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Original scientific paper

GENETIC CONTROL AND HEREDITY OF HARVEST INDEX AND BIOLOGICAL YIELD IN BREAD WHEAT (*Triticum aestivum* L.)

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Assessment of genetic control, mode of inheritance, general and specific combining abilities and effect of drought stress on genetic parameters of harvest index and biological yield traits in bread wheat were achieved by using Diallel mating design. Parents (eight cultivars) along with F_1 progenies (28 crosses) were sown in a randomized complete blocks design with three replications under stress condition in Karadj Agricultural Research Center. The data were analyzed according to methed of Hallauer and Miranda as well as fixed model of Griffing's method II. Jinks-Hayman model was used to estimate broad and narrow-sense heritabilities and mean degree of dominance. There were significant differences between genotypes for mentioned traits in both environments. Studying mean of squares of general combining ability (GCA), specific combining ability (SCA), the ratio of GCA to SCA mean of squares and portion of additive and dominance variances showed importance of both additive and non additive gene effects for harvest index, but in biological yield heredity, additive effect was more important. Estimating broad-sense and narrow-sense heritabilities showed low efficiency of harvest index and high efficiency of biological yield for selection programs in stress environments.

Key words: biological yield, diallel mating design, harvest index, gene action, hexaploid wheat

INTRODUCTION

GRIFFING (1956 a,b) expressed analysis of diallel crosses in four various methods including complete diallel with parents, half diallel with parents, complete diallel without parents

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and half diallel without parents, and explained every of these methods in four statistical model; randomized, constant, mixed A and mixed B (GRIFFING, 1956 a,b). Half diallel method (without reciprocal crosses) has the most use because of easiness in conduct. In JINKS and HAYMAN (1953) method, phenotype diversity is divided to genotype and environmental components and then genotype diversity is divided to additive and dominance components. Thus, lots of information will be obtained about genetic nature of evaluating trait. CHOWDHRY *et al.* (1999) in a study about some quantitative traits in bread wheat found that the way of gene action and estimation of genetic parameters is very different for all those traits in both stress and non-stress environments and for this reason presented different breeding strategies for improving each of evaluating traits in both environments. Parent selection with desirable traits and making crosses among them is an important procedure for increased production. Plant height, spike length, spikelet number per spike, kernel number per spike, grain yield per spike, and 1000 kernel weight are major components of wheat yield used as selection criteria in breeding (TOPAL *et al.,* 2004). Advantages of hybrids over pure lines have been known for years and diallel crossing has long been exploited in plant breeding programs. In wheat, however, although the first hybrid was commercially released 40 years ago (EDWARDS, 2001), the utilization of hybrids on a large scale is at present not considered very successful (GURMANI *et al*., 2007; KOEMEL *et al.,* 2004).

In diallel analysis, determination of the general combining abilities (GCAs) and specific combining abilities (SCAs) allows the investigation of the effects of reciprocal crosses. Information on general and specific combining ability effects is very important in making the next phase of a breeding program. Many workers have reported GCA and SCA effects for yield and yield components in wheat (ALTINTAS *et al*., 2008). Through diallel analysis a number of parental lines can be tested in all possible combinations. Thus, the main objective of the present study was to identify the best combiners and their crosses on the basis of their general and specific combining ability for yield and its component traits.

The goal of this study was comparing the mode of inheritance, combining ability and genes action in genetic control of harvest index and biological yield under drought stress condition.

MATERIALS AND METHODS

Seeds of eight winter wheat cultivars (Iranian and Foreigners) entitled: Sardaari, Zarrin, Zagros, Alamoot, Vee-Nac, M75-7,C75-5,and Sakha-8 were sown as parents of diallel crosses in research site of Iran Seed and Plant Certification & Registration Institute (November 2009). In 2010 spring, diallel crosses were done between parents in half diallel method to produce F_1 seeds. Produced seeds were harvested in same summer. In autumn 2010 sterilized seeds of parents (8 parents) and their half diallel crosses (28 crosses) totally 36 treatments were sown in a randomized complete blocks design with three replications under drought stress in Karadj Agricultural Research Center. Plots had two rows with 20 cm inter-rows distance and distances between plants on rows were 5 cm. Ten normal and matured plants were harvested from each plot (Spring 2011). After drying them for 48 hours at 60°c in Oven, biological yield (gr/plant) was determined. Then harvest index (%) was calculated from grain yield to biological yield ratio. Obtained data were analyzed according to HALLAUER and MIRANDA (1982) method. So, sum of squares of genotypes (parents and crosses) was divided to three components: parents, crosses and parents versus crosses. Also using second method formulas (half diallel with parents) in Griffing's fixed model sum of squares of crosses was divided to two components; General combining ability (GCA) and specific combining ability (SCA), and GCA effects for each parent and SCA for each cross were calculated (GRIFFING, 1956a). In F test, the experimental error was used in genotypes analysis of variance to determine which source of variances was significant. Calculating of additive and dominance genetic variances and their percentage were also done using Sum of squares of GCA and SCA and related formulas (GRIFFING, 1956a). T-test was used to test the general and specific combining abilities (GRIFFING, 1956a). Preliminary test of Jinks-Hayman model was done to estimate broad-sense (H_b) and narrow-sense (H_n) heritabilities and mean degree of dominance $(H_1/D)^{1/2}$ for both traits. In cases where preliminary test included that model assumptions were observed, estimation of genetic parameters was done (JINKS and HAYMAN, 1953). Estimation of genetic parameters and statistical indices were conducted using Diallel and D2 softwares.

RESULTS AND DISCUSSION

Analysis of variance showed that there was highly significant difference between genotypes (parents and crosses) for harvest index trait under stress. Mean of squares of parents versus crosses were also significant ($p<0.01$) that shows heterosis existence for harvest index under drought stress condition (KOEMEL *et al.,* 2004). Significancy of GCA and SCA mean of squares (Table 1) expresses portion of both additive and non-additive effects in genetic control of this trait. It is inferred that additive gene effects have more portion here by comparing mean of squares of GCA and parents versus crosses. But non-significant GCA/SCA mean of squares and belonging all of genetic variance to dominance variance (Table 2) shows that non-additive gene effects are more important than additive effects in genetic control of harvest index. DAGUSTO (2008) and TOPAL *et al.* (2004) also emphasized on more portion of non-additive gene effects for harvest index under stress.

Table 1. Analysis of variance of combining ability for studied traits

Source of variations	Degree of freedom	Mean of squares	
		Harvest index	Biological yield
GCA	7	15.60**	23.95*
SCA	28	22.82**	0.89**
Error	70	0.07	0.19
GCA/ SCA		0.68	36.91**

Parents Sakha8, Sardaari and Zarrin had the highest significant and positive GCA effects, respectively (Table 3). Then considering high means of these cultivars and their GCA effects for harvest index under stress, selection from progenies of these cultivars crosses, not only improves this trait, but also increases contribution of additive gene effects and will increase genetic efficiency of selection. In this regard, we can only emphasize on Sakha8 * Zagros and Sardaari * Zagros crosses. Mean degree of dominance (Table 2) shows that harvest index under stress is affected by over dominance effects of genes. In this situation portion of non-additive gene effects will be more than additive effects that is in agreement with Griffing's method (GRIFFING 1956b). DERE and YILDIRIM (2006) and KOEMEL *et a*l. (2004) also reported existence of over-dominance effects for harvest index under stress.

Table 2. Estimation the portion of dominance and additive variances, degree of dominance and heritability

Genetic parameters		Stress environment	
		Harvest index	Biological yield
Dominance variance	$б^2{}_D$(%)	98	18.4
Additive variance	$б^2{}_A$(%)	2	81. 6
Degree of dominance	$(H_1/D)^{1/2}$	2.77	0.45
Broad-sense heritability	H_b(%)	97.9	94.7
Narrow-sense heritability	H_n(%)	12.5	85.8

Table 3. Mean of parents and crosses (on and below diameter) and SCA (above diameter) and GCA for harvest index

	Specific combining ability (SCA)								(GCA)
Parent	Sardaari	Zarrin	Zagros	Alamoot	Vee-Nac	M 75-7	C75-5	Sakha-8	
Sardaari	32.37	-0.65**	1.82**	3.30**	-0.88**	-1.62**	-4.05**	-1.88**	0.78**
Zarrin	27.30	27.37	-0.12	1.46**	2.38**	3.80**	-1.59**	-2.06**	0.59**
Zagros	30.43	28.27	28.27	1.07**	0.25	-1.09**	-3.15**	0.35**	-0.05**
Alamoot	31.20	29.13	28.20	29.30	-4.89**	-3.72**	-2.10**	-0.86**	-0.82**
Vee-Nac	26.32	30.13	27.47	21.62	26.20	-2.48--	2.67**	3.62**	-0.63**
M 75-7	26.40	31.60	26.17	22.83	24.15	24.27	6.66**	3.24**	-0.58**
C75-5	24.43	26.67	24.57	24.91	29.76	33.79	29.47	-2.17**	-0.22**
Sakha-8	27.67	27.27	29.13	27.22	31.78	31.43	26.49	29.60	0.88**

*and**: Significant at 5% and 1% probability levels, respectively.

Analysis of variance showed highly significant difference between parents and crosses for biological yield. Mean of squares of Parents versus crosses was not significant which expresses that there is no heterosis for this trait (HALLAUER and MIRANDA, 1982). Mean of squares of GCA and SCA was significant ($p<0.01$) that shows importance of both additive and non-additive effects in genetic control of biological yield under stress (Table 1). Significant GCA/SCA mean of squares, comparing GCA mean of squares and parent versus crosses mean of squares and belonging more than 81% of genetic variance to additive variance (Table 3) shows that portion of additive gene effects is highly more than non-additive effects in genetic control of biological yield. KAYA *et al.* (2006) and ALTINTAS *et al.* (2008) reported non-additive gene effects more important than additive effects in genetic control of biological yield under stress.

Parents GCA effects (Table 4) showed that Alamoot, C75-5 and Vee-Nac cultivars had the best general combining ability for biological yield under stress and then in progenies of their crosses, some genotype can be selected for higher amounts of this trait plus increasing in portion of additive gene effects. Mean degree of dominance (Table 2) is an explainer of relative dominance effect extent for this trait. In these cause additive effects have more portion than non-additive, which is in agreement with Griffing's method. DERE and YILDIRIM (2006) and HAYDARI (2001) emphasized on existence of over-dominance effects for biological yield under stress that is inconsistent with results of this study.

Table 4. Mean of parents and crosses (on and below diameter) and SCA (above diameter) and GCA for biological yield

	Specific combining ability (SCA)								(GCA)
Parent	Sardaari	Zarrin	Zagros	Alamoot	Vee-Nac	M 75-7	C75-5	Sakha-8	
Sardaari	8.36	0.05	-0.03	0.32	-0.62	0.40	0.14	0	0.22*
Zarrin	8.45	6.41	0.09	-1.48**	0.22	0.43	-0.04	0.54	-0.84**
Zagros	7.11	6.14	5.38	0.58*	0.47	-0.17	0.11	-0.06	-1.14**
Alamoot	10.10	7.25	9.10	11.79	0.23	-0.56	0.01	-0.37	1.63**
Vee-Nac	7.83	7.73	7.77	10.18	9.43	-0.06	-1.26**	-0.37	0.42**
M 75-7	7.94	6.91	6.10	8.36	7.65	6.45	0.36	0.05	-0.69**
C75-5	9.43	8.19	8.14	10.68	8.20	8.79	10.31	0.40	1.18**
Sakha-8	7.44	6.93	6.12	8.45	7.24	6.63	8.74	6.40	-0.84**

*and**: Significant at 5% and 1% probability levels, respectively.

In conclusion, considering low amount of narrow-sense heritability and high importance of non-additive gene effects in genetic control of harvest index it is better to postpone selection for improving this trait until advanced breeding generations. To this goal, we emphasize on use of Sakha8, Sardaari and Zarrin cultivars and their progenies. On the other hand, estimations of broad-sense and narrow-sense heritabilities (Table 2), little difference between these estimates and higher portion of additive gene effects showed that selection for biological yield improving not only is possible from early breeding generations not only have high genetic efficiency. For this, using Alamoot and C75-5 cultivars is highly emphasized. Furthermore, using biological yield as an indirect selection criterion to improve grain yield can have favorable results. Yield heritability is low because of high interaction between genotype and environment especially under stress and in early generations which evaluations are done with no replication designs, then indirect selection via traits which have high heritability and also have high genetic correlation with grain yield can be advisable breeding strategy (Falconer, 2002). So, in early generations of breeding programs, genetic efficiency of indirect selection is much more than direct selection for yield per se (DAGUSTO, 2008; KAYA *et al*., 2006).

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GENETIČKA KONTROLA I NASLEĐIVANJE ŽETVENOG INDEKSA I BIOLOŠKOG PRINOSA U HLEBNOJ PŠENICI

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Izvod

Procena genetičke kontrole, načina nasleđivanja, generalne (GCA) i specifične (SCA) kombinacione sposobnosti i efekta stresa suše na genetičke parametre žetvenog indeksa i biološkog prinosa hlebnoe pšenice je izvršena u dialelnom setu ukrštanja. Podaci su obrađeni metodom Hallauer i Miranda kao fiksnim modelom Griffing – II. Jinks-Hayman model je primenjen za utvrđivanje široke i usko – osetljive naslednosti i prosečnog stepena dominantnosti. Utvrđene su začajne razlike između genotipova za ispitivane osobine u dve različite ekološke sredine. Studying mean of squares of general combining ability (GCA), specific combining ability (SCA), Odnos GCA i SCA kvadrata sredine i deo aditivne i dominantne variance su pokazali značaj kako aditivnog tako i neaditivnof efekta gena za žetveni indeks. Za naslednost biološkog prinosa aditivni efekat gena je značajniji. Utvrđivanje široke i uske heritabilnosti je pokazalo nisku efikasnost žetvenog indeksa i visoku efikasnost biološkog prinosa za programe selekcije u uslovima stresa.

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