indicators of drought tolerance. Many physiological parameters have now been identified as indicators for drought tolerance, for example inhibition of photosynthesis and stomatal conductance (32, 48), osmotic adjustment (36) cell membrane stability (35) accumulation of proline concentrations (37) and leaf water potential, O_2 evolution and stomatal conductance (38). The physiological processes involved in the stress tolerance are too complex and often intermingled with other stresses like heat. More over the measurement of above mentioned traits requires expertise in physiological process and high precision advance scientific instruments.

Within boll yield components are the most basic attributes determining the final yield of seed cotton and quality of lint (2, 4, 5, 39, 40). These parameters are relatively easy to measure and require not any advanced scientific instruments. One approach to improving cotton (*Gossypium hirsutum* L.) yield and quality is to identify crop management practices that may exploit the most basic (i.e., within-boll) yield components. One of the parameters that may influence within-boll yield components is plant density. Previously no study has been reported focusing on behavior of within boll yield attributes under moisture deficit conditions. Therefore, side by side evaluation of within boll yield contributing traits under normal and low moisture stress conditions may guide the breeders in choosing appropriate selection criteria among these basic traits and to devise suitable selection strategy based on the mode of inheritance of the traits under drought stress. Understanding the combining ability and genetic behavior of various basic determinants of seed cotton yield and fiber quality under normal and water deficit condition will be helpful in developing the stress resilient cultivars through traditional breeding.

METHODOLOGY

In order to collect information on the genetic mechanism controlling variations in within boll yield components under normal and water deficit conditions, present studies were conducted at Regional Agricultural Research Institute, Bahawalpur 2020 and 2021. During winter season of the first year five cotton genotypes viz; PB-39, MNH-886, MNH-147, CIM-598, BH-95 were planted in pots placed in the glass house with coordination of Cotton Research Station Bahawalpur. These five parents were crossed in half diallel fashion to develop 10 F_1 hybrids. The F_1 hybrids along with parents were grown in the field following split plot design under RCBD with two replications in normal cotton growing season in 2021. One main-plot given normal irrigation (normal number of irrigations) while other main-plot were subjected to water deficit condition (50% reduced number of irrigations through alternate irrigation as compared to normal). The second main plot was grown under permanent high tunnel structure so as to provide cover with polythene sheet during rain.

PLANTS DISTANCE

Row to row and plant to plant distance were kept 75cm and 30cm, respectively. All the recommended agronomic practices were followed from sowing till harvest. At maturity data were recorded from five guarded plants in each row for various traits related to boll, seed cotton yield and fiber quality from both normal and water deficit condition.

STATISTICAL ANALYSIS

The collected data were subjected to analysis of variance technique (41) in order to determine the significance of variation among the genotypes for the plant traits under study. The characters showing significant genotypic differences were further analyzed for general and specific combining ability effects. Combining ability was analyzed using Griffing's approach Model-I, Method-II (42).

RESULTS

Mean square values from analysis of variance showed highly significant differences among treatments (normal and water deficit), genotypes and treatment × genotype interaction for all the traits including bolls number per plant, weight per boll, seed cotton yield per plant, seeds number per boll, seed mass per boll, lint mass per boll, GOT, fiber length, fiber strength and micronaire; however interaction variance for micronaire revealed non-significant value (Table I).

Table I. Analysis of variance (mean square values) through split plot layout for various traits of cotton

Sources of variation	D.F	Bolls number/ plant	Weight/ boll	Seed cotton yield/plant	Seeds number/ boll	Seed mass/ boll	Lint mass/ boll	G.O.T	Fiber length	Fiber strength	Micronaire
Replications	1	1.600	0.065	372.600	5.460	0.0345	0.0005	33.150	9.375	1.591	0.005
Treatments	1	1066.820*	34.961**	31155.800*	561.204*	4.756*	0.1476**	4806.150*	335.050*	292.383*	20.434*
Error 1	1	3.700	0.002	54.300	0.504	0.011	0.0001	27.740	1.474	0.491	0.007
Genotype	14	61.810**	0.119**	401.600**	4.055**	0.098**	0.0083**	148.540**	3.100**	2.239**	0.390**
Treatment × Genotype	14	36.910*	0.106**	319.600**	2.528*	0.100**	0.0021**	141.740**	1.833**	0.953*	0.040ns
Error 2	28	16.330	0.279	104.600	0.969	0.024	0.0002	46.620	0.460	0.453	0.024

Under normal conditions, the variance due to GCA was significant for weight per boll, seeds number per boll, GOT, fiber length, fiber strength, and micronaire but non-significant for bolls number per plant, seed cotton yield per plant, seed mass per boll and lint mass per boll. While variance due to SCA was significant for all the traits excluding GOT. Values of dominance variance were greater than additive ones for all the traits except seed mass per boll for which the situation was vice versa (Table II).

Table II. Genetic components for various traits of cotton under normal conditions

Genetic components	D.F	Bolls number/ plant	Weight/ boll	Seed cotton yield/ plant	Seeds number/ boll	Seed mass/boll	Lint mass/boll	G.O.T	Fiber length	Fiber strength	Micronaire
GCA	4	16.020ns	0.030*	131.200ns	0.784*	0.019ns	0.0003ns	156.180**	0.776**	0.948**	0.139**
SCA	11	22.870*	0.028**	227.000*	0.581*	0.020*	0.0008**	48.180ns	0.450*	0.593*	0.054**
Error	14	7.284	0.007	61.030	0.182	0.007	0.0001	21.900	0.145	0.204	0.010
Additive variance		1.249	0.003	10.030	0.086	0.016	0.0001	19.182	0.090	0.106	0.0181
Dominance variance		15.590	0.021	166.000	0.399	0.012	0.0007	26.285	0.305	0.300	0.444

Under water deficit conditions, GCA variance was significant for almost all the traits excluding bolls number per plant and seed cotton yield per plant while SCA variance was significant for all the traits except seeds number per boll and fiber strength. Dominance variance was higher in magnitude than additive variance for all the traits except seeds number per boll where difference between the two values was non-significant (Table III).

Table III. Genetic components for various traits of cotton under moisture deficit conditions

Genetic components	D.F	Bolls number / plant	Weight / boll	Seed cotton yield/ plant	Seeds number / boll	Seed mass/boll	Lint mass/boll	G.O.T	Fiber length	Fiber strength	Micronaire
GCA	4	16.260ns	0.109**	102.510ns	5.222**	0.091**	0.0011**	103.400*	3.186**	1.105*	0.187**
SCA	11	28.200*	0.063*	146.860*	1.423ns	0.065**	0.0005**	42.120ns	1.247*	0.491ns	0.099**
Error	14	9.042	0.021	43.550	0.787	0.015	0.0001	24.710	0.314	0.248	0.013
Additive variance		1.031	0.012	8.422	0.633	0.012	0.0002	11.240	0.410	0.122	0.024
Dominance		19.160	0.041	103.310	0.635	0.049	0.0004	17.400	0.933	0.442	0.086

variance

Results pertaining to general combining ability effects of parental genotypes under normal conditions (Table IV) revealed that MNH-147 showed the superlative GCA values for bolls number per plant, seed cotton yield per plant, lint mass per boll and GOT. MNH-88 was indicated as good general combiner for weight per boll and seed mass per boll while for fiber strength and micronaire value, CIM-598 was considered the best. The cross PB-39 × BH-95 showed the highest value for SCA effects for weight per boll and seed mass per boll. MNH-88 × BH-5 displayed the finest SCA effects for seed cotton yield and fiber strength. PB-39 × MNH-147 displayed the best results for SCA effects regarding lint mass per boll and micronaire while for the traits like GOT and fiber length, the cross CIM-598 × BH-95 was the most desirable.

Table IV. General combining ability effects of parent and specific combining ability effects of crosses under normal conditions

	Bolls number/ plant	Weight/ boll	Seed cotton yield/ plant	Seeds number/ boll	Seed mass/boll	Lint mass/ boll	G.O.T	Fiber length	Fiber strength	Micronaire
Parents										
PB-39	0.591	-0.025	0.983	0.160	-0.038	-0.001	3.585**	0.162	0.954**	-0.091**
MNH-886	-1.366*	0.094**	-2.519	-0.297*	0.076**	0.004	-6.414**	-0.143	0.402**	0.001
MNH-147	2.073**	-0.002	6.350**	-0.097	-0.012	0.009*	5.585**	-0.338**	0.095	0.175**
CIM-598	-1.598**	0.034	-4.009*	-0.268*	0.026	0.006	-1.728	0.414**	-0.264*	-0.179**
BH-95	0.301	-0.080**	-0.804	0.503**	-0.053	-0.007	-1.285	-0.096	-0.328**	0.094**
S.E.	0.753	0.028	2.765	0.161	0.030	0.006	1.408	0.120	0.154	0.038
Direct crosses										
PB-39 × MNH-886	3.719**	-0.148**	8.785**	-0.360*	-0.166**	0.029**	-5.738**	-0.035	-0.940**	0.110**
PB-39 × MNH-147	0.155	-0.086**	-3.044	-0.160	-0.151**	0.043**	-3.738**	-0.311**	-0.673**	-0.153**
PB-39 × CIM-598	2.126**	0.066*	8.913**	0.012	-0.119**	-0.041**	6.726**	-0.345**	-0.949**	0.311**
PB-39 × BH-95	0.526	0.185**	6.343*	-0.060	0.160**	-0.004	4.426**	0.575**	0.810**	0.227**
MNH-886 × MNH-147	1.512*	0.070*	2.305	1.098**	-0.065*	-0.028**	2.262*	0.134	-0.340*	0.074*
MNH-886 × CIM-598	1.683*	0.072**	7.503**	-1.131**	0.062*	0.022**	-6.824**	0.090	0.231	0.078*
MNH-886 × BH-95	3.183**	0.151**	14.697**	-1.202**	0.146**	-0.017**	0.376	-1.099**	0.832**	0.070
MNH-147 × CIM-598	-3.455**	-0.105**	-13.531**	0.269	-0.094**	-0.033**	-3.824**	0.525**	-0.720**	0.245**
MNH-147 × BH-95	8.844**	-0.027	-26.468**	0.598**	-0.090**	-0.002	8.676**	-0.185	-0.019	-0.108**
CIM-598 × BH-95	3.415**	-0.208**	4.390	0.569**	-0.212**	-0.019**	10.040**	1.366**	0.533**	0.586**
S.E.	0.972	0.036	3.570	0.207	0.039	0.008	1.818	0.154	0.199	0.050

Critical review of the GCA effects of parents and SCA effects of crosses under water deficit conditions revealed that the parental genotype BH-95 presented the upper most values of GCA effects for higher number of traits including seed number per boll, lint mass per boll and GOT. PB-39 was indicated as good general combiner for seed cotton yield per plant and fiber strength. MNH-147 presented the best GCA effects for weight per boll and seed mass per boll while CIM-598 was considered the most desirable parental genotype for fiber quality traits including fiber length and micronaire value. PB-39 × CIM-598 revealed the highest SCA effects for a number of traits including bolls number per plant, GOT, fiber length, fiber strength and micronaire. For the traits like weight per boll, seed cotton yield and seed mass per boll, the cross CIM-

598 × BH-95 exhibited the superlative SCA effects. PB-39 × BH-95 and MNH-886 × CIM-598 revealed the unsurpassed SCA effects for seeds number per boll and lint mass per boll, respectively (Table V).

Table V. General combining ability effects of parent and specific combining ability effects of crosses under deficit conditions

	Bolls number/ plant	Weight/ boll	Seed cotton yield/ plant	Seeds number/ boll	Seed mass/ boll	Lint mass/ boll	G.O.T	Fiber length	Fiber strength	Micronaire
Parents										
PB-39	0.416	0.100**	4.083*	-1.097**	0.093**	-0.008	0.421	0.541**	0.436**	0.132*
MNH-886	1.573*	-0.055	2.960	0.660**	-0.071*	-0.002	-2.521*	-0.262	-0.178	0.028
MNH-147	-2.470**	0.149**	-5.584**	-0.525*	0.143**	-0.016**	-4.921**	-0.886**	-0.251*	0.089
CIM-598	0.705	-0.160**	-1.396	-0.068	-0.132**	0.012**	2.150*	0.797**	0.412**	-0.193**
BH-95	-0.224	-0.034	0.064	1.031**	-0.031	0.014**	4.871**	-0.191	-0.418**	0.208**
S.E.	1.050	0.053	2.193	0.316	0.043	0.005	1.515	0.284	0.156	0.073
Direct crosses										
PB-39 × MNH-886	0.763	-0.108*	-0.486	-0.742	-0.279**	-0.022**	-6.77**	0.054	-1.146**	-0.217**
PB-39 × MNH-147	3.605**	-0.068	12.124**	-1.157**	-0.019	0.011*	4.283**	-1.241**	0.276	-0.178*
PB-39 × CIM-598	5.700**	-0.092	12.095**	-0.114	-0.104*	0.008	7.611**	2.454**	1.191**	0.624**
PB-39 × BH-95	0.659	-0.333**	-7.841**	2.385**	-0.808**	-0.005	-10.900**	-0.589*	-0.056	0.324**
MNH-886 × MNH-147	4.648**	-0.222**	9.756**	1.085**	-0.161**	-0.001	-1.573	-0.127	-0.888**	-0.099
MNH-886 × CIM-598	3.474**	0.133*	10.043**	-0.771	0.150**	0.019**	2.004	0.508	0.957**	-0.017
MNH-886 × BH-95	-0.097	-0.008	-0.308	-1.171	0.001	0.012*	-4.921**	0.607*	0.119	0.133
MNH-147 × CIM-598	3.816**	-0.181**	-2.788	0.814*	-0.222**	-0.042**	-2.745	1.042**	-1.289**	0.251**
MNH-147 × BH-95	0.545	-0.313**	-2.693	-1.485**	-0.287**	-0.001	4.983**	0.571	-0.088	0.088
CIM-598 × BH-95	5.495**	0.242**	17.629**	0.957**	0.231**	-0.032**	6.861**	-1.062**	-0.092	0.092
S.E.	1.356	0.068	2.831	0.4074	0.056	0.007	1.956	0.366	0.201	0.095

DISCUSSION

Significant genotypic difference among parents and their crosses is the indication of genetic diversity among parental genotypes (4, 5). The genetic variability in each character was further portioned in to various components i.e. due to general and specific combining ability as out lined by Griffing (1956). The relative contribution of general and specific combining ability provides some understanding on the genetic control of the characters (2, 5, 24,). GCA and SCA variance for almost all the traits were significant under both normal and water deficit conditions which indicated the involvement of both additive and non-additive (dominance) types of gene control in the inheritance of these traits. Earlier reports by Abro *et al.* (2009); Ahmad *et al.* (2009) and Imran *et al.* (2012) advocated the involvement of both additive and dominant genes in the inheritance of various yield and quality attributes in cotton (25, 44, 45). However higher values of dominance variance over additive variance for all the traits under study indicated the preponderant role of dominant genes. Imran *et al.* (2012) ; Shakeel *et al.* (2012); Zare *et al.* (2014); Ali *et al.* (2016a, b, c) testified the major role of dominant genes in the genetic mechanism of various within boll yield components and fiber quality traits (2, 4, 5, 11, 25, 40).

However performance of genotypes (parents and crosses) with respect to general and specific combining ability for various included traits varied greatly under the two growing conditions. Drought condition affected the behavior of genotypes to a great extent. Rehman, *et al.*, (1993) reported environmental effects on seed weight in upland cotton (45). Agronomic practices affecting both physical and chemical properties of cotton seed have also been reported (46). Rehman *et al.* (2007) put emphasis on seeds number per boll and seed weight per boll as important plant traits to be focused while breeding cotton against heat and/or drought stress (47). The differential response of cultivars for depression in seed traits under drought suggested that these traits could be useful in assessing drought tolerance in upland cotton and relatively tolerant or sensitive cultivars and hybrids could be differentiated based on higher number of seeds per boll and seed weight.

CONCLUSION

It was concluded that the phenotypic expression of all the genotypes varied greatly under the two growing conditions.

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