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DIALLEL ANALYSIS OF GRAIN YIELD AND SOME AGRONOMIC TRAITS IN NEW SEVEN YELLOW MAIZE INBRED LINES

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ABSTRACT: *Diallel crosses, without reciprocals, among seven new yellow maize inbred lines derived from different maize populations were made in 2012 season at Giza Agric. Res. Station. The resultant 21 crosses along with two commercial check hybrids, i.e. SC 162 and SC 168 were evaluated in a randomized complete block design with four replications conducted at three locations, i.e. Sakha, Sids and Mallawy Agric. Res. Stations in 2013 season. The results indicated that mean squares due to GCA and SCA were highly significant for all traits studied, i.e. days to 50 % silking, plant and ear heights, ear length, ear diameter, No. of rows per ear, No. of kernel per row and grain yield per feddan indicating the importance of both additive and non-additive gene effects in the inheritance of the traits studied. The ratio of general to specific combining ability mean squares (δ^2 GCA/ δ^2 SCA) exceeded unity for all traits studied, indicating that the additive gene action was more important than non-additive gene action in the inheritance of traits studied. The parental inbred lines P_1, P_2, and P_6 had significant positive GCA effects for grain yield. For other traits the best general combiner were P_6 for earliness, and P_3 and P_4 for both shorter plants and lower ear placement. The best cross combinations for earliness were P_1 X P_4 and P_4 X P_6. Concerning plant and ear heights, the cross P_3 X P_5 had the shortest plants with the lowest ear placement. The cross P_4 X P_6 had the best SCA effects for grain yield. The crosses P_1xP_2, P_2xP_6 and P_5xP_6 significantly outyielded the check hybrid SC 168. These promising crosses may be released as commercial hybrids by maize research program after further evaluation.*

Key words: *Diallel crosses, yellow maize, (GCA and SCA), Promising crosses, combining ability.*

INTRODUCTION

Maize is a major crop for both livestock feed and human nutrition. It contributes substantially to the total cereal grain production of the world and also occupies a relevant place in the world economy and trade as a food, feed, and an industrial grain crop. Maize products are used in the manufacture of diverse commodities including glue, soap, paint, insecticides, toothpaste, shaving cream, rubber tires, rayon, molded plastics, fuels, and others (White and Johnson, 2003). In Egypt, 2013 growing season, it was grown in about 1,724,000 million feddan (one feddan = 4200 m2) which produce about 5,788,000 million tons of grain with an average yield of 23.98 ardab per feddan (one ardab = 140 kg) (Economic Affairs Sector, Ministry of Agriculture and Land Reclamation).

Much efforts are devoted to increase maize productivity through genetical improvement. To carry out a successful breeding program, enough knowledge about the type of gene action and relative amounts of genetic variance components and their interaction by environments for the traits in question. One of the most informative methodology in this concern is the diallel analysis system which is widely and extensively used for estimating types of gene action. The two main genetic parameters of diallel analysis are GCA and SCA which are essential in developing breeding strategies. Furthermore, the magnitude of genetic components for a certain trait would depend mainly upon the environmental fluctuations under which the breeding populations will be tested. Therefore, much effort has been devoted by corn breeders to estimate the interactions between genetic components and environments.

In this concern, 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), Sibiya *et al.* (2011) and Abd El-Mottalb *et al.* (2013) 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 the environments than the additive effects for grain yield.

This investigation was aimed at: 1) estimating the magnitude of both general (GCA) and specific combining ability (SCA) effects and their interaction with different locations for the traits studied, i.e. days to 50 % silking, plant and ear heights, ear length, ear diameter, No. of rows per ear, No. of kernel per row and grain yield per feddan and 2) identifying the best promising crosses for possible release as commercial hybrids.

MATREIALS AND METHODS

The field work of this research was carried out on two successive summer seasons of 2012 and 2013 at Sakha, Sids and Mallawy Agric. Res. Stn., Field Crops Res. Inst. (FCRI), Agricultural Research Center (ARC), Egypt.

The materials consisted of seven yellow maize inbred lines developed at Giza Res., Stn. namely P_1 to P_7 were chosen based on genetic diversity and flowering information. In 2012 season, the seven inbred lines were crossed in a half- diallel mating design to produce 21 F_1 crosses. In 2013 season, the resultant 21 F_1 crosses along with two commercial single crosses as checks hybrids, namely SC 162 and SC 168, were evaluated in a randomized complete block design (RCBD) with four replications conducted at three locations, *i.e*. Sakha, Sids and Mallawy Res. Stns. Plot was one row, 6 m long and 0.8 m apart. Planting was made in hills spaced at 25 cm along the row. All recommended agronomic practices for maize production were applied at the proper time. Data were recorded for days to 50% silking (DTS), calculated as the number of days from planting date to date when 50% of plants in the plot produced visible silks; Plant height (PH), measured in cm on 10 competitive plants plot^{-1} as the distance from soil surface to the point of flag leaf insertion; Ear height (EH), measured in cm on 10 competitive plants plot^{-1} as the distance from soil surface to the ear leaf; Ear length (EL) (cm), Ear diameter (ED) (cm), No. of rows per ear^{-1} (RE), and No. of kernels per row^{-1} (KR) were measured as an average of 10 randomly selected ears plot^{-1}. Grain yield per feddan (GYPF) was estimated on a per plot basis then adjusted to 15.5% grain moisture and expressed in ardab per feddan (ard/fed), one ardab = 140 kg of maize grains and one feddan =4200 m^2. The statistical analysis of RCBD was performed based on plot means according to Steel and Torrie (1980). Bartlett test was used to test the homogeneity of error variances for all studied traits. The combined statistical analysis across locations was conducted according to Meintosh (1983) with genotypes considered as fixed and locations as fixed variables. The combining ability analysis was done following Griffings (1956) Method 4 Model 1 to estimate general (GCA) and specific (SCA) combining ability variances and effects.

RESULTS AND DISCUSSION

Analysis of variance

The combined analysis of variance for all traits studied, i.e. days to 50 % silking, plant and ear heights, ear length, ear diameter, No. of rows per ear, No. of kernel per row and grain yield per feddan is presented in Table. 1. Highly significant differences were obtained among the three locations for all traits studied except for No. of rows ear^{-1} and No. of kernels/row^{-1}, indicating that the three locations differed in their environmental conditions. Crosses mean squares were found to be highly significant for all traits, indicating that wide diversity exist between the parental materials used in this investigation. Mean squares due to crosses × locations interactions were also highly significant for all traits studied except for ear diameter, no. of rows/ear and no. of kernels/row, indicating that these crosses behaved differently from location to another. The absence of interaction (not significant) indicate that the crosses performed similarly at the test locations. Mean squares due to GCA and SCA were highly significant for all traits studied, indicating that both additive and non-additive gene effects were important in the inheritance of the studied traits. Variances due to the interaction between location and GCA were either significant or highly significant for all traits studied, except ear diameter, no. of rows/ear and no. of kernels/row, 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. Similar results were obtained by El-Hosary (1989), Barakat *et al*. (2003) and Osman *et al. (*2012*)*, They found that the interactions between both types of combining abilities and the environment were highly significant. Variances due to SCA × location were not significant for all studied traits, except for plant height and grain yield per feddan where variances were significant. The absence of interactions between locations and each of GCA and SCA indicated that GCA and SCA variances did not differ from one location to another.

High GCA/SCA ratio (Table.1), which exceed the unity for all traits, indicating the importance of additive and additive by additive gene effects for these traits. Similar results were reported by Abd El-Aty and Katta (2002) and Bujak *et al.* (2006), they 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.

The ratio of SCAxL/ SCA was higher than the ratio of GCAxL/ GCA for all the traits studied, except for days to 50% silking and no. of rows/ear indicating that non-additive genetic effects were more influenced by the environmental conditions than additive genetic effects for these traits. These results are in 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. days to 50% silking and no. of rows/ear. 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 two check hybrids for all traits studied are presented in Table. 2. For no. of days to 50% silking, seven crosses were significantly earlier than the latest check hybrid SC 162 (63.25 day). While, only three crosses were significantly earlier than the earlier check hybrid SC 168 (62.58 day). These crosses are P_1xP_7, P_3xP_7 and P_6xP_7. While, the cross P_4xP_7 was the latest one. With respect to plant and ear heights, twenty crosses were significantly shorter than the check hybrid SC 162. While, only three crosses; P_3xP_4, P_3xP_5 and P_4xP_5 gave the least values than the shorter check hybrid, i.e. SC 168, for plant height. However, thirteen crosses gave lower values than the shortest check hybrid, i.e. SC 168, for ear height. The highest values for both traits were recorded by the cross P_1xP_2 (252.83/ 141.50 cm). Short plants would allow for increasing plant population density, consequently increasing grain and green yield potentialities, As well as minimizing the hazard of stalk lodging.

TABLE 1

Table (2). Means of traits studied for 21 single crosses and two checks based on combined data across three locations (Sakha, Sids and Mallawy) in 2013 season.

Crosses	DTS	PH	EH	EL	ED	RE	KR	GYPF
P_1 X P_2	65.00	252.83	141.50	19.32	4.65	13.75	39.60	*35.69*
P_1 X P_3	61.83	243.17	135.58	22.17	4.90	14.35	43.45	*31.35*
P_1 X P_4	61.75	239.50	130.67	21.77	4.93	14.88	43.58	*28.45*
P_1 X P_5	62.83	252.83	141.42	22.70	5.02	14.60	43.48	*32.57*
P_1 X P_6	64.08	242.75	141.75	21.33	4.88	14.45	41.78	*34.58*
P_1 X P_7	61.00	231.83	126.42	22.37	4.90	14.40	42.50	*27.39*
P_2 X P_3	62.83	251.25	141.42	20.42	4.83	13.90	42.48	*32.08*
P_2 X P_4	63.33	252.33	141.75	20.18	4.88	14.00	42.30	*31.47*
P_2 X P_5	64.58	259.42	151.42	21.52	4.98	14.15	42.03	*34.31*
P_2X P_6	64.25	246.17	140.42	20.10	4.85	14.30	40.03	*35.94*
P_2 X P_7	62.67	233.50	131.83	21.53	4.92	13.79	42.43	*33.27*
P_3 X P_4	67.50	174.00	97.83	14.38	4.35	14.10	32.00	*7.03*
P_3 X P_5	67.75	181.58	94.00	15.93	4.55	13.45	33.85	*7.84*
P_3 X P_6	62.08	237.67	132.17	22.28	5.02	14.50	42.85	*27.22*
P_3 X P_7	61.08	220.17	121.92	20.25	4.82	14.65	40.58	*21.21*
P_4 X P_5	67.42	168.92	97.00	15.10	4.32	13.50	31.45	*7.30*
P_4 X P_6	61.83	233.50	128.67	22.35	5.03	15.05	44.49	*34.84*
P_4 X P_7	68.25	207.42	116.33	14.45	4.13	13.45	28.75	*7.10*
P_5 X P_6	62.92	237.08	133.92	21.77	4.95	14.30	41.30	*36.56*
P_5 X P_7	62.67	219.17	120.75	19.83	4.75	14.35	39.63	*21.99*
P_6 X P_7	61.25	226.08	128.58	22.30	4.75	14.00	44.23	*29.83*
Checks:								
SC. 162	63.25	267.33	150.08	23.65	4.90	13.70	44.58	*34.26*
SC. 168	62.58	226.92	141.25	22.34	5.00	14.75	44.60	*32.23*
LSD. 0.05	*1.09*	*10.04*	*6.89*	*1.42*	*0.18*	*0.54*	*2.76*	*3.13*

For ear length, none of the crosses significantly surpassed any of check hybrids. While, five crosses; i.e. P_1xP_5, P_1xP_7, P_3xP_6, P_4xP_6 and P_6xP_7 did not differ significantly from the better check hybrid (SC 162).

Regarding ear diameter, none of the crosses significantly surpassed the values of the check hybrids SC 162 and SC 168. While, the fourteen crosses; i.e., P_1xP_3, P_1xP_4, P_1xP_5, P_1xP_6, P_1xP_7, P_2xP_3, P_2xP_4, P_2xP_5, P_2xP_6, P_2xP_7, P_3xP_6, P_3xP_7, P_4xP_6 and P_5xP_6 did not differ significantly from the better check hybrids; i.e., SC 168. For No. of rows/ear, none of the crosses significantly surpassed the check hybrid SC 168. However, eleven crosses significantly surpassed the cheek hybrid SC 162 for this trait. For the trait of number of kernels per row, the mean values ranged from 28.75 kernels for P_4 X P_7 to 44.49 kernels for P_4 X P_6. None of the crosses significantly exceeded either of check hybrids. However, eleven crosses possessed similar performance to that of the check hybrids, while the remaining ten crosses possessed significantly inferior performance.

Concerning grain yield, eleven crosses gave similar yields to that of the highest yielding check hybrid SC 162, since differences were not significant. The crosses P_1xP_2, P_1xP_3, P_1xP_5, P_1xP_6, P_2xP_3, P_2xP_4, P_2xP_5, P_2xP_6, P_2xP_7, P_4xP_6 and P_5xP_6. exhibited significant increase for one or more traits contributing to grain yield Table.2. Meanwhile, three of these crosses significantly outyielded the check hybrid SC 168. These are P_1xP_2, P_2xP_6 and P_5xP_6. They gave the highest yield values; i.e., 35.69, 35.94 and 36.56 ard/fed., respectively. These three crosses may be released as commercial hybrids after further testing and evaluation.

Combining ability effects:

A. General combining ability :

Estimates of GCA effects ($\hat{g}_i$) of the parental inbred lines for each trait are presented in Table. 3. From breeder's point of view, significant positive values would be required for all traits studied, except for days to 50% silking and plant and ear heights where significant negative values are most required. Accordingly, the parental inbred line P_6 would the best combiner for earliness, since it was the only inbred to posses significant negative estimates of GCA effects ($\hat{g}_i$). With respect to plant and ear heights, significant negative ($\hat{g}_i$) effects were obtained for the inbred lines P_3, P_4 and P_5 (-13.36, -19.79 and -11.12 for plant height, and -9.44, -11.57 and -6.32, for ear height, respectively) So, these three parents are characterized by additive genes for shorter plants and lower ear placement. On the other hand, the parental inbred lines P2 and P1 exhibited significant positive ($\hat{g}_i$) effects toward tall plants and high ear placement. Also, the inbred line P6 exhibited significant positive ($\hat{g}_i$) effects for ear height. The parental inbred lines P1 and P6 showed significant positive ($\hat{g}_i$) effects for ear length. While, none of the parental inbred lines exhibited significant positive estimates for ear diameter, No. of rows/ ear and no. of kernels/ row.

With respect to grain yield (ard /fed), highly significant positive ($\hat{g}_i$) effects were obtained by P_1, P_2 and P_6 (6.12, 8.66 and 7.91, respectively), indicating that these inbred lines possess favorable additive genes for yield which can be utilized in the hybrid breeding program.

B. Specific combining ability :

Specific combining ability effects were only estimated whenever significant SCA variances were obtained. Specific combining ability effects of 21 crosses for all traits studied are presented in Table. 4.

With regard to days to 50% silking, plant height and ear height, negative SCA effects are desired, while for other traits positive effects are desired.

TABLE 3

Table. (4). Specific combining ability (SCA) effects for all traits studied across three locations (Sakha, Sids and Mallawy) in 2013 season.

Cross	DTS	PH	EH	EL	ED	RE	KR	GYPF
P1 X P2	2.29*	-18.11	-11.94	-3.09*	-0.34	-0.45	-4.86	-5.67
P1 X P3	-0.96	9.76	7.22	1.29	0.04	-0.06	1.72	5.20
P1 X P4	-2.44*	12.53	4.44	2.33	0.24	0.46	4.37	4.41
P1 X P5	-0.97	17.19	9.94	1.54	0.14	0.31	2.44	3.65
P1 X P6	2.63*	-13.74	-3.13	-2.49	-0.17	-0.29	-3.85	-6.02
P1 X P7	-0.56	-7.64	-6.53	0.43	0.08	0.05	0.19	-1.58
P2 X P3	-1.19	11.33	6.86	0.85	0.01	-0.01	1.85	3.38
P2 X P4	-2.09	18.84	9.32	2.06	0.23	0.09	4.20	4.88
P2 X P5	-0.46	17.26	13.74	1.67	0.14	0.36	2.09	2.84
P2X P6	1.56	-16.84	-10.66	-2.40	-0.17	0.06	-4.50	-7.21*
P2 X P7	-0.12	-12.49	-7.31	0.91	0.13	-0.05	1.22	1.77
P3 X P4	1.99	-21.96*	-9.51	-2.21	-0.18	-0.02	-3.37	-4.35
P3 X P5	2.63*	-23.04*	-18.59**	-2.39	-0.16	-0.55	-3.35	-8.42**
P3 X P6	-0.69	12.19	6.17	1.31	0.12	0.05	1.06	-0.72
P3 X P7	-1.79	11.71	7.86	1.15	0.16	0.59	2.10	4.91
P4 X P5	0.89	-29.27**	-13.46	-1.78	-0.23	-0.50	-3.23	-6.85*
P4 X P6	-2.34*	14.46	4.81	2.81	0.30	0.60	5.23	9.01**
P4 X P7	3.98**	5.39	4.41	-3.21*	-0.35*	-0.61	-7.20*	-7.09*
P5 X P6	-0.87	9.38	4.81	0.51	0.04	-0.03	0.20	5.85
P5 X P7	-1.22	8.48	3.57	0.45	0.08	0.41	1.84	2.92
P6 X P7	-0.29	-5.46	-1.99	0.26	-0.10	-0.39	1.85	-0.92
S.E. $\hat{S}_{ij}$	1.12	10.25	7.03	1.45	0.18	0.55	2.82	3.20
S.E. $\hat{S}_{ij} - \hat{S}_{ik}$	1.73	15.88	10.89	2.24	0.28	0.85	4.37	4.96
S.E. $\hat{S}_{ij} - \hat{S}_{kl}$	1.50	13.75	9.43	1.94	0.24	0.73	3.78	4.29

As for days to 50% silking, the two crosses P_1xP_4 and P_4xP_6 expressed significant negative ($\hat{S}_{ij}$) effects. So, it could be useful in areas which require early maturity hybrids. The other crosses had either significant positive or insignificant ($\hat{S}_{ij}$) effects.

Regarding plant height, three crosses; namely P_3 x P_4 (-21.96*), P_3 x P_5 (-23.04*) and P_4 x P_5 (-29.27**); gave significant and negative ($\hat{S}_{ij}$) effects.

For ear height, only one cross, i.e. P_3xP_5, expressed highly significant negative ($\hat{S}_{ij}$) effects. Therefore, this cross was considered the best among the studied crosses for ear height. This may suggest the immediate use to decrease lodging, and in turn, increase the yield potentiality.

None of the crosses expressed significant positive ($\hat{S}_{ij}$) effects for ear length, ear diameter, No. of rows/ear and No. of kernels/row.

With regard to grain yield, only one cross, i.e. P_4xP_6, expressed significant positive ($\hat{S}_{ij}$) effects estimated at a value of (9.01**). This cross was among the 5 best performing crosses with a mean performance for grain yield of 34.84 ard/fed. It represented a parental combination of (high x low) GCA effects. Which suggests that additive x dominance genetic interaction was involved in this cross. Hence, this cross may be considered for release as a commercial hybrid 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).

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تحليل الهجن الدائرية لصفة المحصول وبعض الصفات الزراعية لسبعة سلالات جديدة من الذرة الشامية الصفراء

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الملخص العربى

تم إجراء جميع الهجن الممكنة (فى إتجاه واحد) بين 7 سلالات جديدة من الذرة الشامية الصفراء والتى تم عزلها من عشائر مختلفة من الذرة الشامية وذلك بمحطة البحوث الزراعية بالجيزة فى الموسم الزراعى 2012.

تم تقييم هجن الجيل الأول وعددها 21 هجين مع هجينين تجاريين للمقارنة هما هـ.ف . 162 ؛ هـ.ف . 168 فى تجربة ذات تصميم قطاعات كاملة العشوائية من اربع مكررات اقيمت فى ثلاث محطات للبحوث الزراعية بسخا، سدس و ملوى فى الموسم الزراعى 2013 حيث تم دراسة الصفات التالية : عدد الأيام حتى طرد 50% من النورة المؤنثة، إرتفاع النبات والكوز، طول الكوز، قطر الكوز، عدد صفوف الكوز، عدد حبوب الصف، صفة المحصول بالأردب / فدان ويمكن إيجاز أهم النتائج فيما يلى :

1. أظهرت النتائج وجود اختلافات عالية المعنوية بالنسبة لكل من القدرة العامة والخاصة على التالف لكل الصفات موضع الدراسة ، وأظهرت نسبة تباين القدرة العامة على الائتلاف الى تباين القدرة الخاصة على التآلف أهمية نسبية اكبر لفعل الجين المضيف فى وراثة جميع الصفات محل الدراسة.
2. تشير النتائج إلى أن السلالات الأبوية P_1، P_2 وP_6 كانت أفضل السلالات من حيث تأثيرات القدرة العامة على التآلف لصفة المحصول والسلالة الأبوية P_6 لصفة التبكير ، بينما كانت السلالات الأبوية P_1، P_2 وP_6 لقصر طول النبات وانخفاض موقع الكوز.
3. تشير نتائج القدرة الخاصة على التالف أن الهجين P_6xP_4 قد أظهر قدرة خاصة عالية المعنوية لصفة محصول الحبوب وكذلك الهجين(P_6xP_5) لكل من صفتى قصر النبات وانخفاض موقع الكوز ثم الهجينين (P_6xP_4)، (P_4xP_1) لصفة التبكير فى النضج.
4. تفوقت ثلاث هجن (P_2xP_1) و (P_6xP_2) و (P_6xP_5) في محصول الحبوب للفدان تفوقا معنويا على هجين المقارنة (هـ.ف 168). هذا ويمكن إدخال هذه الهجن المبشرة فى مراحل التقييم المختلفة لإطلاقها كهجن تجارية جديدة مستقبلا.

Table. (1). Combined analysis of variance for the traits studied over three locations (Sakha, Sids and Mallawy) in 2013 season.

S.O.V	d.f	Mean squares							
		DTS	PH	EH	EL	ED	RE	KR	GYPF
Locations(Loc.)	2	633.41**	59969.78**	59723.87**	118.94**	7.18**	1.04	0.50	1553.02**
Rep./(Loc.)	9	5.47	819.56	311.06	2.14	0.13	2.49	19.29	25.26
Crosses	20	63.71**	8169.97**	3004.81**	89.85**	0.74**	2.38**	250.29**	1301.32**
Crosses X Loc.	40	2.87*	424.31**	183.51**	4.82*	0.06	0.47	12.07	51.81**
GCA	6	76.90**	17379.12**	6705.97**	149.03**	1.00**	2.51**	357.93**	3206.83**
SCA	14	58.04**	4223.18**	1418.60**	64.49**	0.63**	2.32**	204.16**	484.68**
GCA X Loc.	12	4.24**	827.46**	394.31**	6.50*	0.05	0.77	17.08	66.88**
SCA X Loc.	28	2.28	251.53*	93.16	4.11	0.06	0.34	9.92	45.35**
Pooled error	180	1.87	157.54	74.12	3.15	0.05	0.45	11.94	15.35
GCA/SCA		1.32	4.12	4.73	2.31	1.59	1.08	1.75	6.62
GCA X Loc./GCA		0.06	0.05	0.06	0.04	0.05	0.31	0.05	0.02
SCA X Loc./SCA		0.04	0.06	0.07	0.06	0.10	0.15	0.05	0.09

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

Table 3. Estimates of general combining ability (GCA) effects of each parental line for the characters studied across three locations (Sakha, Sids and Mallawy) in 2013 season.

Inbred	DTS	PH	EH	EL	ED	RE	KR	GYPF
P1	-1.09	17.66**	9.45**	1.81*	0.12	0.26	2.72	6.12**
P2	0.14	24.17**	15.65**	0.50	0.09	-0.25	1.61	8.66**
P3	0.22	-13.36**	-9.44**	-1.03	-0.04	-0.03	-1.12	-6.54**
P4	1.62**	-19.79**	-11.57**	-2.47**	-0.21*	-0.03	-3.64*	-8.65**
P5	1.23*	-11.12*	-6.32	-0.75	-0.02	-0.15	-1.81	-3.78*
P6	-1.11*	9.73	7.08*	1.91**	0.14	0.30	2.78	7.91**
P7	-1.01	-7.29	-4.85	0.03	-0.08	-0.10	-0.54	-3.72*
S.E. $\hat{g}_i$	0.57	5.20	3.56	0.73	0.09	0.28	1.43	1.62
S.E. $\hat{g}_i - \hat{g}_i$	0.87	7.94	5.44	1.12	0.14	0.42	2.19	2.48

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