Egypt. J. Plant Breed. 14 (3): 7 – 22 (2010)

HETEROSIS AND COMBINING ABILITY FOR YIELD AND ITS COMPONENTS IN DIALLEL CROSSES AMONG SEVEN BREAD WHEAT GENOTYPES

F. F. Saad[1], S. R. E. Abo-Hegazy[1],
E. A. M. EL-Sayed[2] and H. S. Suleiman

1- Agronomy Department, Faculty of Agriculture, Cairo University, Giza, Egypt.
2- Wheat Dept., Field Crops Res. Inst., ARC, Giza, Egypt.

ABSTRACT

The present investigation was carried out during the two successive seasons 2008-2010. A diallel cross excluding reciprocals among seven bread wheat genotypes (Sids 12 (P_1), Giza 168(P_2), Sakha 93(P_3), Gemmeiza 9 (P_4), Line 109(P_5), Line 147 (P_6) and Line 172 (P_7)) was used to estimate the heterotic effects of F_1 crosses relative to their respective mid and better parents and combining ability analysis for heading and yield and its components. Highly significant differences among the tested entries were detected for different traits, indicating wide genetic variability among studied genotypes for all traits (days to heading, number of spikes per plant, number of kernels per spike, kernels weight per spike (g), 100-kernel weight (g) and grain yield per plant (g)). Results showed that mean square due to both general and specific combining ability were highly significant for all characters studied, indicating the importance of both additive and non-additive genes effects in the inheritance of these characters. The ratio of GCA/SCA being more than unity indicated that the additive gene effects were more important for all traits, except number of kernels per spike. Line 147 was the best general combiner for both number of spikes per plant and grain yield per plant, while best general combiners for number of kernels per spike, kernels weight per spike and 100 –kernel weight were Line 172, Sids12 and Line109, respectively. Sids12 (-2.58), Giza 168 (-0.97) and Sakha 93 (-0.86) had the lowest significant GCA effects for days to heading. These parents were the best general combiners for the days to heading. Maximum positive SCA effects were exhibited by crosses $P_2 \times P_4$ (4.45), $P_1 \times P_3$ (8.41), $P_4 \times P_5$ (0.44) and $P_3 \times P_4$ (0.41) for number of spikes per plant, number of kernels per spike, kernels weight per spike and 100 –kernel weight, respectively. The best specific combiners for grain yield per plant were $P_1 \times P_3$ (8.39), $P_5 \times P_6$ (7.72) and $P_2 \times P_4$ (7.23). The best heterosis (relative to the mid parent) was recorded by $P_5 \times P_6$ (-7.46), $P_2 \times P_4$ (52.21), $P_2 \times P_3$ (23.86), $P_4 \times P_5$ (27.56), $P_4 \times P_6$ (19.79), $P_3 \times P_6$ (51.50), for days to heading, number of spikes per plant, number of kernels per spike, kernels weight per spike, 100 –kernel weight and grain yield per plant, respectively. While the best heterobeltiosis was recorded by $P_5 \times P_6$ (-7.20), $P_2 \times P_4$ (50.88), $P_2 \times P_3$ (20.94), $P_4 \times P_5$ (23.35), $P_3 \times P_4$(16.58), $P_3 \times P_6$ (37.83), for days to heading, number of spikes per plant, number of kernels per spike, kernels weight per spike, 100 –kernel weight and grain yield per plant, respectively.

Key words: ***Triticum aestivum*, Combining ability, GCA, SCA, Heterosis**.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important and strategic cereal crops in the world and is a staple food for over 35% of the world's population in more than 40 countries. In Egypt, wheat is the main winter cereal crop used as a staple food for urban and rural societies and the major source of straw for animal feeding. However, total wheat consumption has increased drastically due to over population growth by about 2.5% per year. Egypt imports about 45% of its wheat requirements. 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.

Combining ability analysis is the best technique for the proper choice of the parents for improving specific traits as well as the breeding value of the genetic variability which can be successfully used in future hybridization programs (Chaudhry *et al* 1994). Significant levels of heterosis have been reported in a number of self-pollinated crops, and were first observed in wheat by Freeman (1919). In wheat there are several reports on combining ability and heterosis (%) using F_1 generation. Briggle (1963) and Sajnani (1968) suggested the possibility of heterotic effects in wheat. Khan and Khan (1996) reported that maximum heterosis was obtained for tillers per plant (31.91%) followed by grain yield per plant (19.41%), 1000-grain weight (17.32%), number of grains per spike (11.37%). Chowdhry *et al* (2001) observed heterosis for tillers per plant, 1000-grain weight and grain yield per plant.

Akhter *et al* (2003) studied heterosis for grain yield per plant. Hussain *et al* (2006) found significantly positive heterosis (1.43-52.01%) in four crosses and positively significant heterobeltiosis (5.0-48.19%) in three crosses out of 15 crosses for grain yield per plant. They also reported a range of heterosis from 2.33 to 21.22% and heterobeltiosis from 1.53 to 5.71% for tillers per plant, 1.62 to 20.90% heterosis and 4.65 to 15.33 % heterobeltiosis for 1000-grain weight, 1.61 to 13.12% heterosis and 1.48 to 6.86% heterobeltiosis for grains per spike. Dawwam *et al* (2007) studied heterosis for traits: days to heading, grain yield and its components, i.e. no. of grains per spike and 1000-grain weight.

High positive values of heterosis were reported in most of characters studied. However, days to heading gave high negative heterosis percentages, which is a desired approach in breeding for earliness. Salem and Abdel Dayem (2006) found significant positive heterosis for all the characters studied, ranging from (7.59 to 64.09%) for No. of spikes per plant, (6.19 to 25.23%) for No. of kernels per spike, (15.41 to 55.41%) for 100-kernel weight and (27.64 to 37.95%) for grain yield per plant. Mahmood and Chowdhry (2002) observed that additive genetic control was found for tillers per plant, 1000-grain weight and grain yield per plant, while Kashif and Khaliq (2003) observed non-additive genetic effects with higher magnitude of SCA variance for 1000-grain weight and grain yield per plant. Ahmed and Mohamed (2009) established a half diallel set of crosses among seven wheat genotypes in order to study the genetic analysis for some traits i.e., days to heading, No. of spikes per plant, No. of kernels per spike, 1000-kernel weight and grain yield per plant. Mean squares associated with GCA and SCA were highly significant for all the studied traits. The results indicated that both additive and non additive gene effects were involved in the inheritance of all the studied traits.

Therefore, the major objectives of this work were:

1- Evaluating performance of seven parents of bread wheat and their F_1 crosses to identify the best performing genotypes.
2- Estimating heterosis, general and specific combining ability to identify the best combiner parents and for grain yield and its components.

MATERIALS AND METHODS

Four commercial cultivars and three introduced lines of bread wheat were selected for this study. Names, pedigree and origin of these genotypes are presented in Table (1).The experimental field work was carried out at Giza Agricultural Research Station, Agricultural Research Center (ARC) during the two successive seasons 2008/2009 and 2009/2010. The seven parents were crossed in all possible combinations, excluding reciprocals in 2008/2009 growing season. The seven parents and their resulting 21 F_1's were grown in a randomized complete block design with four replications in 2009/2010 growing season. Plots of parents and F_1's consisted of two rows, 1.5 m long, with spacing of 30 cm between rows and 10 cm between plants. Ten guarded plants from parents and the F_1's were selected randomly from each plot for recording observations on six different characters, namely, days to heading (50%), number of spikes per plant, number of kernels per spike, kernels weight per spike (g), 100-kernel weight (g) and grain yield per plant (g). Analysis of variance was conducted as outlined by Steel and Torrie (1980) for all the characters. The analysis of GCA and SCA was done following the procedure given by Griffing (1956) using Method II Model I. Percentages of heterosis relative to mid (MP) and better (BP) parents were calculated according to Fonsecca and Patterson (1968) as follows:

MP= (value of F_1- mean of the two parents/mean of the two parents) × 100.
BP= (value of F_1- value of the best parent/value of the best parent) ×100.

Analysis of variance was done using the computerized statistical program MSTAT-C.

Table 1. Names, pedigree and origin of the parental genotypes

No	Genotype	Pedigree	Origin
P_1	**Sids 12**	BUC//7C/ALD/5/MAYA74/ON//1160. 147/3/BB/GLL/4/CHAT"S"/6/MAYA/ VUL//CMH74A.630/4*SX. SD7096-4SD-1SD-0SD.	Egypt
P_2	**Giza 168**	MRL/BUC//SERI CM93046-2M-0Y-0M-2Y-0p-0GZ.	Egypt
P_3	**Sakha93**	Sakha 92 / TR 810326 S 8871-1S-2S-1S 0S.	Egypt
P_4	**Gemmeiza 9**	ALD'S'/HUAC//CMH74A.630/SX CGM4583-5GM-1GM-OGm.	Egypt
P_5	**Line 109**	SW8488*/KURUKU	CIMMYT
P_6	**Line 147**	SKAUZ/BAV92	CIMMYT
P_7	**Line 172**	THB/KEA/PF85487/3/RIVADENEIRA	CIMMYT

RESULTS AND DISCUSSION

Analysis of variance

Mean squares of the analysis of variance for the studied traits of 21 wheat genotypes (7 parents and 21 F_1 hybrids) are listed in Table (2). Results illustrated that differences among genotypes as well as parents and crosses are highly significant except number of spikes per plant in parents. These results revealed the presence of sufficient genetic variability among genotypes regarding the studied traits. Besides, also mean squares due to parents vs. crosses were highly significant for all studied traits suggesting the presence of significant heterosis for studied traits.

Performance of wheat genotypes

Means of different studied traits of the seven wheat parental genotypes and their 21 diallel F_1's are presented in Table (3). The days to heading for the parents ranged from 83.5 for Sids 12 to 93.75 days for Line 172 with an average of 88.21 days. While, the F_1 crosses ranged from 82.25 for cross $P_1 \times P_2$ and $P_1 \times P_3$ to 90.00 days for cross $P_4 \times P_7$ with an average of 84.88 days.

For grain yield per plant and its components, the average of the F_1 was more than average of the parents indicating positive heterotic effect. The parent (Line 172) recorded the highest number of spikes per plant. Mean, the parent (Sids 12) recorded the highest values for number of kernels per spike, kernels weight per spike, 100 –kernel weight and grain yield per plant.

The highest values for number of spikes per plant, number of kernels per spike, kernels weight per spike, 100-kernel weight and grain yield per plant recorded by crosses ($P_2 \times P_4$, $P_1 \times P_3$, $P_4 \times P_5$, $P_4 \times P_5$, $P_1 \times P_5$ and $P_1 \times P_3$), respectively. Comparing the performance of crosses to corresponding highest parents, nine ($P_2 \times P_4$, $P_6 \times P_7$, $P_2 \times P_7$, $P_5 \times P_6$, $P_2 \times P_6$, $P_3 \times P_6$, $P_4 \times P_6$, $P_4 \times P_5$, and $P_4 \times P_7$) one ($P_1 \times P_3$) three ($P_1 \times P_5$, $P_4 \times P_5$ and $P_3 \times P_5$) and seven crosses ($P_1 \times P_3$, $P_2 \times P_4$, $P_3 \times P_6$, $P_5 \times P_6$, $P_4 \times P_6$, $P_2 \times P_6$, and $P_1 \times P_2$) significantly exceeded the highest parental genotypes for number of spikes per plant, number of kernels per spike, 100-kernel weight and grain yield per plant, in same order. One cross ($P_1 \times P_6$) had the earliest plants compared to parents for heading. However, none of the crosses exceeded their highest parents for kernel weight per spike. It could be concluded that the above mentioned parents and crosses would prospect in bread wheat breeding and therefore may be valuable for improving seed yield via its component characters.

Combining ability

Mean squares of both general (GCA) and specific (SCA) combining ability estimates were highly significant for all the studied traits (Table 4). Thus, both additive and non-additive gene effects were important in controlling the inheritance of all the characters studied. The ratio of GCA/SCA being more than unity indicated that the additive gene effects were more important for all of the traits, except number of kernels per spike (0.40). Thus, the non-additive gene effect had a greater influence in the inheritance of this trait. In general, for all studied traits, the magnitude of mean squares due to GCA was much higher than that due to SCA except for number of kernels per spike. The higher importance of GCA than SCA variance for studied traits was also reported by (Larik *et al* 1995, Chowdhry *et al* 1999, Sangwan *et al* 1999, Menshawy 2000, Joshi *et al* 2003, Koumber and EL-Beially, 2005, Abdel Nour, 2006, Salem and Abdel Dayem, 2006).

Table 4. Mean squares for general and specific combining ability effects for studied characters in (2009/2010 season).

		Mean squares					
SV	**df**	**Days To heading**	**Number of spikes /plant**	**Number of kernels /spike**	**Kernels weight /spike**	**100-Kernel weight (g)**	**Grain yield/plant (g)**
GCA	**6**	108.58**	40.11**	53.21**	0.63**	2.46**	130.09**
SCA	**21**	18.35**	24.03**	131.95**	0.26**	0.45**	109.70**
Error	**81**	1.07	1.43	3.76	0.08	0.06	5.14
GCA/SCA		5.92	1.67	0.40	2.42	5.47	1.19

*** and ** significant at 0.05 and 0.01 probability levels, respectively.**

General Combing Ability (GCA) effects

The (GCA) effects are presented in Table (5). Data showed that Sids 12 (-2.58), Giza 168 (-0.97) and Sakha 93 (-0.86) had the lowest significant GCA effects for days to heading. These parents could be considered the best general combiners for the improvement of earliness in the breeding programs. For yield attributes, the largest positive GCA effect was exhibited by Line 147 for number of spikes per plant (1.13) and grain yield per plant (2.59), Line 172 (1.98) for number of kernels per spike, Sids12 (0.18) for kernels weight per spike and Line 109 (0.42) for 100 –kernel weight. Line 147 was the best general combiner for number of spikes per plant and grain yield per plant, while best general combiners for number of kernels per spike, kernels weight per spike and 100 –kernel weight were Line 172, Sids12 and Line 109, respectively. For grain yield per plant, the best general combiners were Line 147 (2.59) followed by Sids12 (1.85) and Gemmeiza 9 (0.74).

Specific combining ability (SCA) effects

Specific combining ability (SCA) effects of the F_1 crosses for the studied traits are presented in Table (6). The results showed that best SCA effects for days to heading was obtained from the crosses $P_1 \times P_7$ (-3.39), $P_5 \times P_6$ (-2.72) and $P_4 \times P_6$ (-2.33). Maximum positive SCA effects were exhibited by crosses $P_2 \times P_4$ (4.45), $P_1 \times P_3$ (8.41), $P_4 \times P_5$ (0.44) and $P_3 \times P_4$ (0.41) for number of spikes per plant, number of kernels per spike, kernels weight per spike and 100 –kernel weight, respectively. The best specific combiners for grain yield per plant were $P_1 \times P_3$ (8.39), $P_5 \times P_6$ (7.72) and $P_2 \times P_4$ (7.23).

Heterotic effects

Percentages of heterosis relative to mid (MP) and better (BP) parents in studied wheat crosses are presented in Table(7). Values of heterosis percentage relative to (MP) were significantly positive in twenty, fourteen, fifteen, eighteen, eleven crosses with range of 2.70-52.21, 5.45-23.86, 3.98-27.56, 0.81-19.79 and 11.08-51.50% for number of spikes per plant, number of kernels per spike, kernels weight per spike, 100 –kernel weight and grain yield per plant, respectively (Table 7). However, heterosis percentage relative to (BP) were significantly positive in twenty, nine, eight, sixteen, ten crosses with range of 1.79-50.88, 3.00-20.94, 7.05-23.35, 0.59-16.58 and 9.20-37.83% for number of spikes per plant, number of kernels per spike, kernels weight per spike, 100 –kernel weight and grain yield per plant, respectively. With respect to days to heading, nineteen and eleven crosses exhibited significantly negative heterosis compared to the respective mid and better parents, respectively and recorded a range of -1.44 to -7.46, -1.50 to -7.20 for mid and better parents, respectively.

Averages of heterosis percentages across all F_1 hybrids were preceded with a desirable sign, *i.e.* exhibiting on average a desirable heterosis relative to mid parent for all studied traits. Average heterosis relative to mid parent was highest for number of spikes per plant (20.93%). On the other hand, the lowest average of heterosis estimates was shown by number of kernels per spike (7.17%). For days to heading, the average heterosis was (-3.77%).

The best heterosis (relative to the mid parent) was recorded by $P_5 \times P_6$ (-7.46), $P_2 \times P_4$ (52.21), $P_2 \times P_3$ (23.86), $P_4 \times P_5$ (27.56), $P_4 \times P_6$ (19.79) and $P_3 \times P_6$ (51.50) for days to heading, number of spikes per plant, number of kernels per spike, kernels weight per spike, 100-kernel weight and grain yield per plant, respectively.

Averages of all heterotic effects relative to better parent across all studied hybrids were preceded with a desirable sign, *i.e.* showing in average a desirable heterobeltiosis for all traits. Average heterobeltiosis was highest for number of spikes per plant (17.60%). On the other hand, the lowest average of heterobeltiosis estimates was shown by grain yield per plant (0.01%). For days to heading, the average heterosis was (-1.30%).The best heterobeltiosis (relative to the better parent) was recorded by $P_5 \times P_6$ (-7.20), $P_2 \times P_4$ (50.88), $P_2 \times P_3$ (20.94), $P_4 \times P_5$ (23.35), $P_3 \times P_4$ (16.58) and $P_3 \times P_6$ (37.83), for days to heading, number of spikes per plant, number of kernels per spike, kernels weight per spike, 100-kernel weight and grain yield per plant, respectively.

Pronounced and favorable heterosis has been obtained by several researchers for wheat traits (Sadeque *et al* 1991, Krishna and Ahmad, 1992, Khan *et al* 1995, Munir *et al* 1999, Rasul *et al* 2002, Motawea, 2006, Dawwam *et al* 2007).

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قوة الهجين والقدرة على الائتلاف للمحصول ومكوناته في الهجن الدائرية لسبعة تراكيب وراثية من قمح الخبز

فوزي فتحي سعد[١]، سمير ربيع السيد أبو حجازى[١]،
عزالدين عبد الرحمن محمد السيد[٢]، حسن صالح سليمان

١– قسم المحاصيل – كلية الزراعة – جامعة القاهرة – الجيزة – مصر
٢– قسم بحوث القمح – معهد بحوث المحاصيل – مركز البحوث الزراعية – الجيزة – مصر

أجريت الدراسة في محطة بحوث الجيزة (مركز البحوث الزراعية) خلال الموسمين الزراعيين ٢٠٠٨/٢٠٠٩ و٢٠٠٩/٢٠١٠. تم في الموسم الأول التهجين بين سبع تراكيب وراثية من القمح الخبز (أربعة أصناف تجارية مصرية هي: سدس ١٢(P_1) ، جيزا ١٦٨(P_2) ، سخا ٩٣ (P_3)، جميزة ٩ (P_4) وثلاث سلالات مستوردة هي: سلالة ١٠٩ (P_5)، سلالة ١٤٧ (P_6)، سلالة ١٧٢(P_7)) بطريقة التهجين الدائرى في اتجاه واحد. وفي الموسم الثاني زرعت هجن (F_1) والبالغة ٢١ هجيناً مع آبائها فى تصميم القطاعات الكاملة العشوائية في أربع مكررات لدراسة القدرة العامة والخاصة على التآلف، وقوة الهجين على مستوى متوسط الأبوين والأب الأفضل لصفات عدد الأيام من زراعة حتى طرد السنابل، عدد السنابل/النبات، عدد الحبوب/السنبلة، وزن الحبوب/السنبلة، وزن الـ

١٠٠ حبة ومحصول الحبوب/النبات. كما تم تقدير القدرة العامة والخاصة على الائتلاف بطريقة Griffing (1956) الطريقة الثانية- النموذج الاول.

وتتلخص اهم نتائج دراسة فيما يلي:

١- كانت متوسطات المربعات الراجعة للتراكيب الوراثية الابوية عالية المعنوية لجميع الصفات المدروسة، مما يدل على وجود اختلافات وراثية بين هذه التراكيب. وكذلك أظهرت النتائج اختلافات عالية المعنوية لقوة الهجين لجميع الصفات تحت الدراسة.

٢- أظهرت النتائج اختلافات عالية المعنوية لكل من القدرة العامة والخاصة على الائتلاف بالنسبة لجميع الصفات المدروسة. وكانت متوسطات مربعات القدرة العامة على الائتلاف أكبر من متوسطات مربعات القدرة الخاصة على الائتلاف لكل الصفات ماعدا عدد الحبوب/السنبلة مما يدل على أن تأثيرات الجين المضيف كانت أكثر أهمية عن تأثيرات الجين غير المضيف في توريث هذه الصفات.

٣- كانت السلالة ١٤٧ هي أحسن الآباء في القدرة العامة على الائتلاف بالنسبة لصفة عدد السنابل/النبات ومحصول الحبوب/النبات، بينما كانت السلالة ١٧٢ والصنف سدس ١٢ والسلالة ١٠٩ والصنف سدس١٢ هي أفضل الآباء بالنسبة لصفة عدد الحبوب/السنبلة، وزن الحبوب/السنبلة، وزن الـ ١٠٠ حبة وعدد الأيام من الزراعة حتى طرد السنابل على التوالي.

٤- أظهرت الهجن $P_2 \times P_4$ و $P_1 \times P_3$ و $P_4 \times P_5$ و $P_3 \times P_4$ و $P_1 \times P_3$ أعلى قيم موجبة للقدرة الخاصة على الائتلاف بالنسبة لعدد السنابل/النبات، عدد الحبوب/السنبلة، وزن الحبوب/السنبلة، وزن الـ ١٠٠حبة ومحصول الحبوب/النبات على التوالي.

٥- سُجلت أفضل قيم لقوة الهجين بالنسبة للأب الاحسن بواسطة الهجن التالية:(-7.20) $P_5 \times P_6$ و $P_2 \times P_4$ (50.88) و $P_2 \times P_3$ (20.94) و $P_4 \times P_5$ (23.35) و $P_3 \times P_4$ (16.58) و $P_3 \times P_6$ (37.83) لصفة عدد الأيام من الزراعة حتى طرد السنابل وعدد السنابل/النبات و عدد الحبوب/السنبلة، وزن الحبوب/السنبلة، وزن الـ ١٠٠ حبة ومحصول الحبوب/النبات على التوالي.