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Combining ability for some inbred lines in half-diallel crosses of maize under two different locations conditions

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Abstract

A half diallyl cross among eight new yellow maize inbred lines, *i.e.* Gm. 142, Gm. 224, Gm. 233, Gm. 152, Gm. 297, Gm. 330, Gm. 201, and Gm. 303, was made in 2015 summer season. Twenty eight F_1 crosses along with two yellow commercial check hybrids, SC162 and SC168 were evaluated in randomized complete block design with four replications at two locations (Gemmeiza, Gharbia and Sids, Bani Sweif, Egypt) in 2016 summer season to study the combining ability to identify the most superior parental inbred lines that produce superior hybrids and develop high yielding new yellow single crosses. Results indicated that mean squares of crosses exhibited significant or highly significant for all studied traits. Mean squares due to GCA and SCA were significant or highly significant for all studied traits at combined over the two locations, except GCA for ear diameter trait and SCA for ear length trait, which were non-significant. The ratio of GCA/SCA was more than unity for all studied traits at combined over the two locations, except days to 50% silking and ear diameter traits, indicating that additive gene was more important than non-additive gene action. The interaction between GCA and SCA and locations were highly significant for all studied traits, except GCA x Loc. for ear diameter trait and SCA x Loc. for ear length trait. The magnitude of the interaction was highest for GCA × locations than the SCA × locations for plant height, ear height, ear length and grain yield, indicates that additive genetic variance was influenced by environment and the additive component interacted more with the environment than the non-additive and vice versa for days to 50% silking and ear diameter. According to analysis of GCA effects, the best general combiners were P_3 (Gm.233) for earliness; P_4 (Gm.152), P_5 (Gm.297), P_6 (Gm.330) and P_7 (Gm.201) for plant height (shortness); P_5 (Gm.297), P_6 (Gm.330) and P_7 (Gm.201) towards lower ear position; P_4 (Gm.152) and P_6 (Gm.330) for ear length; P_1 (Gm.142) for ear diameter; and P_1 (Gm.142), P_5 (Gm.297) and P_8 (Gm.303) for grain yield. Based on mean performance and SCA effects analysis, there were seven crosses No. 1, 2, 5, 7, 9, 25 and 26 (P_1 x P_2, P_1 x P_3, P_1 x P_6, P_1 x P_8, P_2 x P_4, P_5 x P_8 and P_6 x P_7) were the best combinations where they recorded significant or highly significant positive SCA effects for grain yield.

Keywords: maize, half-diallel cross, combining ability, *Zea mays*.

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1. Introduction

Maize has a remarkable place among cereals and it is used as human food, animal feeding and industry (Keskin *et al.*, 2005). Predictors of single-cross hybrid value or heterosis between parental inbred lines could therefore increase the efficiency of hybrid breeding programs (Betran *et al.*, 2003). Plant breeders and geneticists often use diallel mating designs to obtain genetic information about a trait of interest from a fixed or randomly chosen to set of parental lines (Murray *et al*., 2003). The diallel analysis is an important method to know gene actions and it is frequently used by crop breeders to choose the parents with a high general combining ability (GCA) and hybrids with high specific combining ability (SCA) effects (Yingzhong, 1999). Combining ability analyses are widely used in maize breeding programs to determine GCA and SCA information from maize populations for genetic diversity evaluation, inbred line selection, heterotic pattern classification, heterosis estimation, and hybrid development (Barata and Carena, 2006; Fan *et al*., 2002; Kauffman *et al.*, 1982; Melani and Carena, 2005; Sughroue and Hallauer, 1997). Dialled mating models developed by Griffing (1956) and Gardner and Eberhart (1966), are the major models used in combining ability analyses. Large genotype× environment effects tend to be viewed as problematic in breeding because the lack of a predictable response hinders progress from selection (Dudley and Moll, 1969), influence the environment and interaction between genotype and environment (Novoselovic *et al.*, 2004). Found that mean squares for general combining ability (GCA) and specific combining ability (SCA) were highly significant for most studied traits of maize under both normal and drought stress conditions, Abdel-Moneam and Ibraheem (2015a,b) indicated that mean squares of crosses were highly significant for all studied traits under both low and high N fertilization rates, indicating significant genotypic differences among the studied crosses and suggest that almost all variables exhibited some degree of heterosis. Breeders still contend, however, that dominance effects caused by genes with over dominant gene action are also important (Horner *et al*., 1989). Most of the literature about maize, the most extensively studied plant species, suggests that additive effects of genes with partial to complete dominance are more important than dominance effects in determining grain yield (Lamkey and Lee, 1993). The objectives of this study were evaluation of eight parental inbred lines and their crosses thought half-diallel, estimate of (GCA) and (SCA), selection the best crosses for grain yield, earlier and shortness, lower ear placement, determine the best allot for these crosses and identify type of gene action controlling the inheritance for studied traits.

2. Materials and methods

The following eight new yellow parental inbred lines were studied: *i.e.* Gm. 142, Gm. 224, Gm. 233, Gm. 152, Gm. 297, Gm. 330, Gm. 201, and Gm. 303. These lines were differed considerably in expression of various agronomy traits (Table 1). These inbred lines were crossed at Gemmeiza in a half-diallel to give 28 crosses (excluding reciprocal crosses) in the summer of 2015 at Agricultural Research Centre, Egypt. The 28 F_1

hybrids and two check hybrids (single cross 162 and single cross 168) were evaluated at two locations (Gemmeiza and Sids) on randomized complete block design (RCBD) with four replications during 2016 summer season. Kernels were hand–sewn at 2 to 3 grains per hill then thinned at one plant per hell after emergence. Each replication contained 30 plots and each plot consisted of one ridge with 6 m a long and spacing of 25 cm between plants within ridge and 80cm between ridges. In Experiments for each location were recorded on the following characters on plot basis:

- Days to 50% silking: (number of days to 50% silking).
- Plant height (cm): was measured from the soil surface to the base of the flag leaf.
- Ear height (cm): was measured from the soil surface to ear node.
- Ear length (cm): average length of five husked ears/plot at harvesting.
- Ear diameter (cm): average diameter at the middle of five-husked ears/plot measured at harvesting by a Vernier Caliper.
- Grain yield (ard/fed) (ardab (ard.)= 140kg, feddan (fed) = 1.037 acres), which was adjusted to 15.5 % moisture content (estimated in kg/plot and converted to ard/fed).

2.1 Statistical analysis procedure

Analysis of variance for mean of performance according to the method outlined by Snedecor and Cochran (1977) was used for each location and then combined over the two locations. The L.S.D. test at 5% according to (Steel and Torrie, 1980) was used for comparison the mean of performance of the different crosses. General combining ability (GCA) and specific combining ability (SCA) effects were estimated according to Griffings (1956) Method 4 Model 1. In addition, the mathematical model for a single inbred cross were tested for normality by statistical software. Then, data were analyzed using AGR 21 statically software (2001).

3. Results and Discussion

3.1 Analysis of variance

The analysis of variance for the studied traits (days to 50% silking, plant height, ear height, ear length, ear diameter and grain yield) of 28 F_1 single crosses combined over two locations (Gemmeiza, Gharbia and Sids, Bani Sweif, Egypt) are presented in Table (2). Mean squares of crosses exhibited significant or highly significant for all studied traits at combined over the two locations, indicating that the crosses performance differed from location to another. These results agree with those obtained by Nawar and El-Hosary (1985), Venugopul *et al*. (2002), Barakat and Ibrahim (2006), Ibrahim *et al.* (2007) and Sultan *et al.* (2016). Partition sum of squares due to crosses into its components showed that mean squares due to GCA and SCA were significant or highly significant for all studied traits at combined over the two locations, except GCA for ear diametertrait and SCA for ear lengthtrait, which were non-significant. These results indicated that both additive and non-additive types of gene effects were involved in the inheritance of these traits.

Table (1): The name and Origin of the studied eight yellow inbred lines.

No. of parent	Name	Origin
P_1	Gm. 142	Comp#45
P_2	Gm. 224	Comp#45
P_3	Gm. 233	SK21
P_4	Gm. 152	SK21
P_5	Gm. 297	Gm. Y. Pop.
P_6	Gm. 330	Gm. Y. Pop.
P_7	Gm. 201	Pool-(18-627) M
P_8	Gm. 303	Pool-(18-627) M

The ratio of GCA/SCA was more than unity for all studied traits at combined over the two locations, except days to 50% silking and ear diameter traits at the combined data over the two studied locations. These results indicating that the additive genetic effects were more important and played the major role in the inheritance of these studied traits (plant height, ear height, ear length and grain yield), indicating that additive gene was more important than non-additive gene action. These results agree with the finding of Soliman *et al*. (2001) and Sultan *et al.* (2016). But, this ratio of GCA/SCA for the two exceptions traits i.e. days to 50% silking and ear diameter was less than unity at the combined data over the two studied locations, indicating that the non-additive genetic effects were more important and played the major role in the inheritance of these two traits. The interaction between GCA and SCA and locations (Table 2) were highly significant for all studied traits, except GCA X Loc. for ear diameter trait and SCA X Loc. for ear length trait. The magnitude of the interaction was highest for GCA × locations than the SCA × locations for plant height, ear height, ear length and grain yield. This indicates that additive genetic variance was influenced by environment and the additive component interacted more with the environment than the non-additive and vice versa for days to 50% silking and ear diameter. This conclusion supports the findings by, Soliman *et al.* (2001) and Abdel-Moneam *et al*. (2014a,b,c).

3.2 Mean performance

Mean performance of 28 F_1 crosses and two check hybrids for days to 50% silking, plant height, ear height, ear length, ear diameter and grain yield at combined data over two locations (Gemmaiza and Sids) during 2016 season, are presented in Table (3). For days to 50% sllking, 9 crosses out of the 28 studied crosses were significantly earlier than the both checks SC 168 and SC 162, with range from 60.13 days for cross No. 8 (P_2 x P_3) to 62.50 days for cross No. 27(P_6 x P_8), compared with 65 days for the both studied checks at combined data over two locations, as shown in Table 3. For plant height (cm), means of studied crosses ranged between 190.0 cm for cross No. 21 (P_4x P_7) to 257.5 cm for cross No. 7 (P_1 x P_8) at the combined data over both locations. Also, 19 crosses out of 28 crosses were significantly shorter than the tallest check SC 162 (246.0 cm) at the combined data over two locations, as presented in Table (3). With respect to ear height (cm), means of studied crosses for this trait ranged between 102.5 cm for crosses No. 21 (P_4x P_7) and 23 (P_5 x P_6) to 149.38 cm for cross No. 7 (P_1 x P_8) at the combined data over both locations. Also, there were 9 crosses out of the 28 studied crosses exhibited significantly lower position in ear height than the lowest check SC. 168in ear height at the combined data over two locations, as illustrated in Table (3). Considering of ear length (cm) for the studied 28 crosses and the two checks SC 168 and SC 162 are presented in Table (3). The differences between crosses in ear length were highly significant and ranged from 18.48 cm for cross No. 6 (P_1 x P_7) to 21.55 cm for cross No. 26 (P_6 x P_7). Also, there were 12 crosses, out of the studied 28 crosses, surpassed the highest check SC. 162 (20.05 cm) in ear length. Whereas, most of studied crosses (25 crosses out of 28 crosses) surpassed the lowest check SC. 168 (19.23 cm) in ear length, as combined data over the two studied locations. With respect to ear diameter (cm), the differences between ear diameters for all studied crosses were significant. Ear diameter ranged from3.95 cm for cross No. 18 (P_3 x P_8) to 4.43 cm for cross No. 1 (P_1 x P_2). There were six crosses, out of 28 crosses, recorded values of ear diameter higher than the highest check variety SC. 162 (4.25 cm).

Table (2): Analysis of variance for crosses, general (GCA) and specific (SCA) combining abilities for days to 50% silking, plant height, ear height, ear length, ear diameter and grain yield of 28 crosses combined over two locations (Gemmaiza and Sides), during 2016 season.

S. O. V	d. f.	Days to 50 % silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Grain yield (ard/fad)
Loc.	1	3560.04**	18852.79**	9516.07**	351.50**	27.16**	1160.52**
Rep/loc.	6	593.34	3142.13	1586.01	58.58	4.53	193.42
Crosses	27	15.982**	1618.30**	838.36**	4.44**	0.07*	98.50**
GCA	7	0.658**	496.11**	204.13**	1.05**	0.005	15.07**
SCA	20	2.467**	99.45**	70.03**	0.38	0.01*	11.35**
Cr x L	27	3.346**	151.87**	177.65**	3.45**	0.12**	38.36**
GCA x Loc.	7	0.924**	520.99**	240.07**	2.61**	0.02	35.61**
SCAx Loc.	20	3.503**	142.00**	117.41**	1.00	0.05**	17.10**
Error term	162	0.668	43.847	30.374	0.787	0.017	2.868
GCA/SCA		0.27	4.99	2.91	2.76	0.50	1.33
GCA x loc. / SCA x loc.		0.26	3.67	2.04	2.61	0.40	2.08

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

Table (3): Mean performance of 28 F_1 crosses and two check hybrids for days to 50% silking, plant height, ear height, ear length, ear diameter and grain yield at combined data over two locations (Gemmaiza and Sids), during 2016 season.

Crosses		Days to 50 % silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Grain yield (ard/fad)
P_1 x P_2		63.00	233.75	123.13	19.40	4.43	30.03
P_1 x P_3		63.63	229.38	130.00	19.98	4.25	30.53
P_1 x P_4		63.25	246.25	135.00	20.50	4.20	19.78
P_1 x P_5		62.88	238.13	131.88	19.43	4.23	25.30
P_1 x P_6		62.25	226.88	123.13	19.73	4.33	29.41
P_1 x P_7		65.25	236.25	128.75	18.48	4.20	23.22
P_1 x P_8		64.38	257.50	149.38	21.03	4.23	33.93
P_2 x P_3		60.13	215.00	119.38	19.53	4.05	22.03
P_2 x P_4		61.63	221.88	121.88	20.50	4.10	28.32
P_2 x P_5		62.13	206.88	116.25	19.00	4.15	26.69
P_2 x P_6		65.88	226.25	123.13	19.40	4.28	22.54
P_2x P_7		62.75	220.00	122.50	19.38	4.23	23.59
P_2x P_8		64.63	224.38	120.63	19.48	4.25	21.26
P_3 x P_4		65.00	228.75	120.63	19.98	4.40	21.28
P_3 x P_5		64.00	229.38	125.63	19.63	4.23	25.96
P_3 x P_6		63.63	230.00	131.25	20.63	4.10	24.05
P_3x P_7		60.88	210.63	110.00	19.88	4.25	23.19
P_3x P_8		61.63	216.25	106.25	19.95	3.95	20.49
P_4 x P_5		60.38	206.88	115.63	21.00	4.23	24.39
P_4 x P_6		63.63	215.00	113.75	20.30	4.23	23.36
P_4x P_7		63.63	190.00	102.50	20.68	4.20	22.72
P_4x P_8		63.13	216.88	118.13	20.73	4.23	26.96
P_5 x P_6		64.00	200.63	102.50	21.20	4.13	25.28
P_5 x P_7		63.25	209.38	120.00	19.05	4.18	25.49
P_5 x P_8		63.00	220.00	113.75	20.28	4.28	31.19
P_6 x P_7		61.25	212.50	113.75	21.55	4.25	27.30
P_6 x P_8		62.50	213.13	116.25	20.73	4.28	28.36
P_7 x P_8		63.50	207.50	107.50	19.40	4.20	24.58
Checks	SC 162	65.00	246.00	135.13	20.05	4.25	27.72
	SC 168	65.00	239.25	131.26	19.23	4.15	26.61
L.S.D. (0.05)		2.29	18.54	15.43	2.48	0.37	4.74

Meanwhile, most of studied crosses (22 crosses out of 28 crosses) surpassed the lowest check SC. 168 (4.15 cm) in ear diameter, as combined data over the two studied locations, as shown in Table (3). Sultan *et al*. (2012) came to similar results. For grain yield (ard/fad), the result in Table (3) revealed that the differences between crosses in this trait were highly significant and ranged from 19.78 ard/fed for cross No. 3 (P_1x P_4) to 33.93 ard/fed for cross No. 7 (P_1 x P_8). In addition, there were seven crosses out of the studied 28 crosses were surpassed in grain yield/fed over the highest check cultivar SC 162 (27.72 ard/fed). However, there were ten crosses out of the studied crosses were surpassed in grain yield/fed over the lowest check cultivar SC 168 (26.68 ard/fed), as combined data over the two studied locations. Abdel-Moneam and Ibraheem (2015a,b) reported similar results.

3.3 General combining ability effects (g^i)

High positive of general combining

ability effects would be useful in most traits, while for days to 50 % silk, plant height and ear height, high negative values would be useful from plant breeder point of view. General combining ability effects would be estimated, wherever the significant of GCA mean square for the trait in view. Estimation of (g^i) for six traits as the combined data over two locations (Gemmaiza and Sids) are presented in Table (4). For days to 50% silking, the parental inbred line P_3 (Gm. 233), exhibited negative and significant (g^i) towards earliness, therefore, this inbred line is considered the best general combiners for earliness. However, the parental inbred line P_1 (Gm. 142), exhibited positive and highly significant (g^i) towards lateness, as the combined data over two locations. With respect to plant height, results in Table (4) showed that four parental inbred lines P_4 (Gm. 152), P_5 (Gm. 297), P_6 (Gm. 330) and P_7 (Gm. 201) exhibited negative and highly significant (g^i) towards plant shortness. This means that these four lines could be considered as the best general combiners for plant height trait (shortness). On the other side, inbred line P_1 (Gm 142) showed positive and highly significant (g^i) towards plant tallness, as the combined data over two locations. Regarding to ear height, results in Table 4 showed that parental inbred lines P_5 (Gm. 297), P_6 (Gm. 330) and P_7 (Gm. 201) exhibited negative and highly significant (g^i) towards lower ear position. This means that these three lines can be considered as the best general combiners for ear height trait (lower ear position). On the other hand, inbred line P_1 (Gm. 142) showed positive and highly significant (g^i) towards higher ear position on the plant, as the combined data over two locations. With respect to ear length, results in Table (4) showed that two parental inbred lines c as the combined data over two locations. This means that these two lines could be considered as the best general combiners for this trait. For ear diameter, results in Table 4 showed that the parental inbred line P_1 (Gm. 142) exhibited positive and significant (g^i) towards increasing ear diameter, as the combined data over two locations.

Table (4): Estimates of GCA effects (g^i) for the eight inbred lines of maize for days to 50% silking, plant height, ear height, ear length, ear diameter and grain yield at combined data over two locations (Gemmaiza and Sids), during 2016 season.

Parents		Days to 50 % silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Grain yield (ard/fad)
P1 (Gm. 142)		0.56**	20.13**	13.44**	-0.29	0.06*	2.40**
P2 (Gm. 224)		-0.19	0.13	1.04	-0.59**	0.00	-0.56
P3 (Gm. 233)		-0.40*	2.01	0.42	-0.12	-0.05	-1.71**
P4 (Gm. 152)		-0.11	-3.62**	-2.19	0.57**	0.01	-1.83**
P5 (Gm. 297)		-0.28	-6.02**	-2.50*	-0.11	-0.02	1.08*
P6 (Gm. 330)		0.31	-3.83**	-2.81*	0.55**	0.01	0.42
P7 (Gm. 201)		-0.13	-10.18**	-5.94**	-0.27	0.00	-1.29**
P8 (Gm. 303)		0.24	1.38	-1.46	0.26	-0.02	1.49**
LSD gi	0.05	0.34	2.63	2.35	0.36	0.06	0.86
	0.01	0.44	3.42	3.05	0.47	0.07	1.12
LSD (gi –gj)	0.05	0.51	3.98	3.56	0.55	0.09	1.30
	0.01	0.67	5.16	4.62	0.71	0.11	1.69

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

This means that this line (Gm. 142) could be considered as the best general combiner for this trait. For grain yield/fad, results in Table (4) showed that three parental inbred lines namely: P_1 (Gm. 142), P_5 (Gm. 297) and P_8 (Gm. 303) showed significant or highly significant positive (g^i), as the combined data over two locations, indicating that these inbred lines could be considered as the best combiners for increasing grain yield. Similar results were reported by Soliman and Osman (2006), Sultan *et al.* (2012 and 2013), Attia *et al.* (2013 and 2015) and Abdel-Moneam *et al.* (2014a, b, c).

Table (5): Estimates of SCA effects (s^ij) for the 28 F_1 crosses of maize for days to 50% silking, plant height, ear height, ear length, ear diameter and grain yield at combined data over two locations (Gemmaiza and Sids), during 2016 season.

Crosses		Days to 50 % silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Grain yield (ard/fad)
P_1 x P_2		-0.41	-7.56*	-11.44**	0.25	0.16*	2.78**
P_1 x P_3		0.43	-13.81**	-3.94	0.34	0.02	4.44**
P_1 x P_4		-0.24	8.69**	3.66	0.18	-0.09	-6.19**
P_1 x P_5		-0.45	2.96	0.85	-0.21	-0.03	-3.58**
P_1 x P_6		-1.66**	-10.48**	-7.59**	-0.57	0.04	1.20*
P_1 x P_7		1.78**	5.25	1.16	-1.00**	-0.07	-3.30**
P_1 x P_8		0.53	14.94**	17.31**	1.02**	-0.03	4.63**
P_2 x P_3		-2.32**	-8.18**	-2.17	0.20	-0.11	-1.10
P_2 x P_4		-1.11**	4.32	2.93	0.49	-0.12	5.31**
P_2 x P_5		-0.45	-8.29**	-2.38	-0.33	-0.04	0.76
P_2 x P_6		2.72**	8.90**	4.81	-0.59	0.05	-2.72**
P_2x P_7		0.03	9.00**	7.31**	0.21	0.01	0.04
P_2x P_8		1.53**	1.82	0.95	-0.22	0.06	-5.07**
P_3 x P_4		2.47**	9.32	2.31	-0.52	0.22**	-0.57
P_3 x P_5		1.64**	12.34**	7.62**	-0.18	0.07	1.19
P_3 x P_6		0.68	10.77**	13.56**	0.16	-0.08	-0.05
P_3x P_7		-1.64**	-2.25	-4.57	0.23	0.08	0.79
P_3x P_8		-1.26**	-8.18**	-12.8**	-0.23	-0.20**	-4.70**
P_4 x P_5		-2.28**	-4.54	0.22	0.51	0.01	-0.26
P_4 x P_6		0.39	1.40	-1.34	-0.85*	-0.01	-0.63
P_4x P_7		0.82*	-17.25**	-9.46**	0.34	-0.03	0.44
P_4x P_8		-0.05	-1.93	1.68	-0.14	0.01	1.90
P_5 x P_6		0.93*	-10.58**	-12.28**	0.73	-0.09	-1.62
P_5 x P_7		0.62	4.52	8.35**	-0.60	-0.02	0.29
P_5 x P_8		-0.01	3.59	-2.38	0.09	0.09	3.21**
P_6 x P_7		-1.97**	5.46	2.41	1.24**	0.02	2.77**
P_6 x P_8		-1.09**	-5.48	0.43	-0.12	0.06	1.05
P_7 x P_8		0.35	-4.75	-5.19	-0.40	0.00	-1.02
L S D Sij	0.05	0.75	5.82	5.21	0.80	0.13	1.91
L S D Sij	0.01	0.98	7.56	6.76	1.04	0.16	2.48
L S D Sij- SKI	0.05	1.15	8.89	7.95	1.23	0.19	2.91
L S D Sij- SKI	0.01	1.49	11.54	10.32	1.59	0.25	3.78

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

3.4 Specific combining ability effects (s^ij)

Estimation of SCA effects (s^ij) for the six studied traits as the combined data over the two locations (Gemmaiza and Sids) are presented in Table (5). Regarding days to 50% silking, there were eight crosses; No. 5, 8, 9, 17, 18, 19, 26 and 27 at combined data over both locations exhibited desirable (s^ij) towards earliness, where they recorded highly significant and negative SCA effects for this trait. With respect to ear height, result in Table 5 cleared that, out of the studied 28 crosses, there were five crosses (P_1 x P_2, P_1 x P_6, P_3x P_8, P_4x P_7 and P_5 x P_6) at combined data over both locations, exhibited desirable (s^ij) towards lower ear position, where they showed highly significant and negative SCA effects for this trait. With respect to ear length, results in Table (5) showed that, out of the studied 28 crosses, there were two crosses No. 7 and 26 (P_1 x P_8 and P_6 x P_7) at combined data over both locations, exhibited desirable (s^ij) towards increasing ear length, where they showed highly significant and positive SCA effects for this trait. Regarding to ear diameter, results in Table 5 showed that, out of the studied 28 crosses, there were two crosses No. 1 and 14 (P_1 x P_2 and P_3 x P_4) at combined data over both locations, exhibited desirable ($s^{\wedge}$ij) towards increasing ear diameter, where they showed significant or highly significant and positive SCA effects for this trait. For grain yield, result in Table 8 showed that, out of the studied 28 crosses, there were seven crosses No. 1, 2, 5, 7, 9, 25 and 26 (P_1 x P_2, P_1 x P_3, P_1 x P_6, P_1 x P_8, P_2 x P_4, P_5 x P_8 and P_6 x P_7) at combined data over both locations, exhibited desirable (s^ij) towards high grain yield, where they recorded significant or highly significant positive SCA effects for this trait. Similar results were reported by other authors such as, Sultan *et al.* (2012 and 2013), Attia *et al.* (2013 and 2015) and Abdel-Moneam *et al.* (2014a, b, c).

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