ANALYSIS OF COMBINING ABILITY, GENE ACTION AND HETEROSIS IN A FULL DIALLEL CROSS OF BREAD WHEAT

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ABSTRACT

This experiment involved implementation of a full diallel crosses between five genotypes of bread wheat in the 2009-2010. Then the parents and their F_1 generation including reciprocals were cultivated in the 2010-2011 growing season at the Agricultural Research Station in Koya / Erbil under rainfall conditions using a randomized complete block design with four replications. Some growth characters, grain yield and its components were studied. Genetic statistical analysis were done to estimate general combining ability (GCA) of the parents and specific combining ability (SCA) of F_1 hybrids and reciprocals, also the genetic variance components (additive and dominance), environmental variance, average degree of dominance, heritability in broad and narrow sense, expected genetic advance, heterosis and genetic correlation coefficients among the characters were estimated. The results showed that some parents exhibited positive and high GCA, while some hybrids showed SCA for the majority of the characters. The values of additive genetic variance was more than the values of dominant genetic variance for days to flowering, days to maturity, plant height, spike length, 1000-grain weight, and harvest index. While the values of dominance genetic variance was more than additive for flag leaf area, number of spikes per plant, number of grains per spike, biological and grain yield per plant. The values of heritability in broad sense were high for all characters, while heritability in narrow sense was high for some characters but moderate for others. The values of average degree of dominance was greater than one for flag leaf area, number of spikes per plant, number of grains per spike, biological and grain yield per plant. The expected genetic advance was moderate for plant height, spike length, and 1000-grain weight. Grain yield per plant revealed a significant positive correlation with flag leaf area (0.921), number of spikes per plant (0.883) and 1000 grain weight (0.698).
Keywords: Bread wheat, Diallel cross, Combining ability, Gene action, Heterosis,

INTRODUCTION

In plant breeding programs, diallel crosses are mostly used to provide information on genetic effects for a number of parental varieties or estimates of general and specific combining ability variance components and heritability for plant population from randomly chosen parental varieties. This technique starts to develop with the developing concept of general and specific combining ability by Sprague and Tatum (1942), then Jinks and Hayman (1953), Hayman (1954), Griffing (1956) and Kempthorne (1969), presented various statistical analysis for diallel crossing. Combining ability analysis is a biometrical method which identifies the parent varieties possessing best combining ability and genetic effects involved in the parent varieties possessing best combining ability and genetic effects

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involved in inheritance of various plant characters (Griffing, 1956). It also helps to select the cross combinations having desirable characters to enhance grain yield in wheat and to determine the nature and extent of various types of genetic effects involved in the expression of polygenic character. These points are helpful for selecting parents for next hybridization program. General and specific combining ability had been studied for the different characters in wheat by many researchers using F_1 generation. Kashif and Khaliq (2003) reported that mean square of G.C.A. were significant for plant height, flag leaf area, spikes per plant, spike length and grains per spike, Mean squares of S.C.A. were significant for all characters except spikes per plant, whereas the reciprocal mean square were significant for spike length and grain yield per plant only. Many researchers worked on wheat and observed the presence of additive type of gene action for grain yield per plant and some characters, but some other researchers determined involvement of dominance for these characters. Selection would be successful during the early generations for characters that controlled by additive gene action; otherwise, the selection would be effective at later generations (Liu, 2005). Additive gene action was observed for flag leaf area, spikes per plant, spike length, grains per spike, while dominance gene action was observed for plant height, 1000 grain weight and grain yield per plant (Kashif and Khaliq, 2003). Akram *et al*. (2009) reported that spike length, grains per spike, 1000-grain weight and grain yield per plant were controlled by dominance gene action, and average degree of dominance was greater than one, it means that these characters controlled by over dominance. On the other hand, heritability estimates indicate that certain morphological characters that influence grain yield in wheat are more heritable than yield because yield is a polygenic character and is greatly influenced by the environment. So, selection of wheat varieties on the basis of yield is difficult and needs to be delayed. High heritable estimates for spikes per plant, spike length, and1000-grain weight found by Cheema *et al*. (2006) in their studies of full diallel crosses between five varieties of wheat. Many workers worked on hybrid wheat and found that most of F_1 hybrids and reciprocals showed significant and desirable hrterosis for spikes per plant, spike length, grains per spike and grain yield per plant (Ansari, 2002), while Ilker *et al*. (2010) observed that all hybrids showed significant and positive heterosis over mid parents for spike length and fourteen hybrids for grains per spike and two hybrids for 1000-grain weight.

The present investigation is employed to study the magnitude of combining ability effects of parents and crosses, gene action controlling the inheritance, estimation of variability parameters, heritability, genetic advance and genetic correlation coefficients of growth characters, yield and its components in bread wheat (*Triticum aestivum* L.).

MATERIALS AND METHODS

Five bread wheat genotypes (*Triticum aestivum* L.) which their numbers and pedigrees are presented in Table (1) obtained from Sulaymania and Erbil Research Center were crossed in a complete diallel during 2009-2010. The F_1 grains and reciprocals and their parents were sown during the next growing season 2010-2011 at the Agricultural Research Station in Koya / Erbil [under rainfall conditions (487 mm) depend on meteorological in the search site] using a randomized complete block design with four replications. Each replication consist 25 rows (in addition 2

rows as guard), one row for each genotype, 3.0 m long, with 20 cm row to row and 15 cm plant to plant distance. The data were recorded from mean of ten plants randomly selected in each row for days to flowering, days to maturity, plant height, flag leaf area, spike length, spikes per plant, grains per spike, 1000-grain weight, biological yield, grain yield per plant and harvest index. Mean values of 10 plants from each replication for all the characters were subjected to analysis of variance technique and the significant differences among the means were compared according to least significant difference (LSD) test. Estimates of combining ability were computed by using the method as described by Griffing (1956) Method I, random model. The G.C.A. effects for the parents, S.C.A. effects for the F_1 hybrids and reciprocal effects were calculated. Also estimations of variance for general and specific combining ability effects of the parents, genetic components variance (Additive and dominance), environment variance, heritability in broad and narrow senses, average degree of dominance, expected genetic advance . Each of heritability in broad sense, narrow sense, and genetic advance was categorized as low, moderate and high as suggested by Ali (1999), Adary (1987) and (Agarwal and Ahmad, 1982), respectively. Heterosis over mid parents was computed according to Singh and Chaudhary (1985) and genetic correlation between studied characters was calculated according to Walter (1975).

Table (1): Pedigree of used genotypes as parents and their sources .

No	Source	Pedigree
1.	A.R.C. Erbil	Saberbeg X UP 114 (Adnania)
2.	A.R.C. Sulaymai	PBW 450 – ONPL
3.	A.R.C. Sulaymai	BHRIKUTI NL623 - ONPL
4.	A.R.C. Sulaymai	PASTOR/3/KAUZX2/OPATA/KAUZCMSS93 B003085-29Y-0l0M-0l0Y-0l0M-7Y-OM
5.	A.R.C. Sulaymai	KAUZ//ALTRA84AOS/3/MILAN/KAUZ/4/HUITES CMSS97-M03912T-040Y-020Y-030M-020Y-040M-LY-2M-OY

RESULTS AND DISCUSSION

The analysis of variance revealed significant genotypic differences for all the characters studied (Table 2). The means of the parents and crosses for the characters (Table, 3) had revealed that parent (1) exceeded over the other parents in most characters, it was the earliest in days to flowering, and better in plant height, flag leaf area, spike length, spikes per plant, biological yield per plant and grain yield per plant. Parent (2) exceeded for spikes per plant and grains per spike and parent (4) for 1000-grain weight and harvest index. Regarding the crosses, it was noted that hybrid (5×1) exceeded for most characters earlier to flowering, flag leaf area, spikes per plant, 1000- grain weight, biological yield and grain yield per plant. Hybrid (1×4) exceeded for plant height and spike length. Hybrid (2×4) was the earliest to maturity. Hybrid (5×2) had the highest number of grains per spike, and the hybrid (3×5) exceeded for harvest index. Combining ability analysis (Table 4) showed that means squares for GCA and SCA were highly significant for all the characters except days to maturity which was not significant for SCA, whereas,

mean squares for reciprocals were significant for plant height, flag leaf area, spike length, grains per spike and biological yield per plant.

Table (2): Analysis of variance for the characters studies in a 5 × 5 diallel cross of bread wheat.

SOV	df	Days to flowering	Days to maturity	Plant height (cm)	Flag leaf area (cm^2)	No. of spikes/plant	Spike length (cm)
Replications	3	2.4	1.573	2.160	81.245	0.892	2.298
Genotypes	24	18.769**	7.294**	207.588**	102.310**	8.556**	3.558**
Error	72	1.712	3.011	5.986	9.117	1.328	0.130

SOV	df	No. of grains/spike	1000-grain weight (g)	Biological yield/plant (g)	Grain yield/plant (g)	Harvest index (%)
Replications	3	147.509	7.695	231.126	44.007	5.710
Genotypes	24	57.645**	64.393**	648.686**	104.905**	10.410
Error	72	12.850	5.662	82.806	19.599	2.313

** Significant (P = 0.01)

Table (3): Mean performance of parents and hybrids for the studied characters.

	Days to flowering	Days to maturity	Plant height (cm)	Flag leaf area (cm^2)	No. of spikes/plant	Spike length (cm)
Parents						
1	128.25	172.5	119.67	53.78	11.75	15.33
2	132.00	170.75	95.24	43.91	11.75	11.94
3	134.75	172.25	98.51	45.09	8.90	13.09
4	136.50	173.75	101.65	46.41	9.05	13.25
5	129.25	172.00	98.61	42.02	10.40	12.34
F1 hybrids						
1 × 2	129.50	173.00	115.36	58.99	14.40	14.30
1 × 3	130.25	172.75	111.78	55.59	12.05	14.27
1 × 4	131.50	174.50	117.96	58.53	13.78	15.15
1 × 5	129.75	174.25	113.51	56.59	11.93	14.25
2 × 3	133.50	172.25	100.41	52.35	11.50	12.78
2 × 4	130.75	170.50	101.00	49.05	11.60	12.64
2 × 5	130.50	171.25	102.05	47.59	11.93	12.45
3 × 4	136.50	174.00	102.80	45.99	10.00	13.08
3 × 5	130.75	171.50	103.69	48.54	11.75	13.28
4 × 5	131.00	173.75	107.13	52.96	11.80	13.46
Reciprocals						
5 × 4	130.50	171.50	105.05	53.60	11.95	13.88
5 × 3	130.50	172.00	103.93	53.18	12.25	13.28
5 × 2	130.50	171.25	104.15	53.12	12.35	13.15
5 × 1	129.50	174.75	115.86	61.58	14.88	15.00
4 × 3	134.50	173.75	101.08	52.99	10.90	13.36
4 × 2	131.25	172.75	106.05	52.02	12.03	13.16
4 × 1	131.25	174.50	116.96	55.70	13.18	15.06
3 × 2	133.00	172.25	99.86	51.35	11.23	12.55
3 × 1	132.25	175.50	114.45	56.44	12.58	14.20
2 × 1	130.00	174.25	113.95	57.74	14.25	14.18
Grand mean	131.52	172.88	106.85	52.20	11.93	13.58
L.S.D 1%	2.461	3.264	4.602	5.679	2.168	0.679

	No. of grains/spike	1000-grain weight (g)	Biological yield/plant (g)	Grain yield/plant (g)	Harvest index (%)
Parents					
1	65.93	44.82	74.45	30.09	40.31
2	73.68	36.70	62.83	27.52	43.83
3	70.95	48.00	68.13	28.15	44.13
4	64.18	48.25	56.60	25.23	44.51
5	68.93	47.05	63.03	27.77	41.37
F1 hybrids					
1 × 2	68.70	48.69	95.10	39.79	41.85
1 × 3	70.20	48.14	81.58	35.61	43.56
1 × 4	71.63	51.23	95.05	42.70	44.84
1 × 5	60.83	53.25	86.40	33.92	39.24
2 × 3	73.20	41.57	68.65	29.97	43.66
2 × 4	67.25	44.18	70.03	31.55	44.98
2 × 5	71.58	54.63	76.68	33.53	43.75
3 × 4	68.90	46.06	64.35	28.51	44.28
3 × 5	73.45	51.32	81.80	36.98	45.23
4 × 5	73.73	49.93	82.05	36.67	44.72
Reciprocals					
5 × 4	75.98	49.72	84.23	38.05	45.13
5 × 3	71.60	48.78	85.75	37.31	43.48
5 × 2	78.68	42.05	79.00	33.81	42.69
5 × 1	67.88	54.11	110.25	44.31	40.18
4 × 3	74.53	45.02	71.05	30.71	43.20
4 × 2	71.70	44.08	79.08	34.44	43.55
4 × 1	70.63	50.17	92.73	39.59	42.64
3 × 2	70.00	41.05	66.35	28.76	43.09
3 × 1	67.53	47.93	85.40	35.83	41.82
2 × 1	69.18	46.78	94.15	39.93	42.34
Grand mean	70.43	46.98	78.99	34.03	43.13
L.S.D 1%	6.742	4.476	17.116	8.327	2.861

Parent (1) showed desirable GCA effects for days to flowering, flag leaf area, spikes per plant, spike length, 1000-grain weight, biological yield and grain yield per plant, while parent (2) had desirable effects for days to flowering, days to maturity, plant height, spikes per plant, grains per spike and harvest index and parent (5) for days to flowering, days to maturity, plant height, 1000-grain weight, biological yield and grain yield per plant, then parent (4) for plant height, spike length, grains per spike, 1000-grain weight and harvest index and parent (3) for plant height, grains per spike and harvest index (Table, 5). Other researchers also obtained parents which showed desirable GCA effects for different mentioned characters (Akram *et al*., 2011, and Yadav and Sirohi, 2011).

Table (4): Combining ability analysis in a 5×5 diallel cross of bread wheat according to (Griffing, 1956) Method I, random model.

SOV	df	Days to flowering	Days to maturity	Plant height (cm)	Flag leaf area (cm^2)	No. of spikes/ plant	Spike length (cm)
GCA	4	21.923**	5.317**	271.637**	68.761**	6.486**	4.656**
SCA	10	2.033**	1.247**	13.320**	26.552**	1.995**	0.189**
Reciprocals	10	0.459 [n.s.]	1.003 [n.s.]	2.578*	7.330**	0.544**	0.083**0
Error	72	0.428	0.753	1.496	2.279	0.332	.033
$\sigma^2_{gca} / \sigma^2_{sca}$		2.000	1.392	3.678	0.300	0.462	4.797

SOV	df	No. of grains/spike	1000-grain weight (g)	Biological yield/plant (g)	Grain yield/plant (g)	Harvest index (%)
GCA	4	24.111**	68.153**	428.869**	44.792**	9.360**
SCA	10	16.010**	10.067**	180.285**	38.312**	1.658**
Reciprocals	10	8.933**	1.308 [n.s.]	37.379*	6.715 [n. s.]	0.844 [n. s.]
Error	72	3.212	1.416	20.702	4.900	0.578
$\sigma^2_{gca} / \sigma^2_{sca}$		0.114	1.136	0.270	0.041	1.207

* Significant (P = 0.05) ; ** Significant (P = 0.01) ; n. s. = non- significant

Table (5): Estimates of GCA effects for studied characters in a 5×5 diallel cross of bread wheat.

parents	Days to flowering	Days to maturity	Plant height (cm)	Flag leaf area (cm^2)	No. of spikes/ plant	Spike length (cm)
1	-1.470	0.970	9.071	4.668	1.127	1.131
2	-0.220	-0.930	-3.515	-1.202	0.351	-0.669
3	1.555	-0.030	-3.346	-1.544	-0.921	-0.280
4	1.505	0.395	-0.668	-0.838	-0.593	0.052
5	-1.370	-0.405	-1.542	-1.084	0.036	-0.235
$S.E.(g_i - g_j)$	0.131	0.174	0.245	0.302	0.115	0.036

parents	No. of grains/spike	1000-grain weight (g)	Biological yield/plant (g)	Grain yield/plant (g)	Harvest index (%)
1	-2.591	2.014	9.968	3.156	-1.426
2	1.331	-4.237	-3.519	-1.348	0.221
3	0.699	-0.585	-5.889	-2.107	0.525
4	0.786	0.710	-3.812	-0.761	1.100
5	-0.226	2.098	3.253	1.061	-0.420
$S.E.(g_i - g_j)$	0.358	0.238	0.910	0.443	0.152

The data regarding SCA effects presented in Table (6) showed that the cross (3×5) had the desirable SCA effects for all the studied characters except plant height, followed by cross (1×4) which showed desirable SCA effects for all characters except days to flowering, days to maturity and plan height also a cross (4×5) showed desirable SCA effects for all characters except days to maturity, plant height and 1000-grain weight. They followed by cross (1×2) for six characters flag leaf area, spikes per plant, spike length, 1000-grain weight, biological and grain yield per plant. Then a cross (1×5) for five characters, flag leaf area, spikes per plant, spike length, 1000-grain weight and biological yield, and a cross (2×4) for

four characters, days to flowering, days to maturity, 1000-grain weight and biological yield, then cross (2×5) for spike length and number of grains per spike, and a cross (1×3) for days to flowering and harvest index, then cross (3×4) for plant height. Finally, cross (2×3) for flag leaf area. Other researchers also obtained desirable or non desirable SCA effects for different characters such as (Mahpara, 2008, Ameen, 2008, Sharma and Chaudhary, 2009, and Akram *et al*., 2011).

Table (6): Estimates of SCA effects for studied characters in a 5 × 5 diallel cross of bread wheat.

Crosses	Days to flowering	Days to maturity	Plant height (cm)	Flag leaf area (cm^2)	No. of spikes/ plant	Spike length (cm)
1 × 2	-0.080	0.705	2.254	2.697	0.921	0.203
1 × 3	-0.355	0.305	0.542	0.685	0.181	-0.194
1 × 4	-0.180	0.255	2.214	1.081	1.016	0.346
1 × 5	0.945	1.055	0.313	3.301	0.311	0.152
2 × 3	0.395	0.330	0.152	2.390	0.006	0.034
2 × 4	-1.805	-0.720	0.862	0.369	0.129	-0.061
2 × 5	0.570	-0.045	1.311	0.435	-0.177	0.127
3 × 4	0.920	0.630	-0.894	-0.333	0.038	-0.129
3 × 5	-1.080	-0.695	1.849	1.283	0.958	0.217
4 × 5	-0.905	-0.245	1.677	2.997	0.506	0.273
$S.E.(g_i - g_j)$	0.312	0.4254	0.599	0.740	0.282	0.088

Crosses	No. of grains/spike	1000-grain weight (g)	Biological yield/plant (g)	Grain yield/plant (g)	Harvest index (%)
1 × 2	-0.234	2.978	9.190	4.022	0.165
1 × 3	0.323	-0.377	0.422	0.638	0.459
1 × 4	2.498	0.998	8.744	4.721	0.929
1 × 5	-3.264	2.588	6.117	0.870	-1.582
2 × 3	-0.862	-0.850	-2.078	-1.211	-0.502
2 × 4	-3.074	0.677	2.894	1.073	-0.195
2 × 5	3.589	-1.001	-0.883	-0.072	0.281
3 × 4	-0.204	-1.564	-1.586	-1.550	-1.021
3 × 5	1.621	1.554	7.425	4.165	1.116
4 × 5	3.859	0.039	4.710	3.034	1.108
$S.E.(g_i - g_j)$	0.878	0.583	2.229	1.084	0.373

The data in Table (7) showed that the cross (3×1) had a desirable reciprocal effects for days to flowering, days to maturity, plant height, grains per spike and harvest index, and a cross (4×1) for flag leaf area, spikes per plant, grain yield per plant and harvest index, then a cross (4×2) for days to maturity, plant height and harvest index and a cross (5×2) for plant height, 1000-grain weight and harvest index, then a cross (5×3) for grains per spike, 1000- grain weight and harvest index, then cross (2×1) for days to maturity and 1000- grain weight, and (3×1) for spike length and grains per spike, and a cross (4×3) for harvest index, then a cross (5×1) for plant height. Reciprocal effects have obtained for various characters by other researchers when they used different genetic sources such as (Khan *et al*., 2007, Ameen, 2008, and Akram *et al*., 2011).

Table (7): Estimates of reciprocal effects for studied characters in a 5×5 diallel cross of bread wheat.

Reciprocals	Days to flowering	Days to maturity	Plant height (cm)	Flag leaf area (cm^2)	No. of spikes/ Plant	Spike length (cm)
2×1	-0.250	-0.625	0.706	0.628	0.075	0.061
3×1	-1.000	-1.375	-1.337	-0.424	-0.262	0.037
4×1	0.125	0.000	0.500	1.411	0.300	0.045
5×1	0.125	-0.250	-1.175	-2.495	-1.475	-0.374
3×2	0.250	0.000	0.275	0.500	0.138	0.114
4×2	-0.250	-1.125	-2.525	-1.485	-0.212	-0.263
5×2	0.000	-0.250	-1.050	-2.765	-0.212	-0.346
4×3	1.000	0.125	0.863	-3.503	-0.450	-0.144
5×3	0.125	-0.250	-0.119	-2.321	-0.250	0.003
5×4	0.250	1.125	0.813	-0.319	-0.075	-0.211
$S.E.(r_{ij} - r_{ij}^{'})$	0.293	0.388	0.547	0.675	0.258	0.081

Reciprocals	No. of grains/spike	1000-grain weight (g)	Biological yield/plant (g)	Grain yield/plant (g)	Harvest index (%)
2×1	-0.237	0.953	0.475	-0.072	-0.249
3×1	1.337	0.105	-1.913	-0.110	0.871
4×1	0.500	0.530	1.163	1.556	1.100
5×1	-3.525	-0.428	-11.925	-5.191	-0.469
3×2	1.600	0.260	1.150	0.602	0.285
4×2	-2.225	0.047	-4.525	-1.444	0.715
5×2	-3.550	1.788	-1.162	-0.139	0.531
4×3	-2.813	0.520	-3.350	-1.103	0.538
5×3	0.925	1.270	-1.975	-0.166	0.875
5×4	-1.125	0.105	-1.088	-0.689	-0.203
$S.E.(r_{ij} - r_{ij}^{'})$	0.802	0.532	2.035	0.990	0.340

The evaluation of genetic and environmental variation (σ^2_A, σ^2_D and σ^2_E) as presented in Table (8) for studied characters revealed that values for additive genetic variance were significant for all characters except for number of grains per spike and grain yield per plant, while values for dominance genetic and environment variances were significant for all the studied characters. Also the same table showed that the values of additive genetic variance were greater than dominance genetic variance for days to flowering, days to maturity, plant height, spike length, 1000-grain weight and harvest index, which depicts the importance of additive gene effect for controlling these characters, whereas the values of dominance genetic variance were greater than the additive genetic variance for flag leaf area, spikes per plant, grains per spike, biological yield and grain yield per plant, which indicates to the importance of dominant gene effect for controlling these characters. These results are in agreement with those previously reported by other researchers (Joshi, *et al* 2004, Hassan, 2004, Mahpara *et al*., 2008 and Ullah *et al*., 2010).

Table (8): Estimates of genetic variation (σ^2_A, σ^2_D) and environmental variation σ^2_E for studied characters.

Variations	Days to flowering	Days to maturity	Plant height (cm)	Flag leaf area (cm^2)	No. of spikes/ plant	Spike length (cm)
Additive (σ^2_A)	3.993** ± 0.904	0.819** ± 0.219	51.776** ± 11.202	8.673** ± 2.836	0.914** ± 0.268	0.895** ± 0.192
Dominance (σ^2_D)	0.955** ± 0.208	0.294* ± 0.131	7.038** ± 1.361	14.448** ± 2.712	0.990** ± 0.204	0.093** ± 0.019
Environment (σ^2_E)	0.428** ± 0.070	0.753** ± 0.124	1.496** ± 0.246	2.279** ± 0.375	0.332** ± 0.055	0.033** ± 0.005

Variations	No. of grains/spike	1000-grain weight (g)	Biological yield/plant (g)	Grain yield/plant (g)	Harvest index (%)
Additive (σ^2_A)	1.742 ± 0.995	11.700** ± 2.811	51.237** ± 17.688	1.614** ± 1.848	1.551** ± 0.386
Dominance (σ^2_D)	7.617** ± 1.639	5.149** ± 1.029	94.990** ± 18.420	19.888** ± 3.915	0.642** ± 0.171
Environment (σ^2_E)	3.212** ± 0.528	1.416** ± 0.233	20.702** ± 3.403	4.900** ± 0.806	0.578** ± 0.095

* Signifiant (P = 0.05),   ** Signifiant (P = 0.01)

Table (9) showed that the average degree of dominance (ā) was more than one for flag leaf area, spikes per plant, grains per spike, biological yield/plant and grain yield/plant indicate that these characters are controlled by over dominance. These results are in agreement with previous results (Ameen, 2008, and Khattab *et al*., 2010); while it was less than one for days to flowering, days to maturity, plant height, spike length, 1000-grain weight and harvest index indicate that these characters are controlled by partial dominance. These results are in agreement with those previously reported by Hassan (2004) and Esmail (2007). The values of heritability in broad sense ($H^2_{b.s.}$) were high for all characters ranged between (%74.447) for grains per spike and (%97.519) for plant high except the days to maturity which was moderate (%59.650). These findings correspond with the results published by some other authors (Ahmed *et al*., 2007, Ajmal *et al*., 2009, and Yadav *et al*., 2011). The estimated values of heritability in narrow-sense ($H^2_{n.s.}$) varied between high for days to flowering, plant height, spike length, 1000-grain yield and harvest index and moderate for days to maturity, flag leaf area, spikes per plant and biological yield while they were low for grains per spike and grain yield per plant. These results agreed with those previously reported by Hassan, (2004), Eid, (2009), Khattab *et al*. (2010) and Erkul *et al*. (2010). The expected genetic advance (E.G.A) was between 0.553 for grain yield per plant and 11.734 for plant height. The expected genetic advance as a percent of mean was moderate for plant height, spike length and 1000-grain weight and it was moderate for spikes per plant, while it was low for the rest of the characters. These results are in agreement with those reported by Eid, (2009) and Bilgin *et al*. (2011).

Table (9): Average degree of dominance and heritability in broad sense and narrow sense and expected genetic advance for studied characters.

Genetic parameters	Days to flowering	Days to maturity	Plant height (cm)	Flag leaf area (cm^2)	No. of spikes/ plant	Spike length (cm)
(ā)	0.692	0.847	0.521	1.825	1.472	0.457
H$^2_{b.s.}$	92.037	59.650	97.519	91.026	85.149	96.808
H$^2_{n.s.}$	74.272	43.890	85.849	34.145	40.876	87.671
E.G.A.	3.031	1.055	11.734	3.029	1.076	1.559
E.G.A. (%)	2.305	0.610	10.982	5.802	9.020	11.484

Genetic parameters	No. of grains/spike	1000-grain weight (g)	Biological yield/plant (g)	Grain yield/plant (g)	Harvest index (%)
(ā)	2.957	0.938	1.926	4.964	0.910
H$^2_{b.s.}$	74.447	92.250	87.599	81.442	79.135
H$^2_{n.s.}$	13.857	64.057	30.694	6.114	55.956
E.G.A.	0.865	4.818	6.980	0.553	1.640
E.G.A. (%)	1.228	10.256	8.836	1.625	3.801

The estimates of heterosis over mid parents of F1 hybrids and reciprocals for all the studied characters are presented in Table (10) revealed that the best crosses which showed the maximum heterosis in a desirable direction for grain yield per plant were (1×4) and (5×1) and they recorded 15.043 and 15.185 g/plant, these hybrids also showed the desirable heterosis in other characters like flag leaf area, spikes per plant, spike length, 1000-grain weight, biological yield per plant and harvest index. In addition to desirable SCA by cross (1×4) for flag leaf area, spikes per plant, spike length, number of grains per spike, 1000-grain weight, biological yield, grain yield and harvest index. Based on these results, it is possible to use heterosis estimates for evaluation of dominance gene action in hybrids. The appearance of the heterosis over mid parents for any characters indicate that the dominance gene action controlled it, while the hybrid which doesn't show significant heterosis indicated that the additive gene action controlled it (Ansari, 2002) and agrees that dominance hypothesis is an acceptable explanation of heterosis. Based on the results of this study showed that %67of heterosis were for characters that controlled by dominant gene action more than additive gene action for their inheritance, while %42.8 of heterosis characters that controlled by additive gene action, and this is coming from the fact that both of heterosis and specific combining ability are originated from the dominance gene effects (Shamsuddin, 1985). These results are in agreement with those reported by other researchers (Kundan *et al.,* 2010, Khattab *et al.,* 2010, Akbar *et al.,* 2010 and Ilker *et al.,* 2010).

Table (10): Heterosis estimates of studied characters in bread wheat of mid parent.

Crosses	Days to flowering	Days to maturity	Plant height (cm)	Flag leaf area (cm^2)	No. of spikes/ plant	Spike length (cm)
1 × 2	-0.625	1.375	7.911**	10.153**	2.651**	0.670**
1 × 3	-1.250	0.375	2.690	6.155**	1.725*	0.061
1 × 4	-0.875	1.375	7.300**	8.431**	3.375**	0.860**
1 × 5	1.000	2.000	4.374**	8.696	0.850	0.416
2 × 3	0.125	0.750	3.541*	7.848**	1.175	0.264
2 × 4	-3.500**	-1.750	2.556	3.886*	1.200	0.042
2 × 5	-0.125	-0.125	5.125**	4.624*	0.850	0.316
3 × 4	0.875	1.000	2.723	0.234	1.025	-0.094
3 × 5	-1.250	-0.625	5.129**	4.981**	2.100**	0.568*
4 × 5	-1.875**	0.875	6.994**	8.743**	2.075**	0.661**
5 × 4	-2.375**	-1.375	5.369**	9.380**	2.225**	1.084**
5 × 3	-1.500	-0.125	5.366**	9.624**	2.600**	0.563*
5 × 2	-0.125	0.375	7.225**	10.154**	1.275	1.009**
5 × 1	0.750	2.500*	6.724**	13.686**	3.800**	1.164**
4 × 3	-1.125	0.750	0.997	7.239**	1.925**	0.194
4 × 2	-3.000**	0.500	7.606**	6.856**	1.625*	0.567*
4 × 1	-1.125	1.375	6.305**	5.609**	2.775**	0.770**
3 × 2	-0.375	0.750	2.991	6.848**	0.900	0.036
3 × 1	0.750	3.125**	5.365**	7.003**	2.250**	-0.014
2 × 1	-0.125	2.625	6.499**	8.897**	2.500**	0.547*

Crosses	No. of grains/spike	1000-grain weight (g)	Biological yield/plant (g)	Grain yield/plant (g)	Harvest index (%)
1 × 2	-1.100	7.925**	26.463**	10.981**	-0.223
1 × 3	1.762	2.203	12.838*	6.675*	1.343
1 × 4	4.200	4.695**	29.525**	15.043**	2.426*
1 × 5	-4.225	6.843**	15.113**	4.802	-1.603
2 × 3	0.888	-0.308	5.725	2.319	-0.315
2 × 4	-4.050	1.700	10.313	5.174	0.806
2 × 5	2.650	3.278*	11.200*	5.694*	1.150
3 × 4	-1.037	-1.588	4.537	2.008	-0.046
3 × 5	5.888**	3.795*	16.225**	9.018**	2.480**
4 × 5	7.175**	1.808	19.688**	9.983**	1.779
5 × 4	9.425**	1.598	21.863**	11.360**	2.184*
5 × 3	4.037	1.255	20.175**	9.350**	0.730
5 × 2	9.750**	-0.298	13.525**	5.971*	0.087
5 × 1	2.825	7.698**	38.963**	15.185**	-0.665
4 × 3	4.588**	-2.628	11.238*	4.213	-1.121
4 × 2	0.400	1.605	19.363**	8.061**	-0.624
4 × 1	3.200	3.635*	27.200**	11.930**	0.226
3 × 2	-2.213	-0.828	3.425	1.114	-0.885
3 × 1	-0.912	1.993	16.663**	6.895*	-0.400
2 × 1	-0.625	6.020**	25.513**	11.126**	0.275

* Significant (P = 0.05), ** Significant (P = 0.01)

Genetic correlation coefficients between studied characters are shown in Table (11). There were significant and positive genetic correlation between grain yield and most of its components and between themselves, thus selection for any of these characters lead to improve other characters including grain yield. Similar

results have been reported by Ajmal *et al.* (2009) and Bilgin *et al.* (2011). The results of this study revealed that parents (1), (2) and (5) had the possibility to use in crossing programs because they have showed desirable GCA effects for most of the studied characters and obtaining some crosses like (3×5), (5×4), (4×5) and (1×4), which they had high desirable heterosis for most of the characters and could used in the future breeding programs.

Table (11): Genetic correlation coefficients between studied characters.

	Harvest index	Grain yield/plant	Biological yield/plant	1000-grain weight	No. of grains/ spike	Spike length	No. of spikes/plant	Flag leaf area	Plant height	Days to maturity
Days to flowering	.609**	-.609**	-.675**	-.226	.239	-.407*	-.721**	-.517**	-.554**	.030
Days to maturity	-.417*	.514**	.576**	.860**	-.602**	.797**	.378	.677**	.762**	
Plant height	-.545**	.786**	.830**	.624**	-.408*	.971**	.761**	.862**		
Flag leaf area	-.467*	.921**	.940**	.551**	-.127	.820**	.910**			
No. of spikes/plant	-.496*	.883**	.912**	.338	-.151	.609**				
Spike length	-.483*	.707**	.746**	.691**	-.345					
No. of grains/ spike	.719**	-.065	-.231	-.393						
1000-grain weight	-.318	.698**	.709**							
Biological yield/plant	-.510**	.973**								
Grain yield/plant	-.302									

تحليل القدرة على الائتلاف والفعل الجيني وقوة الهجين
للتهجين التبادلي الكامل في حنطة الخبز

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الخلاصة

تضمنت هذه التجربة إجراء تهجين تبادلي كامل بين خمسة تراكيب وراثية من حنطة الخبز في الموسم 2009-2010، ثم زراعة الآباء وهجن الجيل الأول والهجن العكسية في الموسم 2010-2011 في محطة التجارب الزراعية في كوية/محافظة أربيل تحت الظروف الديمية باستخدام تصميم القطاعات العشوائية الكاملة بأربعة مكررات، ودرست بعض صفات النمو والحاصل ومكوناته. أجري التحليل الإحصائي الوراثي للبيانات لتقدير القدرة على الإئتلاف ومكونات التباين الوراثي (الإضافي والسيادي) والتباين البيئي ومعدل درجة السيادة وقوة التوريث بالمعنيين الضيق والواسع والتحسين الوراثي المتوقع وقوة الهجين، وكذلك إيجاد معامل الإرتباط الوراثي بين مختلف الصفات المدروسة. أظهرت النتائج أن لبعض الآباء قدرة عامة موجبة عالية على الائتلاف وكذلك الحصول على بعض الهجن ذات قوة هجين عالية وبالإتجاه المرغوب لأغلب الصفات. كانت قيم التباين الوراثي الإضافي أكبر من قيم التباين الوراثي السيادي لعدد الأيام للتزهير وعدد الأيام للنضج وإرتفاع النبات وطول السنبلة ووزن 1000حبة ودليل الحصاد، بينما كانت قيم التباين الوراثي السيادي أكبر من الإضافي لمساحة ورقة العلم وعدد السنابل/نبات وعدد الحبوب/سنبلة والحاصل البيولوجي/نبات وحاصل الحبوب/نبات. كانت درجة التوريث بالمعنى الواسع عالية لجميع الصفات المدروسة، بينما كانت قيمة التوريث بالمعنى الضيق عالية لبعض الصفات ومتوسطاً لصفات أخرى. بلغت قيم معدل درجة السيادة أكبر من الواحد لمساحة ورقة العلم وعدد السنابل/نبات وعدد الحبوب/سنبلة والحاصل البيولوجي وحاصل الحبوب/نبات. وتم الحصول على تحسين وراثي متوقع متوسط

لإرتفاع النبات وطول السنبلة ووزن 1000حبة. أظهر حاصل الحبوب/نبات إرتباطا وراثياً معنوياً وموجباً
مع مساحة ورقة العلم وعدد السنابل/نبات وطول السنبلة ووزن 1000حبة.

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