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GENETIC VARIABILITY STUDY AMONG WHEAT GENOTYPES UNDER NORMAL AND DROUGHT CONDITIONS

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Present studies were conducted under normal and drought conditions using Line × Tester analysis in experimental field of Department of Plant Breeding and Genetics, University of Agriculture Faisalabad during Rabi season of 2010-2012. Analysis of variance indicated significant differences among the genotypes for flag leaf area, grains per spike, RWC, stomatal size, 1000-grain weight and grain yield per plant under both planting conditions. The results of line × tester analysis exhibited significant to highly significant difference between parents, crosses and lines × tester cross combinations. In case of general combining ability under normal and drought conditions, the lines 9438, 9444 and 9428 were found best. While observing testers, the genotype Seher-06 and 9437 displayed highest GCA effects for most of the traits. The cross combinations 9444 × 9451 and 9372 × Saher-06 exhibited highest SCA effects under normal conditions but could not retain its position for the observed traits under water stress situation. These superior genotypes could be included as promising parents in future breeding programs and crosses like 9444 × 9451 and 9372 × Saher-06, can be exploited in future breeding programs for improvement of morpho-physiological characters conferring resistance to water stress under drought situations with stable grain yield.
Keywords: Wheat, Genotype, Drought, Water stress, Gene action.

INTRODUCTION

Wheat (*Triticum aestivum* L. em Thell.) is among the important cereal crop world over and is the most important staple food of about two billion people (36% of the world population). In Pakistan, considering the main consumable crop, wheat is ranking at first position among all cereals crops. It contributes 10.3 percent to the value added in agriculture and 2.2 percent to GDP (Economic Survey of Pakistan, 2013-14). Presently, the national wheat production is less than the food demand as a result of increasing population, low annual precipitation, and diminishing of underground freshwater resources that are main yield influencing parameters and have become a serious threat to national wheat production. Water scarcity has become the common problem of the globe and severely affecting the plant growth (Ashraf *et. al* 1995; Ashraf (1998). During Rabi season, the water availability was estimated at 29.4 MAF, which was 19.2 percent less than the normal availability and 15 percent less than of last year's Rabi crop. The canal head withdrawals declined to 29.4 MAF, compared to 34.6 MAF during the same period last year ((Economic Survey of Pakistan, 2013-14). It is widely grown in the areas where drought is becoming a serious problem.

Agricultural drought is one of the most common environmental stresses that affect normal plant growth and development through alterations in metabolism and gene expression (HongBo *et al*., 2006; Akhter *et al*., 2008; Royo *et al*, 2000). About one third of Pakistan's wheat growing area is perpetually devoid of supplemental irrigation. Drought tolerance has been shown to be positively correlated with yield under stress across genotypes of wheat (Keim and Kronstad, 1981; Sojka *et al.* 1981). Sukhorukov (1989) observed that under drought conditions reduction in number of fertile tillers, grains per spike and 1000-grain weight reduced the grain yield per plant. In case of wheat, yields in extremely dry years are reduced as much as 81% (Dragović, 1999). Water is the single most important factor determining crop yield and its limitation can change the ecological and physiological responses of plants during their different growth and development stages. Hence environmental stresses particularly water deficit can cause different changes in spike characteristics and its related reproductive traits, which are important organs in crop production and also yield and yield components (Casati and Walbot, 2004; Canadian Food Inspection Agency, 2006; Passioura, 2007). Under such conditions there is a dire need to develop such varieties having efficient mechanism to escape, avoid or resist water stress conditions. Syndromes of plant exposure to drought in the vegetative phase are reduced plant leaf area, tillers per plant, number and area of leaves, grain weight and yield of crop (Boyer, 1982; Passioura *et al*., 1993). Drought stress at the grain filling period dramatically reduces 1000-grain weight, grains per spike and ultimately grain yield per plant (Ehdaie and Shakiba, 1996). Breeding for drought resistance is complicated by the lack of fast, reproducible screening techniques and the inability to routinely create defined and repeatable water stress conditions when a large number of genotypes can be evaluated efficiently (Ramirez and Kelly, 1998). Achieving a genetic increase in yield under such environments has been recognized to be a difficult challenge for plant breeders while progress in grain yield has been much higher in favorable environments (Richards *et al*., 2002).

Development of promising genotypes for drought resistance is primary objective for breeding future wheat. The Plant breeders are making their efforts to acquire best amalgamation of yield potential and drought resistance from pre existing germplasm by using many primitive as well as advance methods of hybridization and selection (Blum 1989). Assessment of genotypes for drought resistance on the basis of combining ability estimates for leaf and other physiological attributes, play a vital role in water relations of wheat under different sowing regimes (Seropian, C. and C. Planchon. 1984; Matin *et al*. 1989). The knowledge of general combining ability (GCA) provided an estimation of degree of additive gene action and specific combining ability (SCA) exhibited the performance of two particular varieties/lines in a specific cross, which would reflect non-additive type of gene action (Phoelman, J.M. and D.A. Sleper, 1997). The present study was designed to determine the nature of genetic mechanisms involved in the expression of some economic and drought related traits of wheat under drought condition. The information derived from the present study can be effectively used to formulate and establish breeding programme for the development of new varieties symbolizing such characteristics as required to ensure sustainable wheat production in water deficit areas of the country.

MATERIALS AND METHODS

The present research work was carried out in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The experimental material consisted of six elite wheat lines (9372, 9407, 9428, 9432, 9438 and 9444) and three testers (9437, 9451 and Saher-2006) These wheat genotypes were crossed in a Line × Tester fashion (Kempthorne (1957)) during the Crop Season 2009-10.

In the 2nd year of study (2010-11), the F_1 seed along with 9 parents were sown under normal and drought conditions in randomized complete block design with 3 replications. One experiment was conducted under normal conditions with regular irrigations while other with pre-irrigation before sowing and subjected to rainfall for water requirements. The experimental unit consisted of single row of 5 meter length with row to row and plant to plant distance 30 cm and 15 cm respectively. Both experimental units were provided with all cultural practices. At maturity, guarded plants from each line were randomly selected to record the data for flag leaf area (cm²) (Muller 1991), fertile tillers per plant, grains per spike, relative water contents (%), stomatal size (µm²), 1000-grains weight (g) and grain yield per plant (g).

Relative water content (RWC) was determined for detached leaves using the method of Mata and Lamattina (2001). Size of the stomata was measured in microns. An ocular micrometer (scaled at 10 mm),xstandardized using a 1.0 mm stage micrometer, was used. Each unit of ocular micrometerxwas found to be equal to 3.33 microns at 40x at the time of standardization. Length and width of three stomata per strip was measured to calculate stomatal size. Average stomatal size was computed. The leaf area was calculated in cm2 after measuring the length and width of fully mature green and turgid flag leaf as reported.

Flag leaf area = Maximum length × maximum width × 0.74

Data were subjected to analysis of variance (Steel *et al.*, 1997) to sort out significant differences. Character showing significant differences were further subjected to line × tester analysis as given by Kempthorne (1957) to estimate general and specific combining ability as under:

Estimation of GCA effects:

Lines

$$g_l = \frac{X_{i..}}{tr} - \frac{X_{...}}{ltr}$$

Testers

$$g_t = \frac{X_{i.j.}}{lr} - \frac{X_{...}}{ltr}$$

Where

l = Number of lines

t = Number of testers

r = Numbre of replications

(Xi..) = Total sum of F1 resulting from crossing *i*th lines with all testers

(X..) = Total of all crosses

b) Estimation of SCA effects

$$S_{ij} = \frac{X_{ij.}}{r} - \frac{X_{i..}}{tr} - \frac{X_{.j.}}{lr} - \frac{X_{...}}{ltr}$$

Where

(Xij) = Total sum of F_1 resulting from crossing ith lines with all jth testers

(Xj..) = Total of all crosses of *j*th testers with line

RESULTS AND DISCUSSION

Significant variability (P ~ 0.01) was observed among in genetic architecture of genotypes and their F1 hybrids showed significant for all the traits under study (Table.1). Analysis of variance o Combining ability and specific combining ability (Table 2) for parents and crosses was performed to identify superior progeny when one parent combined with another parent in a line x tester fashion.

Table 1: Analysis of variance for various morphological and physiological traits of 6 lines × 3 tester cross of wheat under normal (N) and drought (D) condition

Source	Df	Flag leaf area (cm²)		Fertile tiller/ plant		Grains/ spike		RWC (%)		Stomatal size (µm²)		1000- grain weight (g)		Grain yield/ plant (g)	
		N	D	N	D	N	D	N	D	N	D	N	D	N	D
Rep	2	0.11 NS	7.31*	0.17 NS	0.34 NS	1.13*	2.58 NS	1.16*	5.65*	1573**	4059**	2.40*	0.05 NS	0.35 NS	1.40 NS
Treat	26	45.52**	45.43**	1.54 NS	2.20*	16.92**	54.38**	151.3**	456.5**	24781**	32483**	7.45**	25.35**	5.13**	3.83*
Parents	8	84.97**	53.32**	1.67 NS	3.09*	16.50**	45.87**	36.53**	909.2**	32635**	35039**	4.01*	10.07**	6.05*	7.31*
P vs C	1	102.2**	8.11*	6.21**	1.70 NS	0.13 NS	37.54**	615.7**	481.3**	17428**	10904**	22.08**	0.015 NS	2.03 NS	3.12 NS
Crosses	17	23.62**	43.91**	1.20 NS	1.81 NS	18.11**	59.37**	178.0**	242.0**	21518**	32550**	8.20**	34.03**	4.88*	2.23*
Lines	5	5.87**	30.15**	1.43 NS	2.06 NS	30.25**	22.94**	94.14**	166.5**	28837**	50113**	7.74**	60.96**	6.30**	0.83 NS
Testers	2	61.23**	191.8**	0.43 NS	1.06 NS	7.49**	9.72*	60.34**	862.0**	6503**	1947**	7.24**	2.43 NS	21.04**	0.56v
L × T	10	24.97**	21.20**	1.24 NS	1.84 NS	14.17**	87.52**	243.6**	155.7**	20861**	29889**	8.63**	26.88**	0.93 NS	3.27*
Error	52	2.68	5.58	0.28	0.24	2.85	6.08	14.40	11.15	4683.7	3202.1	1.29	2.54	0.71	0.60

RW = relative water content

Table 2: Mean square values for various morphological and physiological traits of wheat genotypes derived from line × tester analysis under normal and drought conditions

Source	Df	Flag leaf area (cm²)		Fertile tillers per plant		Grains per spike		RWC (%)		Stomatal size (µm²)		1000-grain weight (g)		Grain yield per plant (g)	
		N	D	N	D	N	D	N	D	N	D	N	D	N	D
Replication	2	0.11 NS	7.31**	0.17 NS	0.34 NS	1.13*	2.58*	1.16*	5.65**	1573**	4059**	2.40*	0.05 NS	0.35 NS	1.40 NS
Genotypes	26	45.52**	45.43**	1.54 NS	2.20 NS	16.92**	54.38**	151.3**	456.5**	2478**	32483**	7.45**	25.35**	5.13*	3.83*
Error	52	2.68	21.20	0.28	0.24	2.85	6.08	14.40	11.15	4683.7	3202.1	1.29	2.54	0.71	1.60
Total	80	48.31	73.94	1.99	2.78	20.9	63.04	166.92	473.33	31039	40545	11.14	27.94	6.19	6.83

RW = relative water content

A perusal of Table 1 revealed significant differences among genotypes for flag leaf area, grains per spike, relative water content (RWC), stomata size, 1000-grain weight and grain yield per plant under both normal and drought conditions. Differences for fertile tillers per plant were non-significant under normal but significant under drought condition while differences for excised leaf water loss and stomatal frequency were non-significant under both conditions.

Partitioning of significant genotypic differences into parents and crosses further highlighted the presence of variation. Parents as well as crosses showed significant differences for all the traits studied under both planting conditions except fertile tillers per plant which were non-significant in crosses under drought condition. Interaction of parents and crosses (parents vs crosses) displayed significant differences for flag leaf area, RWC and stomata size and non-significant differences for grain yield under both plantings. However, differences for grains per spike were non-signiifcant under normal and significant under drought. Similarly, differences for 1000-grain weight were significant under normal and non-significant under drought.

The crosses were further partitioned into lines, testers and line × tester interaction (Table 2). Both female (lines) and male (testers) parents exhibited significant differences for flag leaf area, grains per spike, RWC and stomat size under both planting conditions and significant differences for 1000-grain weight and grain yield per plant under normal conditions. Differences for grain yield per plant were non-significant under drought conditions. Differences for line × tester interaction component were found non-significant for fertile tillers per plant but significant for the remaining traits studied under both plantings except non-significant differences for grain yield per plant under normal planting.

General combining ability (GCA): Flag leaf area has a direct relationship with grain yield. Higher GCA variance of component under both sowing environments (Table 4), exhibited the additive genetic base for this trait (Kashif and Khaliq 2003); Choudhry et al 2005). A perusal of Table 2 showed that the line 9438 and the male parent 9437 showed significant GCA effects under normal conditions (1.03 & 1.43, respectively). The line 9428 and the tester 9451 showed negative GCA effects under normal conditions and showed positive GCA effects under drought conditions which are desirable for further study. GCA effects calculated for fertile tillers per plant were non-significant. The results showed that the lines 9372, 9407, 9428, 9432 and the tester 9437, 9451 showed desirable positive GCA effects under both conditions whereas the line 9438 and the variety Saher-06 showed undesirable negative GCA effects under both planting. A perusal of Table 2 revealed that under normal conditions, the lines 9372 exhibited highest positive GCA effects for grains per spike (2.82) followed by the lines 9428 and 9432 (1.34 and 0.01, respectively) Among testers, the line 9437 showed highest GCA effects (0.59) followed by Saher-06 (0.10). However, under drought conditions, the line 9444 occupied first position with respect to GCA effects (1.88) followed by the lines 9428 (1.82) and 9432 (0.22). Among testers, the line 9451 have highest positive GCA effects of 0.49 closely followed by the tester line 9437 (0.34) which is desirable under normal and drought conditions.

Table 3: Estimate of general combining ability for various physiological and morphological traits in six lines and three testers of wheat under normal and drought conditions

Parents	Flag leaf area (cm^2)		Fertile tiller/ plant		Grains/ spike		RWC (%)		Stomatal frequency		1000-grain weight (g)		Grain yield/ plant (g)	
Lines	**N**	**D**	**N**	**D**	**N**	**D**	**N**	**D**	**N**	**D**	**N**	**D**	**N**	**D**
9372	0.67	-0.26	0.05	-0.01	2.82*	-0.93	-4.01	-5.50	-0.05	0.23	-1.24	-0.17	0.11	-0.07
9407	0.07	1.86	0.30	0.03	-1.17	-1.05	0.92	-1.40	-0.14	-0.26	-0.43	-2.01	-0.77	-0.48
9428	-0.05	1.65	0.26	-0.44	1.34	1.82*	2.45*	-3.07	-0.05	0.34	-0.59	1.10	0.70	0.42
9432	-1.19	-1.79	0.37	0.84	0.01	0.22	4.58**	1.08*	-0.25	-0.35	0.96	-3.93	-1.27	-0.05
9438	1.03	1.03	-0.32	-0.48	-0.76	-1.95	-2.44	2.20*	0.29	-0.11	0.20	2.99*	0.54	0.19
9444	-0.53	-2.49	-0.62	0.06	-2.24	1.88*	-1.50	6.69**	0.20	0.15	1.10*	2.02*	0.68	-0.03
Testers														
9437	1.43	-3.75	0.09	-0.23	0.59	0.34	0.98	-7.90	0.30	-0.02	-0.71	0.23	-1.06	-0.18
9451	-2.08	1.56	0.08	0.25	-0.69	0.49	1.13*	2.91*	0.04	-0.25	0.21	-0.42	-0.05	0.16
Saher-06	0.64	2.18*	-0.17	-0.02	0.10	-0.84	-2.11	4.98**	-0.34	0.27	0.49	0.19	1.11*	0.02

Table 4: Estimate of specific combining ability for various physiological and morphological traits in six lines and three testers of wheat under normal and drought conditions

Crosses	Flag leaf area (cm^2)		Fertile tiller/ plant		Grains/ spike		RWC (%)		Stomatal frequency		1000-grain weight (g)		Grain yield/ plant (g)	
	N	**D**	**N**	**D**	**N**	**D**	**N**	**D**	**N**	**D**	**N**	**D**	**N**	**D**
9372 × 9437	0.03	4.19**	-0.61	0.64	-0.36	5.32**	7.49**	-0.06	-0.96	0.09	0.86	-1.72	0.04	0.84
9407 × 9437	2.56*	-0.07	0.64	0.52	-1.47	-5.20	4.28	8.33**	0.16	-0.49	0.12	-2.15	-0.54	0.02
9428 × 9437	-0.26	0.84	0.01	0.56	3.11**	-6.53	-4.52	6.91**	-0.46	-0.30	0.90	0.85	0.01	-0.84
9432 × 9437	-3.88	0.31	-0.32	-0.72	-0.88	-1.49	-8.58	-1.74	-0.05	-0.35	-0.39	2.90*	0.44	-0.01
9438 × 9437	-0.09	-3.09	0.16	0.04	-2.66	2.50*	-4.33	-12.53	0.29	0.04	-0.83	0.83	-0.04	0.46
9444 × 9437	1.65	-2.18	0.12	-1.05	2.26*	5.39**	5.66	-0.90	1.03*	1.01	-0.65	-0.72	0.08	-0.49
9372 × 9451	-0.41	-2.87	0.17	-0.44	2.02*	-1.41	1.24	4.11**	0.22	0.85	-2.76	1.66	-0.74	-1.86
9407 × 9451	-2.03	-0.44	-0.89	-0.05	0.57	-0.32	-8.72	-9.12	-0.12	0.001	-1.27	-0.13	0.34	-0.22
9428 × 9451	-2.53	2.26*	0.03	-0.80	-2.71	6.17**	-7.12	-2.71	0.99	0.30	1.46*	-3.25	0.69	0.42
9432 × 9451	1.89*	0.43	-0.08	0.88	0.17	-3.07	3.86*	3.11*	-0.11	-0.26	0.23	-2.54	-0.37	0.48
9438 × 9451	-0.03	0.97	-0.15	-0.54	1.17*	1.97*	4.72**	4.29*	-0.23	-0.42	0.79	-0.57	-0.19	-0.37
9444 × 9451	3.10*	-0.34	0.91	0.98	-1.23	-3.34	6.02**	0.31	-0.74	-0.47	1.54*	4.83**	0.26	1.54*
9372 × Saher-06	0.38	-1.32	0.43	-0.19	-1.66	-3.91	-8.73	-4.05	0.74	-0.95	1.90*	0.05	0.70	1.01*
9407 × Saher-06	-0.53	0.52	0.25	-0.46	0.89	5.52**	4.43**	0.78	-0.03	0.49	1.15	2.28*	0.20	0.20
9428 × Saher-06	2.79*	-3.10	-0.04	0.24	-0.40	0.35	11.64**	-4.19	-0.52	-0.01	-2.36	2.39*	-0.71	0.41
9432 × Saher-06	1.98*	-0.74	0.40	-0.15	0.70	4.56**	4.72*	-1.36	0.17	0.62	0.16	-0.35	-0.08	-0.48
9438 × Saher-06	0.12	2.12*	-0.01	0.50	1.49*	-4.47	-0.38	8.23**	-0.05	0.37	0.03	-0.25	0.23	-0.09
9444× Saher-06	-4.75	2.52*	-1.04	0.07	-1.03	-2.05	-11.68	0.59	-0.29	-0.53	-0.89	-4.11	-0.35	-1.05

Plants having high relative water contents are considered suitable under drought conditions., Under normal condition, 3 lines i.e. 9432, 9428 and 9407 showed positive GCA effects (4.58, 2.45 and 0.92, respectively) for this trait while two testers 9451 and 9437 exhibited positive GCA value of 1.13 and 0.98, respectively. Under drought conditions, the line 9444 exhibited highest positive GCA effects (6.69) closely followed by the lines 9438 and 9432 (2.20 and 1.08, respectively). In case of testers, the male parent Saher-06 ranked first with GCA effects of 4.98 followed by the tester 9451 with GCA effects of 2.91.

The genotypes showing positive GCA estimates for stomata size are more desirable for selection in breeding programme focused on drought tolerance. In the present study, the lines 9407 (-49.15), 9438 (-34.72), 9372 (-33.58) and 9432 (-4.84) while among testers 9437 (- 17.53) and 9451 (-2.65) indicated negative effects of GCA. Whereas under drought conditions, the lines 9372 (-126.88), 9407 (-15.29), 9438 (-14.36) and the testers 9437 (-1.04) retained their negative values for GCA and performed better under drought conditions.

1000-grain weight directly contributes to grain yield thus, positive GCA is preferred. Under normal conditions, the lines 9444 displayed highest GCA effects (1.10) followed by the lines 9432 and 9438 with GCA values of 0.96 and 0.20, respectively, while in case of male parents, Saher-06 ranked first among the male parents exhibiting GCA effects of 0.49 followed by the line 9451 (0.21). Under drought conditions we see lines but with different positions on the basis of GCA values of 2.99, 2.02 and 1.10 were evident from the results while among the testers, Saher-06 and 9437 contributed positive values of 0.19 and 0.23, respectively. These results are in accordance with Seropian and Planchon, and 1984 and Matin *et al*. 1989 who also worked on combiningabilitz and reported similar findings.

The main focus of the most research programs remains the grain yield and every effort is made for the improvement of this trait. Positive combining ability effects are, thus, considered useful. Under normal condition, four out of six lines viz. 9428, 9444, 9438, 9372 and 1 out of 3 testers (Saher-06) displayed positive GCA effects (0.70, 0.68, 0.54, 0.11 and 1.11, respectively). Under drought conditions, the results were very different. Only 2 out of 6 lines exhibited positive GCA lead by the line 9428 (0.42) followed by the line 9438 (0.19) and among the testers, 9451 (0.16) was at top position followed by Saher-06 (0.02)..

The elite lines 9428, 9438 and the tester Saher-06 roved to be good general combiners having positive GCA effects. So these lines can be suitable for breeding program to develop a variety and due to high GCA values early selection will be suitable. These results are supported by the findings of Ehdaie and Shakiba, (1996) who also worked on wheat and reported comparable results.

***Specific combining ability (SCA)*:** Specific combining ability analysis has been presented in Table 4. A perusal of the analysis for flag leaf area under normal conditions showed that cross 9444 × 9451 exhibiting the highest positive SCA effects (3.10) was the best specific combiner closely followed by cross 9428 × Saher-06 (2.79) and 9407 × 9437 (2.56). While reviewing the results under drought conditions, the cross 9428 × Saher-06 ranked first under drought conditions with high SCA effects of -3.10 having less FLA closely followed by 9438 × 9437 with SCA effects of -3.09. The genotype 9372 × 9437 was the poorest cross combination of drought conditions with SCA effects of 4.19 due to maximum FLA under drought.

Considering fertile tillers per plant under normal conditions, out of eighteen crosses, ten indicated positive SCA effects ranging from 0.91 to 0.01 as in the Table 4. The highest positive SCA effects were displayed by the hybrid 9444 × 9451 while the lowest negative effects were displayed by the hybrid 9444 × Saher-06. Under drought conditions, 50 % of the crosses indicated positive SCA effects. The hybrid 9444 × 9451 retained the first position with a SCA value of 0.98, followed by two other crosses 9432 × 9451 (0.88) and 9372 × 9437 (0.64). Positive SCA effects were exhibited by 9 out of 18 crosses under normal conditions for number of grains per spike. Potential crosses showing significant values of SCA effects under normal sown conditions were 9428 × 9437 (3.11) and 9444 × 9437 whereas the cross combinations 9428 × 9451 (6.17), 9407 × Saher-06 (5.52), 9444 × 9437 (5.39), 9372 × 9437 (5.32) and 9432 × Saher-06 (4.56) show significant behavior under drought conditions. The cross combinations which perform well under both experimental conditions were 9444 × 9437, 9438 × 9451, 9407 × saher-06 and 9432 × saher-06.

It was observed that genotypes with higher relative water content (RWC) were more drought tolerant as compared to those with lower RWC (Ashraf *et al.*, 1994). The cross 9428 × Saher-06 showed maximum SCA effects (11.64) for RWC under normal conditions, however, under drought it showed negative SCA effects. Under drought the cross 9407 × 9437 displayed the highest positive SCA effects (8.33) for RWC followed the cross combination 9438 × Saher-06 (8.23).

The values of SCA for stomatal size ranged from -122.69 to 153.0 and - 102.27 to 196.42 under normal and drought conditions, respectively (Table 4). Nine of the cross combinations showed desirable positive SCA effects under normal conditions and nearly 39 % crosses indicated decrease in stomatal size on viewing the hybrid performance under drought conditions. The cross combinations 9407 × 9451, 9428 × 9451, 9444 × 9451, 9428 × saher-06 and 9438 × saher-06 exhibited desirable positive SCA effects under both normal and drought conditions.

Considering 1000-grain weight under normal planting, positive SCA effects were observed ranging from 1.90 to 0.03. The best specific combinations were found to be 9372 × Saher-06, 9444 × 9451, 9428 × 9451 and 9407 × Saher-06 with values of 1.90, 1.54, 1.46 and 1.15, respectively.

Variable SCA effects were also found among crosses for grain yield per plant. Under normal planting, 10crosses exhibited acceptable positive SCA effects. The cross 9372 × Saher-06 remained at the top with a value of 0.70followed by 9428 × 9451 and 9432 × 9437 (0.69 and 0.44, respectively). Under drought conditions, 9 of the crosses displayed positive SCA effects. The SCA effects ranged from 1.54 to 0.02 lead by the cross combination 9444 × 9451. The hybrid 9372 × Saher-06 retained its performance even under stress conditions. So it is suggested that this cross combination could be potentially more useful in breeding variety for drought stress as it shows stability in retaining its yield potential.

CONCLUSION

The above illustrated results concluded that 9432and 9438 with higher GCA effects for most of leaf traits can be used as general combiners in further wheat hybridization programs. The cross combination 9444 × 9451 exhibited highest SCA values can be improved in next successive generations regarding leaf traits under both normal and drought prevailing conditions. The hybrid 9372 × Saher-06 was found to be second best with maximum SCA effects under drought conditions. These superior genotypes could be included as promising parents in future breeding programs and crosses like 9444 × 9451 and 9372 × Saher-06, can be further exploited in further generations for more improved morpho-physiological characters conferring resistance to water stress under drought situations with stable grain yields.

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