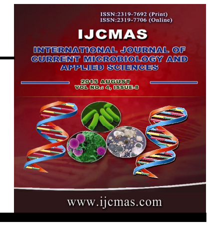

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Original Research Article

Heterosis and Combining Ability Analysis for yield and its Components in Bread Wheat (*Triticum aestivum L.*)

Samier. K. A. Ismail*

Agronomy Department, Faculty of Agriculture, Fayoum University, 63514-Fayoum, Egypt
**Corresponding author*

Keywords

Wheat, *Triticum aestivum* L., Heterosis, GCA and SCA

A B S T R A C T

A half diallel crosses was practiced among six diversed bread wheat (*Triticum aestivum* L.) cultivars. The F_1 of the fifteen crosses and the six parents were grown in a field experiment at Demo in 2013/2014 season to estimate heterosis and combining abilities. Data revealed that the mean square of genotypes, parents and crosses were significant for all studied characters. Positive and negative heterosis over the better parents was detected for all studied characters indicating that parental genotypes were genetically diversed. The analysis of variance for combining ability showed that mean square due to general (GCA) and specific (SCA) combining ability, were generally significant for all studied characters reflecting the importance of both additive and non- additive gene effects in the inheritance of these characters. Combining ability were higher than those of specific combining ability, consequently the GCA/SCA ratios were more than unity indicating the prevailing of additive gene effect which have considerable roles in the inheritance of these characters. In general, the cultivar Sids 4 was a good combiner for early heading and maturity, long spike and great number of kernels/spike. Giza 168 was good combiner for high grain yield/plant and Gemmiza 10 for heavy1000-kernel weight. Besides Sakha 94 was a good combiner for tall plant. These results seem to be useful for wheat breeding program in making the proper decision when initiating a crossing plan.

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important and strategic crops all over the world. In Egypt, wheat is the main cereal crop used as a stable food for urban and rural societies and the major source of straw for animal feeding. However, total wheat consumption has drastically increased due to over population growth by about 2.5% per year. Egypt imports about 45% of its wheat requirement. This reflects the size of the problem and the efforts needed to increase wheat production. Thus, increasing production per unit area appears to be one of the important factors for narrowing the gap between wheat production and consumption.

During breeding programs, it is necessary to select pure lines of high general combining ability (GCA) that indicates the additive gene effect. On the base of that predicting progenies and making choice of cross combination and genotypes can be carried out. Combining ability investigations carried out by breeders to select parents with efficient transferring desirable genes to the progenies (Madic *et al.*, 2005).

For starting a breeding program to improve any crop, the breeder need to knew the type of gene action and genetic system controlling the inheritance of the interest characters and the best breeding strategy to be used to improve them.

Combining ability analysis of Griffing (1956) is most widely used as biometrical tool for identifying parental lines in terms of their ability to combine in hybrid combination. With this method, the resulting total genetic variation is partitioned into the variance effects of general combining ability, as a measure of additive gene action and specific combining ability, as measure of additive gene action.

The main objectives of this study were to detect the magnitude of both general and specific combining ability (GCA and SCA) as well as heterosis for grain yield and some agronomic characters in 15 wheat crosses made among six bread wheat genotypes using one way diallel crosses.

Materials and Methods

The present study was carried out during the two successive seasons 2012/13 and 2013/14 at the experimental farm of Demo, Faculty of Agriculture, Fayoum University, Egypt. The aim of this work was to study the general (GCA) and specific (SCA) combining ability and heterosis through half diallel mating among six different wheat varieties.

These genotypes represent a wide range of variability. The commercial names, pedigree and origin these genotypes are presented in table 1. In 2012/ 2013 season, the six parental genotypes were planted and all possible combinations of crosses without reciprocals between each two of the six parents were done to produce 15 F_1 hybrids. In 2013/ 2014 season, seeds of the fifteen F_1 hybrid and the six parents were sown in randomized complete block design (RCBD) with three replications.

Each plot consisted of four rows for parents and $F_{1.}$ Each row was 3m long and 20 cm apart, and the seeds within row were spaced 10 cm apart. All recommended cultural practices were considered.

Data were recorded on 10 individual guarded plants chosen at random from each row. The studied characters were plant height (cm), number of days to heading (DH), number of days to maturity (DM), spike length (cm), number of kernels/spike, 1000-kernel weight (g) and grain yield/plant (g). Data analysis was done according to Steel and Torrie (1980)

General and specific combining ability estimates were obtained by employing Griffin's diallel cross analysis, model 1 (fixed model) method 2 (Griffing, 1956). Heterosis effect (Heterobeltiosis) was computed as the percentage increase of F_1 over the better parent according to Wynne *et al.* (1970).

Results and Discussion

Analysis of variance

The analysis of variance for plant height, days to heading, days to maturity, spike length, number of kernels/spike, 1000-weight kernel and grain yield/plant are presented in table 2. The results reflected significant differences among genotypes mean squares for all the above mentioned characters. Moreover, mean squares due to parents as well as differences among crosses were significant for studied characters. These data suggested that the parental cultivars were mostly different in their mean performance.

The analysis of combining ability revealed that variance associated with general and specific combining ability reached the level of significance for all studied characters (Table 2).

The significant variances due to both general and specific combining abilities reflect the importance of additive and non-additive types of gene actions. However, general combining ability effects which were extremely of high magnitude suggested the predominant role of additive gene action. This result supported by the over unity of GCA and SCA values, indicating that additively play a considerable role in the inheritance of these characters. Therefore, selection in the early generation could be successfully practiced to improve these characters.

These results were agreed with those reported by Bhutta *et al.* (1997), Abd El-Aty and Hamad (2006), Hayam S. Mohgoub (2007), Kumar *et al.* (2011) and Barot *et al.* (2014).

Genotypic performance

The means performance of the six wheat parental genotypes was presented in table 3. It is obvious that Sids 4 (P_6) ranked first as the shortest cultivar. It was also the earliest heading and maturity, and had longest spike and greatest number of kernels. Nevertheless, it was the poorest yielding cultivar due to its poorly habit tillering (unicalm). However, Sids 1 (P_1) and Gemmiza 10 (P_4) had the tallest plant, and latest heading as well as maturity, respectively. Giza 168 (P_2) ranked first as highest productive cultivar. On the other hand, Sakha 94 (P_3) and Sakha 93 (P_5) were intermediate for all studied characters.

The means performance of the tested fifteen crosses presented in table 3 indicates that for plant height, the tallest three crosses were P_2 x P_4, P_3 x P_4 and P_3x P_6. The five crosses P_1 x P_6, P_2 x P_6, P_3 x P_6, P_4 x $P_6$and P_5 x P_6 were the earliest in maturity. In addition, the three crosses P_1 x P_6, P_2 x P_6 and P_4 x P_6 possessed the highest spike length, while the three crosses P_1 x P_6, P_2 x P_6 and P_4 x P_6 gave the highest number of kernels/spike. These results revealed the positive contribution of the genes concerned with early maturity, tallest spike and highest number of kernels in P_6 (Sids 4) on its hybrids. In particular, P_2 x P_6 hybrid out yielded its parent, and all other tested hybrid. For heavy kernel weight, the best four crosses P_1 x P_3, P_1 x P_4, P_1 x $P_5$and P_4 x P_6. On the other side, the four crosses P_1 x P_2, P_1 x P_4, P_2 x P_4 and P_2x P_6 had in the highest grain yield/plant. These results were obtained by El-Beially and El-Sayed (2002), Abdel-Majeed *et al.* (2004), Abd El-Aty and El-Borhamy (2007) and Nagwa R. A. Salem (2007).

Heterosis

As shown in table 4, parents vs. crosses mean squares as an indication for average heterosis of overall crosses, were found to be highly significant for all studied characters except for plant height, days of maturity and spike length.

The values of heterosis for the six studied characters are in table 4. Results showed that these values were significantly different among hybrids for all studied characters. The negative values of days to maturity indicate that the hybrid is earlier than the earliest parent. However, four out of the 15 crosses were insignificantly earlier than their corresponding earliest parents. On the other hand, the hybrids P_1 x P_6, P_2 x P_6 and P_4 x P_6 were later than their corresponding latest parents.

With respect to plant height, three crosses P_1 x P_6, P_3 x P_4 and P_3 x P_6 exhibited significant positive heterotic effect reflecting over dominance toward tallness.

Regarding spike length, thirteen and two crosses exhibited significant positive and negative heterotic effects, respectively, comparing to the corresponding better parents. Data in table 4, also, show that ten crosses had number of kernels larger than the corresponding better parents and only one (p_1 x p_2) significantly lower than the better parents.

For kernel weight, nine crosses had positive and significant heterosis values, while two other hybrids (P_2 x P_5) and (P_2 x P_6) had negative heterotic values. Taking grain yield/plant into consideration, twelve crosses showed significant positive heterotic effects relative to their corresponding values of better parents. However, the highest heterosis values were that of the hybrids P_1 x P_6, P_2x P_6, P_4 x P_6 and P_5x P_6. Superiority of these hybrids may be again due to the good contribution of Sids 4 (P_6). This information should be considered in wheat national breeding program. However, Walton (1971) stated that a parent superior for one yield component showed be crossed with parent superior for the other components to obtain heterosis in a complex characters such as grain yield. These results are in harmony with these Abdel-Majeed *et al.* (2004), El-Sayed and Moshref (2005) Abd El-Nour (2005), Nagwa R. A. Salem (2007), Aida Rizkalla *et al.* (2012) and Jains and Sastry (2012).

General combining ability (GCA)

Estimates of general combining ability effects for each parent are presented in table 5. High positive values would be of great interest in all studied characters except plant height, days to heading and days to maturity which if had negative values become more useful from the breeder's point of view. Results indicated that the cultivar Giza 168 (P_2) proved to be a good combiner for grain yield/plant followed by P_4 (Gommiza 10) and P_1 (Sids 1), but the other three parent exhibited negative SCA for this character. Gammiza 10 (P_4) showed also positive GCA for heading, maturity and spike length. The results indicated that cultivar Sakha 94 (P_3) and Sakha 93 (P_5) showed significant negative combining ability for all studied characters except number of days of heading and maturity. Moreover, the cultivar Sakha 94 (P_3) showed general combining ability effects for plant height. The cultivar Sakha 93 (P_5) showed significant negative general combining ability effects for spike length, number of kernels/spike and 1000-kernel weight. Sids 4 (P_6) showed significant general combining ability effects for short plant early heading, early maturity, long spike, great number of kernels/spike and heavy1000-kernel weight. The crosses involving these good general combining ability genotypes should produce promising sergeants with higher mean performance of those character. Consequently, the results of the average performance of the respective characters are in agreement with those reported by Singh and Paroda (1986), El-Hennawy (1996), El-Shami *et al.* (1996), Tammam and Abdel-Gawad (1999), Tolba (2000), Hassan *et al.* (2007), Mohamed (2007), Cifi and Yagdi (2010), Kumar *et al.* (2011), Aida Rizkalla *et al.* (2012) and Ashraf *et al.* (2015).

Table.1 Names, pedigree and origin of the six bread wheat parents used in the study

No	Parents	Pedigree	Origin
P_1	Sids 1	HD 2172 /Pavon "S" //1158.57/ Maya 74 "S"- SD 46- 4SD- 1SD- 0SD	Egypt
P_2	Giza 168	MRL/BUC//Seri CM93046-8M-OY-OM-2Y-OB	Egypt
P_3	Sakha 94	Sakha 93/ Ri4220 CM15430- 2S-5S- 0S- 0S	Egypt
P_4	Gemmiza 10	Ald " S" / Huac// CMH47A.30/SX CGM4583-5GM-1GM-0GM	Egypt
P_5	Sakha 93	Sakha 92/TR 81032858871- 1S-2S-1S-0S	Egypt
P_6	Sids 4	Maya S/Mon S//CMH74A.592/3/Giza 157* 2	Egypt

Table.2 Mean squares from analysis of variance and general and specific combining ability analysis for all studied characters in bread wheat crosses

Source of variation	d.f	Plant height (cm)	Days to heading	Days to maturity	Spike length(cm)	Number.of kernels /spike	1000-kernel weight (g)	Grain yield /plant (g)
Replication	2	21.35	1.97	4.70	0.75	14.11	3.82	10.63
Genotypes	20	190.31*	352.25*	191.63*	37.11*	1225.71*	71.62*	568.42*
Parent (P)	5	238.48*	901.60*	429.12*	40.16*	2511.87*	55.25*	818.05*
Crosses (C)	14	185.71*	177.42*	120.29*	38.51*	849.90*	79.97*	475.67*
P x C	1	13.69	53.13*	2.94	2.19	56.27*	36.60*	618.78*
GCA	5	502.72*	1271.67*	706.47*	127.23*	4307.16*	143.96*	1386.88*
SCA	15	86.16*	45.78*	19.97*	7.06*	198.55*	47.50*	295.60*
Error	40	25.69	4.27	4.28	1.24	32.28	5.59	22.23
GCA/SCA		1.95	9.26	11.79	6.00	7.23	1.01	1.56

* Indicate significant at 0.05 level of probability.

Table.3 Mean performance of the six parents and their F1'sfor the studied characters

Genotypes	Plant height (cm)	Days to heading	Days to maturity	Spike length(cm)	Number of kernels/spike	1000-kernel weight (g)	Grain yield /plant (g)
P_1 Sids 1	110.00	109.20	159.00	14.80	67.20	49.00	54.11
P_2 Giza 168	105.40	101.80	156.80	14.20	72.60	46.40	66.13
P_3 Sakha 94	114.00	107.60	159.60	10.80	55.60	49.40	53.69
P_4 Gemmiza 10	106.60	113.80	162.80	15.80	76.00	50.60	57.92
P_5 Sakha 93	105.00	105.80	157.20	10.60	58.00	49.40	60.00
P_6Sids 4	93.60	76.20	137.00	17.80	79.00	56.40	60.00
P_1 x P_2	105.00	108.00	157.40	15.40	62.40	51.80	66.64
P_1 x P_3	109.00	105.80	158.80	13.60	65.00	55.20	61.96
P_1 x P_4	102.00	110.80	165.40	15.20	68.80	58.60	67.64
P_1 x P_5	109.00	103.60	156.40	13.40	70.80	55.00	61.12
P_1 x P_6	100.00	101.00	149.80	19.20	97.80	52.60	53.16
P_2 x P_3	107.00	103.40	155.00	13.80	74.40	47.00	55.50
P_2 x P_4	110.00	108.00	160.40	14.80	72.00	50.60	66.12
P_2 x P_5	104.00	103.40	154.00	10.00	64.80	44.60	56.21
P_2 x P_6	94.00	91.00	151.40	18.40	92.40	51.60	70.83
P_3 x P_4	113.00	111.00	160.40	13.60	66.20	49.00	59.80
P_3 x P_5	107.00	107.60	157.60	10.40	54.20	48.60	51.46
P_3 x P_6	116.00	97.80	151.20	14.00	76.20	47.60	35.50
P_4 x P_5	104.00	110.00	160.20	10.60	59.60	51.20	51.24
P_4 x P_6	97.00	104.20	149.60	18.20	96.20	58.40	62.32
P_5 x P_6	98.00	94.00	148.80	14.20	71.60	51.80	41.53
L.S.D at 0.05	6.28	2.56	2.57	1.38	7.04	2.93	5.84

Table.4 Percentage of Heterosis in the hybrids over better parents (heterobeltiosis)

Genotype	Plant height (cm)	Days to heading	Days tomaturity	Spike length (cm)	Number of kernels/spike	1000-kernel weight (g)	Grain yield /plant (g)
	B. P	B. P	B. P	B. P	B. P	B. P	B. P
P_1 x P_2	-0.38	6.09*	0.38	8.45*	-7.14*	11.64*	23.17*
P_1 x P_3	-0.91	-1.67	-0.13	25.93*	16.91*	12.65*	15.41*
P_1 x P_4	-4.32	1.47	4.03*	2.70*	2.38	19.59*	24.68*
P_1 x P_5	3.81	-2.08	-0.51	26.42*	22.07*	12.25*	16.71*
P_1 x P_6	6.84*	32.55*	9.34*	29.73*	45.24*	7.35*	89.86*
P_2 x P_3	1.52	1.57	-1.15	27.78*	33.81*	1.29	3.37
P_2 x P_4	4.36	6.09*	2.30	4.23*	-0.83	9.05*	14.15*
P_2 x P_5	-0.95	1.57	-1.79	-5.66*	11.72*	-3.88*	7.33*
P_2 x P_6	0.42	19.42*	10.51*	29.58*	27.28*	11.21*	152.96*
P_3 x P_4	6.00*	3.16*	0.50	25.93*	19.06*	-0.81	11.30*
P_3 x P_5	1.90	1.70	0.25	-1.89*	-2.52	-1.62	-1.73
P_3 x P_6	23.93*	28.35*	10.37*	29.63*	37.05*	-3.64*	26.78*
P_4 x P_5	-0.95	3.97*	1.91	1.78*	2.76	2.81	-1.59
P_4 x P_6	3.63	36.75*	9.20*	15.19*	26.58*	15.42*	122.54*
P_5 x P_6	4.70	23.36*	8.61*	33.96*	23.45*	4.02*	48.31*
L.S.D 5%	6.28	2.56	2.57	1.38	7.04	2.93	5.84

* Indicate significant at 0.05 level of probability.

Table.5 Estimates of general combining ability effects (g i) for the studied characters

parents	Plant height (cm)	Days to heading	Days tomaturity	Spike length (cm)	Number of kernels /spike	1000-kernel weight (g)	Grain yield /plant (g)
P_1 Sids 1	1.05	2.87*	2.03*	0.85*	-1.74*	1.60*	3.43*
P_2 Giza 168	-0.73	-0.91*	0.28	0.15	-0.22	-2.50*	7.06*
P_3 Sakha 94	5.48*	2.02*	1.58*	-1.85*	-8.22*	-1.53*	-2.44*
P_4Gemmiza 10	0.33	5.87*	4.00*	0.55*	0.23	-1.33*	3.99*
P_5 Sakha 93	-0.58	0.69*	0.23	-2.48*	-9.49*	-0.95*	-3.07*
P_6Sids 4	-5.55*	-10.53*	-8.10*	2.50*	19.43*	2.05*	-8.97*
L.S.D.$_{g\,i}$0.05	1.43	0.58	0.59	0.32	1.61	0.67	1.33
L.S. D$_{gi-gi}$ 0.05	2.22	0.91	0.91	0.49	2.49	1.04	2.07

* Indicate significant at 0.05 level of probability.

Table.6 Estimates of specific combining ability effects (Si j) for 15 F1 crosses

Parents	Plant height (cm)	Days to heading	Days to maturity	Spike length (cm)	Number of kernels/spike	1000-kernel weight (g)	Grain yield /plant (g)
$P_1 \times p_2$	-0.55	2.52*	-0.56	0.17	-8.92*	1.50	0.28
$P_1 \times p_3$	-2.75	-2.61*	-0.46	0.09	1.68	3.93*	5.10*
$P_1 \times p_4$	-4.60*	-1.46	3.72*	-0.43	-2.97	4.48*	4.16*
$P_1 \times p_5$	3.30	-3.48*	-1.51	0.80	8.76*	3.15*	4.88*
$P_1 \times p_6$	-0.73	5.14*	0.22	1.62*	6.63*	-2.25*	2.83
$P_2 \times p_3$	-2.98	-1.23	-2.51*	0.99*	9.56*	-0.18	-4.99*
$P_2 \times p_4$	5.17*	-0.48	0.47	-0.13	-1.29	0.58	-0.80
$P_2 \times p_5$	0.07	0.09	-2.16*	-1.90*	1.23	-3.15*	-3.66*
$P_2 \times p_6$	-4.95	-1.08	3.57*	1.52*	-0.09	0.85	19.88*
$P_3 \times p_4$	1.98	-0.41	-0.83	0.40	0.91	-2.00*	2.37
$P_3 \times p_5$	-3.13	1.37	0.14	0.22	-1.37	-0.13	1.09
$P_3 \times p_6$	10.85*	2.79*	2.07*	-1.15*	-8.30*	-4.13*	-8.96*
$P_4 \times p_5$	-0.98	-0.08	0.32	-1.70*	-4.42*	-0.38	-5.27*
$P_4 \times p_6$	-3.00	5.34*	-196*	0.92*	3.26	3.83*	11.42*
$P_5 \times p_6$	-1.10	0.32	1.02	-0.05	-11.62*	-0.50	-2.31
L.S.D $(Sij)_{0.05}$	3.94	1.61	1.61	0.87	4.41	1.84	3.66
L.S.D $(Sij\text{-}Sik)_{0.05}$ Ski)0.05jjfffffffssikS	5.88	2.40	2.39	1.29	6.59	2.74	5.47
L.S.D $(Sij\text{-}Ski)_{0.05}$	5.44	2.22	2.22	1.20	6.10	2.54	5.06

* Indicate significant at 0.05 level of probability.

Specific combining ability effects:

Specific combining ability effects for each cross are presented in table 6. Specific combining ability effects can be defined as the magnitude of deviation exhibited by the parental line in the cross from its expected performance on the basis of its general combining ability (GCA) effects. A significant deviation from zero in cross would indicate specially high or low specific combining ability (SCA) according to the sign wither positive or negative. The crosses P_2 x P_3, P_2 x P_5 and P_4 x P_6 showed significant specific combining ability effects for early maturity. Also, two, four, three, four and six crosses showed significant positive specific combining ability effects for plant height, spike length, number of kernels/spike, 1000-kernel weight and grain yield/plant, respectively. The crosses P_1 x P_3, P_1 x P_4, P_1 x P_5, P_2 x P_6, and P_4 x P_6 are considered promising for grain yield improvement as they showed high specific combining ability effects. These crosses could account for the highest average performance of the respective characters. In such hybrids, desirable transgressive segregates would be expected in the subsequent genotypes. Similar results were obtained by Abd El-Majeed *et al.* (2004), El-Sayed and Moshref (2005), Hassan *et al.* (2007), Akinci (2009), Kumar *et al.* (2011), Aida Rizkalla *et al.* (2012) and Ashraf *et al.* (2015).

In conclusion, cultivar Sids 4 was a good combiner for early maturity, number of kernel/spike and 1000-kernel weight, Giza 168 for grain yield/plant. Gemmiza 10 for number of kernel/spike and 1000-kernel weight, while Sakha 94 was a good combiner for plant height. This result may useful to wheat breeders in making the proper decision for future crossing plants.

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