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GENETIC CONTROL AND COMBINING ABILITY OF FLAG LEAF AREA AND RELATIVE WATER CONTENT TRAITS OF BREAD WHEAT CULTIVARS UNDER DROUGHT STRESS CONDITION

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In order to compare mode of inheritance, combining ability, heterosis and gene action in genetic control of traits flag leaf area, relative water content and grain filling rate of bread wheat under drought stress, a study was conducted on 8 cultivars using of Griffing's method2 in fixed model. Mean square of general combining ability was significant also for all traits and mean square of specific combining ability was significant also for all traits except relative water content of leaf which show importance of both additive and dominant effects of genes in heredity of these traits under stress. GCA to SCA mean square ratio was significant for none of traits. Results of this study showed that non additive effects of genes were more important than additive effect for all traits. According to results we can understand that genetic improvement of mentioned traits will have low genetic efficiency by selection from the best crosses of early generations. Then it is better to delay selection until advanced generations and increase in heritability of these traits.

Key words: Diallel analysis, bread wheat, drought stress, genetic improvement, general and specific combining ability

INTRODUCTION

Drought is known as the most important abiotic stress which crop plants experience. Considering reduction in annual rainfalls and increase in drought and temperature, creating tolerant cultivars with high yield potential is so important for breeders. Many researchers (GOLPARVAR *et al*., 2011; QUARRIE *et al*., 1999) believe that drought tolerating as increase in yield potential and stress tolerating is possible via improving of physiological traits. Relative

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water content of leaf is one of the appropriate selection criteria. Higher amounts of this traits show that plant has improved its water relationships under stress. On the other hand, it can be a good criterion for selection plans because of easiness, speed and accuracy of measurement especially in primer generations which high volumes of subjects are being studied (DAGUSTU, 2008). Traits which have the highest dominant effects on environment adaption of plant for maximizing production are phenological related traits. Negative correlation between grain yield under stress and flowering date has been reported in many studies (TOPAL *et al*., 2004). Grain filling rate is an appropriate trait for this. Higher amounts of this trait show shorter grain filling period, better sink-source relations and faster photoassimilate transferring (GOLPARVAR, 2012; KOEMEL *et al*., 2004). Indirect selection in primer breeding generations according traits with good correlation to grain yield and also higher heritability than yield is one of the important breeding strategies. Then, knowing heredity way and genetic control of various traits is very important in breeding plans.

Studying the heredity way of traits in various environments explains that changing in plant living circumstances will change genes action way, estimation of genetic parameters and traits heritability (CHOWDHRY *et al*., 1999; JOSHI *et al*., 2004). This is known mainly because of interaction between genotype and environment especially under stress (SHARMA *et al*., 2002). Then it seems that studying the heredity way of trait and choosing appropriate breeding strategy for each environment is necessary.

Producing new cultivars which are adaptable to various environments is one of the important goals of breeders. Crossing new cultivars and selection superior genotypes for favorite traits in their progenies is one of frequently used methods. In order to estimate general and specific combining abilities of parents and crosses various methods including analysis of diallel crosses have been explained by many researchers (GRIFFING, 1956; HALLAUER and MIRANDA, 1982; KOEMEL *et al*., 2004).

GOLPARVAR *et al.* (2004) by using the method of mean analysis of generations and estimation of heritability and action kind of gene in wheat bread under stress, reported that selection for improving traits RWC and grain filling rate especially in primary generations had average genetic efficiency. Also, grain filling rate and harvest index traits was emphasized in that study as indirect selection criteria for improving grain yield under stress.

HAYDARI (2001) used diallel analysis method in bread wheat cultivars and reported that non additive effects and specific heritability for flag leaf area and harvest index traits were in average level. KHAN and RIZWAN (2000) studied genetic of traits flag leaf area, relative water content of leaf, grain filling period and grain filling rate in cultivars and crosses of bread wheat under stress and reported that non additive effects of genes were more important in heredity of these traits. Also, specific heritability was low for leaf area and average for the other traits. It was shown in these studies that grain filling rate can be a good criterion for selection drought tolerant genotypes which higher yield especially in primary generations.

KAMALUDDIN *et al.* (2007) in a study about heredity way of physiological traits like length and grain filling rate in bread wheat cultivars observed that additive effects of genes were more important than non additive effects in heredity of these traits and then recommended using selection methods for genetic improvement of these traits.

JOSHI *et al* (2007) and JOSHI and CHAND (2002) also reported that flag leaf area, grain filling rate and grain filling period were affected by both additive and non additive effects of genes with higher effect of non additives. It seems that heritability of traits, general and specific combining abilities of cultivars, heterosis of traits, and way of genes action and the other genetic parameters are changed by change in environmental condition and then it is necessary to propose appropriate strategies for improving every trait in different environments. On the other hand, there is no extant study about effect of drought stress on these genetic parameters in physiological traits which is a reason to necessity of these types of studies. So, the aims of this study were comparing mode of inheritance, combining ability, heterosis and gene action in genetic control of physiological traits flag leaf area and relative water content bread wheat cultivars under drought stress condition.

MATERIALS AND METHODS

Eight winter cultivars of bread wheat including four Iranian (Sardari, Zarrin, Zagros, and Alamoot) and four foreigner (Veenaac,M75-7,C75-5, and Sakha8) were sown in 2009 fall as parents of diallel crosses in research farm of Islamic Azad University, Khorasgan branch. In 2010 spring, half diallel crosses were done between parents to produce F1 generation. Obtained seed were harvested in summer and in the same fall seeds of parents and their crosses (36 treatments totally) were sown in a randomized complete blocks design with three replications. Every plot had two rows with 20 cm inter row distance and 5 cm distance between plants on rows. Fertilizer amounts were 300 kg/ha ammonium phosphate and 300 kg/ha urea which all of phosphorus fertilizer and 1/3 of urea were used before planting. The rest of urea was used in 2-3 leaves stage. In order to enforce the drought stress, only one irrigation was done for seed germinating and for the rest of growth period plants used soil moisture and rainfall. The region has a very arid climate with dry summers according to Koppen classification. Long time average of precipitation and temperature are 120 mm and 16˚c, respectively. There is no rainfall from June late to October early .The soil of experimental division had a silty loam texture with 1% organic carbon, pH=7.8 and EC=3.5 mmhos/cm in 0-40 cm depth. After ripening, ten normal plants of each plot were harvested randomly and traits flag leaf area, relative water content and grain filling rate were measured. Relative water content of leaf was measured using flag leaves at flowering 50% time. For that, flag leaves were cut before sunrise and were put in nylon bags and transferred to laboratory. Fresh (wet) weight of leaves were measured, Then, leaves surfaces were dried by clean tissues and their saturated weight were obtained. Dry weight of leaves was measured after 72 hours being in oven at 70°c (SCHNOFELD *et al*., 1988). Finally, relative water content of flag leaf area was calculated from this equation:

$$RWC = \text{Fresh weight- Dry weight/Saturated weight- Dry weight}$$

Obtained data were analyzed and then wherever genotypes differences were significant, diallel variance analysis were done according Griffing's method2 in fixed model (GRIFFING, 1956).
This method was used also to estimate general combining ability (GCA) of parents and specific combining ability (SCA) of crosses. With using second method's formulas (half diallel with parents) in Griffing's constant model, sum squares of crosses were divided to GCA and SCA. GCA effects were calculated for parents and SCA for crosses (GRIFFING, 1956). Experimental error was used in variances analysis of genotypes to define if source of variances were significant in F tests. Calculating of genetic variances (additive and dominancy) and percentage of these parts, environmental variances and finally general and specific heritability were done using SCA and GCA mean squares and related formulas (GRIFFING, 1956). For testing

significance of general and specific combining abilities with using second method of Griffing's constant model (GRIFFING, 1956), variance estimation of these effects and t-test were used. Estimation of genetic parameters and statistical indices were done by Diallel and D2 program (MANJIT, 2003).

RESULTS AND DISCUSSION

Flag leaf area

Variance analysis results showed highly significant differences between studied genotypes (Table1). Mean of flag leaf area varied from 8.32 to 10.99 (cm^2) for parents and from 8.19 to 12.27(cm^2) for crosses (Table 3). Cultivars Veenaac, C 75-5, and Sakha8 had the highest flag leaf area. The highest mean of this trait was belonged to Zarrin * Zagros,Zarrin * Veenaac and Veenaac * Sakha8 crosses. Mean of crosses heterosis was 0.53 according to parent's average. Zagross * Zarrin, M 75-5 * Zarrin and Veenaac *Zagross crosses had the highest amounts of significant positive heterosis whereas C 75-5* Sadri, C 75-5* Zagross, and Sakha8* C 75-5 had the highest significant negative heterosis, respectively (Table 3). Mean squares of GCA and SCA were significant highly.non significant ratio of GCA to SCA and belonging more than 95% of genetic variance to dominance variance (Table 2) show more portions of genes non additive effects for flag leaf area trait under stress. GOLPARVAR *et al.* (2011) and KHAN and RIZWAN (2000) reported also similar results on this trait. Cultivars Veenaac and Zarrin had the highest significant positive GCA effects, respectively, whereas Sardari and M75-5 had the highest significant negative GCA. Then, cultivars Veenaac and Zarrin have the best general combining ability for flag leaf area traits. The highest significant positive SCA was related to Zarrin * M75-7, Alamoot * C 75-5, M75-7* C75-5 and sadari* Sakha8 crosses. These crosses had also the highest heterosis and average flag leaf area (Table 3). Of course, because of negative GCA of cultivars M75-5, C75-5 and Sardari (Table4), using progenies of these crosses may have non predicTable bad results. Amounts of heritability (Table 2) and more portion of additive effects in genetic control of this trait shows that genetic efficiency of selection is low for increasing flag leaf area especially in primary improvement generations. We insist in use of Veenaac and Zarrin cultivar which have highly significant positive combining abilities. Crossing these cultivars has also positive and very significant SCA. Then, selection from their progenies will increase portion of additive effects plus genetical efficiency of selection.

Table 1. Diallel analysis of variance for studied traits in 36 genotypes (8 parents and 28 related crosses)

Source of variance	Degree of freedom	Mean squares	
		Flag leaf area	Relative water content
Genotype	35	4.11**	120.30*
GCA	7	4.74**	166.76*
SCA	28	3.95**	108.69
Error	70	0.15	74.27
GCA/ SCA		1.20	1.53

*and **significant at 5 % and 1% probability levels, respectively.

Table 2. Amounts (upper numbers) and percentage (in parenthesis numbers) of additive, dominance and environmental variances and percentage of GCA and SCA

	Flag leaf area	Relative water content of leaf
Additive variance	0.16	11.61
	(4.04)	(25.22)
Dominance variance	3.80	34.42
	(95.96)	(74.78)
Environmental variance	0.15	74.27
General combining ability	96.35	38.26
Specific combining ability	3.89	9.56

*: Calculated using Griffing's method

Relative water content

There were significant differences between genotypes for relative water content of leaf (Table 1). Mean of this trait varied from 52.82% to 58.85% for parents and from 43.55% to 65.56% for crosses. The highest amount of this trait was belonged to Sardari, Zagros, and Alamoot cultivars (Table 5). Heterosis amount was -1.70 according to parents mean. The only significant negative heterosis was observed in Alamoot * Sardari cross. Then, selection among progenies of this cross will follow by reduction in RWC. The other crosses had positive but non-significant heterosis. Significant mean squares of GCA and non-significant mean squares of SCA (Table 1) show more importance of additive effects in heredity of this trait. But non significant ratio of GCA to SCA mean squares and belonging more than 74% of genetic variance to dominant variance (Table 2), all show average importance of additive effects in genetic control of leaf relative water content under stress. GCA effects of parents and SCA effects of crosses are shown in Table 6. The only significant positive GCA was sawn in Sakha8 parent. Then, using this cultivar in breeding plans of improving leaf's relative water content under stress can be recommended. Crosses Sardari * Alamoot and Alamoot *Veenaac had the highest negative and positive significant SCA effects, respectively. Then, we can select in progenies of these crosses for plants with less and more leaf relative water content. Considering more portions of non additive effects in genetic control of leaf water content and low heritability of this trait (Table 2) it seems that is better to postpone selection for improving that until later generations. GOLPARVAR (2012), SAADALLAH and GHANDORAL (2000), KHAN and RIZWAN (2000) in their studies on cultivars and crosses of wheat bread under stress found that non additive effects of genes were more important in heredity of RWC and heritability of this traits is very low specially in primary generations.

ARAUS *et al* (2003) and DAGUSTU (2008) dedicated on importance of additive effects of genes and possibility of selection in diversing generations for improving this trait. This trait is an important criterion for increasing photosynthesis rate and then grain yield of plant especially under stress (QUARRIE *et al.,* 1999; SIDDIQUE *et al*., 2000).

In conclusion, based on findings of present study, it can be said that genetic improvement of flag leaf area and relative water content traits under drought stress, by selection among the progenies of the best crosses in early generations has low genetic gain. On the other hand, delaying this selection until advanced generations and increase in heritability of these traits will increase efficiency of breeding programs.

Table 3. Mean of flag leaf area for 8 parents (on diameter) and their 28 crosses (above diameter) and amount of crosses heterosis according to parents means (beneath diameter)

Parents	Sardari	Zarrin	Zagros	Alamoot	Veenaac	M75-7	C75-5	Sakha8
Sardari	10.43	8.61	9.76	8.69	9.62	10.28	8.92	11.29
Zarrin	-1.44**	9.67	12.27	11.45	12.24	11.86	10.25	10.30
Zagros	0.10	2.98**	8.90	11.04	11.90	9.68	8.19	9.63
Alamoot	-1.45**	1.69**	1.66**	9.85	10.44	9.27	11.97	11.33
Veenaac	-1.09**	1.91**	1.96**	0.03	10.99	10.94	11	12.15
M75-7	0.91**	2.86**	1.07**	0.18	1.28**	8.32	11.22	9.75
C75-5	-1.71**	0	-1.68**	1.63**	0.09	1.64**	10.83	9.09
Sakha8	0.81**	0.19	-0.09	1.14**	1.39**	0.33	-1.60**	10.53

*and **significant at 5 % and 1% probability levels, respectively.

Table 4. The general and specific combining ability effects of flag leaf area trait for 8 parents and their 28 crosses

Parent	SCA							
	Zarrin	Zagros	Alamoot	Veenaac	M75-7	C75-5	Sakha8	GCA
Sardari	-1.54**	0.21	-1.22**	-0.93**	0.80**	-0.83**	1.31**	-0.52**
Zarrin		1.89**	0.71**	0.86**	1.54**	-0.33	-0.51*	0.32**
Zagros			0.90**	1.13**	-0.03	-1.79**	-0.57**	-0.29**
Alamoot				-0.69**	-0.81**	1.63**	0.76**	0.07
Veenaac					0.23	0.03	0.94**	0.71**
M75-7						1.31**	-0.39	-0.35**
C75-5							-1.32**	-0.09
Sakha8								0.14

SE(gi)=0.066 SE(sij)=0.201 *and **significant: at 5 % and 1% probability levels, respectively.

Table 5. Mean of relative water content for 8 parents (on diameter) and their 28 crosses (above diameter) and amount of crosses heterosis according to parents mean (beneath diameter)

Parents	Sardari	Zarrin	Zagros	Alamoot	Veenaac	M75-7	C75-5	Sakha8
Sardari	58.85	56.08	50.82	43.55	46.78	51.11	59.47	57.10
Zarrin	-1.01	55.33	47.18	51.55	54.52	53.22	46.50	46.88
Zagros	-7.62	-9.50	58.03	52.41	50.43	53.09	51.05	57.27
Alamoot	-14.59*	-4.83	-5.32	57.43	65.56	64.87	59.84	59.90
Veenaac	-8.22	1.28	-4.16	11.27	52.82	49.73	46.19	56.56
M75-7	-5.34	-1.46	-2.95	9.14	-2.87	54.04	58.94	62.56
C75-5	2.27	-8.94	-5.74	3.35	-7.16	4.15	55.55	61.57
Sakha8	-0.37	-8.83	0.21	3.14	2.94	7.49	5.94	56.09

LSD(α=0.05)=12.16 LSD(α=0.01)=16.17

*and **significant at 5 % and 1% probability levels, respectively.

Table 6. The general and specific combining ability effects of relative water content for 8 parents and their 28 crosses

Parent	SCA							GCA
	Zarrin	Zagros	Alamoot	Veenaac	M75-7	C75-5	Sakha8	
Sardari	4.75	-1.68	-12.38*	-5.10	-3.73	5.31	1	-1.77
Zarrin		-3.73	-2.78	4.24	-0.01	-6.06	-7.61	-2.37
Zagros			-3.09	-1.02	-1.31	-2.67	1.60	-2.20
Alamoot				10.69*	7.05	2.69	0.81	2.22
Veenaac					-4.05	-6.91	1.52	-2.83
M75-7						2.88	4.56	2.01
C75-5							4.44	1.45
Sakha8								3.49*

SE(gi)=1.47 SE(sij)=4.51

*and **significant at 5 % and 1% probability levels, respectively.

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GENETIČKA KONTROLA I KOMBINACIONA SPOSOBNOST POVRŠINE VRŠNOG LISTA I RELATIVNOG SADRŽAJA VLAGE HLEBNE PŠENICE U USLOVIMA SUŠE

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Izvod

U cilju poređenja načina nasleđivanja, kombinacione sposobnosti, heterozisa i dejstva gena u genetičkoj kontroli osobina kao što su površina vršnog lista, relativnog sadržaja vlage i brzine nalivanja zrna hlebne pšenice u uslovima suše, vršena su istraživanja 8 genotipova primenom Griffing's metoda u fiksnom modelu.2 Sredina kvadrata generalne kombinacione sposobnosti (GCA) je bila značajna za sve ispitivane osobine dok je sredina kvadrata specifične kombinacione sposobnosti (SCA) bila značajna za sve osobine izuzev za relativni sadržaj vlage. Odnos sredine kvadrata GCA prema SCA nije bio značajan ni za jednu ispitivanu osobinu. Rezultati ovih istraživanja pokazuju da je neaditivni način dejstva gena značajniji od aditivnog efekta kod svih ispitivanih osobina. Dobijeni rezultati pokazuju da je genetička efikasnost u poboljšanju ovih osobina niska ako se koriste ukrštanja ranih generacija i upućuju na počinjanje procesa selekcije u kasnijim generacijama.

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