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Original Article

Multivariate assessment to determine drought tolerant genotypes to combat drought risk in wheat (*Triticum aestivum* L.)

Saira Sattar[1], Muhammad Kashif[1], Rabail Afzal[1], Muazim Ali[2]

[1]Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad-38040, Pakistan

[2]Department of Agronomy, University of Agriculture, Faisalabad-38040, Pakistan

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**Corresponding author email:*
sairasattar9@yahoo.com

Abstract

Wheat is one of the leading cereal crops of the world. Being a staple food in Pakistan it gains more consideration by the specialists. With the increasing population and fluctuation in climatic conditions, it requires more attention to save people from hunger. Drought is one of the yield threatening stress in wheat crop and alarming for food security. In developing countries where water resources are not satisfied according to the crop requirement, drought tolerant/resistant genotypes are key to feed people. Although MAS selection and other advances in molecular breeding are done widely to compete with such stresses but still it is not contributing efficiently so breeding efforts should be emphasized to cope with drought stressed areas. Hence, there is a need to do genetic improvement through advanced breeding efforts and evaluation of best performing genotypes to get new hybrid/variety by combining their genetic potential in a proper way. By developing specific crosses and selection through proper breeder's eye, genetic variability can be created for best executing genotypes that will also increase our germplasm. In wheat crop, genetic gain has been successfully brought out through breeding efforts by the breeders. The present research is done to gain genetic variability by combining alleles through hybridization and analyze yield contributing traits under drought stress and normal environment to select the yield boosting genotypes for this stress. Yield influencing traits are evaluated and ultimately exploitation of best genotype is done based on difference of performance and adaptability of genotypes under normal and stressed conditions.

Keywords: Wheat, Drought stress, Biplot analysis, Combining ability, Genetic effects

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Introduction

The cereal crop breeding should be invigorated primary to eliminate stress of low water supply and high temperature (Tester and Bacic, 2005). Wheat is significantly affected at post anthesis drought due to which grain filling and development is influenced. Post anthesis drought also negatively affect the yield and cause leaf senescence (Nawaz et al., 2013). On the other side, drought stress at earlier anthesis can badly affect the seed setting (Weldearegay et al., 2012) while terminal drought stress can lead to lessen the number of grains in wheat crop (Madani et al., 2010). Drought is complicated environmental stress to understand with respect to specific phenology of crop and certain other perspectives (duration, extent, frequency and severity of drought) (Zhang et al., 2017). Peculiar target specific wheat cultivars are required that can cope with the future threatening stresses hence, it become thought-provoking for the breeders to develop varieties with suitable traits within limited resources (Zheng et al., 2012).

With the increasing world population rate and decline of water resources, drought became most important restraining factor to food supply especially in rain fed areas. Thus, drought resistant varieties should be developed, and drought tolerant genotypes should have identified by suitable sowing time of crop genotypes for future breeding objectives (Hossain et al., 2012). It was reported that during April 2016, -52%% below normal rainfall in Punjab, -91.1% in Sindh, -17.8% in Baluchistan and -29.4% below normal was received in Kashmir and Gilgit-Baltistan. During the year 2016, maximum temperature in March was less than 20^{O}C in KP and upper Punjab while less than 29^{O}C was recorded in southern areas of Punjab in the same month (Pakistan Metrological Department, 2016).

Extensive variation can be a source of selecting suitable character to get results according to our objectives. Wheat is widely grown all over the world due to its high adaptation within the fluctuating environment and its resistance towards various biotic and abiotic stresses (Khayatnejad et al., 2010). Keeping in view the climatic changes and increasing population, wheat breeder should have accentuated on varieties of high yield potential. To accomplish the future objectives, it is necessary to select the desirable genotypes through the knowledge of nature of inheritance of genotypes to use them in the breeding programs.

Material and Methods

These trails accomplished at “Wheat research block” University of agriculture Faisalabad, Pakistan (31.4^{o} North and 73^{o} East coordinates). The parental material was mustered from the crop genetic resource area and evaluated by using a factorial arrangement with three replications. Lines and testers mated in line × Tester mating design and accessions randomized separately for each replication in field. All the lines and testers evaluated by growing under normal irrigation and drought stress trials. Severe drought treatment applied under field condition in which after first irrigation all irrigations were suspended till harvesting stage while complete irrigations were given in the trial of normal irrigation.

Choice of parental material

Breeding material included three testers (Chakwal 50, Kohistan 97 and Chakwal 86) and five lines collected from the Research area of the University that were 9737,9738,9739,9740 and 9741. The crosses of the parental material made by hand emasculation and pollination in both trials.

Data collection of traits contributing yield under drought stress

Data of the yield enhancing traits for all the five lines, three testers and all their progenies collected in drought stress and normal trail. Best performing genotypes evaluated for drought condition. The traits selected according to the target objectives as they can play remarkable role for increase overall production of grain under water stressed environments. Hence, the best performing traits and genotypes assessed to maintain the production of dry land/ arid zone areas.

Following traits were measured in both experiments:

1- **Number of fertile tillers** (At the time of maturity, number of fertile tillers per plant of the selected plants counted. Average data calculated by dividing the total number of tillers with the number of selected plants).
2- **Peduncle length** (measured from the upper node to the node at base of a spike)
3- **Awns length** (measured from the awns of two central spikelets).
4- **Chlorophyll contents** (measured with the help of chlorophyll meter (atLEAF ver. 1.0))
5- **Grain number/Spike** (Number of grains manually counted from the main shoot/mother spike of the selected plants and number of grains recorded).
6- **Weight of 1000 grains** (Weight of 1000 grains calculated in grams from the randomly selected spikes of a plant with the help of electronic balance).
7- **Seed yield/plant** (Mature plant spikes harvested at the time of maturity, threshed them and grains weight measured for each plant with the help of electronic balance).

Statistical analysis

Data were interpreted using XLSTAT software for graphical presentation of biplots that can provide us information of principal component analysis, present the map of multi-locational genotypes trials and help in ranking the tested genotypes. General and specific combining abilities were evaluated using SAS statistical tool version 9.2.

Results and Discussion

Principal component Analysis of Parental Material

Outcomes of all the variables are summarized in principal component analysis to ensure imperative selection of genotypes which possess productive outcomes. The combined biplot of parental accessions and their hybrids performance for all the target traits is mentioned in figure 3, interpretation shows the contribution of PC1 30.04% and PC2 25.94% in the total variation (Fig. 3). PC 1 interpreted 35.37% influence of overall variation on parental performance (figure. 1).

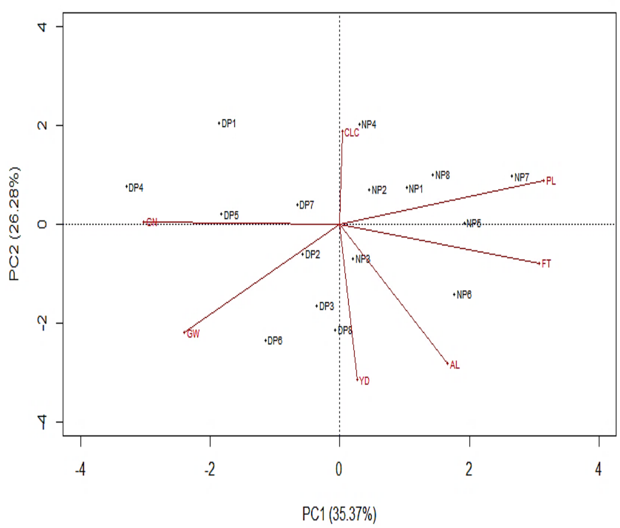


Figure-1: Principal component Analysis of Parental

NP4 characterized as high performing parent for chlorophyll contents while NP7 and NP2 parents categorized for high and low contributing parents for peduncle length character respectively. The short peduncle length reported as favorable to avoid water logging problems and maintain plant stability for beneficious growth of plant (Khamssi and Najaphy, 2012). NP5 exhibited best performing for number of fertile fillers per plant while NP8 and DP 8 values of parental material displayed desirable performance for awn length and yield respectively. Sarwar et al. (2018) observed that the production of fertile tillers is an important yield contributing trait. It was detected that the deficiency of water can reduce the number of tillers which results in decrease in yield. From the cluster of accessions lie on the upper left side of this biplot graphical presentation, DP1 considered better performing for number of grains per plant.

Principal component analysis of hybrids

The results evaluated using principle component technique for multivariate data. Figure 2 and 3 presented the information about the progenies (crossed material/hybrid) of prenatal material, progenies observed under stressed as well as in normal conditions to find out the profitable combination of parent for each trait. Number of grains per plant and grain weight are treasured characters contributing towards yield. From the assessment of hybrids, PC1 showed that accessions DC3, DC10 and DC2 considered as appraisal performing under drought stress for number of grains per plant and grain weight. Weyhrich et al. (1995) deliberated that awns are imperative for the increase in the grain yield for developing ideal plant for dry areas. They play protagonist role in different functions and cellular processes like photosynthesis, storing carbohydrates as well as in increasing water use efficiency. Li et al. (2010) assessed that the awns on the wheat spike are vital for photosynthesis and transpiration.

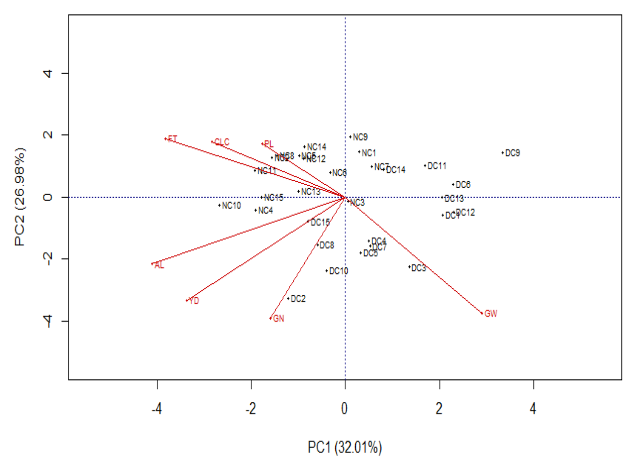
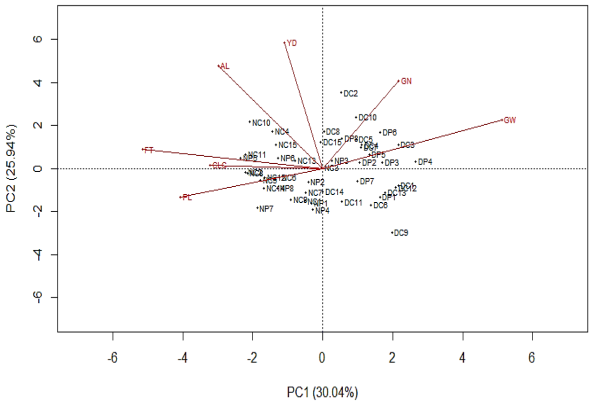


Figure-2: Principal component Analysis of Hybrids

Duwayri (1984) determined that the awns have a direct relation with the kernel weight and by removing the awn from the spike the kernel weight was 11.3 %

declined. NC10 and NC4 parents displayed acceptable and profitable awn length performance among all the hybrids under studied.



Abbrevations	Genotypes
NC1	9737×C50
NC2	9737×K97
NC3	9737×C86
NC4	9738×C50
NC5	9738×K97
NC6	9738×C86
NC7	9739×C50
NC8	9739×K97
NC9	9739×C86
NC10	9740×C50
NC11	9740×K97
NC12	9740×C86
NC13	9741×C50
NC14	9741×K97
NC15	9741×C86
DC1	9737×C50
DC2	9737×K97
DC3	9737×C86
DC4	9738×C50
DC5	9738×K97
DC6	9738×C86
DC7	9739×C50
DC8	9739×K97
DC9	9739×C86
DC10	9740×C50
DC11	9740×K97
DC12	9740×C86
DC13	9741×C50
DC14	9741×K97
DC15	9741×C86

Abbrevation	Genotypes
NP1	9737
NP2	9738
NP3	9739
NP4	9740
NP5	9741
NP6	C50
NP7	K97
NP8	C86
DP1	9737
DP2	9738
DP3	9739
DP4	9740
DP5	9741
DP6	C50
DP7	K97
DP8	C86

Figure-3: Comparison of Principal component Analysis of Parental Material and Hybrids:

Peduncle length is a good indicator of grain yield in the areas where water is limited. It helps in determining yield capacity in dry environments and has a positive correlation with grain yield. Heidari et al. (2012) assessed that peduncle length is important trait for breeding resistance against head disease and in disease escape. Generally, plants with shorter peduncle are susceptible to diseases. Muhammad et al. (2018) reported that the short plant height and peduncle lengths are preferred in order to avoid water logging too. From the figure 3 peduncle length inspected less valued for NP7 and NP4 hybrids (NP7 and NP4) hence less peduncle length value contributes to enhance yield according to our objectives.

Biplot analysis is a technique or indicator having low dimensional graph to access multivariate data. It has been reported as interesting data interpreting tool and utilize to explore research data for better evaluation. But this data is further estimated using combining ability analysis for better understanding.

Estimation of Means & Combining Ability Analysis

The concept given by Sprague and Tatum (1942) about combining ability was to check the average performances of a lines/genotypes of parental material by performing series of crosses that was named as General combining ability while to check the hybrids average performances by selecting specific parental combination was named as Specific combining ability. Through this technique, total variation in the breeding material can be split in to GCA and SCA variations, using this information, breeders can decide either information used in varietal development program or development of hybrid

Analysis of variance

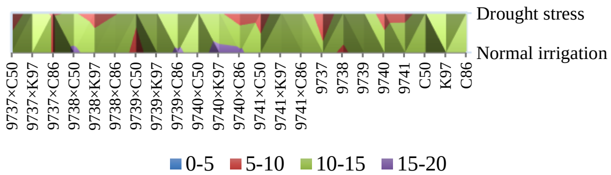
The analysis of variance of all traits are shown in Table 1. Genotypes exhibit significant differences for all the traits viz peduncle length, no. of fertile tillers/plant, chlorophyll contents, awns length, seeds/spike, grain yield/plant and 1000 grain weight. Yao et al. (2011), Ahmad et al. (2013) and Barot et al. (2014) also reported such findings.

Estimation of mean square values under drought stress

Number of fertile tillers per plant: As the productive tiller per plant are directly related to yield that's why it is important to measure. Under drought stress condition, genotype Chakwal-50 (used as male parent in study) showed greater mean productive tillers while among hybrids, 9741 × Kohistan-97 had highest mean value followed by 9740 × Chakwal-50 (Fig.4).

Table-1: Analysis of variance for productive traits in wheat

Source of variance	Degree of freedom	Fertile Tillers per plant	Peduncle length (cm)	Awn length (cm)	Chlorophyll content	Grains per spike	1000 grains weight (g)	Grain yield per plant (g)
Replication	2	1.28 n.s	2.08 n.s	0.04n.s	8.78**	0.31 n.s	0.98 n.s	1.94 n.s
Genotype	22	9.90**	47.3**	1.91**	36.6**	220.2**	60.78**	75.1**
Treatment (Drought)	1	244.7**	688.1**	1.74 **	100.7**	877.6**	6282.4**	0.34 n.s
Genotype × Treatment	22	13.96**	5.87**	0.25**	4.62**	207.0**	34.5**	44.6**
Error	90	0.87	1.77	0.0061	0.841	0.495	0.21	0.22
Total	137							



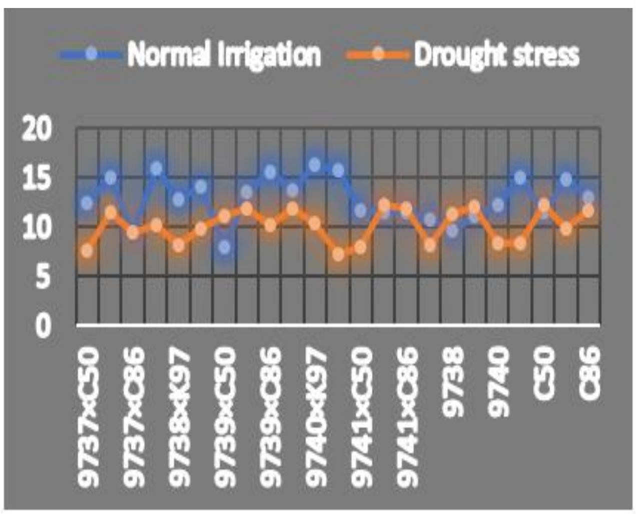
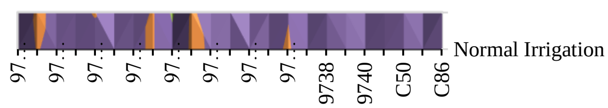


Figure-4: No. of fertile tillers

Peduncle length: Peduncle length is important trait for yield as it has maximum soluble carbohydrates and it is important site for storage of nutrients that play significant role during grain filling stage. Under drought stress condition, peduncle length was recorded for parents (lines and testers) along with their crosses that were significantly different. It was noted that among parents Kohistan-97 and genotype 9740 had highest and lowest mean values of peduncle length respectively. On the other hand, among their crosses, 9739 × Kohistan-97 had highest mean value (Fig. 5).

Awn length: Awns are important morphological trait that has great contribution in photosynthesis as well as provide protection for grains in wheat. Awn are located on the spike that has high water use efficiency (WUE).



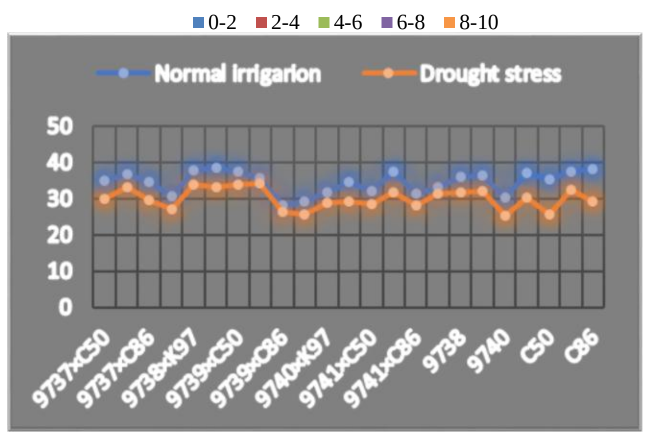


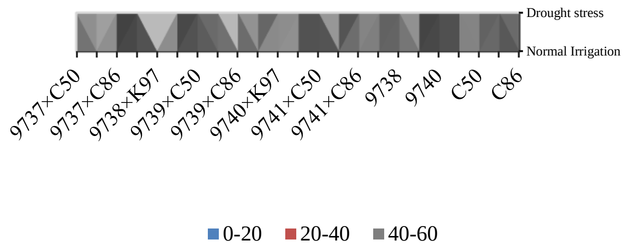
Figure-5: Aw length

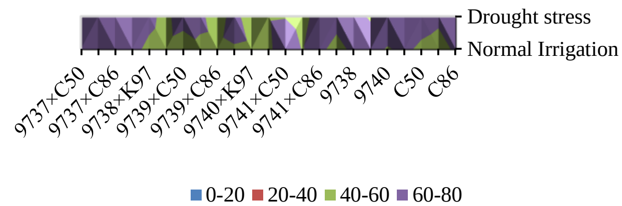
Under drought stress condition, awn length was significantly varied range from 5.7167cm to 8.3167cm. It was noted that among parents Chakwal-86 and 9740 had greatest and lowest value respectively. On the other hand, among crosses, 9737 × Kohistan-97 was recorded as greatest mean value for awn length (Fig. 6).

Chlorophyll contents: Under drought stress condition, chlorophyll contents were among all lines, testers and crosses. It was found that among lines, highest and lowest mean chlorophyll contents were present in 9741 and 9739 respectively while among testers highest and lowest mean values were present in Chakwal-86 and Chakwal-50 respectively. On the other hand, among cross combinations, 9741 ×

Chakwal-86 had maximum mean chlorophyll content that was 58.408 (Fig. 7).

Kohistan-97 was recorded as greatest mean yield/plant among crosses (F1) while lowest mean yield per plant was found in 9739 ×Chakwal-86.





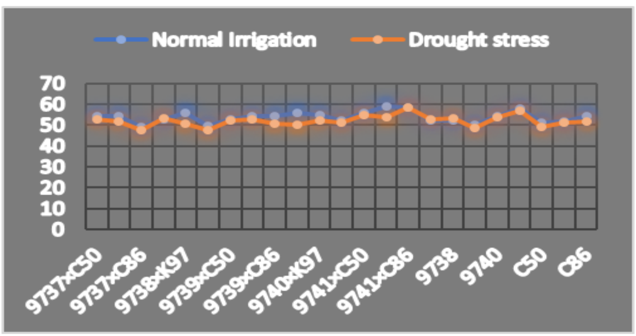


Figure-6: Chlorophyll contents

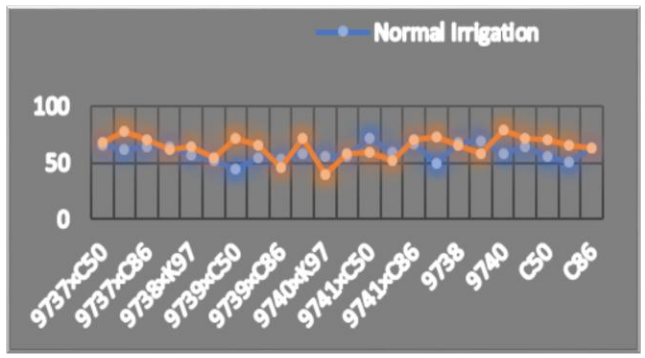
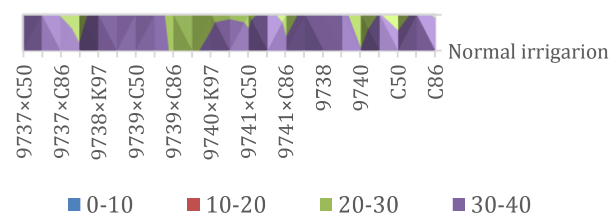


Figure-7: Grain numbers per spike

Number of grains per spike: Under drought stress, mean no. of grain per spike had maximum value 78.833g in line 9740 while among testers highest mean no. of grains per spike was found in Chakwal-50 (70.833g). From the hybrids, greatest mean value for this trait was noted in 9737 × Kohistan-97 (78.25g) followed by 9740 × Chakwal-50 (72.333g).

1000-grains weight (g): "1000-garins weight" recorded under drought stress was found more than the "1000-grain weight" of normal irrigation trial among all parents and crosses. Among lines (female parents) 9739 had maximum mean 1000-grain weight while in testers (male parents) Chakwal-50 showed highest mean value for 1000-grain weight. Among crosses (F1 hybrids), 9739 × Chakwal-50 was showed greatest mean value for this trait (Fig. 9).

Grain yield per plant: Under drought stress condition, maximum mean yield per plant was noticed in Chakwal-86 (21.092g) and minimum yield per plant was observed in 9737. While among crosses 9737 ×



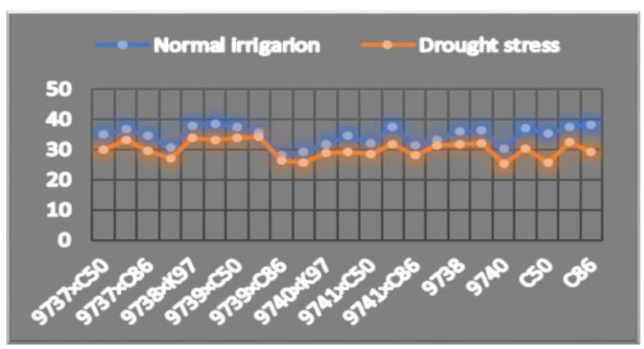


Figure-8: Peduncle length

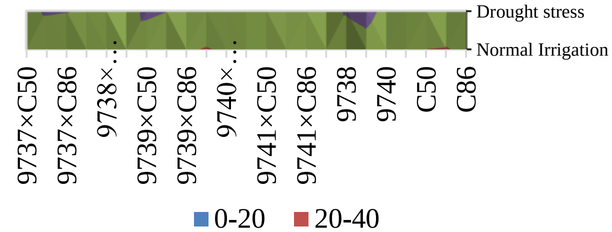
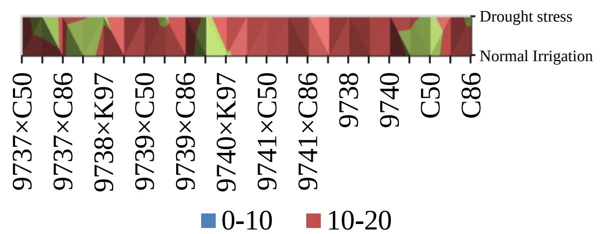


Figure-9: 1000- grain weight



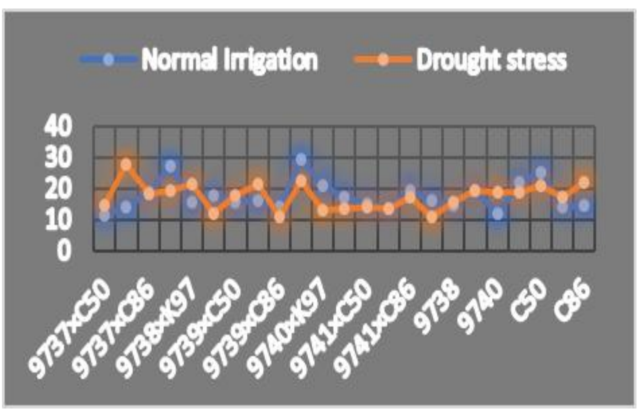


Figure-10: Yield per plant

General combining ability (GCA) effects

Number of fertile tillers per plant: Number of fertile/productive tillers is good indication for high yield as it can increase the number of spikes that lead to increase number of grains that will ultimately increase production (Hammad et al., 2013; Uzair et al., 2016). Genotype 9739, 9740 and Chakwal_50 were performed best among parents under drought as well as in normal irrigation conditions.

Peduncle length: Peduncle length has its advantages as it maintain plant stability and source of important assimilates that are helpful during grain filling stage. Genotype 9740 (line) and Chakwal-50 (tester) were performed best for this trait among parents under drought stress condition as well in non-stress condition.

Awn length: Awn plays important role in photosynthesis hence high value of GCA for awn length will be preferred (Rebetzke et al., 2016). Under both trials (stressed & non-stressed), genotype 9740 was showed best performing while among testers, Kohistan-97 was considered good general combiner for this trait.

Chlorophyll contents: High value of chlorophyll contents will be considered best in categorizing the genotypes hence high positive value of GCA will be considered valuable for this trait (Rad et al. 2013). Genotype 9741, Chakwal-50 and Kohistan-97 were designated as good general combiner for chlorophyll contents under both conditions.

Number of grains per spike: No. of grains is important yield contributing trait so high the GCA value for this trait more it will contribute to increase yield (Saeed et al., 2010; Naseem et al., 2015). Among lines genotype 9737 and 9741 considered best for this trait while among testers Chakwal-50 and Kohistan_97 were performed well under both conditions.

1000-grain weight: High positive GCA value is considered valuable for 1000 grain weight (Noorka and Tabasum, 2015; Uzair et al., 2016). Genotypes 9737, 9738, 9739, Kohistan-97 and Chakwal-50 showed good GCA results for 1000-grain weight indicating good contribution toward yield and can be a good general combiner under both stressed as well as in non-stressed conditions.

Grain yield per plant: The ultimate objective of the research was to find out best traits among genotypes that provide overall more grain production under dry areas. Hence, grain yield/plant is the final and most important trait need to be focused. Genotypes 9738 and 9737 exhibited high performing among female parents under both conditions. Among testers that are male parents Kohistan-97 performance is attractive for drought condition while Chakwal_50 performed well under normal condition for this trait. Results of all traits are shown in Table. 2 and Table. 3.

Specific Combing ability

Number of fertile tillers per plant: Under drought stress condition, high positive SCA effects were observed in 9740 × Chakwal-50 while under non-stress condition, high positive SCA effects found in 9739 × Chakwal-86 for this character.

Peduncle length: 9739 × Chakwal-86 specific hybrid considered good for this trait under both conditions as it can maintain stability of plant and use less resources (less assimilates used for vegetative growth that can be used in grain filling stage.

Awn length: In case of awn length high positive SCA effects were found in 9741 × Chakwal-86 followed by 9740 × Chakwal-50 and considered best for this trait under stressed as well in non-stressed condition.

Chlorophyll contents: High positive SCA effect was revealed in 9741 × Chakwal-86 under drought and normal irrigation conditions and used as best specific combiner for this trait specially for dry areas wheat production programs.

Number of grains per spike: In case of number of grains per spike wide variation in SCA effects were observed. High positive SCA effects were found in 9741 × Chakwal-86 that was 12.03 followed by 9740 × Chakwal-50 and 9737 × Kohistan-97 that were 11.16 and 8.09 respectively under water stressed condition while 9739 × Kohistan-97 (5.34) followed by 9738 × Chakwal-50 (4.69) showed valuable result for this character under normal condition.

Table-2: -Estimation of general combining ability (GCA) effects under drought stress (Line × Tester)

Parents	Fertile Tillers per plant	Peduncle length (cm)	Awn length (cm)	Chlor-ophyll contents	Grains per spike	1000 grains weight(g)	Grain yield per plant(g)
Lines (Females)							
9737	-0.57	0.77	0.08	-1.24	10.07	2.53	2.98
9738.	-0.71	1.12	0.18	-1.54	-1.76	-0.62	0.44
9739.	0.97	1.25	-0.29	-0.12	-0.93	1.88	-0.37
9740.	-0.27	-2.33	0.18	-0.64	-5.71	-1.23	-0.83
9741.	0.58	-0.81	-0.15	3.54	-1.68	-2.55	-2.23
S.E.	0.44	0.55	0.015	0.23	0.30	0.15	0.16
Testers (Males)							
Chakwal-50	-0.34	-1.19	-0.08	0.67	4.57	0.67	0.54
Kohistan -97	0.74	2.09	0.43	0.34	-2.23	1.03	2.22
Chakwal-86	-0.41	-0.90	-0.35	-1.01	-2.23	-1.69	-2.75
S.E.	0.34	0.43	0.01	0.18	0.23	0.11	0.13

Table-3: Estimation of general combining ability (GCA) effects under normal condition (Line × Tester)

Parents	Fertile Tillers per plant	Peduncle length (cm)	Awn length (cm)	Chlorophyll content	Grains per spike	1000 grains weight(g)	Grain yield per plant(g)
Lines/Females							
9737.	-0.82	1.37	-0.18	-1.71	4.47	-0.98	-3.09
9738.	1.09	1.68	-0.07	-1.45	-1.23	2.88	2.51
9739.	-0.82	-0.31	-0.12	-0.37	-7.92	0.04	-2.35
9740.	2.12	-2.34	0.19	0.12	-2.39	-1.80	4.65
9741.	-1.57	-0.39	0.18	3.40	7.08	-0.14	-1.73
S.E.	0.09	0.20	0.04	0.29	0.20	0.18	0.19
Testers/males							
Chakwal-50	-0.76	-1.21	-0.04	0.09	1.78	0.04	2.03
Kohistan -97	0.64	1.83	0.20	1.32	-1.42	-0.49	-1.67
Chakwal-86	0.11	-0.62	-0.17	-1.41	-0.36	0.45	-0.38
S.E.	0.07	0.16	0.03	0.22	0.16	0.14	0.15

1000-grain weight: For 1000-grain weight, high positive SCA effect was observed in 9739 × Chakwal-50 for both conditions (drought as well as normal irrigation) hence, important and helpful to utilize for increase wheat production in drought stressed areas.

Grain yield per plant: Best positive SCA effect was observed for 9740 × Chakwal-50 and 9741 × Chakwal-86 in both trials and can be valuable for dry land areas for enhancing wheat production in those areas. Results for specific combing ability are shown in Table. 4 and Table. 5.

Abbreviations: General combining ability (GCA), Specific combining ability (SCA), Marker assistant selection (MAS), Drought cross (DC), Normal cross (NC), Normal parent (NP), Drought parent (DP), Principal component (PC).

Table-4: Specific combining ability (SCA) under drought stress condition

Crosses	Fertile tillers per plant	Peduncle length (cm)	Awn length (cm)	Chlorophyll contents	Grains per spike	1000 grain weight (g)	Grain yield per plant (g)
9737×C-50	-1.63	0.15	-0.95	1.50	-8.46	-5.38	-5.95
9737×K-97	1.28	0.21	0.43	0.60	8.09	2.07	5.19
9737×C-86	0.35	-0.37	0.53	-2.09	0.36	3.31	0.77
9738×C-50	1.18	-3.13	0.32	2.09	-2.62	1.13	1.28
9738×K-97	-1.90	0.27	0.08	0.04	6.09	0.76	1.53
9738×C-86	0.72	2.86	-0.39	-2.13	-3.47	-1.90	-2.80
9739×C-50	0.41	3.57	0.42	-0.28	6.04	4.25	0.51
9739×K-97	-0.00	0.65	0.60	0.73	6.76	0.77	2.52
9739×C-86	-0.41	-4.22	-1.02	-0.46	-12.81	-5.02	-3.02
9740×C-50	2.38	-1.02	0.72	-1.63	11.16	-0.96	5.81
9740×K-97	-0.18	-1.28	-0.57	0.73	-15.04	-1.80	-5.68
9740×C-86	-2.20	2.30	-0.15	0.89	3.89	2.75	-0.14
9741×C-50	-2.34	0.42	-0.50	-1.68	-6.12	0.96	-1.65
9741×K-97	0.80	0.14	-0.53	-2.10	-5.91	-1.81	-3.53
9741×C-86	1.54	-0.57	1.03	3.78	12.03	0.85	5.17

Table-5: Specific combining ability (SCA) under normal irrigation

Crosses	Fertile tillers per plant	Peduncle length (cm)	Awn length (cm)	Chlorophyll content	Grains per spike	1000 grain weight (g)	Grain yield per plant (g)
9737×C-50	0.92	0.67	-0.7	1.7	-0.08	1.33	-5.36
9737×K-97	2.02	-0.47	0.4	0.28	-0.72	0.3	1.00
9737×C-86	-2.94	-0.2	0.3	-1.98	0.8	-1.63	4.36
9738×C-50	2.51	-3.72	-0.06	0.12	4.69	-2.07	5.05
9738×K-97	-2.14	0.23	-0.08	1.51	0.39	-0.72	-3.12
9738×C-86	-0.36	3.5	0.14	-1.62	-5.09	2.79	-1.93
9739×C-50	-3.58	4.85	0.33	-1.3	-8.03	4.64	-1.57
9739×K-97	0.52	0.17	0.37	-0.73	5.34	-2.53	2.55
9739×C-86	3.06	-5.02	-0.7	2.02	2.69	-2.11	-0.99
9740×C-50	-0.77	-1.48	0.44	1.43	-0.56	-3.07	4.8
9740×K-97	0.33	-1.98	-0.17	-0.92	0.64	0.94	0.34
9740×C-86	0.44	3.46	-0.27	-0.51	-0.09	2.13	-5.04
9741×C-50	0.92	-0.32	0	-1.95	3.97	-0.83	-2.84
9741×K-97	-0.73	2.05	-0.52	-0.14	-5.66	2.01	-0.78
9741×C-86	-0.19	-1.74	0.53	2.09	1.69	-1.18	3.60

Table-6: Estimation of GCA, SCA, additive and dominance variances under drought stress

	Fertile tillers per plant	Peduncle length (cm)	Awn length (cm)	Chlorophyll content	Grains per spike	1000 grain weight (g)	Grain yield per plant (g)
Cov. H.S (lines)	0.33	-1.61	-0.07	2.96	26.6	0.2008	4.50
Cov. H.S (testers)	-0.73	0.07	-0.02	1.14	-2.37	-1.54	-0.67
Cov. H.S (average)	-0.03	-0.14	-0.008	0.36	2.24	-0.099	0.37
Cov. F. S	5.26	11.11	0.19	8.05	46.2	6.40	23.9
Variance of GCA	-0.03	-0.14	-0.008	0.36	2.24	-0.099	0.37
Additive variance when F=0	-0.10	-0.57	-0.03	1.42	8.97	-0.39	1.44
Additive variance when F=1	-0.05	-0.28	-0.02	0.71	4.49	-0.197	0.73
Dominance variance when F=0	24.6	50.06	1.16	13.7	99.94	34.8	82.63
Dominance variance when F=1	6.14	12.5	0.29	3.43	24.98	8.70	20.8
Variance of SCA	6.14	12.5	0.29	3.43	24.98	8.70	20.8
σ^2 GCA/ σ^2 SCA	-0.004	-0.01	-0.03	0.103	0.09	-0.01	0.01

Table-7: Estimation of GCA, SCA, additive and dominance variances under normal irrigation

	Fertile tillers per plant	Peduncle length (cm)	Awn length (cm)	Chlorophyll content	Grains per spike	1000 grain weight (g)	Grain yield per plant (g)
Cov. H.S (lines)	-0.67	-0.02	-0.19	2.45	-7.40	-0.007	-4.56
Cov. H.S (testers)	-0.32	1.85	0.017	-0.27	-9.92	-0.57	1.41
Cov. H.S (average)	-0.09	0.14	-0.02	0.20	-1.42	-0.04	-0.32
Cov. F. S	1.93	9.26	0.55	6.99	104.5	12.8	22.7
Variance of GCA	-0.09	0.14	-0.02	0.20	-1.42	-0.04	-0.32
Additive variance when F=0	-0.34	0.55	-0.06	0.81	-5.70	-0.18	-1.24
Additive variance when F=1	-0.17	0.28	-0.03	0.40	-2.85	-0.09	-0.62
Dominance variance when F=0	12.3	25.2	2.83	20.5	510.15	54.85	98.6
Dominance variance when F=1	3.07	6.29	0.71	5.13	127.54	13.7	24.7
Variance of SCA	3.07	6.29	0.71	5.13	127.54	13.7	24.7
σ^2 GCA / σ^2 SCA	-0.03	0.02	0.02	0.04	-0.01	-0.003	-0.02

Table-8: Proportional contribution of lines, testers and line × tester interaction to the total variance under drought stress condition

Traits	Lines	Testers	L × T interaction
Fertile tillers	16.37	10.42	73.21
Peduncle length	23.97	27.63	48.40
Awn length	6.94	20.34	72.72
Chlorophyll contents	50.18	7.84	41.98
Grain number per spike	26.38	9.77	63.85
1000-grain weight	29.41	11.68	58.91
Grain yield per plant	14.51	20.79	64.73

Table-9: Proportional contribution of lines, testers and their interaction to the total variance under normal irrigated condition

Traits	Lines	Testers	L × T interaction
Fertile tillers	34.47	6.02	59.51
Peduncle length	19.72	16.41	63.87
Awn length	11.58	11.50	76.91
Chlorophyll contents	51.06	19.01	29.93
Grain number per spike	64.88	4.10	31.02
1000-grain weight	34.12	2	63.88
Grain yield per plant	40.55	10.33	49.15

Conclusion

Results concluded that all the parents and their hybrids were significantly vary for all the traits. For grains/spike, 1000-grain weight and seed yield per plant line 9737 was performed very well under drought stress condition unlike other lines. For chlorophyll contents line 9741 while line 9740 was best for awn length under drought stress as awn length plays significant role for "water use efficiency". Tester Kohistan-97 was considered as best general combiner under stress condition for all traits. Hybrids 9737× K-97, 9740× C-50 and 9741× C-86 were considered best specific combiners for most of the traits under drought stress that contribute more towards high grain yield. The genotypes evaluated from this analysis were also assessed from biplot analysis. The best general and specific combiners can be used to transfer valuable traits in current cultivars and highly appreciated for future breeding programs of wheat under dryland areas.

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Contribution of Authors

Sattar S: Conceived idea, data collection, data analysis, manuscript writing, statistical analysis, literature review, designed research methodology, data interpretation, manuscript final reading and approval.
Kashif M: Designed research methodology, data interpretation, manuscript final reading and approval.
Afzal R: Designed research methodology, data interpretation.
Ali M: Manuscript final reading and approval.