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COMBINING ABILITY ANALYSIS IN NEW WHITE MAIZE INBRED LINES (*ZEA MAYS* L.)

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ABSTRACT: *Diallel crosses among seven advanced white inbred lines derived from different maize populations without reciprocals were made in 2011 season at Sids Agric. Res. Station. The resultant 21 crosses along with three commercial check hybrids i.e. (SC 10, SC 128 and SC 129) were evaluated in a randomized complete block design with four replications at two locations i.e. Sids and Sakha Agric. Res. Stations in 2012 season. Mean squares due to crosses, G.C.A. and S.C.A. were highly significant for all studied traits. The ratio of G.C.A. variance to S.C.A.variance was exceed than unity for all studied traits, except for grain yield, indicating that the relative importance of additive gene effects vs. non-additive gene effect in the inheritance of these traits. The parental inbred lines P_2, P_3, and P_7 had significant positive GCA effects for grain yield, and five crosses P_1xP_7, P_2xP_5, P_3xP_5, P_3xP_6 and P_4xP_7 showed significant positive SCA effects. Four crosses had significant superiority over the check hybrid SC 10. The crosses P_2xP_5 and P_4xP_7 showed higher mean value than the highest yielding check hybrid SC 128. These promising crosses may be released as commercial hybrids by maize research program after further testing.*

Key words: *Maize, diallel crosses, gene effect, combining ability.*

INTRODUCTION

Maize (Zea mays L.) is one of the most important cereal crops in Egypt. It ranks the third among cereal crops, after wheat and rice. Maize is used as food, feed, and fodder. It also has several industrial uses such as oil extraction, starch, gluten, alcohol, glucose and ethanol production and many more products.

The conventional crop breeding methodology mainly depends upon the development of inbred lines from open pollinated varieties or other heterogeneous sources and evaluation of these lines through different techniques and select the best hybrids for commercial use.

The choice of inbred lines to be included in the development of hybrids is based on the results of diallel analysis. The diallel analyses have been widely used to estimate the combining ability of parents in hybrids. Such information serves as a useful guide in the determination of the best hybrid combinations.

Griffing (1956) gave a complete analysis of diallel crosses for fixed and random set of parents. El-Shamarka (1995), Mostafa *et al.* (1996), Abd El-Aty and Katta (2002) and Ibrahim *et al.* (2010) reported that specific combining ability effects were much more important in the inheritance of grain yield and its components. Meanwhile, Beck *et al.* (1991), El-Hosary *et al.* (1999), Abd El-Moula (2005), Derera *et al.* (2008), Vivek *et al.* (2010) and Sibiya *et al.* (2011) reported that general combining ability was more important in determining yield and other characters. El-Hosary and sedhom (1990), Mohamed (1993) and sedhom (1994) concluded that the additive genetic variance was more affected by genotype x environment interaction than the non-additive variance for grain yield per plant. On the contrary, Nawar *et al.* (2002), El-Hosary *et al.* (2006) and Sedhom *et al.* (2007) reported that the non-additive effects were more affected by interaction with environments than the additive effects for grain yield. The present study was planned to 1) obtain information on relative importance of general and specific combining ability for grain yield, and some agronomic traits. 2) to identify the best promising crosses.

MATREIALS AND METHODS

Seven (*Zea mays* L.) inbred lines selected with a wide range of diversity for several traits Table.1. were crossed in a half diallel mating scheme in 2011 season at Sids Agric. Res. Station by hand method giving a total of 21 crosses seed. The resultant 21 crosses along with three commercial check hybrids i.e. (SC 10, SC 128 and SC 129) were evaluated in a randomized complete block design with four replications at two locations i.e. Sids and Sakha Agric. Res. Stations in 2012 season. The experimental plot was one ridge of six m length and 0.80 m width.

Planting was done in hills evenly spaced by 25 cm with two kernels per hill on one side of the ridge. The seedlings were thinned one plant per hill. Agricultural practices were done as recommended for maize cultivation. Data were recorded for No. of days to 50% silking, plant height, ear height, ear length, ear diameter and grain yield/fad adjusted to 15.5 percent grain moisture and calculated in ardab per faddan (ard fad^{-1}) (ardab=140kg, faddan=4200m^2). Bartlett test was used to test the homogeneity of error variance between the two locations. Analysis of variance was performed for the combined data over the two locations according to Steel and Torri (1980). General and specific combining abilities were computed using method 4, model 1 of Griffing (1956).

RESULTS AND DISCUSSION

Analysis of variance:

Analysis of variance for all studied traits over the two locations are presented in Table 2. Location mean squares were highly significant for all the studied traits, indicating that the two locations differed in their environmental conditions. Crosse mean squares were highly significant for all the studied traits indicating that, the wide diversity between the parental materials used in this investigation. Insignificant interaction mean squares between crosses and locations were detected for all studied traits, except ear height, revealing the performance of crosses responded similarly to location changes. For the exceptional trait i.e. ear height significant interaction mean squares between crosses and locations indicating that, these crosses behaved somewhat differently from location to another. Mean squares due to G.C.A. and S.C.A. were highly significant for all studied traits, indicating that both additive and non-additive gene effects were important in the inheritance of the studied traits.

The mean squares of interaction between locations and G.C.A were significant for all the studied traits, except for days to 50 % silking, plant height and ear diameter indicating that the additive type of gene action varied from location to another. So, it would not be effective to make selection on the basis of evaluation in a single environment and more environments are needed. The same results were obtained by El-Hosary (1989), Barakat *et al.* (2003) and Osman *et al.* (2012), they found that the interaction between both types of combining abilities and environment was highly significant. While, the mean squares due to S.C.A. x locations was detected to be insignificant for all the studied traits.

Table.1. Sources of parental inbred lines used in currently study.

Parents	Source
P_1	G-2 Ev- 7
P_2	G-2 Ev- 8
P_3	G-2 Ev- 9
P_4	Tep-5
P_5	Pool BC 1
P_6	TWC 2665
P_7	Exotic

Table. 2. Combined analysis of variance for studied traits over two locations, 2012 season.

S.O.V.	df	MS					
		Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Grain yield (ard fad^{-1})
Loc. (L)	1	575.72**	3750.06**	90211.01**	72.29**	11.42 **	500.91 **
Reps/Loc.	6	11.35	2683.01	923.41	0.82	0.04	43.41
Crosses (C)	20	25.04**	902.96**	439.66**	6.04**	0.23**	109.04**
C x L	20	2.76	155.49	109.27*	1.55	0.02	18.22
GCA	6	50.15**	2115.50**	813.59**	8.60**	0.59**	94.66**
SCA	14	14.27**	383.30**	279.41**	4.95**	0.07**	115.20**
GCA x L	6	2.65	206.12	186.20*	3.99**	0.05	25.62**
SCA x L	14	2.80	133.80	76.30	0.49	0.01	15.05
Error	120	1.78	149.68	63.25	0.97	0.03	11.44
GCA/SCA	-	3.51	5.52	2.91	1.74	7.50	0.82
GCAxL/GCA	-	0.05	0.09	0.22	0.46	0.08	0.27
SCAxL/SCA	-	0.19	0.34	0.27	0.10	0.11	0.13
C.V.	-	2.21	4.91	5.66	4.83	3.67	11.86

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

GCA/SCA ratio, which exceed the unity, was obtained for all traits, except for grain yield revealing the predominance of additive and additive by additive gene effect for these traits. The same trend results were reported by Abd El-Aty and Katta (2002) and Bujak *et al.* (2006) found that ear length was mostly determined by additive gene action. Abd El-Moula (2005), Derera *et al.* (2008), Vivek *et al.* (2010), Sibiya *et al.* (2011) and Ibrahim (2012) found that the additive gene action was more important than the non-additive for grain yield. However, Salama *et al.* (1995), Sadek *et al.* (2001), Singh and Roy (2007), Abdallah and Hassan (2009) and Osman *et al.* (2012), reported that the non-additve type of gene action appeared to be more important in the inheritance of yield.

The ratio for SCAxL/ SCA was higher than the ratio of GCAxL/ GCA for all the studied traits, except for ear length and grain yield indicating that non-additive genetic effects were more influenced by the environmental condition than additive genetic effects for these traits. These results are in well agreement with those reported by Gilbert (1958). While the additive genetic effects were more influenced by the environmental condition than non-additive genetic effects for the exceptional traits i.e. ear length and grain yield. Similar findings were reported by Motawei (2006), Ibrahim *et al.* (2010) and Ibrahim (2012) for grain yield.

Mean performance:

Mean performance of the 21 crosses along with the three check hybrids for all studied traits are presented in Table.3. For no. of days to 50% silking, three crosses were significantly earlier than the earliest check hybrid SC 128. These crosses were P_2xP_4, P_2xP_7 and P_3xP_4; whereas,10 crosses did not differ significantly from the same check. On the other hand, eighteen crosses were significantly earlier than the latest check hybrid SC 10. While, only three crosses were significantly earlier than the earliest check hybrids SC 128. The earliest crosses were P_2xP_4, P_2xP_7 and P_3xP_4. While, the cross P_5xP_6 was the latest one. With respect to plant and ear heights, all crosses were significantly shortest than the check hybrid SC 10. While, only one cross P_1xP_7 gave the lowest values (226.75/124.13 cm) than the shortest check hybrid i.e. SC 128. However, the highest values for both traits were recorded by the cross P_2xP_4 (269.13/149.63 cm).

Table (3). Combined mean performance of 21 crosses and three check hybrids, for all studied traits, 2012 season.

Crosses	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Grain yield (ard fad^{-1})
P_1xP_2	59.13	252.13	141.13	19.98	4.80	28.89
P_1xP_3	60.50	236.75	129.50	20.70	4.90	26.01
P_1xP_4	61.25	245.50	138.75	19.78	4.73	23.64
P_1xP_5	62.13	240.63	137.50	20.68	4.95	24.70
P_1xP_6	62.50	236.75	134.38	20.73	4.43	27.46
P_1xP_7	60.25	226.75	124.13	19.80	4.50	30.33
P_2xP_3	58.63	251.13	141.75	19.80	4.85	33.20
P_2xP_4	57.25	269.13	149.63	19.58	4.75	24.54
P_2xP_5	61.50	246.88	137.50	20.70	4.95	35.02
P_2xP_6	59.63	246.50	141.75	20.63	4.45	29.17
P_2xP_7	56.63	238.75	128.50	18.98	4.68	31.12
P_3xP_4	57.13	263.13	140.25	19.00	4.88	26.71
P_3xP_5	58.88	260.63	149.50	20.15	4.75	31.28
P_3xP_6	60.38	251.63	141.00	20.15	4.75	33.45
P_3xP_7	61.63	259.50	149.00	20.83	4.75	27.33
P_4xP_5	60.50	260.50	145.63	22.28	4.80	27.58
P_4xP_6	60.50	264.25	151.75	20.08	4.48	27.37
P_4xP_7	61.38	245.38	146.13	21.40	4.70	35.66
P_5xP_6	63.25	248.13	148.75	22.35	4.53	23.59
P_5xP_7	60.38	245.50	136.75	20.35	4.68	23.83
P_6xP_7	61.25	246.88	139.63	20.38	4.45	28.14
Checks:						
SC 10	63.00	292.00	167.88	22.65	4.53	28.97
SC 128	59.63	253.50	135.00	22.35	4.83	34.43
SC 129	60.63	275.75	155.00	21.60	4.68	32.99
LSD 0.05	1.31	11.99	7.79	0.96	0.17	3.31

For ear length, no one of the crosses surpassed superiority over the highest value of the check hybrid SC 10. While, two crosses P_4xP_5 and P_5xP_6 did not differ significantly from the check hybrid SC 10. The highest mean value for this trait was detected by the hybrid P_5xP_6 (22.35 cm).

Regarding to ear diameter, none of the crosses surpassed superiority over the highest value of the check hybrid SC 128. While, five crosses P_1xP_3, P_1xP_5, P_2xP_3, P_2xP_5 and P_3xP_4 showed significant difference from the check hybrid SC 129. The highest mean value for this trait was detected by the hybrid P_1xP_5 (4.95 cm). Concerning grain yield, four crosses had significant superiority over the check hybrid SC 10. While, six crosses showed insignificant difference from the highest yielding check hybrid SC 128. These crosses exhibited significant increase of one or more of traits contributing to grain yield, especially SC P_2xP_7 which was earlier and shortest than the check hybrid SC 128 (Table 3). The hybrids P_2xP_5 and P_4xP_7 showed higher mean value (35.02 and 35.66 ard/fed.), respectively. These crosses may be released as commercial hybrids by maize research program after further testing and evaluation.

Combining ability effects:

a. General combining ability effects:

Estimates of GCA effects ($\hat{g}_i$) for individual parental inbred lines for each trait are presented in Table.4. The obtained high positive values for all traits in question except days to 50% silking as well as plant and ear heights would be useful from the breeder's point of view.

The parental inbred line P_1 exhibited significant negative $\hat{g}_i$ effects for plant and ear heights, indicating that this inbred line could be considered as a good combiner for developing shortest genotypes. However, it gave (undesirable) $\hat{g}_i$ effects for days to 50% silking and grain yield.

The parental inbred line P_2 behaved as the best combiner for days to 50% silking, indicating that this inbred line could be considered as a good combiner for developing early genotypes. In addition, it showed significant positive $\hat{g}_i$ effects for ear diameter and grain yield. However, it is exhibited either undesirable $\hat{g}_i$ effects for ear length.

The parental inbred line P_3 expressed significant negative $\hat{g}_i$ effects for days to 50% silking. Also, it showed significant positive $\hat{g}_i$ effects for ear diameter and grain yield. However, it gave (undesirable) $\hat{g}_i$ effects for the other traits.

The parental inbred line P_4 exhibited significant negative $\hat{g}_i$ effects for days to 50% silking. In addition, it gave (undesirable) $\hat{g}_i$ effects for plant and ear heights and grain yield.

The parental inbred line P_5 seemed to be the best combiner and ranked the first best inbred line for ear length. Also, it showed positive $\hat{g}_i$ effects for ear diameter. However, it showed significant (undesirable) or insignificant $\hat{g}_i$ effects for other traits.

The parental inbred line P_6 behaved as the best combiner for ear length. However, it is exhibited either (undesirable) $\hat{g}_i$ effects for days to 50% silking, ear height and ear diameter.

The parental inbred line P_7 expressed significant desirable $\hat{g}_i$ effects for plant and ear heights. Also, it is exhibited significant positive $\hat{g}_i$ effects for grain yield. In addition, it gave (undesirable) $\hat{g}_i$ effects for ear diameter.

From the previous result, it could be concluded that the parental inbred line P_2, P_3 and P_4 the best combiners and possessed favorable genes for improvement of hybrid, with earliness, P_1 and P_7 for shortness and lower placement, P_5 and P_6 for ear length , P_2, P_3 and P_5 for ear diameter and P_2, P_3 and P_7 for grain yield.

Table. (4). Estimates of GCA ($\hat{g}_i$) effects of 7 inbred lines for all studied traits, combined over two locations, 2012 season.

Inbred lines	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Grain yield (ard fad^{-1})
P_1	0.88**	-11.52**	-7.66**	-0.14	0.02	-2.02**
P_2	-1.71**	1.68	-0.69	-0.54**	0.05**	2.16**
P_3	-0.84**	5.33**	1.46	-0.34*	0.13**	1.36**
P_4	-0.66**	10.35**	5.68**	-0.05	0.02	-1.13*
P_5	1.06**	1.23	2.38*	0.82**	0.09**	-1.03*
P_6	1.23**	-0.40	2.71*	0.38**	-0.23**	-0.39
P_7	0.04	-6.67**	-3.91**	-0.13	-0.09**	1.05*
S.E. ($\hat{g}_i$)	0.19	1.79	1.16	0.14	0.02	0.49
S.E. ($\hat{g}_i$- $\hat{g}_j$)	0.29	2.73	1.77	0.21	0.03	0.75

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

b. Specific combining ability effects:

Specific combining ability effects were only estimated whenever significant SCA variances were obtained. Specific combining ability effects of 21 crosses for all studied traits are presented in Table 5. With regard to days to 50% silking, plant height and ear height, negative SCA effects are desirable, while for other traits positive are desirable.

As for days to 50% silking, five crosses expressed significant negative $\hat{S}_{ij}$ effect. Also, results indicated that the crosses P_2xP_7 and P_3xP_4 gave the highest desirable $\hat{S}_{ij}$ values. So, it could be useful in areas that require early maturing hybrids. The other crosses had either significant positive or insignificant $\hat{S}_{ij}$ effects. Regarding plant height, only one cross combinations namely, P_4xP_7 (-7.65**) gave the highest significant and negative $\hat{S}_{ij}$ effects. For ear height, five crosses (P_1xP_3, P_1xP_7, P_2xP_5, P_2xP_7 and P_3xP_4) expressed the highest significant and negative $\hat{S}_{ij}$ effects. Therefore, these crosses were considered the best among studied crosses for ear height. This may suggest the immediate used to decrease lodging, and in turn, increase the yield potentiality.

Five crosses (P_1xP_2, P_3xP_7, P_4xP_5, P_4xP_7 and P_5xP_6) had significant positive $\hat{S}_{ij}$ effects for ear length. While, only three crosses (P_1xP_5, P_2xP_5 and P_3xP_6) showed significant effects for ear diameter. With regard to grain yield, five crosses (P_1xP_7, P_2xP_5, P_3xP_5, P_3xP_6 and positive $\hat{S}_{ij}$ P_4xP_7) expressed significantly positive $\hat{S}_{ij}$ effects. These crosses (P_2xP_5, P_3xP_6, P_4xP_7) exhibited the highest $\hat{S}_{ij}$ effects (5.36, 3.59 and 7.21), respectively and also it gave the highest mean performance for grain yield (35.02, 33.45 and 35.66 ard/fed), respectively. These crosses represented the parental combinations of (high x low) GCA effects. So, this suggests that additive x dominance genetic interaction were involved in these crosses. Hence, these crosses may be released as a good inbred lines commercial hybrids by the Maize Research Program after further testing and evaluation. Similar findings were reported earlier by Nawar and El-Hosary (1985), Soliman *et al.* (2001), Sadek *et al.* (2002), Gaber *et al.* (2008) and Abdallah *et al.* (2009).

Table (5). Estimates of SCA ($\hat{s}_{ij}$) effects of 21 crosses for all studied traits combined over two locations, 2012 season.

Crosses	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Grain yield (ard fad^{-1})
P_1xP_2	-0.267	12.617**	8.858**	0.267	0.027	0.232
P_1xP_3	0.233	-6.408	-4.917*	0.797**	0.047	-1.858
P_1xP_4	0.808*	-2.683	0.108	0.423	-0.018	-1.730
P_1xP_5	-0.042	1.567	2.158	-0.403	0.142**	-0.774
P_1xP_6	0.158	-0.683	-1.292	0.087	-0.068	1.354
P_1xP_7	-0.892*	-4.408	-4.917*	-0.323	-0.128**	2.776**
P_2xP_3	0.958*	-5.233	0.358	0.297	-0.038	1.149
P_2xP_4	-0.592	7.742*	4.008	-0.223	-0.028	-5.015**
P_2xP_5	1.933**	-5.383	-4.817*	0.022	0.107*	5.366**
P_2xP_6	-0.117	-4.133	-0.892	0.387	-0.078	-1.119
P_2xP_7	-1.917**	-5.608	-7.517**	-0.748**	0.012	-0.614
P_3xP_4	-1.592**	-1.908	-7.517**	-0.993**	0.017	-2.052*
P_3xP_5	-1.567**	4.717	5.033	-0.723**	-0.173**	2.417*
P_3xP_6	-0.242	-2.658	-3.792	-0.283	0.142**	3.598**
P_3xP_7	2.208**	11.492**	10.833**	0.907**	0.007	-3.615**
P_4xP_5	-0.117	-0.433	-3.067	1.107**	-0.013	1.219
P_4xP_6	-0.292	4.942	2.733	-0.635*	-0.023	0.366
P_4xP_7	1.783**	-7.658*	3.733	1.187**	0.067	7.212**
P_5xP_6	0.733	-2.058	3.033	0.742**	-0.038	-3.513**
P_5xP_7	-0.942*	1.592	-2.342	-0.743**	-0.023	-4.714**
P_6xP_7	-0.242	4.592	0.208	-0.278	0.067	-1.045
S.E ($\hat{s}_{ij}$)	0.380	3.531	2.290	0.281	0.042	0.971
S.E ($\hat{s}_{ij}$ - $\hat{s}_{ik}$)	0.591	5.473	3.552	0.430	0.060	1.511
S.E ($\hat{s}_{ij}$ - $\hat{s}_{kl}$)	0.512	4.730	3.070	0.372	0.063	1.301

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

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تحليل القدرة على التآلف فى بعض سلالات الذرة الشامية البيضاء

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الملخص العربى

تم إجراء جميع الهجن الممكنة (ماعدا العكسية) بين 7 سلالات من الذرة الشامية البيضاء المرباة داخليا بمحطة البحوث الزراعية بسدس فى الموسم الزراعى 2011. تم تقييم هجن الجيل الأول وعددها 21 هجين مع ثلاثة هجن للمقارنة وهما هـ.ف . 10 ؛ هـ.ف . 128 و هـ.ف 129فى الموسم الزراعى 2012 بمحطتى البحوث الزراعية بسدس وسخا بهدف تحديد أفضل التراكيب الوراثية الجديدة . أظهرت النتائج وجود اختلافات عالية المعنوية بالنسبة للهجن والقدرة العامة والخاصة على التالف لكل الصفات موضع الدراسة. أظهرت النسبة بين تباين القدرة العامة والخاصة على التآلف أهمية نسبية لفعل الجين المضيف بالنسبة لجميع الصفات محل الدراسة ما عدا صفة المحصول. أظهرت النتائج أيضا أن السلالات الأبوية P_7 ، P_3 ، P_2 كانت أفضل السلالات من حيث تأثيرات القدرة العامة على التالف لصفة الإنتاجية أما بالنسبة للقدرة الخاصة على التالف فان الهجن P_1xP_7 و P_2xP_5 وP_3xP_5 و P_3xP_6 وP_4xP_7 أظهرت قدرة خاصة عالية المعنوية. بالنسبة لمحصول الحبوب للفدان تفوقت أربع هجن تفوقا معنويا مقارنة بهجين المقارنة هـ.ف 10 بينما كان هناك هجينين فقط (P_2xP_5) و (P_4xP_7) والذى أعطوا أعلى متوسط لإنتاجية الحبوب للفدان مقارنة بأعلى هجن المقارنة إنتاجية هـ.ف 128. تعتبر هذه الهجن مبشرة ويمكن إدخالها فى مراحل التقييم المختلفة لإطلاقها كهجن تجارية.