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COMBINING ABILITY AND HETEROSIS FOR SOME AGRONOMIC TRAITS IN CROSSES OF MAIZE.

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ABSTRACT

In 2007, five maize inbred lines were crossed in all possible combinations without reciprocals by using a half diallel crosses mating design to obtain 10 single cross. Inbred parents and their F_1 single crosses were evaluated through 2008 season to evaluate the role of general and specific combining ability and heterosis for some agronomic traits.

Results indicated that mean squares of genotypes were highly significant for all studied traits i.e. ear diameter, ear length, number of kernels/row, 100-kernel weight, ear yield per plant, grain yield per plant and shelling percentage. General combining ability (GCA) and specific combining ability (SCA) mean squares were highly significant for all studied traits. The GCA/SCA ratio was less than unity for all studied traits; this means that these traits are predominantly controlled by non-additive gene action.

Significant positive GCA effects were found for all studied traits. Based on GCA estimates, it could be concluded that the best combiners were Rg5 and Rg8 inbred lines for most of studied traits. This result indicated that these inbred lines could be considered as good combiners for improving these traits.

Significant positive SCA effects were found for all studied traits. Based on SCA effects, it could be concluded that the best crosses for ear diameter and 100-kernels weigh was G507A X G516; for ear length was G516 X Rg8; for kernels number/row was G516 X G278; for ear yield/plant, grain yield/plant and Shelling percentage was G278 X Rg5. These crosses could be selected and used in breeding programs for improving these traits.

Results showed positive significant heterosis values for all studied traits. The best crosses over both their mid-parents and better-parents for ear diameter and 100-kernel weigh was G507A x G516; for ear length and kernels number/row was G516 x G278; for ear yield/plant and grain yield/plant was G278 x Rg8; and for Shelling percentage was G278 x Rg5.

INTRODUCTION

Maize is one of the most important cereal crops. For many years, it is used as food for human and different animals. Therefore, corn breeders give great and continuos efforts to improve and increase the yielding ability of this crop. In the year 1763, Koelreituer and Sprangel (Allard,1960) were the first research workers who observed that hybrids were often possessed the most striking and unusual vigor. Since that time, many research workers generally, and corn breeders specially started a new area of plant breeding to benefit from this phenomena, which is now known as heterosis. Hybridization in corn started as early as the year 1908 by the work of East

(1908) and Shull (1909) who clearly indicated that hybridization is the opposite of inbreeding. Mosa (1996) evaluated 10 inbred lines of maize and 45 F1 hybrids among them. He revealed that both general and specific combining abilities were significant for ear length, ear diameter, number of kernels/row and grain yield. Amer, *et al.,* (1998) revealed that the GCA and SCA mean squares were highly significant for all studied traits i.e., grain yield, ear length, ear diameter and number of kernels/row. Aly (1999) indicated that both GCA and SCA variances were significant for grain yield, ear diameter, ear length and number of kernels/row for the two years and from the combined data over both years. Choukan (1999) indicated that general combining ability effects were highly significant for grain yield and 1000 grains weight. He also added that specific combining ability was significant for grain yield and he concluded that both additive and non-additive effects were found to be important in genetical control of the previous traits. Soliman and Sadek (1999) observed that five inbred lines exhibited the highest positive and significant GCA effects for grain yield trait. El-Absawy (2002) cleared that GCA mean squares were significant for grain yield per plant, ear diameter and 100 grain weight. He also added that the mean squares of SCA were significant for ear diameter and 100 grain weight. El-Shouny *et al.,* (2003) reported that the GCA and SCA mean squares were highly significant for ear diameter, number of kernels/row and grain yield/plant. Meanwhile, the GCA/SCA ratio was larger than unity for all the studied traits except grain yield/plant, indicating that the GCA were important than SCA in the inheritance of these traits. EL-Moselhy (2005) found that the mean squares for general combining ability (GCA) specific combining ability (SCA)were highly significant for most of yield and yield components traits under different drought stress and non-stress treatments in both seasons.

Amer *et al.,* (1998) evaluated a half-diallel set of ten inbred lines of maize. And showed that heterosis as average percentage from mid-parents were 259.76, 48.81, 27.72, 59.06 and 61.19% for grain yield, ear length, ear diameter and number of kernels/row, respectively. Yassien (1999) estimated heterosis in three crosses of maize and found that the highest values of heterotic effects were 61.15 and 57.5% for grain yield/plant relative to mid and higher parents, respectively. Abd El-Aal (2002) evaluated a set of half-diallel crosses among eight inbred lines and the six populations of each cross. He revealed that heterosis values relative to the better parent were negative and significant for ear length, ear diameter, number of kernels/row and grain yield/plant. Venugopal *et al.,* (2002) evaluated a set of diallel crosses among ten parental lines of maize for the extent of heterosis over better parent and standard check for yield and its component traits. Their results indicated the presence of pronounced hybrid vigor for all studied traits. Forty two out of forty five hybrids exhibited significant positive heterosis with a maximum of 136.67%. Mosa (2003) evaluated half-diallel crosses between eight inbred lines of maize for the presence of heterotic effect for grain yield under two locations. and revealed that heterosis percentage relative to mid parents and better parent were highly significant

and positive. The values of heterosis relative to mid-parents ranged from 58.33 to 751.98% for grain yield. While, the values relative to better parent ranged from 24.08 to 709.88% for the same trait. Alvi *et al.,* (2003) evaluated eight F1 hybrids of maize and cleared that theF_1 hybrids exceeded their parents. The obtained values of heterosis ranged from (21.44 and 8.81%) to (11.49, 22.73, 34.41 and 33.04%) for ear length and weight of 1000 kernels, respectively. Shafey *et al.,* (2003) studied 28 F1 hybrids of corn and their eight parental inbred lines and he obtained quite large and medium values of heterosis formost. Abd El Maksoud *et al.,* (2004) evaluated five inbred lines of maize and 10 F1 hybrids among them in two growing seasons and they revealed that the superior F1 hybrids were : (G2-628 x L-8084) , (Sd-7 x L-7041) and (L-7041 x L-8084). El-Gazzar (2004) evaluated 28 fi hybrids of maize. He illustrated that the calculated values of heterosis were positive and highly significant for all studied vegetative and yield component traits. Welcker (2005) studied the behavior of some genotypes of maize at five environments and obtained highly significant heterosis versus the mid-parents for grain yield with a mean value of 32%. EL-Diasty (2007) For yield component traits, the largest amounts of heterosis estimated from the mid-parent and the better parent for ear weight trait which showed 72.38% and 72.33% for the hybrid 4 x 10, respectively. For ear length. trait, the largest amounts of heterosis were 43.92% and 41.30% for hybrid 2 x 10 from the mid-parent and the better parent, respectively. For ear diameter trait, the largest amounts of heterosis were 20.87% and 19.70% for the hybrid 3 x 10 from the mid-parent and the better parent, respectively. For rows no./ear trait, the largest amounts of heterosis were 19.55% and 16.46% for hybrid 3x7 from the mid-parents and the better parent, respectively. For the last trait, 100-kernel weight, the largest amounts of heterosis were 29.89% and 16.51% for hybrids 3x10 and 2x10 from the mid-parent and the better parent, respectively. The objective of this study was evaluate of combining ability and estimate the heterosis for some agronomic traits in diallel crosses of maize.

MATERIALS AND METHODS

Five white maize inbred lines were used. These inbred lines were: Giza 507 A, Giza 516, Giza 278, Rg 5 and Rg 8. The seeds of all inbred lines were obtained from Maize Research Department, Field Crop Research Institute, Agricultural Research Center (ARC), Ministry of Agriculture and Land Reclamation, Egypt. In 1st May 2007 growing season, the seeds of all parental inbred lines were planted in the Farm of the Agronomy Department, Faculty of Agriculture, Mansoura University. All parental inbred lines were crossed according to a half diallel crosses mating design to obtain 10 single crosses during 2007 season. In 21 April 2008 growing season, all 15 genotypes, which included 5 parental inbred lines and 10 F_1 hybrids were cultivated using the dry methods (Afir). In both seasons, maize crop was preceded by Clover (*Trifolium Alexandrinume*, L.). The soil was ploughed two times then ridged. Calcium super phosphate (15.5 % P2O5) was

incorporated in the soil during tillage operation at a rate of 150 kg/fed. Nitrogen fertilizer in the form of Urea (46 % N) was added at the rate of 120 kg N/fed in two equal doses, the first was after thinning and before the first irrigation, and the second before the second irrigation. The first irrigation was applied after 21 days from planting and then at 15 days intervals during the growing seasons. Weeds were controlled by using manual method before irrigation. Plants were thinned later to one plant per hill before the first irrigation, providing a population density of about 24000 plants/fed. Other agricultural practices were carried out as recommended by Ministry of Agriculture and Land Reclamation. The plot size was10.5 m^2 and each plot consisted of 5 ridges, 3 meters long and 70 cm wide. Samples of ten guarded plants were taken at random from middle two rows of each plot to determine the quantitative and qualitative characters.

Studied traits: The following measurements were recorded: ear diameter, ear length, number of kernels/row, 100-kernel weight, ears yield per plant, grain yield per plant and shelling percentage.

Diallel analysis for General and Specific Combining Ability: Ten single crosses comprise a half diallel between 5 inbred parents. Data of all 15 genotypes were analyzed as randomized complete blocks. The sum of squares of genotypes was partitioned to general and specific combining ability following method 2 model 1 (fixed effects) of Griffing (1956) as shown in Table 1.

Table 1: Analysis of variance and expected mean squares for combining ability analysis.

S.V	d.f	M.S	E.M.S
GCA	P-1	Mg	$\sigma^2_e + (p+2)(1/p-1)\sum g^2 i$
SCA	P(P-1)/2	Ms	$\sigma^2_e + 2/p\ (p-1)\sum i \sum j\ S^2\ ij$
Error	(r-1)(c-1)	Me	σ^2_e

Where, Me= the error mean squares of the main randomized complete block design divided by number of replications (Me= Me/r). , P= number of parents.

The relative importance of GCA to SCA was expressed as follows:
k^2 GCA / k^2 SCA = $[(MS_{GCA} - Ms_e)/(P+2)] / (MS_{SCA} - Ms_e)$, where:MS= mean squares, P= No. of parents and k^2= is the average squares of effects.

General combining ability effects for the inbred parents, specific combining ability effects for cross combinations and their respective standard errors were computed using formulae given in Griffing (1956).

RESULTS AND DISCUSSION

Analysis of variance for all studied traits are presented in table (2). Results indicated that mean squares of genotypes were highly significant for all studied traits i.e. ear diameter, ear length, number of kernels/row, 100-kernel weight, ear yield per plant, grain yield per plant and shelling percentage. General combining ability mean squares (GCA) were highly

significant for all studied traits. Also, mean squares of specific combining ability (SCA) were highly significant for all studied traits. The GCA/SCA ratio was less than unity for all studied traits; this means that these traits are predominantly controlled by non-additive gene action. Similar results were reported by El-Enany (1998), Atta (2001), Hassaballa *et al.,*, (2002), El-Morshidy *et al.,*, (2003), EL-Moselhy (2005) and EL-Diasty (2007).

Table 2: Mean squares from analysis of variance, for general combining ability (GCA) and specific combining ability (SCA) of all studied traits of maize.

S.V	df	Ear diameter	Ear length	Kernels/ row	100-kernels weight	Ear yield/plant	Grain yield/plant	Shelling%
Genotypes	14	4.38**	90.42**	314.90**	115.82**	12207.71**	9473.29**	305.91**
GCA	4	2.56**	27.12**	244.76**	41.18**	5749.21**	3236.62**	126.67**
SCA	10	5.12**	115.74**	342.96**	145.67**	14791.12**	11967.97**	377.60**
Error	42	0.02	1.11**	4.93	0.593	30.69	45.94	21.57
SCA/GCA	**-**	**0.07**	**0.03**	**0.10**	**0.04**	**0.06**	**0.04**	**0.04**

***,** significant at level of probability 0.05 and 0.01, respectively.**

General combining ability effects (gi):

Estimates of general combining ability effects (gi) for inbred parents for all studied traits of maize are shown in table (3). Significant positive GCA effects were found for all studied traits. Based on GCA estimates, it could be concluded that the best combiners for ear diameter and ear lenghth were inbred lines of Rg5 and Rg8; for kernels no / row were G516, G507A and Rg5 inbred lines ; for 100-kernels weight were Rg5 and G516 inbred lines ; for ear yield / plant was Rg5 inbred line ; for grain yield / plant was inbred line Rg5 and for Shelling percentage was G507A inbred line. These results indicated that these inbred could be considered as good combiners for improving these traits.

Table 3: Estimates of general combining ability effects (gi) for inbred parents for all studied traits of maize.

Traits / Crosses	Ear diameter	Ear length	Kernels /row	100-kernel weight	Ear yield/plant	Grain yield/plant	Shelling%
P1(G507A)	-0.231**	-0.431	2.150**	-1.378**	-9.017**	-7.006**	2.440*
P2(G516)	-0.358**	0.427	2.293**	0.661**	0.323	-0.248	0.233
P3(G278)	0.07	-0.659*	-4.279**	0.197	-9.301**	-5.788**	-3.337**
P4(Rg5)	0.407**	1.526**	1.757**	1.558**	24.674**	18.659**	0.936
P5(Rg8)	0.112*	0.862**	-1.921**	-1.039**	-6.680**	-5.617**	-0.272**
S.E (g_i)[1]	**0.032**	**0.178**	**0.375**	**0.130**	**0.936**	**1.146**	**0.785**
S.E (g_i-g_j)[2]	**0.045**	**0.281**	**0.594**	**0.205**	**1.481**	**1.811**	**1.241**

***,** significant at level of probability 0.05 and 0.01, respectively.**
1 Standard error for an GCA effect.
2 Standard error for the difference between estimates of GCA effects.

Specific combining ability effects (Sij) :

Estimates of specific combining ability effects (Sij) for all F_1 crosses for all studied traits are presented in table (4). Significant positive SCA effects were found in all studied traits for most crosses. Based on SCA effects, it could be concluded that the all crosses showed significant and positive SCA effects for ear diameter. The crosses for ear length and kernels

no./row were seven crosses i.e. no. 1,2,5,6,7,8 and 9; for 100-kernel weight were all crosses, except cross no.10; for ear yield/plant and grain yield/plant were all crosses, except cross no.3 and for shelling percentage were five crosses i.e. no. 2,5,7,8 and 9. These crosses could be selected and used in breeding programs for improving these traits.

Table 4: Estimates of specific combining ability effects (s_{ij}) for all F_1 crosses for all studied traits of maize.

Traits / Crosses	Ear diameter	Ear length	Kernels / row	100- Kernel weight	Ear yield/plant	Grain yield/plant	Shelling%
G507A xG516	1.111**	3.456**	3.857**	5.992**	40.813**	27.840**	-3.367
G507AxG278	0.933**	4.918**	9.679**	0.257*	29.980**	24.260**	5.129*
G507A x Rg5	0.271**	0.083	-3.107**	1.370**	-1.144	3.397	1.748
G507A x Rg8	0.716**	-0.255	-0.429ns	4.817**	42.709**	37.719**	2.674
G516 x G278	0.763**	5.060**	10.536**	5.342**	40.415**	39.802**	11.169**
G516 x Rg5	0.231**	1.750**	7.000**	2.516**	25.636**	20.492**	0.597
G516 x Rg8	0.918**	5.888**	6.679**	4.278**	50.471**	46.356**	5.735*
G278 x Rg5	0.320*	3.086**	3.071**	2.120**	54.585**	57.869**	12.402**
G278 x Rg8	0.615**	3.224**	6.500**	5.167**	39.493**	32.396**	7.664**
Rg5 x Rg8	0.203*	-0.711**	-2.036	0.241	9.458**	7.763*	0.981
S.E sca (ij)[1]	**0.071**	**0.46**	**0.97**	**0.34**	**2.42**	**2.96**	**2.03**
S.E sca (ij-ik)[2]	**0.1**	**0.69**	**1.54**	**0.5**	**3.63**	**4.44**	**3.04**
S.E sca (ij-kl)[3]	**0.09**	**0.63**	**1.33**	**0.46**	**3.3**	**4.05**	**2.78**

***,** significant at level of probability 0.05 and 0.01, respectively**
[1] Standard error for an SCA effect.
[2] Standard error for the difference between two SCA effects for a common parent.
[3] Standard error for the difference between two SCA effects for a non-common parent.

Heterosis over mid-parents:

Table (5) showed the percentage of heterosis over mid-parents for all studied traits. Results showed positive significant heterosis values for all studied traits for all crosses except crosses no.3 and 10 for kernels no./row and cross no.1 for shelling percentage.

Table 5: Percentages of heterosis over mid-parents for all studied traits.

Traits / Crosses	Ear diameter	Ear length	Kernels No./ row	100- Kernel weight	Ear yield/plant	Grain yield/plant	Shelling%
G507A xG516	153.96**	100.85**	51.69**	102.73**	215.52**	222.16**	2.26ns
G507AxG278	105.38**	132.37**	103.97**	47.27**	255.43**	311.42**	23.66**
G507A x Rg5	43.1**	23.51**	2.01	34.9**	53.48**	71.86**	9.5**
G507A x Rg8	90.06**	37.66**	18.27**	93.9**	226.06**	260.48**	11.39**
G516 x G278	103.33**	182.66**	172.42**	36.14**	327.29**	464.85**	38.1**
G516 x Rg5	43.41**	55.05**	57.01**	50.09**	96.91**	118.17**	11.22**
G516 x Rg8	104.57**	132.3**	75.72**	37.43**	277.711**	349.36**	19.24**
G278 x Rg5	36.49**	72.64**	59.49**	29.07**	150.14**	219.07**	40.5**
G278 x Rg8	69.43**	117.8**	113.68**	87.35**	344.29**	479.29**	34.33**
Rg5 x Rg8	31.11**	18.1**	6.97	31.56**	77.44**	98.82**	12.99**
LSD 5%	**0.16**	**1.06**	**2.24**	**0.78**	**5.58**	**6.83**	**4.68**
LSD 1%	**0.23**	**1.5**	**3.17**	**1.1**	**7.89**	**9.65**	**6.62**

***,** significant at level of probability 0.05 and 0.01, respectively**

The highest crosses over their mid-parents for ear diameter and 100-kernel weight was cross no.1; for ear length and kernels no./row was cross no. 5; for ear yield/plant and grain yield/plant was cross no.9 and for shelling percentage was cross no.5

Heterosis over better-parents:

Table (6) showed the percentages of heterosis over better parents for all studied traits. Results showed positive significant heterosis values over better-parents in all studied traits for most crosses. The highest crosses over their better-parents for ear diameter and 100-kernel weight was cross no.1; for ear length, kernels no./row and shelling percentage was cross no.5; for ear yield/plant and grain yield/plant was cross no.9.

Table 6: Percentages of heterosis over better-parents for all studied traits.

Traits / Crosses	Ear diameter	Ear length	Kernels No./ row	100- Kernel weight	Ear yield/plant	Grain yield/plant	Shelling%
G507A xG516	136.61**	79.41**	29.75**	92.44**	203.99**	194.63**	-3.1
G507AxG278	74.14**	83**	27.27**	33.31**	164.73**	58.67**	3.06
G507A x Rg5	3.41	1.39	-0.78	6.38**	7.18**	23.71**	4.18
G516 x Rg8	57.14**	32.2**	1.65	91.11**	194.17**	205.44**	3.83
G516 x G278	62.74**	144.66**	83.72**	79.55**	226.51**	293.47**	20.49**
G516 x Rg5	-0.73**	16.67**	31.25**	19.47**	34.65**	48.85**	10.75**
G516 x Rg8	60**	115.38**	74.71**	82.51**	252.74**	312.92**	17.18**
G278 x Rg5	11.92**	18.18**	-1.56	17.16**	49.36**	82.4**	22.14**
G278 x Rg8	64.29**	76.92**	43.68**	67.40**	257.37**	325.57**	18.99**
Rg5 x Rg8	10.22	-6.06	-10.16	2.73	17.03**	29.77**	10.58**
LSD 5%	**0.18**	**1.32**	**2.59**	**1**	**6.44**	**7.88**	**5.4**
LSD 1%	**0.26**	**1.73**	**3.66**	**1.27**	**9.11**	**11.15**	**7.64**

***,** significant at level of probability 0.05 and 0.01, respectively**

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القدرة على التآلف وقوة الهجن لبعض الصفات المحصولية فى هجن الذرة الشامية

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أجري البحث خلال موسمى ٢٠٠٧ و ٢٠٠٨ ، فى الموسم الأول تم إجراء التهجين بين خمسة سلالات نقية محسنة بواسطة مركز البحوث الزراعية بالجيزة بنظام التزاوج نصف الدائرى للحصول على ١٠ هجن فردية من الذرة الشامية ، ثم فى الموسم الثانى (٢٠٠٨) تم تقييم الهجن الفردية وآبائها لتقييم دور القدرة العامة والخاصة على التآلف بين السلالات النقية و قوة الهجين لبعض الصفات المحصولية لهجن الذرة الشامية. **ويمكن تلخيص أهم النتائج المتحصل عليها فى الآتى:**

بينت نتائج الدراسة أن متوسطات مربعات القدرة العامة على التآلف والقدرة الخاصة على التآلف كانت معنوية لجميع الصفات المدروسة وهى قطر الكوز ، طول الكوز ، عدد الحبوب بكل صف ، وزن ١٠٠ حبة ، محصول الكيزان/نبات ، محصول الحبوب/نبات و نسبة التفريط. كما أوضحت النتائج أن النسبة بين القدرة العامة على التآلف والقدرة الخاصة على التآلف كانت أقل من الوحدة لكل الصفات المدروسة وهذا يعنى أن هذه الصفات يتحكم فيها أساساً الفعل الجينى السيادى.

أوضحت النتائج وجود تأثير معنوى وموجب للقدرة العامة على التآلف لجميع الصفات المدروسة ، وأن أفضل الآباء للقدرة العامة على التآلف هى السلالتين Rg5, Rg8 لصفات المحصول ومعظم الصفات المدروسة.

بينت النتائج وجود تأثير معنوى وموجب للقدرة الخاصة على التآلف لجميع الصفات المدروسة ، وأن أفضل الهجن قدرة خاصة على التآلف G507A X G516 لصفتى قطر الكوز ووزن ١٠٠ حبة ، والهجين G516 X Rg8 لصفة طول الكوز ، والهجين G516 X G278 لصفة عدد الحبوب بالصف ، والهجين G278 X Rg5 لصفات محصول الكيزان والحبوب للنبات ونسبة التفريط.

بينت النتائج وجود تأثير معنوى وموجب لقوة الهجين لجميع الصفات المدروسة ، وأن أفضل الهجن فى قوة الهجين بالنسبة لمتوسط آبائها وبالنسبة لأفضل آبائها الهجين G507A x G516 لصفتى قطر الكوز ووزن ١٠٠ حبة ، الهجين G278 x G516 لصفات طول الكوز و عدد الحبوب بالصف ، الهجين G278 x Rg8 صفات محصول الكيزان والحبوب/نبات ونسبة التفريط.