

# Diallel Analysis for Area, Chlorophyll and Temperature of Flag Leaf in Bread Wheat under Well Watered and Drought Stress Conditions

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## Abstract

To study genetic analysis of some physiological traits of drought stress in wheat using diallel techniques, an experiment was performed on ten bread wheat genotypes as parents and their 45 F<sub>1</sub> hybrids in a randomized complete block design with three replicates under well-watered and drought stress conditions at the Research Farm of Faculty of Agriculture, Sohag University, Egypt during season of 2018/19. The results showed significant differences between the genotypes (G), Parents (P), F<sub>1</sub> crosses, P vs. F<sub>1</sub>, GCA and SCA under well-watered and drought stress in the flag leaf area (FLA), flag leaf chlorophyll content (FLCC) and flag leaf temperature (FLT), except FLCC for F<sub>1</sub> crosses exhibited insignificant differences. The significant differences were found in the interaction of SCA × Env., in all studied traits and GCA × Env., for FLT., indicating the involvement of both additive and dominance gene action in their inheritance. The most desirable heterotic effects were considered as the largest positive heterosis estimates for FLA and FLCC, and the lowest negative for FLT. The parent numbers P<sub>9</sub>, P<sub>8</sub> and P<sub>3</sub> were the best general combiner for FLA under normal irrigation and drought stress. While the parents P<sub>2</sub>, P<sub>7</sub> and P<sub>9</sub> were the best general combiner for FLCC, under normal irrigation and (P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub>) under drought stress. Therefor the parents P<sub>1</sub>, P<sub>4</sub> and P<sub>5</sub> were the best general combiner for FLT under normal irrigation, also the P<sub>3</sub>, P<sub>4</sub> and P<sub>5</sub> were the best general combiner for FLT under drought stress conditions. Under normal irrigation and drought stress conditions as well as the combined data, the additive genetic components of variation (V<sub>A</sub>) in F<sub>1</sub>'s was much greater than dominance component (V<sub>D</sub>), as expressed by the (V<sub>A</sub>/V<sub>D</sub>) ratio which was more than unity for the FLA, and FLT under normal irrigation and their combined. This indicates that the additive gene effects in F<sub>1</sub> crosses are more important than dominance and plays the major role in the inheritance of these studied traits.

**Keywords:** Diallel analysis, Drought stress, GCA, SCA, physiological

## 1. Introduction

Wheat is the most important cereal crops in terms of area and production. Its importance is derived from many properties and uses of its grain, which make it a staple food for more than one third of the world's population. Wheat supplies about 20 percent of the food calories for the world's people and is a national staple in many countries (Braun et al., 2010). Wheat is the most important and widely adapted food cereal in Egypt. Wheat production per unit area is 6.38 ton/ha with the actual local production is about 9.00 million tons (<http://www.fao.org/faostat>) (FAO, 2019). However, still there is a big gap between the consumption and local production (48%). Another challenge facing Egypt is the growth of its population that is expected to reach 170 million by 2050 (Boko et al., 2007). Flag leaf photosynthesis rate depressed dramatically under abiotic stress at anthesis stage, cell membrane peroxidation enhanced due to enhancement of O<sub>2</sub> production and activities of antioxidant enzymes were reduced (Wang et al., 2011). Dehydration avoidance in a wheat spike in late drought or heat stress induced senescence related to the flag leaf (Tambussi et al., 2007; Vicente et al., 2018). Gámez et al. (2020) reported that the higher ear gross photosynthesis, together with leaf photosynthesis enhancement, explained the increase in plant biomass and yield under the contribution of flag leaf to grain filling is important not only under good agronomic conditions, but also under high (CO<sub>2</sub>). Carbon dioxide fixed after anthesis by the ear in wheat is ranged from 17 up to 30% of the grain weight, whereas in the absence of severe drought stress of wheat plant largely succeeds in grain development within the ear and the flag leaf area correlation with yield not by physiological activity but also by the correlation in development of large flag leaves and large ears (Thorne,

1965). Under favorable conditions, flag leaf is an important contribution to grain yield, 1000-kernel weight, and grain number, compared to penultimate and antepenultimate leaves. Flag leaf can contribute up to 48 and 22% for grain yield and number of grains (El Wazziki, 2015). The importance of flag leaf might be due to its longer green period, short distance to the spike, and direct implication in solar radiation interception (Birsin, 2005; Khaliq et al., 2004). Using drought tolerant wheat cultivars that consume less water and can tolerate soil water deficit could solve this problem. Producing new alleles and new allelic combinations that may have provided more ground for adaptation and selection (Contreras-Moreira et al., 2019). Diallel crosses represent the best strategy for determining the general (GCA) and specific (SCA) combining abilities between putative parents as subsequently, the choice of breeding methods (Chukwu et al., 2016; Samah, 2019). The current investigation aimed to: (1) Study the effect of drought stress at anthesis stage on some physiological traits for  $F_1$  crosses and their parents. (2) Estimation of the general and specific combining ability effects and the genetic behavior of the parents and their crosses related to physiological traits.

## 2. Materials and Methods

### 2.1 Plant Materials and Layout

The current investigation was carried out during winter season of 2018/19 at Research Farm, Faculty of Agriculture, Sohag University, Egypt. Ten genetically diverse of bread wheat (*Triticum aestivum* L.) genotypes (Table 1) included of three Egyptian cultivars (Giza-168, Sids-12 and Misr-1) and seven accessions, their seeds were imported in 2010 from Nordic Genetic Resource Center (Nord Gen) then, after adapted under Sohag conditions.  $F_1$  seeds of each 45 crosses as well as their parents were sown in the field of two experiments in a randomized complete block design (RCBD) with three replications. Each plot consisted of 3 rows, 3 m long and 20 cm wide; with seed spaced 10 cm a part (plot size = 1.8 m<sup>2</sup>). The first experiment was subjected to normal irrigation conditions and the second one exposed to drought stress conditions at anthesis stage (withholding water from anthesis to maturity).

### 2.2 Measurements

Three physiological traits were recorded for 45  $F_1$  crosses and their parents as following: (1) Flag leaf Chlorophyll content (FLCC): was recorded in the middle of 20 flag leaves using SPAD 502. (2) Flag leaf area was measured by (maximum length  $\times$  maximum width  $\times$  0.75) of 20 flag leaves according to (Blum, 1983). (3) Flag leaf temperature: it was measured by Infrared thermometer at mid-day in 20 flag leaves.

Table 1. The 10 parents including Giza168, Sids12, Misr1 and 7 imported genotypes

Parents	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Code	NGB6404	NGB6406	NGB10893	NGB11099	NGB9955	NGB6681	NGB8950	Giza 168	Sids 12	Misr 1
Country	unknown	unknown	Denmark	Denmark	Sweden	Sweden	unknown	Egypt	Egypt	Egypt

### 2.3 Biometrical and genetic analyses

Data of the  $F_1$  diallel (45  $F_1$ s and 10 parents) recorded under normal irrigation as well as for drought stress were subjected to the single analysis of variance and combine analysis of two environments in randomized complete blocks design using SAS software (SAS ver. 9.2, SAS Institute 2008) according to K. A. Gomez and A. A. Gomez (1984). Analyses of Genetic Designs were performed in R. Version 3.0 (2018-06-20). Genotypes degrees of freedom were partitioned into parents, crosses, and parents vs. crosses. The  $F_1$  degrees of freedom were partitioned into general combining ability (GCA) and specific combining ability (SCA) according to Method-2 Model-I of Griffing (1956), furthermore the interaction degrees of freedom for Genotypes  $\times$  Environment, were partitioned into GCA  $\times$  Environment and SCA  $\times$  Environment according to Method-2 Model-I of Griffing, (1956). The least significant differences (LSD) between means for combined analysis were estimated according to Snedecor and Cochran (1989).

#### 2.3.1 Estimating the Variance Components in $F_1$ Generation

$V_{gca} = (MS_{gca} - MS_e)/(P + 2)$ ;  $V_{sca} = (MS_{sca} - MS_e)$ ;  $V_p = 2V_{gca} + V_{sca} + V_e$ ;  $V_G = 2V_{gca} + V_{sca}$ ;  $V_A = 2V_{gca}$ ;  $V_D = V_{gca} - V_A$ , where,  $MS_{gca}$  = mean squares of general combining ability,  $MS_{sca}$  = mean square of specific combining ability,  $V_{gca}$  = GCA variance,  $V_{sca}$  = SCA variance,  $V_p$  = phenotypic variance,  $V_G$  = genotypic variance,  $V_A$  = additive variance,  $V_D$  = dominance variance.

### 2.3.2 Average Degree of Dominance Calculation

Average degree of dominance [a] was calculated by the following equation:  $[a] = [2V_D/V_A]^{1/2}$ . The estimates of the average degree of dominance [a] were used to indicate the type of dominance, as follows: [a] = 0 indicates no dominance, [a] < 1 indicates partial dominance, [a] = 1 indicates complete dominance and [a] > 1 indicates over dominance.

### 2.3.3 Estimating Heritability and Genetic Advance From Selection

Heritability in the broad ( $H_b$ ) and narrow ( $H_n$ ) sense in  $F_1$  were estimated from the following formulae:  $H_b = (V_G/V_P) \times 100$ , and  $H_n = (V_A/V_P) \times 100$ . The expected genetic advance from selection was calculated as follows:  $GA = K \times H_b \times (V_P)^{1/2}$ , where, k is the intensity of selection ( $k = 2.06$  at 5% selection intensity). Genetic advance over mean (GAM) =  $(GA/\bar{X}) \times 100$ .

### 2.3.4 Heterosis Estimation

Percentages of  $F_1$  relative to the mid parent (heterosis) for studied traits of the  $F_1$  diallel were calculated as follows: Heterosis (%) =  $(F_1 - MP)/MP$ . Percentages of  $F_1$  relative to the best parent (heterobeltiosis) for studied traits of the  $F_1$  diallel were calculated as follows: Heterosis (%) =  $(F_1 - BP)/BP$ , where,  $F_1$  = mean of the  $F_1$  cross, MP = mid parents of the  $F_1$  cross, BP = mean of the better parent.

## 3. Results and Discussions

### 3.1 Analysis of Variance of Ten Parents and Their Crosses

The significant or highly significant differences were found among the 10 parents for studied traits under normal irrigation, drought stress and overall, two environments, the flag leaf area (FLA), flag leaf chlorophyll content (FLCC) and flag leaf temperature (FLT) under normal irrigation and drought stress showed highly significant differences between these parents (Table 2). These results are harmony with those obtained by Esmail et al. (2016), and Samah (2019), they revealed that highly significant differences among the genotypes for all characters indicating the presence of considerable variability among the bread wheat lines. Gautam et al. (2016), and Sharma et al. (2018) revealed that physiological traits like canopy temperature and Chlorophyll (Chl) fluorescence could be used as stress markers in field conditions to screen stress tolerant and sensitive wheat genotypes under adverse conditions. Similarity, highly significant differences were found among the 45  $F_1$  crosses under normal irrigation, drought stress and overall, two environments for all studied traits, except the chlorophyll content of flag leaf showed insignificant differences among the  $F_1$  crosses under drought stress and over two environments (Table 2). These results are similar with those obtained by Masood et al. (2005), Al-Otayk (2010), Mohammadi et al. (2012), Esmail et al. (2016), Moharam et al. (2017), and Sharma and Uddin (2020). Furthermore, highly significant differences were found in the physiological traits except the FLT under normal irrigation only were insignificant differences and overall, two environments (Table 2). The general combining ability (GCA) was highly significant differences in all studied traits under both of normal irrigation, drought stress and overall environments. Specific combining ability (SCA) were exhibited highly significant differences in all studied traits under normal irrigation, drought stress and overall two environments, except the FLT under overall two environments were insignificant. These finding are very similar with those obtained by Ahmad (2010) found that the mean squares of the genotypes (six parents and their 15  $F_1$  crosses), GCA and SCA were highly significant for days to 50% blooming. These results indicated that both additive and non-additive gene effects played important roles in the inheritance of flag leaf area (FLA), flag leaf chlorophyll content (FLCC) and flag leaf temperature (FLT) traits under normal irrigation and drought stress conditions. the interaction of  $GCA \times Env.$ , was highly significant differences in the flag leaf temperature (FLT) and insignificant differences in flag leaf area (FLA) and flag leaf chlorophyll content (FLCC). Golparvar (2013) found that mean square of general combining ability was significant also for flag leaf area (FLA) and mean square of specific combining ability was significant also for the same trait of bread wheat cultivars under drought stress condition. These results due to the insignificant differences  $F_1$  and Parents under normal irrigation, and insignificant differences between  $F_1$  crosses in FLCC under drought stress and overall, two environments. These results confirmed by Said (2014), Jatoi et al. (2014), and Sharma and Uddin (2020). In addition, the interaction of  $SCA \times Env.$ , had highly significant differences in all studied traits, these results due to the significant differences of  $Gen. \times Env.$ , in all studied traits.

### 3.2 Mean Performance of the Parents

Data presented in Table 3 revealed that significant differences were found between the parents in all studied traits under normal irrigation and drought stress conditions. The parents  $P_9$ ,  $P_8$  and  $P_3$  were larger flag leaf area (32.59, 31.14 and 27.57  $cm^2$ ) and (31.34, 20.04 and 20.37  $cm^2$ ) under normal irrigation and drought stress, respectively

indicating that these parents are a higher photosynthetic rate in the end of growth season under normal irrigation and drought stress.

Table 2. Analysis of variance of physiological traits for 10 parents and their F<sub>1</sub> crosses under normal irrigation, drought stress conditions and over two environments

S.O.V	DF	Normal irrigation and drought stress						Combined analysis				
		FLA		FLCC		FLT		S.O.V	DF	FLA	FLCC	FLT
		WW	DS	WW	DS	WW	DS					
Rep	2	2.56	12.35	3.59	5.75	0.01	12.35	Env.	1	758.1**	1521.4**	656.6**
Gen.	54	51.61**	46.98**	31.89**	36.10**	7.70**	46.98**	Rep (Env)	4	7.46	4.67	0.12
parents	9	62.58**	58.03**	37.38**	32.54**	6.71*	58.03**	Gen.	54	88.06**	52.72**	8.77**
F1 Crosses	44	48.70**	37.69**	22.18**	16.27 ns	8.06**	37.69**	Parents	9	111.3**	46.79**	5.58**
P. vs. F <sub>1</sub>	1	80.78**	356.33**	409.5**	940.4**	0.36	356.3*	F <sub>1</sub>	44	76.50**	25.68 ns	9.50**
Error	108	4.76	4.58	8.50	11.44	1.13	4.58	P. vs. F <sub>1</sub>	1	388.2**	1295.5**	5.75 ns
GCA	9	232.19**	171.66**	39.33**	30.35**	25.06**	171.6**	Env × Gen.	54	10.52**	15.27*	4.34**
SCA	45	15.49**	22.04**	30.40**	37.25**	4.22**	22.04**	Error	216	4.67	9.97	1.20
								GCA	9	397.1**	57.67**	29.40*
								SCA	45	26.24**	51.72**	4.65 ns
								Env × GCA	9	6.65 ns	12.01 ns	10.22**
								Env × SCA	45	11.29**	15.92*	3.16**

Note. WW = Normal irrigation, DS = Drought stress, DH = Days to 50% heading, DA = Days to 50% anthesis, DM = Days to 50% maturity, \* = significant differences at 5% levels, \*\* = high significant differences at 1% levels.

The parents P<sub>10</sub>, P<sub>9</sub> and P<sub>2</sub> were the highest in the flag leaf chlorophyll content (50.71, 51.01 and 46.43 SPAD) under normal irrigation, while the higher parents in FLCC were P<sub>7</sub>, P<sub>3</sub> and P<sub>2</sub> (39.59, 39.92 and 40.52 SPAD) under drought stress condition. Furthermore, these parents were differed significantly in the flag leaf temperature. The lowest flag leaf temperature (FLT) was found in P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> (21.40, 23.36 and 23.49 °C) under normal irrigation, while the P<sub>3</sub>, P<sub>4</sub> and P<sub>9</sub> were the lowest FLT (28.01, 28.55 and 27.97 °C) under drought stress conditions. Drought tolerant genotypes had canopy temperature depression (CTD) as compared to intermediate and susceptible genotypes (Hasheminasab et al., 2012).

Table 3. Performance reduction percentage of the parents for physiological traits under normal irrigation, drought stress conditions

Parent	Flag leaf area			Flag leaf chl.			Flag leaf temp.		
	WW	DS	Red. %	WW	DS	Red. %	WW	DS	Red. %
P <sub>1</sub>	21.43	13.459	37.20	37.67	27.02	7.66	21.40	29.2	-36.45
P <sub>2</sub>	26.23	17.697	32.53	46.53	40.57	6.25	23.36	30.07	-28.72
P <sub>3</sub>	27.57	20.366	26.13	43.23	39.92	16.73	23.49	28.01	-19.24
P <sub>4</sub>	14.96	11.934	20.23	40.62	38.08	11.83	24.22	28.545	-17.86
P <sub>5</sub>	17.10	14.003	18.11	43.16	35.94	3.18	24.74	29.135	-17.76
P <sub>6</sub>	23.67	19.306	18.44	43.28	38.16	19.59	27.35	30.345	-10.95
P <sub>7</sub>	22.31	18.282	18.05	40.89	39.59	32.11	26.62	29.355	-10.27
P <sub>8</sub>	31.14	20.038	35.65	41.81	33.62	25.68	26.45	30.685	-16.01
P <sub>9</sub>	32.59	31.342	3.83	51.01	34.63	16.79	25.40	27.975	-10.14
P <sub>10</sub>	24.47	17.919	26.77	50.71	37.69	7.66	26.14	29.665	-13.49
Mean	24.15	18.43	23.69	43.89	36.52	6.25	24.91	29.30	-17.62
LSD 5%	7.67	3.18		3.56	2.86		2.96	2.42	

Note. WW = Normal irrigation, DS = Drought stress, Red. = Reduction percentage.

The P<sub>3</sub> have large flag leaf, high flag leaf chlorophyll content and lower flag leaf temperature. This is indicator for drought stress tolerance and more stability for physiological traits. This finding suggests that the P<sub>3</sub>

(NGB10893) found to be higher in its ability to respond to drought and high temperature, thereby tolerance of such this parent could be useful as genetic stock to develop wheat tolerant varieties in breeding programs. Similar results were found by Khatab et al. (2016), whereas they reported that, tolerant genotypes such as Misr1, Misr2, Sids1 and Sham4 genotypes which are classified as tolerant genotypes had the highest chlorophyll content and flag leaf area. The physiological traits were studied previously by many authors, *i.e.*, Masood et al. (2005) said that landraces having more leaf area and lower chlorophyll content. Zareian and Tabatabae (2014) concluded that water stress through with holding at the ear emergence and grain filling phases reduced chlorophyll.

### *3.3 Mean Performance of the F<sub>1</sub> Crosses*

The data in Table 4 showed that the significant differences among 45 F<sub>1</sub> crosses in physiological traits under normal irrigation and drought stress. Data in Table 4 showed that the FIA and FLCC of F<sub>1</sub> crosses were higher than their parents by (8.42 and 20.22%) and (10.21 and 17.19%) under normal irrigation and drought stress, respectively. while the flag leaf temperature of F<sub>1</sub> crosses increased by 0.6 and decreased by 3.5% more than their parents under normal irrigation and drought stress respectively. Generally, in F<sub>1</sub> the drought stress reduced the FLA and FLCC by 12.40 and 9.80% respectively, also the flag leaf temperature of F<sub>1</sub> increased by 3.25 °C under drought stress. Similar results were found by Almeselmani et al. (2015).

Table 4. Performance and reduction% of F<sub>1</sub> crosses for physiological traits under normal irrigation, drought stress conditions

F <sub>1</sub>	Fag leaf area			Flag leaf Chl.			Flag leaf temperature			
	WW	DS	Red.	WW	DS	Red.	WW	DS	Red.	
P <sub>1</sub>	P <sub>2</sub>	23.67	18.85	20.36	50.70	43.25	14.69	24.09	27.82	-15.48
	P <sub>3</sub>	22.69	24.58	-8.33	52.23	41.63	20.29	22.47	27.83	-23.85
	P <sub>4</sub>	17.38	19.70	-13.35	48.85	43.73	10.48	21.73	26.58	-22.32
	P <sub>5</sub>	19.25	16.00	16.88	46.13	41.05	11.01	24.88	27.42	-10.21
	P <sub>6</sub>	22.43	22.08	1.56	48.73	42.55	12.68	21.90	28.19	-28.72
	P <sub>7</sub>	20.31	18.44	9.21	51.65	42.33	18.04	23.65	29.23	-23.59
	P <sub>8</sub>	27.70	20.28	26.79	47.83	43.35	9.37	22.90	29.97	-30.87
	P <sub>9</sub>	32.15	27.67	13.93	52.08	43.10	17.24	23.87	27.53	-15.33
	P <sub>10</sub>	19.59	17.88	8.73	44.65	43.83	1.84	24.65	30.50	-23.73
	P <sub>2</sub>	P <sub>3</sub>	28.90	25.99	10.07	46.82	45.63	2.54	25.77	28.72
P <sub>4</sub>		17.68	15.17	14.20	44.50	44.80	-0.67	24.52	26.37	-7.54
P <sub>5</sub>		20.65	15.49	24.99	47.33	43.73	7.61	23.25	27.05	-16.34
P <sub>6</sub>		26.74	24.18	9.57	49.88	41.45	16.90	23.67	30.35	-28.22
P <sub>7</sub>		25.83	24.63	4.65	58.80	50.25	14.54	22.34	30.20	-35.18
P <sub>8</sub>		34.39	25.98	24.45	48.52	43.09	11.19	23.85	28.75	-20.55
P <sub>9</sub>		25.17	21.02	16.49	53.83	45.25	15.94	27.62	30.93	-11.98
P <sub>10</sub>		20.79	27.35	-31.55	47.08	41.98	10.83	27.87	29.87	-7.18
P <sub>3</sub>	P <sub>4</sub>	24.84	22.01	11.39	45.38	42.43	6.50	23.72	26.47	-11.59
	P <sub>5</sub>	26.54	21.49	19.03	49.19	45.50	7.50	22.68	26.05	-14.86
	P <sub>6</sub>	30.66	25.60	16.50	49.50	47.45	4.14	25.43	26.55	-4.40
	P <sub>7</sub>	28.73	29.39	-2.30	49.53	45.53	8.08	27.50	26.55	3.45
	P <sub>8</sub>	33.06	31.00	6.23	49.53	41.28	16.66	24.88	25.92	-4.18
	P <sub>9</sub>	33.85	26.91	20.50	47.93	42.00	12.37	28.22	26.68	5.46
	P <sub>10</sub>	28.33	25.90	8.58	46.03	42.20	8.32	26.17	27.92	-6.69
P <sub>4</sub>	P <sub>5</sub>	17.15	22.07	-28.69	50.95	43.15	15.31	24.95	27.00	-8.22
	P <sub>6</sub>	18.82	17.02	9.56	46.03	42.63	7.39	23.62	25.03	-5.97
	P <sub>7</sub>	24.40	18.78	23.03	46.58	43.40	6.83	23.42	27.22	-16.23
	P <sub>8</sub>	29.78	23.31	21.73	47.33	42.60	9.99	25.52	26.20	-2.66
	P <sub>9</sub>	28.53	21.09	26.08	47.50	41.40	12.84	23.90	27.13	-13.51
	P <sub>10</sub>	23.62	20.02	15.24	46.23	43.10	6.77	22.63	27.75	-22.62
P <sub>5</sub>	P <sub>6</sub>	26.17	19.41	25.83	44.80	41.90	6.47	23.37	26.63	-13.95
	P <sub>7</sub>	26.80	21.60	19.40	45.45	43.20	4.95	23.52	27.47	-16.79
	P <sub>8</sub>	24.83	22.25	10.39	46.88	41.35	11.80	24.57	29.17	-18.72
	P <sub>9</sub>	26.08	20.50	21.40	51.90	44.15	14.93	25.10	28.22	-12.43
	P <sub>10</sub>	25.60	17.33	32.30	41.80	43.35	-3.71	25.62	31.37	-22.44
P <sub>6</sub>	P <sub>7</sub>	25.82	23.18	10.22	52.53	36.45	30.61	26.35	30.80	-16.89
	P <sub>8</sub>	27.49	24.82	9.71	56.25	49.01	12.87	27.40	32.84	-19.85
	P <sub>9</sub>	34.61	29.37	15.14	45.88	51.00	-11.16	26.00	29.25	-12.50
	P <sub>10</sub>	25.95	24.19	6.78	50.05	47.55	5.00	25.95	29.55	-13.87
P <sub>7</sub>	P <sub>8</sub>	28.51	23.56	17.36	46.13	46.43	-0.65	29.47	30.10	-2.14
	P <sub>9</sub>	31.40	27.79	11.50	52.98	47.43	10.48	27.42	29.10	-6.13
	P <sub>10</sub>	28.57	24.24	15.16	51.73	48.83	5.61	28.68	30.00	-4.60
P <sub>8</sub>	P <sub>9</sub>	34.08	33.42	1.94	50.43	48.85	3.13	28.83	28.85	-0.07
	P <sub>10</sub>	34.84	29.15	16.33	48.93	43.68	10.73	27.02	27.57	-2.04
P <sub>9</sub>	P <sub>10</sub>	32.20	28.87	10.34	53.30	47.88	10.17	26.88	29.32	-9.08
<b>Mean</b>	<b>26.37</b>	<b>23.10</b>	<b>12.40</b>	<b>48.89</b>	<b>44.10</b>	<b>9.80</b>	<b>25.06</b>	<b>28.31</b>	<b>-12.89</b>	
<b>LSD 5%</b>	<b>3.67</b>	<b>4.32</b>		<b>4.9693</b>	<b>7.32</b>		<b>1.97</b>	<b>2.12</b>		

Note. WW = Normal irrigation, DS = Drought stress, Red. = Reduction percentage.

The largest flag leaf (34.61 and 29.37 cm<sup>2</sup>) and (33.42 and 34.08 cm<sup>2</sup>) were found in P<sub>6</sub> × P<sub>9</sub> and P<sub>8</sub> × P<sub>9</sub> under well water and drought stress respectively. This is an indicator for efficiency of these F<sub>1</sub> crosses in

photosynthesis process under drought stress. The highest values of flag chlorophyll content (58.80 and 56.5 SPAD) and (50.25 and 49.01 SPAD) were found in the  $P_2 \times P_7$  and  $P_6 \times P_8$   $F_1$  crosses under normal irrigation and drought stress, respectively. Furthermore, FLA reduced under drought stress of  $P_1 \times P_8$  and  $P_4 \times P_9$  by 16.79, 26.08 and 32.30% respectively. The  $F_1$  of  $P_2 \times P_7$  and  $P_6 \times P_8$  were the highest FLCC (58.80 and 56.25) and (50.25 and 49.01) under normal irrigation and drought stress respectively. The  $F_1$  crosses ( $P_1 \times P_3$ ), ( $P_1 \times P_4$ ), ( $P_1 \times P_6$ ), ( $P_2 \times P_7$ ) and ( $P_4 \times P_{10}$ ) were the lowest FLT (22.47, 21.73, 21.90, 22.34 and 22.36 °C) under normal irrigation and increased by (5.36, 4.85, 6.29, 7.86 and 5.12 °C) in drought stress respectively. Meanwhile, the crosses ( $P_4 \times P_8$ ), ( $P_7 \times P_8$ ), ( $P_8 \times P_9$ ) and ( $P_8 \times P_{10}$ ) did not affected by drought stress in FLT.

### 3.4 Heterosis and Heterobeltiosis in $F_1$ Crosses

Percentages of heterosis relative to the mid parent (Table 5) and best parent (Table 6) of  $F_1$  crosses for studied traits under normal irrigation, drought stress and over two conditions are presented. The most desirable heterotic effects were considered as the largest positive heterosis estimates for Flag leaf area (FLA) and Flag leaf chlorophyll content (FLCC), and the lowest negative for Flag leaf temperature (FLT). Average heterosis across all  $F_1$  hybrids was preceded significant at 5% and/or 1% probability for FLA and FLCC under normal irrigation, drought stress and combined analysis, with exceptions the cross  $P_4 \times P_5$  was insignificant under the three drought levels for mid and best parents (Table 5). These results were confirmed by Said (2014), and Sharma and Uddin (2020), they reported that high heterosis of bread wheat hybrids was observed for all studied characters under both water treatments in the two crosses, and chlorophyll content (CC) in the first cross. While the crosses ( $P_2 \times P_7$ ), ( $P_2 \times P_9$ ), ( $P_2 \times P_{10}$ ) and ( $P_3 \times P_9$ ) were exhibited  $H_{MP}$  for FLT under well water, the crosses ( $P_3 \times P_8$ ) and ( $P_4 \times P_8$ ) were significant of  $H_{MP}$  under drought stress, and ( $P_5 \times P_6$ ) expressed desirable significant  $H_{MP}$  under the normal irrigation, drought stress and combined. Akinci (2009) revealed that heterosis percentages in bread wheat crosses for high-parent and mid-parent were -2.16% and -0.74% for heading date. Mostly, the interesting desirable  $H_{MP}$  of the  $F_1$  crosses were  $P_4 \times P_8$  (29.22, 45.81 and 36.01%) for FLA,  $P_6 \times P_8$  (32.21, 36.54 and 34.20%) for FLCC and  $P_5 \times P_6$  (10.27, -10.46 and -10.36%) for FLT under normal irrigation drought stress and combined over two conditions, respectively. The heterosis related to the best parent ( $H_{BP}$ ) presented in Table 6. The largest positive  $H_{BP}$  were recorded for FLA in the  $F_1$  crosses  $P_5 \times P_7$  (20.09%) under normal irrigation,  $P_6 \times P_5$  (57.59 and 26.10%) under both of drought stress and combined. The  $P_6 \times P_8$  was the largest  $H_{BP}$  (29.97 and 29.24%) under non stress and combined, and the cross  $P_8 \times P_9$  was the largest  $H_{MP}$  (43.15%) under drought stress for FLCC, also the cross  $P_1 \times P_6$  (-19.91%) and  $P_2 \times P_7$  (-16.07%) were the most desirable  $H_{BP}$  for FLT under non stress, and  $P_4 \times P_6$  were the largest  $H_{BP}$  (-17.31 and -16.67) under drought stress and combined analysis (see Table 6). These finding are in line with those obtained by Jatou et al. (2014) revealed that the  $F_1$  crosses, *i.e.*, (TD-1×TJ-83, Kiran × Sarsabz), (Kiran × Moomaland) and (Sarsabz × Moomal) showed greater mid and high parent heterotic response under both environments for leaf area.

### 3.5 General Combining Ability Estimates (GCA)

Estimates of GCA effects of parents for the studied traits under normal irrigation and drought stress are presented in Table (7). Favorable significant GCA effects were expressed by negative estimates for FLT. The data showed that the  $P_9$ ,  $P_8$  and  $P_3$  were the best general combiner for FLA which is ranked as 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup>, respectively under normal irrigation and drought stress. While the parents  $P_2$ ,  $P_7$  and  $P_9$  were the best general combiner for FLCC, which were ranked as (2<sup>nd</sup>, 3<sup>rd</sup> and 1<sup>st</sup>) under normal irrigation and (2<sup>nd</sup>, 1<sup>st</sup> and 3<sup>rd</sup>) under drought stress. Therefor the parents  $P_1$ ,  $P_4$  and  $P_5$  were the best general combiner for FLT and ranked as (10<sup>th</sup>, 9<sup>th</sup> and 8<sup>th</sup>) under normal irrigation, also the  $P_3$ ,  $P_4$  and  $P_5$  were the best general combiner for FLT and ranked as (9<sup>th</sup>, 10<sup>th</sup> and 8<sup>th</sup>) under drought stress conditions. These results are agreement with those obtained by Ahmad (2010) he found that the best general combiners were  $P_1$ ,  $P_4$  and  $P_6$  (earlier) for days to 50% blooming.

Table 5. Heterosis of F<sub>1</sub> related to Mid-Parents for physiological traits under normal irrigation, stress conditions and overall, two environments

F <sub>1</sub>		Flag leaf area			Flag leaf chlorophyll con.			Flag leaf temperature		
		WW	DS	Comb.	WW	DS	Comb.	WW	DS	Comb.
P <sub>1</sub>	P <sub>2</sub>	-0.66	21.03**	7.91**	20.43**	27.98**	23.79**	7.65	-6.13	-0.21
	P <sub>3</sub>	-7.38*	45.31**	14.14**	29.11**	24.37**	26.96**	0.11	-2.70	-1.47
	P <sub>4</sub>	-4.47	55.14**	20.03**	24.79**	34.33**	29.12**	-4.71	-7.93	-6.51
	P <sub>5</sub>	-0.04	16.49**	6.84*	14.13**	30.40**	21.25**	7.86	-6.00	0.12
	P <sub>6</sub>	-0.53	34.79**	14.33**	20.38**	30.55**	24.92**	-10.14	-5.33	-7.50
	P <sub>7</sub>	-7.11*	16.20**	2.69	31.49**	27.08**	29.47**	-1.49	-0.15	-0.75
	P <sub>8</sub>	5.40	21.06**	11.50**	20.34**	42.97**	30.14**	-4.27	0.08	-1.85
	P <sub>9</sub>	19.05**	23.50**	21.07**	17.44**	39.82**	26.62**	1.99	-3.69	-1.13
	P <sub>10</sub>	-14.62**	13.98**	-3.00	1.04	35.45**	15.59**	3.71	3.63	3.67
	P <sub>2</sub>	P <sub>3</sub>	7.43*	36.57**	19.50**	4.31*	13.37**	8.59**	10.03	-1.11
P <sub>4</sub>		-14.18**	2.39	-7.25	2.12	13.92**	7.72**	3.08	-10.03	-4.16
P <sub>5</sub>		-4.66	-2.28	-3.66	5.53**	14.30**	9.57**	-3.31	-8.62	-6.24
P <sub>6</sub>		7.18*	30.67**	17.18**	11.07**	5.30*	8.37**	-6.64	0.47	-2.78
P <sub>7</sub>		6.41*	36.91**	19.39**	34.52**	25.37**	30.15**	-10.60*	1.64	-3.95
P <sub>8</sub>		19.90**	37.70**	26.96**	9.84**	16.15**	12.72**	-4.23	-5.36	-4.85
P <sub>9</sub>		-14.44**	-14.27**	-14.36**	10.36**	20.35**	14.71**	13.29*	6.58	9.64*
P <sub>10</sub>		-18.00**	53.58**	11.53**	-3.18	7.27**	1.48	12.62*	0.00	5.71
P <sub>3</sub>	P <sub>4</sub>	16.79**	36.26**	25.20**	8.23**	8.78**	8.50**	-0.56	-6.40	-3.73
	P <sub>5</sub>	18.84**	25.08**	21.55**	13.87**	19.96**	16.72**	-5.92	-8.83	-7.50
	P <sub>6</sub>	19.67**	29.06**	23.77**	14.44**	21.54**	17.81**	0.07	-9.01	-4.78
	P <sub>7</sub>	15.18**	52.09**	31.29**	17.75**	14.51**	16.18**	9.77	-7.43	0.59
	P <sub>8</sub>	12.62**	53.45**	29.27**	16.47**	12.25**	14.52**	-0.33	-11.69*	-6.47
	P <sub>9</sub>	12.53**	4.10	8.63**	1.71	12.68**	6.55**	15.44*	-4.68	4.70
	P <sub>10</sub>	8.88**	35.29**	20.07**	-2.01	8.75**	2.86	5.47	-3.19	0.81
P <sub>4</sub>	P <sub>5</sub>	7.02	70.16**	35.26**	21.63**	16.59**	19.26**	1.94	-6.38	-2.56
	P <sub>6</sub>	-2.54	8.94	2.60	9.71**	11.82**	10.72**	-8.39	-14.98**	-11.91*
	P <sub>7</sub>	30.95**	24.28**	27.97**	14.28**	11.75**	13.05**	-7.86	-5.99	-6.86
	P <sub>8</sub>	29.22**	45.81**	36.01**	14.82**	18.83**	16.69**	0.74	-11.53*	-5.88
	P <sub>9</sub>	20.00**	-2.52	9.27**	3.68	13.88**	8.19**	-3.66	-3.99	-3.83
	P <sub>10</sub>	19.83**	34.12**	25.99**	1.23	13.77**	6.91**	-10.10	-4.66	-7.18
P <sub>5</sub>	P <sub>6</sub>	28.38**	16.55**	23.06**	3.66	13.09**	8.01**	-10.27*	-10.45*	-10.36**
	P <sub>7</sub>	35.99**	33.83**	35.01**	8.15**	14.39**	11.10**	-8.41	-6.08	-7.17
	P <sub>8</sub>	2.94	30.72**	14.43**	10.33**	18.89**	14.19**	-4.00	-2.48	-3.18
	P <sub>9</sub>	4.95	-9.59**	-1.98	10.23**	25.12**	16.61**	0.13	-1.18	-0.57
	P <sub>10</sub>	23.18**	8.56	16.83**	-10.94**	17.75**	1.67	0.71	6.69	3.92
P <sub>6</sub>	P <sub>7</sub>	12.31**	23.35**	17.28**	24.81**	-6.24**	9.90**	-2.34	3.18	0.56
	P <sub>8</sub>	0.31	26.17**	11.12**	32.21**	36.54**	34.20**	1.88	7.61	4.92
	P <sub>9</sub>	23.01**	15.98**	19.68**	-2.69	40.13**	15.96**	-1.41	0.31	-0.51
	P <sub>10</sub>	7.80*	29.99**	17.48**	6.50**	25.38**	14.93**	-2.95	-1.52	-2.19
P <sub>7</sub>	P <sub>8</sub>	6.65*	22.96**	13.47**	11.55**	26.83**	18.72**	11.07	0.27	5.33
	P <sub>9</sub>	14.39**	11.99**	13.25**	15.29**	27.80**	20.88**	5.42	1.52	3.37
	P <sub>10</sub>	22.12**	33.93**	27.27**	12.94**	26.36**	19.08**	8.75	1.66	5.01
P <sub>8</sub>	P <sub>9</sub>	6.96**	30.11**	17.29**	8.65**	43.15**	23.27**	11.23	-1.64	4.40
	P <sub>10</sub>	25.31**	53.59**	36.79**	5.76**	22.49**	13.04**	2.76	-8.64	-3.33
P <sub>9</sub>	P <sub>10</sub>	12.86**	17.22**	14.88**	4.80**	32.40**	16.27**	4.33	1.72	2.95

Note. WW = Normal irrigation, DS = Drought stress, Comb = Combined over two conditions. \* = significant differences at 5% levels, \*\* = high significant differences at 1% levels.



Table 6. Heterosis of F<sub>1</sub> related to best-Parents for physiological traits under normal irrigation, stress conditions and overall, two environments

F <sub>1</sub>	Flag leaf area			Flag leaf chlorophyll con.			Flag leaf temperature				
	WW	DS	Comb.	WW	DS	Comb	WW	DS	Comb.		
P <sub>1</sub>	P <sub>2</sub>	-9.76**	6.54	-3.20	8.96**	6.61*	7.86**	3.15	-7.49	-2.85	
	P <sub>3</sub>	-17.70**	20.67**	-1.41	20.81**	4.27	12.87**	-4.34	-4.68	-2.32	
	P <sub>4</sub>	-18.89**	46.35**	6.28	20.26**	14.82**	17.63**	-10.25	-8.96	-8.42	
	P <sub>5</sub>	-10.14*	14.23*	1.04	6.87**	14.22**	10.21**	0.59	-6.11	-2.92	
	P <sub>6</sub>	-5.25	14.38**	3.57	12.58**	11.49**	12.07**	-19.91**	-7.11	-13.18**	
	P <sub>7</sub>	-8.96*	0.88	-4.53	26.31**	6.91**	16.77**	-11.14	-0.42	-5.51	
	P <sub>8</sub>	-11.04**	1.19	-6.25*	14.39**	28.94**	20.87**	-13.41	-2.34	-7.46	
	P <sub>9</sub>	-1.34	-11.73**	-6.43**	2.09	24.46**	11.13**	-6.04	-5.71	-3.70	
	P <sub>10</sub>	-19.93**	-0.20	-11.59**	-11.95**	16.28**	0.09	-5.68	2.81	-1.16	
	P <sub>2</sub>	P <sub>3</sub>	4.82	27.62**	14.50**	0.61	12.46**	6.13**	9.72	-4.50	1.98
P <sub>4</sub>		-32.62**	-14.28**	-25.24**	-4.36*	10.43**	2.53	1.25	-12.31*	-4.76	
P <sub>5</sub>		-21.26**	-12.48	-17.73**	1.71	7.78*	4.54**	-6.00	-10.04	-6.63	
P <sub>6</sub>		1.95	25.23**	15.91**	7.19**	2.17	4.85**	-13.45*	0.02	-6.37	
P <sub>7</sub>		-1.53	34.72**	14.86**	26.37**	23.86**	25.20**	-16.07*	0.43	-6.14	
P <sub>8</sub>		10.45**	29.66**	17.97**	4.27	6.20*	5.17**	-9.83	-6.31	-7.94	
P <sub>9</sub>		-22.78**	-32.93**	-27.76**	5.52*	11.54**	13.75**	8.73	2.87	9.59*	
P <sub>10</sub>		-20.76**	52.63**	9.57**	-7.17**	3.46	0.74	6.63	-0.68	3.47	
P <sub>3</sub>		P <sub>4</sub>	-9.93**	8.05	-2.29	4.96*	6.28*	5.59**	-2.06	-7.28	-4.88
		P <sub>5</sub>	-3.74	5.54	0.20	13.78**	13.98**	13.87**	-8.30	-10.59	-9.54*
	P <sub>6</sub>	11.20**	25.70**	17.36**	14.37**	18.86**	16.60**	-6.99	-12.51*	-9.89*	
	P <sub>7</sub>	4.20	44.30**	21.23**	14.56**	14.04**	14.31**	3.32	-9.56	-3.43	
	P <sub>8</sub>	6.17*	52.21**	25.18**	14.56**	3.39	9.20**	-5.91	-15.54**	-11.08*	
	P <sub>9</sub>	3.87	-14.13**	-4.96*	-6.05**	5.21*	5.00**	11.09	-4.74	2.86	
	P <sub>10</sub>	2.75	27.16**	13.12**	-9.24**	5.71*	-0.20	0.12	-5.89	-3.08	
P <sub>4</sub>	P <sub>5</sub>	0.32	57.59**	26.10**	18.05**	13.31**	18.96**	0.87	-7.33	-3.56	
	P <sub>6</sub>	-20.48**	-11.86*	-16.60**	6.34**	11.70**	8.85**	-13.63*	-17.51**	-15.67**	
	P <sub>7</sub>	9.37*	2.70	6.37*	13.90**	9.62**	11.80**	-12.02	-7.28	-9.53*	
	P <sub>8</sub>	-4.36	16.32**	3.74	13.19**	11.87**	14.26**	-3.51	-14.62*	-9.48*	
	P <sub>9</sub>	-12.46**	-32.70**	-22.39**	-6.88**	8.72**	3.81*	-5.91	-4.95	-4.39	
	P <sub>10</sub>	-3.47	11.72*	2.96	-8.84**	13.18**	1.05	-13.40	-6.46	-9.71*	
P <sub>5</sub>	P <sub>6</sub>	10.55**	0.54	6.06*	3.51	9.80**	6.46**	-14.55*	-12.23*	-13.33**	
	P <sub>7</sub>	20.09**	18.17**	19.22**	5.31*	9.12**	10.15**	-11.64	-6.43	-8.91	
	P <sub>8</sub>	-20.28**	11.03*	-8.02**	8.61**	15.05**	11.54**	-7.10	-4.95	-5.94	
	P <sub>9</sub>	-20.00**	-34.60**	-27.15**	1.74	22.84**	12.16**	-1.18	-3.15	-1.03	
	P <sub>10</sub>	4.62	-3.30	1.27	-17.57**	15.02**	-3.68	-1.98	5.74	2.12	
P <sub>6</sub>	P <sub>7</sub>	9.09*	20.08**	14.03**	21.36**	-7.93**	9.25**	-3.64	1.50	-0.94	
	P <sub>8</sub>	-11.72**	23.87**	2.22	29.97**	28.42**	29.24**	0.20	7.01	4.41	
	P <sub>9</sub>	6.18*	-6.29*	0.07	-10.07**	33.65**	13.12**	-4.92	-3.61	-4.23	
	P <sub>10</sub>	6.04	25.32**	16.67**	-1.30	24.61**	10.41**	-5.10	-2.62	-3.80	
P <sub>7</sub>	P <sub>8</sub>	-8.46**	17.58**	1.74	10.32**	17.26**	15.00**	10.71	-1.91	4.26	
	P <sub>9</sub>	-3.65	-11.35**	-7.42	3.85	19.79**	17.23**	3.01	-0.87	0.98	
	P <sub>10</sub>	16.74**	32.60**	24.58**	2.00	23.33**	13.74**	7.77	1.13	4.85	
P <sub>8</sub>	P <sub>9</sub>	4.57	6.64*	5.59**	-1.15	41.06**	15.92**	9.03	-5.98	0.97	
	P <sub>10</sub>	11.89**	45.47**	25.04**	-3.52	15.88**	4.75**	2.16	-10.16	-4.46	
P <sub>9</sub>	P <sub>10</sub>	-1.20	-7.88*	-4.47*	4.49*	27.02**	14.45**	2.86	-1.17	0.72	

Note. WW = Normal irrigation, DS = Drought stress, Comb = Combined two conditions. \* = significant differences at 5% levels, \*\* = high significant differences at 1% levels.

Table 7. General combining ability estimates and ranks of the parents for physiological traits under normal irrigation and drought stress conditions

Parent	Flag leaf area				Flag leaf chl.				Flag leaf temp.			
	WW	R	DS	R	WW	R	DS	R	WW	R	DS	R
P <sub>1</sub>	-3.13**	8	-2.70**	8	-0.80	8	-2.59**	10	-1.87**	10	0.01	6
P <sub>2</sub>	-0.78	7	-0.89	7	1.06	2	0.88	2	-0.48*	7	0.57*	3
P <sub>3</sub>	2.26**	3	2.40**	3	-0.44	7	0.29	6	-0.13	6	-1.22**	9
P <sub>4</sub>	-4.46**	10	-3.48**	10	-1.94**	10	-0.55	8	-1.08**	9	-1.38**	10
P <sub>5</sub>	-3.20**	9	-3.39**	9	-1.42*	9	-0.89	9	-0.67*	8	-0.40	8
P <sub>6</sub>	0.03	5	0.31	5	0.20	5	0.53	5	0.25	5	0.54*	4
P <sub>7</sub>	-0.05	6	0.28	6	0.78	3	1.09	1	0.85**	4	0.50*	5
P <sub>8</sub>	4.28**	2	2.42**	2	-0.20	6	-0.26	7	0.99**	3	0.61*	2
P <sub>9</sub>	4.80**	1	4.54**	1	2.50**	1	0.86	3	1.10**	1	-0.04	7
P <sub>10</sub>	0.23	4	0.50	4	0.28	4	0.65	4	1.03**	2	0.81**	1

Note. WW = Normal irrigation, DS = Drought stress, R = Ranks. \* = significant differences at 5% levels, \*\* = high significant differences at 1% levels.

### 3.6 Specific Combining Ability Estimates (SCA)

The data presented in Table (8) showed The SCA effects of 45 F<sub>1</sub> crosses for physiological traits of flag leaf and their ranks under normal irrigation and drought stress conditions. Totally 12 (8 positive and 4 negative) and 11 (9 positive and 2 negative) of F<sub>1</sub> crosses exhibited significant SCA effects for FLA under normal irrigation and drought stress, respectively. Whereas the cross (P<sub>1</sub> × P<sub>4</sub>) had positive (desirable) SCA effect under both of normal irrigation and drought stress. For FLCC 6 and 5 F<sub>1</sub> crosses were significant effects of SCA, 4 crosses each out of them was positive (desirable) under normal irrigation and drought stress. Furthermore, the crosses (P<sub>2</sub> × P<sub>7</sub>) and (P<sub>6</sub> × P<sub>8</sub>) were exhibited positive significantly of SCA effects in the FLCC under both of normal irrigation and drought stress conditions. Similar results were found by Mohamed and Morsy (2013), Goma et al. (2014) and Mandal and Madhuri (2016). Regarding to the FLT, 16 (ten positive and six negative) and nine (3 positive and 6 negative) F<sub>1</sub> crosses were found to be significant effects of SCA under normal irrigation and drought stress.

### 3.7 Gene Action, Heritability and Expected Genetic Advance From Selection

The variance components, heritability and selection gain for physiological traits are presented in Table (9) and figure (1). Under normal irrigation and drought stress conditions as well as the combined data, the additive genetic components of variation (V<sub>A</sub>) in F<sub>1</sub> 's was much greater than dominance component (V<sub>D</sub>), as expressed by the (V<sub>A</sub>/V<sub>D</sub>) ratio which was more than unity for the FLA, and FLT under normal irrigation and their combined (Table 9). This indicates that the additive gene effects in F<sub>1</sub> crosses are more important than dominance and plays the major role in the inheritance of these studied traits. On the other hand, the dominance genetic components of variation (V<sub>D</sub>) in F<sub>1</sub> 's was much greater than additive component (V<sub>A</sub>), as expressed by the (V<sub>A</sub>/V<sub>D</sub>) ratio which was less than unity for the FLCC under normal irrigation, drought stress and their combined. This indicates that the dominance gene effects in F<sub>1</sub> crosses are more important than additive and plays the major role in the inheritance of flag leaf chlorophyll content under normal irrigation and drought stress as well as the combined data, except Flag leaf temperature (FLT) under drought stress, where both additive and dominance were of equal importance (V<sub>A</sub>/V<sub>D</sub> = 0.96, equals unity approximately).

Table 8. Specific combining ability and ranks of F<sub>1</sub> crosses for physiological traits under normal irrigation and drought stress conditions

F <sub>1</sub>		Fag leaf area				Flag leaf Chl.				Flag leaf temperature			
		WW	R	DS	R	WW	R	DS	R	WW	R	DS	R
P <sub>1</sub>	P <sub>2</sub>	1.61	14	0.19	30	2.47	12	2.24	15	1.40*	10	-1.25	37
	P <sub>3</sub>	-2.40	38	2.62	10	5.48**	4	1.20	24	-0.56	30	0.56	11
	P <sub>4</sub>	-1.00	32	3.63**	7	3.61	6	4.14	6	-0.35	24	-0.54	28
	P <sub>5</sub>	-0.38	29	-0.17	32	0.37	26	1.81	19	2.38**	2	-0.68	30
	P <sub>6</sub>	-0.44	30	2.22	15	1.35	20	1.89	17	-1.51*	40	-0.85	32
	P <sub>7</sub>	-2.47	39	-1.39	34	3.70	5	1.11	25	-0.36	25	0.24	16
	P <sub>8</sub>	0.59	23	-1.70	36	0.85	23	3.48	10	-1.26	38	0.86	7
	P <sub>9</sub>	4.52**	2	3.57**	8	2.40	13	2.11	16	-0.40	29	-0.93	34
	P <sub>10</sub>	-3.48**	43	-2.17	39	-2.81	43	3.05	12	0.46	15	1.19	5
	P <sub>2</sub>	P <sub>3</sub>	1.45	17	2.23	14	-1.79	35	1.73	21	1.34	11	0.89
P <sub>4</sub>		-3.05*	42	-2.71	43	-2.60	42	1.74	20	1.04	13	-1.31	39
P <sub>5</sub>		-1.34	34	-2.48	42	-0.29	32	1.01	26	-0.64	32	-1.61*	41
P <sub>6</sub>		1.52	15	2.51	11	0.64	24	-2.68	44	-1.14	35	0.75	8
P <sub>7</sub>		0.69	21	2.99**	9	8.99**	1	5.56**	3	-3.07**	45	0.64	9
P <sub>8</sub>		4.93**	1	2.20	16	-0.32	33	-0.26	37	-1.71**	43	-0.92	33
P <sub>9</sub>		-4.83**	45	-4.88**	45	2.29	14	0.78	28	1.95**	5	1.91**	3
P <sub>10</sub>		-4.64**	44	5.49**	2	-2.25	40	-2.28	43	2.28**	3	-0.01	22
P <sub>3</sub>	P <sub>4</sub>	1.07	19	0.83	22	-0.23	30	-0.04	34	-0.10	22	0.58	10
	P <sub>5</sub>	1.51	16	0.23	29	3.06	8	3.38	11	-1.56*	41	-0.82	31
	P <sub>6</sub>	2.40	11	0.64	26	1.76	16	3.91	7	0.28	17	-1.26	38
	P <sub>7</sub>	0.55	25	4.45**	3	1.20	21	1.42	23	1.75**	7	-1.21	36
	P <sub>8</sub>	0.56	24	3.92**	6	2.18	15	-1.48	40	-1.01	34	-1.96**	42
	P <sub>9</sub>	0.82	20	-2.29	41	-2.12	39	-1.88	42	2.21**	4	-0.55	29
	P <sub>10</sub>	-0.13	27	0.74	24	-1.80	36	-1.46	39	0.23	18	-0.16	23
P <sub>4</sub>	P <sub>5</sub>	-1.16	33	6.68**	1	6.33**	3	1.87	18	1.66*	9	0.29	14
	P <sub>6</sub>	-2.72	40	-2.07	38	-0.22	29	-0.08	35	-0.59	31	-2.62**	45
	P <sub>7</sub>	2.95*	8	-0.28	33	-0.25	31	0.14	33	-1.39	39	-0.39	27
	P <sub>8</sub>	4.00**	5	2.11	17	1.48	19	0.68	29	0.57	14	-1.52*	40
	P <sub>9</sub>	2.22	12	-2.23	40	-1.05	34	-1.64	41	-1.16	36	0.06	20
	P <sub>10</sub>	1.88	13	0.75	23	-0.10	28	0.28	32	-2.35**	44	-0.17	24
P <sub>5</sub>	P <sub>6</sub>	3.37*	7	0.24	28	-1.96	38	-0.46	38	-1.25	37	-2.00**	43
	P <sub>7</sub>	4.08**	4	2.45	12	-1.88	37	0.28	31	-1.70**	42	-1.13	35
	P <sub>8</sub>	-2.22	37	0.96	21	0.52	25	-0.22	36	-0.80	33	0.47	13
	P <sub>9</sub>	-1.50	35	-2.91*	44	2.84	9	1.46	22	-0.37	27	0.16	18
	P <sub>10</sub>	2.60	9	-2.04	37	-5.04**	45	0.87	27	0.22	20	2.46**	2
P <sub>6</sub>	P <sub>7</sub>	-0.13	26	0.34	27	3.57	7	-7.89**	45	0.22	19	1.27	4
	P <sub>8</sub>	-2.79	41	-0.16	31	8.27**	2	6.01**	2	1.12	12	3.19**	1
	P <sub>9</sub>	3.80**	6	2.27	13	-4.81**	44	6.89**	1	-0.39	28	0.25	15
	P <sub>10</sub>	-0.29	28	1.14	20	1.59	18	3.65	8	-0.36	26	-0.29	26
P <sub>7</sub>	P <sub>8</sub>	-1.69	36	-1.40	35	-2.43	41	2.87	13	2.59**	1	0.50	12
	P <sub>9</sub>	0.69	22	0.70	25	1.72	17	2.75	14	0.43	16	0.15	19
	P <sub>10</sub>	2.42	10	1.20	19	2.68	10	4.37	5	1.77**	6	0.20	17
P <sub>8</sub>	P <sub>9</sub>	-0.97	31	4.21**	4	0.14	27	5.52**	4	1.70**	8	-0.22	25
	P <sub>10</sub>	4.37**	3	3.98**	5	0.86	22	0.56	30	-0.04	21	-2.35**	44
P <sub>9</sub>	P <sub>10</sub>	1.20	18	1.57	18	2.54	11	3.64	9	-0.28	23	0.05	21

Note. WW = Normal irrigation, DS = Drought stress, R = Ranks. \* = significant differences at 5% levels, \*\* = high significant differences at 1% levels.

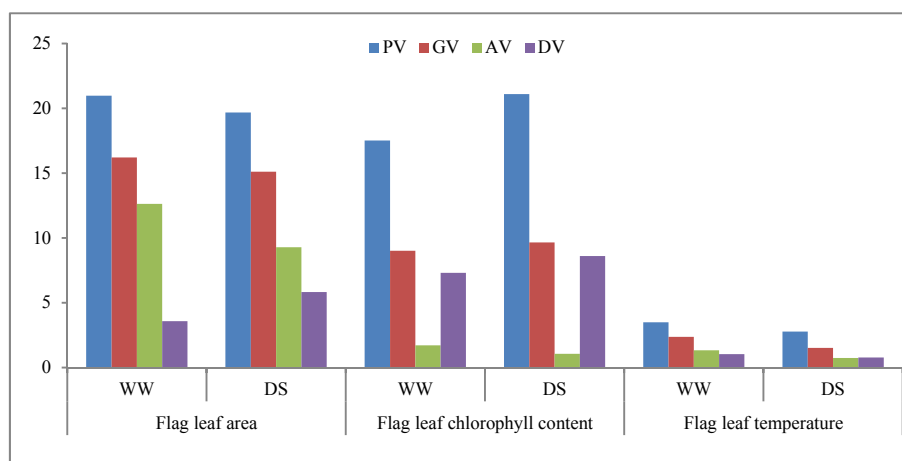


Figure 1. Phenotypic, Genotypic, Additive and Dominance variances under normal irrigation and drought stress conditions for physiological traits

*Note.* WW = normal irrigation, DS = Drought stress, PV = phenotypic variance, GV = Genotypic variance, AV = additive variance, DV = Dominance variance.

Also, when GCA/SCA ratio was used, it was found that Flag leaf area (FLA) in normal irrigation as well as the combined data, exhibited high GCA/SCA ratio of more than unity, indicating the additive gene action in the inheritance of FLA under normal irrigation. While, the GCA/SCA ratio was expressed as less than unity of FLA under drought stress, FLCC and FLT under normal irrigation and drought stress and combined. Indicating the non-additive gene action could be an important in the inheritance of FLCC and FLT under both two environments and FLA under stressed conditions. On the other hand, El-Hosary et al. (2012), Abul-Naas et al. (2000), they found that the degree of dominance of physiological traits in table (9) showed the over dominance ( $a > 1$ ) for all physiological traits, with exception the FLA under normal irrigation and combined data were inherited by partial dominance ( $a < 1$ ), this finding suggested that the selection for imprudent of these traits should be delayed to late generation. These results are agreement with those obtained by Qabil (2017), he showed that the dominance components in bread wheat was more than the corresponding additive one for flag leaf area, chlorophyll content. Contrasting, said (2014) reported that the flag leaf chlorophyll content was controlled by the additive type of gene action. Saleem et al. (2016) revealed that the additive gene action was observed for canopy temperature and Chlorophyll 'a' high GCA/SCA ratio, which exceeded than unity was obtained for leaf temperature (LT) in both treatments and their combined.

In the physiological traits (FLA, FLCC and FLT), the ratio of  $SCA \times Env./SCA$  was much higher than the ratios of  $GCA \times Env./GCA$  was detected. Such results indicated that non additive effects were much more influenced changes by environmental than GCA. El Hosary et al. (2009a, 2009b) found that non additive type of gene action was much more influence by the environmental condition than additive genetic one for some drought traits. The heritability estimates in the broad sense ( $H_b$ ) in the  $F_1$  crosses were high (60-80%) in magnitude for FLT under normal irrigation, and FLA under normal irrigation, drought stress and their combined (Table 9), indicating that the genetic variance is the main component of phenotypic variance and that the environment had little effect on the studied  $F_1$  crosses. Meanwhile the heritability in broad sense ( $H_b$ ) in the  $F_1$  crosses were moderate (40-60%) for FLCC under normal irrigation, drought stress and combined data and FLT under drought stress and combined data, that is meaning that the phenotypic variance as affected by environmental effects as well as the genotypic variance and that the environment had effects on the studied  $F_1$  crosses. Regarding to the narrow sense heritability ( $H_n$ ) in the  $F_1$  crosses was moderate (40-60%) for FLA, and were (60, 47 and 57%) under normal irrigation, drought stress and their combined. On the other hand, the narrow sense heritability ( $H_n$ ) was low ( $< 40\%$ ) for FLCC and FLT under both of two environments and combined analysis. indicating the lower importance of  $V_A$  compared to  $V_D$  in these traits under non-stressed, stressed environments and combined data.

Table 9. Variance component of physiological traits for Parents and their F<sub>1</sub> crosses, under normal irrigation, drought stress conditions and overall two environments

	Flag leaf area			Flag leaf chlorophyll content			Flag leaf temperature		
	WW	DS	Comb.	WW	DS	Comb.	WW	DS	Comb.
VP	20.97	19.68	19.17	17.51	21.09	18.26	3.49	2.77	2.55
VG	16.21	15.10	14.50	9.01	9.65	8.28	2.36	1.51	1.36
VA	12.63	9.28	10.90	1.71	1.05	1.32	1.33	0.74	0.78
VD	3.58	5.82	3.60	7.30	8.60	6.96	1.03	0.77	0.58
VA/VD	<b>3.53</b>	<b>1.59</b>	<b>3.03</b>	<b>0.23</b>	<b>0.12</b>	<b>0.19</b>	<b>1.29</b>	<b>0.96</b>	<b>1.34</b>
[a]	<b>0.75</b>	<b>1.12</b>	<b>0.81</b>	<b>2.92</b>	<b>4.05</b>	<b>3.25</b>	<b>1.24</b>	<b>1.44</b>	<b>1.22</b>
Hn	0.60	0.47	0.57	0.10	0.05	0.07	0.38	0.27	0.31
Hb	0.77	0.77	0.76	0.51	0.46	0.45	0.68	0.55	0.53
GCA	6.32	4.64	5.45	0.86	0.53	0.66	0.66	0.37	0.39
SCA	3.58	5.82	3.60	7.30	8.60	6.96	1.03	0.77	0.58
GCA:SCA	1.77	0.80	1.52	0.12	0.06	0.10	0.65	0.48	0.68
GCA × Env/GCA	-	-	<b>0.02</b>	-	-	<b>0.21</b>	-	-	<b>0.35</b>
SCA × Env/SCA	-	-	<b>0.43</b>	-	-	<b>0.31</b>	-	-	<b>0.68</b>
PCV	89.87	94.05	89.16	60.41	70.26	63.44	37.35	31.19	30.89
GCV	79.02	82.38	77.55	43.33	47.53	42.74	30.70	23.05	22.53
GA	<b>7.29</b>	<b>7.01</b>	<b>6.82</b>	<b>4.44</b>	<b>4.33</b>	<b>3.99</b>	<b>2.60</b>	<b>1.87</b>	<b>1.75</b>
GAM	28.09	31.51	28.30	9.24	10.13	8.81	10.39	6.58	6.54

Note. WW = normal irrigation, DS = drought stress, Comb. = overall, two environments, PV = Phenotypic variance, GV = Genotypic variance, AV = Additive variance, DV = Dominance variance, EV = Environmental variance, Hn = heritability in narrow sense, Hb = Heritability in broad sense, GCA = General combining ability, SCA = Specific combining ability, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, GA = Genetic advance, GAM = Genetic advance over mean.

These results are agreement with those obtained by many previous authors, whereas Kumar et al. (2015) revealed to the estimates of  $h^2$  were found highly significant for flag leaf area, Saleem et al. (2016) reported that canopy temperature and chlorophyll 'a' expressed reasonably high heritability that supports the results of gene action providing an opportunity for early generation selection to use in a breeding program. Khan and Hassan (2017) noticed the high heritability (0.89) was noticed in flag leaf area. Clearly the differences between the phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were high (> 20) for FLCC and moderate (10-20) for FLA, that is an evidence for improving these traits through the selection is not so easy. Contrast, the differences between PCV and GCV of flag leaf temperature (FLT) were low (< 10) that is due to the minimal influence of environment on the expression of these traits, so it easy to select based on the phenotypic values. The high and moderate broad sense heritability coupled with Low (< 10%) expected genetic gain (GA) from selection based on F<sub>1</sub> results and assuming 5% selection intensity (Table 29), which were (7.27, 4.44 and 2.60%), (7.01, 4.33 and 1.87%) and (6.82, 3.99 and 1.75%) for FLA, FLCC and FLT under normal irrigation, drought stress and their combined respectively.

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