Estimate of Heterosis and Combining Ability in Diallel Bread Wheat Crosses (*Triticum aestivum* L.)

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ABSTRACT

This investigation was carried out at the experimental farm of Etai El-Baroud Agricultural Research Station, El-Beheira Governorate (Agricultural Research Center) during the two successive growing seasons 2006/2007 and 2007/2008. Five bread wheat cultivars and lines, *Triticum aestivum* L. en Thell, representing a wide range of diversity for several agronomic characters were selected for the study. The five parents and ten crosses were grown in a randomized complete block design with three replications with recommended fertilization. The genetic analysis (variance, combining ability, heterosis, and path coefficient analysis) of grain yield per plant and some agronomic traits, i.e., (days to anthesis, days to maturity, plant height, spike length, number of tillers/plant, number of spikes/ plant, number of grains/spike and 1000-grain weight) were evaluated. Differences among parents and hybrids were significant. Highly significant heterosis was depicted in two crosses ($P_1\times P_3$) and ($P_1 \times P_2$) for grain yield/plant. Three parental combinations; ($P_1\times P_2$), ($P_1\times P_3$) and ($P_1\times P_5$) expressed significant specific combining ability effects for grain yield/plant. The Number of grains/spike followed by 1000-grain weight proved to be the major grain yield contributors.

Keywords: General combining ability; Specific combining ability, Heterosis, Path analysis, and *Triticum aestivum*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important major cereal crop overall the world. Due to its high adaptation and multiple uses, high nutritive value associated with high crop production it is used as staple food for more than one third of the world population. Wheat breeding programs played the major role in the developing new high yielding varieties. Increasing wheat production as a national goal could be achieved through increasing the production per unit area.

During the recent past, concentrated efforts have resulted in the development of improved genotypes by exploiting Borlaug's wheat improvement programme, which resulted in lack of genetic diversity (Tillman, 1998). It is a general agreement that germplasm diversity and genetic relate differences among elite breeding materials is the fundamental element in plant breeding (Mukhtar *et al.,* 2002). Hence breeding wheat genotypes with diverse genetic base is needed to achieve self-sufficiency and sustainability.

Diallel cross technique is a good tool for identification of hybrid combinations that have the potentiality of producing maximum improvement and identifying superior lines among the progeny in early segregation generations. Combining ability analysis of Griffing (1956) is most widely used as a biometrical tool for identifying parental lines in terms of their ability to combine in hybrid combinations. With this method, the resulting total genetic variations is partitioned into the variance of general combining ability, as a measure of additive gene action and specific combining ability, as a measure of non-additive gene action Afiah, (2002) and Afiah and Darwish, (2002).

Exploitation of heterosis is considered to be one the outstanding achievements of plant breeding in self-pollinated crops like wheat the scope for utilization of heterosis depends mainly upon the direction and magnitude of heterosis. The heterosis relative to mid-parent may be useful for identifying the best parental combinations.

Knowledge of nature and magnitude of interrelationship among grain yield and their related attributes helps to improve the efficiency of selection in breeding program. However, path coefficient analysis allows an effective means of partitioning correlation coefficient into unidirectional and alternate pathways. This analysis permits a critical examination of specific factors that produce a given correlation and can be successfully employed in formulating an effective selection strategy.

The major objectives of this study are a) Evaluating performance of five parents of bread wheat. b) Estimating heterosis, general and specific combining abilities. c) Studying the interrelationships among traits and path coefficient analysis to determine the important traits which can be used as selection criteria for target environments.

MATERIALS AND METHODS

This investigates was carried out at the Experimental Farm of Etai El-Baroud Agricultural Research Station, El-Beheira Governorate (Agricultural Research Center) during the two successive growing

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seasons 2006/2007 and 2007/2008. Five bread wheat cultivars and lines (*Triticum aestivum* L. en Thell.) representing a wide range of diversity for several agronomic characters were selected for this study. Names and pedigree of these varieties and or/lines are presented in Table (1). In 2006/2007 growing season, grains from each of the parental varieties and/or lines were sown at a various planting dates in order to overcome the differences in heading dates. During this season, all possible parental crosses without reciprocals were made between the five parents giving a total of ten crosses.

In 2007/2008 season, the 15 entries (10 F_1's and 5 parents) were sown in a field experiment which arranged in a randomized complete block design with three replicates. Each plot consisted of two rows, three meters long with 30 cm between rows and plants within row were 20 cm apart allowing a total 30 plants per plot. The other cultural practices growing wheat were practiced. Days to anthesis (DA) and maturity (DM) were recorded on plot basis. At maturity, ten plants were randomly selected from each plot for subsequent measurements as follows:

Plant height (PH cm), number of tillers per plant (NT/P), number of spikes per plant (NS/P), spike length (SL cm), number of grains per spike (NG/S), 1000-grain weight (TGW g) and Grain yield (GY g).

Analysis of variance:

Data of the experiment was subjected to proper statistical analysis of variance according to Snedecor and Cochran (1967). For comparison between means, Dunncan's multiple range test was used, as proposed by Duncan (1955). General (GCA) and specific (SCA) combining ability estimates were obtained by employing Griffing's diallel cross analysis (1956) designated as method 2 model I .

The amount of heterosis was expressed as the percentage deviation of F_1 mean performance from the mid-parent as follows:

$$\text{heterosis over mid-parent (\%)} = \frac{\overline{F_1} - M\overline{P}}{M\overline{P}} \times 100$$

Appropriate L.S.D. values were calculated to test the significance of the heterotic effects according to the following formulae:

$$\text{L.S.D. for mid-parental heterosis} = t\left(\sqrt{3\,M\,Se\,/2\,r}\right)$$

Where: t, is tabulated t value at a stated level of probablility for the experimental error degrees of freedom, MSe: is the mean square of the experimental error and r : is the number of replication.

Phenotypic (r_p) correlation coefficient was computed for different pairs of genotypes traits. However, partitioning correlation coefficient into direct and indirect effects at phenotypic level was made by determining path coefficients using method proposed by Wright (1921) and utilized by Dewey and Lu (1959).

RESULTS AND DISCUSSIONS

Analysis of variance and mean performance;

Analysis of variance for number of days to anthesis, maturity, plant height, number of tillers, spikes per plant, spike length, number of grains per spike, 1000-grain weight, and grain yield per plant are presented in Table (2).

The results revealed that, genotypes mean squares were highly significant for all studied characters except number of days to maturity. The significance of the mean squares indicated the presence of true differences among these genotypes. Mean squares due to parents, general (GCA) and specific (SCA) combining abilities for crosses were significant for all studied traits except (SCA) of days to maturity. These findings indicate that parental varieties and/ or lines differed in their mean performance for most of the tested traits. The mean performance of the five parental and ten F_1 crosses are presented in Table (3).

The parental cultivar Sakha 61(P_1) ranked the first for number of days to anthesis, number of tillers and spikes per plant and third for spike length but it took the fifth rank for grain yield per plant. Parental cultivar Gemmeiza 9 (P_2) ranked the first for plant height, spike length and number of grains per spike and the second fo number of tillers, spikes per plant, grain yield per plant and 1000-grain weight. The parental Line 1 (P_3) ranked the first for grain yield per plant and second for number of days to maturity and spike length. The fourth parental Line 2 (P_4) ranked the first for number of tillers and spikes per plant. The parental Lin e 3 (P_5) took the

Table 1. The name and pedigree of the five parental bread wheat genotypes

No.	Name	Pedigree
P_1	Sakha 61	Lina/ RL4220//7C/Yr "s"
P_2	Gemmeza 9	ALD"s"/HAVAC"s"//CMH74A.630/sx
P_3	Line ≠1	Vee "S" 131 Hork "S"// Ymh/Kal-Bb/Roek/Kvz.
P_4	Line ≠2	QAFZH-25.
P_5	Line ≠3	HD2136/SKA/5/TOB/CNO67//BB/4/NA160*2//TT/SN64/3/LR64A/SN64/6/HD2257/7/SPB/8/HE1/5*CNO79/9/89N2081.

first rank for spike length and 1000-grain weight. From the previous results showed the importance of the first parent (Sakha 61) for earliness and number of tillers and spikes per plant, P_4 (Line 2) for number of tillers and spikes per plant and P_5 (Line 3) for spike length and 1000-grain weight.

Performance of the tested ten crosses are presented in Table (3). There was a significant differences in days to anthesis between the *Triticum* genotypes. Genotypes; P_1, P_2 and P_4 as well as crosses; (P_1×P_4), (P_1×P_2), (P_1×P_5), (P_1×P_3) and (P_3×P_4), recorded the lowest days for anthesis compared to the others.

For plant height, results indicated the parent; P_2 and crosses; (P_2 × P_4) and (P_3×P_4) gave the highest values, while, P_1 followed by P_3 and P_5 as well as crosses; (P_1×P_5), (P_1×P_3) and (P_1×P_4) recorded the lowest values for the same trait. It could be concluded that the parent P_1 and its crosses; (P_1×P_2), (P_1×P_3), (P_1×P_4) and (P_1×P_5) had the lowest values for days to anthesis and plant height. It could be concluded that the progeny of this parent and these crosses were used in breeding program for earliness and mechanic harvesting.

On the other side, the highest mean values were detected by the parental varieties P_1, P_4 and P_2 for number of spikes / plant, P_2, P_5 and P_3 for spike length, P_1, P_4 and P_2 for number of tillers/ plant, P_2, P_4 and P_3 for number of grains/ spike P_5, P_2 and P_3 for 1000-grain weight (g) and P_3, P_2 and P_4 for grain yield/ plant. Also, the mean values for crosses ranged from 8.67 to 21.33 for number of spikes/ plant, 13.83 to 15.67 for spike length (cm), 8.67 to 21.33 for number of tillers/ plant, 70 to 85 for number of grains/ spike, 40.33 to 53.13 for 1000-grain weight (g) and 25 to 79.33 for grain yield/ plant (g).

With respect to number of spikes/ plant, two crosses; (P_4×P_5) and (P_1×P_3) had highly mean values followed by crosses; (P_2×P_4), (P_1×P_4) and (P_3×P_5). Data showed that two crosses; (P_1×P_5) and (P_3×P_5) exhibited longer spike length than the rest genotypes. Crosses (P_4×P_5), (P_2×P_4) and (P_1×P_3) gave the highest values for number of tillers/ plant.

Four crosses; (P_2×P_3), (P_1×P_5), (P_3×P_4) and (P_3×P_5) expressed the highest values for number of grains/ spike.

Three crosses; (P_2×P_3), (P_2×P_5) and (P_3×P_5) over weighted all genotypes in 1000-grain weight. While, for grain yield/ plant the parental combinations; (P_1×P_3), (P_2×P_3) and (P_1×P_5) surpassed all the genotypes. Almost similar results were reported by Farooq *et al.* (2005).

It could be concluded from the obtained results that the parental varieties P_3, P_2 and P_4 as well as (P_1×P_3), (P_2×P_3) and (P_3×P_5) crosses recorded greater values for number of spikes/plant, number of grains/ spike, 1000-grain weight and grain yield/ plant. The high grain yield/ plant of the previous crosses could be attributed to the high values of one or more of yield components. These crosses would be efficient and promising in wheat breeding programs for improving grain yield.

These results are in accordance with the finding of Masood *et al.,* (2005). Previous studies on wheat have also demonstrated significant differences among genotypes, for grain yield and related traits of wheat (Menon and Sharma, 1997; Joshi *et al*., 2004).

Heterosis:

Mean squares for parents vs. crosses as an indication to average heterosis over all crosses were significant for all studied traits, except, mean squares for days to maturity, number of tillers/plant, number of grains/ spike, 1000-grain weight and grain yield/ plant Table (2).

Heterosis expressed as the percentage deviation of F_1 mean performance from the mid parent values for all the studied traits are presented in Table (4).

For days to anthesis, three crosses, (P_1×P_2), (P_1×P_4) and (P_3×P_4) expressed significant negative heterotic effects relative to mid-parent. The best cross was (P_1×P_4) -2.86%. significant negative heterotic effect for earliness was previously detected by Asoush *et al.* (2001), Masood, *et al,.* (2005). who reported significant negative heterosis over mid-parent value for days to heading.

The results indicated that eight crosses exhibited significant positive heterotic effects for plant height ranged from 3.15% to 12.95. For spike length, the significant mid-parental heterosis was detected in four crosses out of 10 F_1's ranged from 6.1% to 12.57%. The best cross was (P_1×P_5) 12.57%, Masood *et al.,* (2005) reported positive heterosis for spike length. While only one cross (P_3×P_5) showed significant positive heterosis as a deviation from mid-parent for number of tillers/plant, Akhbar *et al.,* (2007) have also reported negative heterosis for this trait. Highly significant heterosis over mid-parent was detected in two crosses (P_1×P_5) and (P_3×P_5) for number of grains/ spike ranged from 8.71 to 26.32%. The same results were obtained by Akhbar *et al.*, (2007)

Only one cross (P_2×P_3) expressed highly significant mid-parental heterosis for 1000-grain weight.

Highly significant heterosis in two crosses (P_1×P_3) and (P_1×P_2) for grain yield/ plant was obtained. These results agreed to some earlier findings Hussain *et al.* (2006) and Akhbar *et al.*, (2007)

Table 2. Mean squares from the analysis of variance for all studied characters

Source of variation	df	DA	DM	PH	NT/P	NS/P	SL	NG/S	TGW	GY/P
Rep.	2	0.80	8.60	23.36*	24.09	21.62	0.45	2.29	5.02	31.27
Genotypes (G)	14	60.8**	17.06	148.8**	48.18**	44.37**	1.48**	129.55**	53.87**	504.66**
Parents (P)	4	110.1**	39.90*	193.17**	62.27**	45.27**	2.39**	302.43**	54.87**	376.57**
Crosses (F1)	9	44.53**	8.70	99.63**	44.31**	44.31**	0.84*	65.32**	58.02**	617.26**
P vs. F1	1	10.0*	0.90	413.88**	26.68	41.34*	3.60**	16.04	12.58	3.60
Error	28	1.59	13.74	4.93	7.95	9.41	0.29	6.46	5.37	21.27
GCA	4	54.31**	17.19*	116.98**	15.49**	12.15*	1.00**	79.53**	43.06**	224.64**
SCA	10	6.65**	1.09	22.65**	16.29**	15.85**	0.29*	28.64**	7.92**	145.65**
GCA/SCA	-	8.17	15.83	5.16	0.95	0.77	3.49	2.78	5.44	1.54

*, ** Significant differences at 0.05 and 0.01 probability levels, respectively
DA = Days to anthesis, DM= Days to maturity, PH = Plant height (cm), NS/P = No. of spikes/ plant, SL= Spike length (cm), NT/P= No. of tillers, NG/S= No. of grains/ spike, TGW= Thousand grain weight (gm) and GY/P= Grain yield / plant

Table 3. The genotypes mean performance for all studied characters

Genotypes	DA	DM	PH (cm)	NT/P	NS/P	SL (cm)	NG/S	TGW (g)	GY/P (g)
P_1	101a*	151	93.33f	22.33a	22.33a	13.17de	63.67g	45.8cde	38.0g
P_2	114e	159	115.7bc	21.33ab	21.33ab	14.67bc	84.00ab	49.17abc	61.67bcd
P_3	113e	158	105.67e	12.33ef	14.33cd	14.50bc	78.67cd	47.00bc	66.33bc
P_4	109b	160	108e	22.33a	22.33a	12.83e	81.33abc	39.52g	60.0cd
P_5	102a	159	105.67e	15.67cde	15.7bcd	14.67bc	63g	50.57ab	51.00ef
$P_1 \times P_2$	105b	154	108.33e	16.67b-e	16.7a-d	14.50bc	72ef	43.67efg	54.33de
$P_1 \times P_3$	108cd	157	106.67e	20abc	20.0abc	14.17bc	71.33ef	45.53cde	79.33a
$P_1 \times P_4$	102a	157	107.33e	19.33abc	19.3abc	13.83cd	70.00f	40.72fg	25.00h
$P_1 \times P_5$	106bc	157	105e	8.67f	8.67e	15.67a	80.00bc	40.33fg	61.33bcd
$P_2 \times P_3$	114e	157	113.33c	16.67b-e	16.7a-d	14.50bc	85.00a	53.13a	69.00b
$P_2 \times P_4$	110d	159	120a	19.67abc	19.67abc	14bcd	75de	45.37cde	53.33def
$P_2 \times P_5$	113e	158	112.67cd	17.67a-d	17.67a-d	14.83abc	71.67ef	50.80ab	45.33fg
$P_3 \times P_4$	108cd	159	120.67a	12.67def	12.67de	14.50bc	78.00cd	40.45fg	55.67de
$P_3 \times P_5$	113e	159	109de	19abc	19.00abc	15ab	77cd	48.42bcd	61.00bcd
$P_4 \times P_5$	109b	160	118ab	21.33ab	21.33ab	14.67bc	74def	44.40def	55.67de

* Mean followed by the same letter(s) are not significantly different
DA = Days to anthesis, DM= Days to maturity, PH = Plant height (cm), NS/P = No. of spikes/ plant, SL= Spike length (cm), NT/P= No. of tillers, NG/S= No. of grains/ spike, TGW= Thousand grain weight (gm) and GY/P= Grain yield / plant

Combining ability

Combining ability implies the capacity of parent to produce progenies when crossed with other parent. In breeding programs, information on combining ability clues to the nature of gene action, desirable parents and important yield traits may be found. Combining ability studies also, provide useful information for the promising selection of parents for effective breeding, besides elucidating the nature and magnitude of gene action involved. Such information is required to design efficient breeding programs for crop improvement.

Data were further subjected to genetical analysis proposed by Griffing (1956) to estimate the portion of additive and non-additive gene action involved in the inheritance of these traits and variance due to general combining ability and specific combining ability.

As shown in Table (2), combining ability analysis revealed that the mean square associated with general and specific combining abilities were highly significant for all studied traits, except days to maturity, indicating the importance of both additive and non-additive genetic variance in determining the performance of these traits. Similar results were also obtained by Abd EL-Aty, (2000).

To reveal the nature of genetic variance, which had greater role, GCA/SCA ratios were computed. High GCA/ SCA ratio largely exceed the unity were obtained for all studied traits except number of spikes/ plant and number of tillers/ plant, indicating that the largest part of the total genetic variability associated with those measurements was a result of additive and additive x additive types of gene action. On the other hand, Abd EL-Majeed, *et al.,* (2004) found that GCA/SCA ratio were more than unity for all studied traits except, grain yield/ plant.

General combining ability effects ($\hat{g}_i$) of each parent for all studied traits are presented in Table (5). Such effects are being used to compare the average performance of each variety with other. General combining ability effects ($\hat{g}_i$) of parents in this study were found to be significantly different from zero for all studied traits.

Concerning days to anthesis and days to maturity the negative values of GCA effects ($\hat{g}_i$) would be of interest for earliness, two parents; P_1 and P_5 had highly significant negative ($\hat{g}_i$) for days to anthesis, while, only one parent; P_1 gave highly significant negative ($\hat{g}_i$) for days to maturity.

With respect the traits which the positive direction are interested, two parents; P_2 and P_4 expressed highly significant ($\hat{g}_i$) for plant height. While only one parent; P_1 gave highly significant negative ($\hat{g}_i$) for the same trait so this parent my be used in breeding program for mechanical harvesting.

Only one parent; P_4 exhibited significant positive ($\hat{g}_i$) for number of spikes/ plant. Also only one parent; P_5 seemed to be good combiner for spike length. Three parents; P_2, P_3 and P_4 expressed significantly desirable ($\hat{g}_i$) for number of grains/ spike. Also, two parents; P_2 and P_5 gave highly significant positive ($\hat{g}_i$) for 1000-grain weight and only one parent P_3 had highly desirable significant ($\hat{g}_i$) for grain yield/plant.

Generally, the parental variety P_1 seemed to be good combiner for earliness, while only one parent P_3 was the best combiner for grain yield/ plant and number of grains per spike.

Estimates of specific combining ability effects of the parental combinations computed for all studied traits are presented in Table (6).

With regard to days to anthesis, three parental combinations; ($P_1 \times P_2$), ($P_1 \times P_4$) and ($P_3 \times P_4$) expressed highly significant negative ($\hat{S}_{ij}$).

Highly significant positive ($\hat{S}_{ij}$) were obtained from two parental combinations; ($P_1 \times P_5$) and ($P_3 \times P_4$) for plant height.

For number of spikes/ plant and number of tillers/ plant only one parental combination; ($P_1 \times P_3$) exhibited highly significant positive ($\hat{S}_{ij}$).

Three crosses ($P_2 \times P_3$), ($P_3 \times P_5$) and ($P_4 \times P_5$) expressed highly significant ($\hat{S}_{ij}$) for number of grains/ spike, while only one cross; ($P_1 \times P_4$) showed highly significant positive ($\hat{S}_{ij}$) for 1000-grain weight. With respect grain yield/plant, three parental combinations; ($P_1 \times P_2$), ($P_1 \times P_3$) and ($P_1 \times P_5$) expressed highly significant positive ($\hat{S}_{ij}$). The best cross was ($P_1 \times P_3$) for this trait.

Finally, results concerning general and specific combining abilities indicated that the excellent parental combinations were obtained from crossing good × good, good × poor combiners. Also, results showed that the best parental combinations overall heterosis and specific combining ability effects were; ($P_1 \times P_5$) and ($P_1 \times P_3$) for grain yield/plant. Therefore, these crosses might be promising in breeding program for grain yield.

Correlation and path coefficient analysis:

Phenotypic correlation coefficients estimated between different pairs of traits, i.e., number of spikes/ plant, number of grains/ spike and 1000-grain weight and path coefficient analysis is given in Tables (7 and 8). As shown in Table (7) positive correlation was found between grain yield/ plant and each of number of grains/spike and 1000-grain weight. On the other hand, negative correlation coefficient were found between

Table 4. Percentage of heterosis over mid-parent (M.P) for all studied characters

Crosses	DA	DM	PH	NT/P	NS/P	SL	NG/S	TGW	GY/P
$P_1 \times P_2$	-2.33**	-0.65	3.67*	-23.66*	-23.66*	4.19	-2.48	-8.01*	19.36**
$P_1 \times P_3$	0.93	1.62	7.20**	15.38	9.09	2.41	0.23	-1.83	47.00**
$P_1 \times P_4$	-2.86**	0.96	6.62**	-13.43	-13.43	6.41*	-3.45	-4.51	-9.78
$P_1 \times P_5$	4.43**	1.29	5.53**	-54.39**	-54.39**	12.57**	26.32**	-16.26**	14.13
$P_2 \times P_3$	0.44	-0.95	2.41	-0.99	-6.54	-0.57	4.51	10.50**	-0.87
$P_2 \times P_4$	-1.35	-0.31	7.30**	-9.92	-9.92	1.82	-9.27**	2.31	-19.69**
$P_2 \times P_5$	4.63**	-0.63	1.81	-4.50	-4.50	1.14	-2.49	1.87	-24.24**
$P_3 \times P_4$	-2.70**	0.00	12.95**	-26.92*	-30.91*	6.10*	-2.50	-6.49	3.58
$P_3 \times P_5$	5.12**	0.32	3.15*	35.71*	26.67	2.86	8.71**	-0.75	-10.25
$P_4 \times P_5$	3.32**	0.31	10.45**	12.28	12.28	6.67*	2.54	-1.42	-3.55
LSD 5%	1.82	-	3.21	4.08	4.44	0.78	3.68	3.36	7.11
LSD 1%	2.46	-	4.34	5.51	5.99	1.05	4.96	4.53	9.25

*, ** Significant differences at 0.05 and 0.01 probability levels, respectively
DA = Days to anthesis, DM= Days to maturity, PH = Plant height (cm), NS/P = No. of spikes/ plant, SL= Spike length (cm), NT/P= No. of tillers, NG/S= No. of grains/ spike, TGW= Thousand grain weight (gm) and GY/P= Grain yield / plant

Table 5. Estimates of general combining ability effects (ĝi) of parents for all studied characters

Parent	DA	DM	PH	NT/P	NS/P	SL	NG/S	TGW	GY/P
P1	-3.97**	-2.66**	-6.53**	0.44	0.32	-0.24	-4.17**	-1.74**	-5.54**
P2	2.74**	0.06	3.70**	1.01	0.90	0.14	3.11**	2.48**	1.50
P3	2.60**	0.34	0.18	-1.90	-1.44	0.14	2.69**	1.09	8.98**
P4	-0.54	1.34	3.18**	1.63	1.51*	-0.50**	1.40**	-3.42**	-3.59**
P5	-0.83**	0.91	-0.53	-1.18	-1.30	0.47**	-3.03**	1.59**	-1.35
L.S.D.(gi) 5%	0.61	1.81	1.08	1.38	1.50	0.26	1.24	1.13	2.25
L.S.D.(gi)1%	0.68	2.00	1.20	1.52	1.65	0.29	1.37	1.25	2.48
L.S.D. (ĝi-ĝj) 5%	0.97	2.86	1.71	2.17	2.37	0.41	1.96	1.79	3.56
L.S.D. (ĝi-ĝj) 1%	1.07	3.16	1.89	2.40	2.61	0.46	2.16	1.97	3.93

*, ** Significant differences at 0.05 and 0.01 probability levels, respectively
DA = Days to anthesis, DM= Days to maturity, PH = Plant height (cm), NS/P = No. of spikes/ plant, SL= Spike length (cm), NT/P= No. of tillers, NG/S= No. of grains/ spike, TGW= Thousand grain weight (gm) and GY/P= Grain yield / plant

Table 6. Estimates of specific combining ability effects (Ŝij) of crosses for all studied characters

Crosses	DA	DM	PH	NT/P	NS/P	SL	NG/S	TGW	GY/P
$P_1 \times P_2$	-2.238**	-1.000	1.206	-2.492	-2.397	0.238	-1.921**	-2.734	2.571**
$P_1 \times P_3$	0.905	1.714	3.063	3.746**	3.27**	-0.095	-2.159**	0.528	20.095**
$P_1 \times P_4$	-1.952**	0.714	0.730	-0.444**	-0.35**	0.214	-2.206**	0.221**	-21.667
$P_1 \times P_5$	2.333	1.143	2.11**	-8.302	-8.206	1.071	12.222	-5.179	12.429**
$P_2 \times P_3$	0.190	-1.000	-0.508	-0.159	-0.635	-0.143	4.222**	3.911	2.714
$P_2 \times P_4$	-0.667	0.000	3.159	-0.683	-0.587	0.000	-4.492*	0.654	-0.381*
$P_2 \times P_5$	2.619	-0.571	-0.460	0.127	0.222	-0.143	-3.397	1.071	-10.62**
$P_3 \times P_4$	-2.524**	-0.286	7.35**	-4.778**	-5.25**	0.500	-1.063**	-2.867	-5.524**
$P_3 \times P_5$	2.762	0.143	-0.603	4.365	3.889	0.024	2.365**	0.083	-2.429
$P_4 \times P_5$	1.905	0.143	5.397	3.175	3.270	0.333	0.651**	0.575	4.810
L.S.D.(Sij) 5%	1.587	-	2.797	3.551	3.864	0.678	3.201	2.920	5.810
L.S.D.(Sij)1%	1.752	-	3.087	3.921	4.266	0.748	3.534	3.223	6.414
L.S.D.(Sij-Sik) 5%	2.380	-	4.195	5.327	5.797	1.016	4.802	4.380	8.715
L.S.D.(Sij-Sik) 1%	2.627	-	4.631	5.881	6.399	1.122	5.301	4.835	9.621
L.S.D.(Sij-Slk) 5%	2.172	-	3.829	4.863	5.291	0.928	4.383	3.998	7.956
L.S.D.(Sij-Slk) 1%	2.398	-	4.228	5.369	5.842	1.024	4.839	-2.734	8.783

*, ** Significant differences at 0.05 and 0.01 probability levels, respectively

DA = Days to anthesis, DM= Days to maturity, PH = Plant height (cm), NS/P = No. of spikes/ plant, SL= Spike length (cm), NT/P= No. of tillers, NG/S= No. of grains/ spike, TGW= Thousand grain weight (gm) and GY/P= Grain yield / plant

Table 7. Values of simple phenotypic correlation coefficient estimated between different pairs of traits; (X_2), (X_2), (X_2)

Traits	(X_1)	(X_2)	(X_3)	(Gy/ p)
No. of spikes/ plant (X_1)	-	-0.179	0.126	-0.176
No. of grains/ spike (X_2)		-	-0.024	0.548
1000-grains weight (X_3)			-	0.217
Grain yield/ plant (Gy)				-

Table 8. Phenotypic path coefficient analysis and phenotypic components in percent of grain yield and its contributes characters and variation

Source of variation	Direct/ indirect effects	CD	R1%
No. of spikes/ plant (X_1)	0.012	0.012	1.215
No. of grains/ spike (X_2)	0.285	0.277	27.791
1000-grains weight (X_3)	0.059	0.057	5.789
(X_1) x (X_2)	0.021	0.020	2.082
(X_1) x (X_3)	-0.007	0.007	0.671
(X_2) x (X_3)	-0.006	0.006	0.602
Residual	0.635	0.618	61.849
Total	1.00	1.00	100

grain yield and number of spikes/ plant. These results are in agreement with those reported by Tammam *et al.*, (2000), EL-Nagar (2003) and EL-Wakil and Abd-Alla (2004).

The data reveal that the direct effect of number of grains/ spike was positive and high followed by 1000-gain weight and then by number of spikes/ plant (0.285, 0.059 and 0.012, respectively). The indirect effects of number of spikes/ plant via number of grains/ spike was relatively low, while it was negative and unimportant via 1000-grain weight. Also, The indirect effects of number of grains/ spike via 1000-grain weight was negative and unimportant.

The main sources of grain yield/ plant in order of importance were the direct effect of number of grains/ spike (27.791 %) and its joint effects with number of spikes/ plant as well as the direct effect of 1000-grain weight.

Hereby, the direct and simultaneous selection for these traits might be useful for improving wheat grain yield. The total contribution of the three traits was 38.151%, while the residual was 61.849% of the total phenotypic variation.

From the above mentioned results, it is noticed that number of grains/spike followed by 1000-grain weight proved to be the major grain yield contributors. Similar results were obtained by Ismail (2001) and EL-Wakil and Abd-Alla (2004).

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الملخص العربي

تقدير قوة الهجين والقدرة على التآلف فى هجن قمح الخبز

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يهدف البحث الى دراسة سلوك خمسة أباء من قمح الخبز والهجن الفردية الناتجة منها (١٠ هجن) لعدد من الصفات الهامة بالاضافة الى صفة محصول الحبوب للنبات، وتقدير قوة الهجين والقدرة على التألف ومعامل المرور والتى تعتبر اساساً لتحسين قمح الخبز.

أجرى التحليل الوراثى للصفات باستخدام الطريقة الثانية الموديل الاول لجريفنج (١٩٥٦) وقد نفذت التجربة فى مزرعة محطة بحوث ايتاى البارود خلال موسمين زراعيين همـا ٢٠٠٦/٢٠٠٧ و ٢٠٠٧/٢٠٠٨ بتصميم قطاعات كاملة العشوائية ذات ثلاث مكررات.

ويمكن تلخيص اهم النتائج المتحصل عليها فيما يلى:-

١. كان التباين الراجع للتراكيب الوراثية والأباء والهجن، وقوة الهجين عالى المعنوية لكل الصفات فيما عدا التباين الراجع للتراكيب الوراثية والهجن لصفة عدد الأيام حتى النضج.

٢. أظهر الأبوين P_1, P_5 وكذلك الهجن $(P_1 \times P_2), (P_1 \times P_3),$ $(P_1 \times P_4), (P_1 \times P_5)$ تبكيرا فى صفتى عدد الأيام حتى التزهير.

٣. سجل الأباء P_3, P_2 and P_4 وكذلك الهجن $(P_1 \times P_3),$ $(P_2 \times P_3)$،$(P_3 \times P_5)$ أعلى قيم لصفات عدد السنابل/ نبات ، عدد الحبوب للسنبلة، ووزن الألف حبة، ومحصول الحبوب للنبات.

٤. كانت النسبة بين التباين الراجع للقدرة العامة الى التباين الراجع للقدرة الخاصة على الائتلاف تفوق الوحدة لكل الصفات فيما عداعدد السنابل/ نبات، عدد الفروع/ نبات؛ مما يدل على ان جزءاً كبيراً من التباين الوراثى لهذه الصفات يرجع الى الفعل الجينى المضيف والمضيف× المضيف.

٥. أوضحت النتائج أن الأب P_1 كان ذو قدرة عامة عالية على الائتلاف لصفة التبكير والأب P_3 لصفة محصول الحبوب. أما الاباء P_2، P_5 فكانت أباء جيدة لصفة وزن الالف حبة.

٦. كان أفضل الهجن على مستوى القدرة الخاصة على التالف وقوة الهجين هى$(P_1 \times P_3)$, $(P_1 \times P_2)$ حيث أظهرت معنوية عالية للقدرة الخاصة على الائتلاف وقوة الهجين لصفة محصول الحبوب/ نبات، مما يجعلها هجنا واعدة فى برامج التربية لصفة المحصول.

٧. كان الارتباط المظهرى بين قيم محصول الحبوب/ نبات وبين كل من عدد الحبوب/ سنبلة ووزن الالف حبة موجبا بينما كان الارتباط المظهرى سالبا بين قيم محصول الحبوب/ نبات وعدد السنابل/ نبات.

٨. أوضحت نتائج معامل المرور أن كل من صفة عدد الحبوب/ سنبلة يليها صفة وزن الالف حبة كانت أكثر الصفات مساهمة فى تباين محصول الحبوب/ نبات من حيث تأثيرها المباشر، وهذه الصفات تعتبر هامة يجب ان يوليها المربى اهتمامه عند تحسين محصول الحبوب فى قمح الخبز.