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DIALLEL ANALYSIS AMONG NEW YELLOW MAIZE INBRED LINES FOR GRAIN YIELD AND OTHER AGRONOMIC TRAITS

H.A. ABOYOUSEF, A.M. ABU SHOSHA, H.M. EL-SHAHED and M.M.B. DARWICH

Maize Research Department, Field Crops Research Institute, ARC, Egypt
Corresponding author: haboyosef@yahoo.com

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ABSTRACT

Yellow maize (*Zea mays* L.) is one of the important sources of animal feed in Egypt. The national maize programmes uses conventional crop breeding methodology, which depends on the development inbred lines of maize from open pollinated varieties or other heterogeneous sources. The objective of this study was to assess the general and specific combining ability for nine yellow maize inbred lines and their crosses for grain yield and other morphological traits, under Egyptian conditions. Nine new yellow maize inbred lines, derived from different yellow maize sources, were crossed in a half diallel mating scheme in 2020 summer season, at Gemmeiza Agricultural Research Station Gharbia Governorate in Egypt. The resulting 36 crosses, along with two commercial check hybrids (SC 168 and Pioneer SC 3444), were evaluated at three locations, i.e. Gemmeiza, Mallawy and Sids Agricultural Research Stations of the Agricultural Research Center (ARC), in 2021 summer season in Egypt. Overall, the additive gene effects played a major role in the inheritance of days to 50% silking, plant and ear heights; while the non-additive gene effects were mostly responsible for controlling the inheritance of grain yield. The parental inbred lines (P1 and P2) possessed significant ($P<0.05$) negative estimates of GCA effects for days to 50% silking towards earliness. The best general combiners were inbred lines P2 and P6 for plant and ear height, and these inbred lines would be good combiners for breeding to short hybrids and low ear placement. Crosses (P1xP9 and P3xP4) had desirable SCA effects and significantly out-yielded the two checks.

Key Words: Additive gene effects, combining ability

RÉSUMÉ

Le maïs jaune (*Zea mays* L.) est l'une des principales sources d'alimentation animale en Égypte. Les programmes nationaux de maïs utilisent une méthodologie conventionnelle de sélection des cultures, qui dépend du développement de lignées consanguines de maïs à partir de variétés à pollinisation libre ou d'autres sources hétérogènes. L'objectif de cette étude était d'évaluer la capacité de combinaison générale et spécifique de neuf lignées consanguines de maïs jaune et de leurs croisements pour le rendement en grain et d'autres caractères morphologiques, dans les conditions égyptiennes. Neuf nouvelles lignées consanguines de maïs jaune, dérivées de différentes sources de maïs jaune, ont été croisées dans un schéma d'accouplement semi-diallèle au cours de la saison estivale 2020, à la station de recherche agricole de Gemmeiza, dans le gouvernorat de Gharbia, en Égypte. Les 36 croisements résultants, ainsi que deux hybrides témoins commerciaux (SC 168 et Pioneer SC 3444), ont été évalués à trois endroits, à savoir les stations de recherche agricole de Gemmeiza, Mallawy et Sids du Centre de recherche agricole (ARC), au cours de la saison estivale 2021 en Égypte. Dans l'ensemble, les effets additifs des gènes ont joué un rôle majeur dans l'hérédité des jours à 50 % d'apparition des soies, des hauteurs de plantes et d'épis ; tandis que les effets génétiques non additifs étaient principalement responsables du contrôle de l'hérédité du rendement en grain. Les lignées consanguines parentales (P1 et P2) possédaient des estimations négatives significatives (P <0,05) des effets de la GCA pendant des jours jusqu'à 50 % de soyage vers la précocité. Les meilleurs combineurs généraux étaient les lignées consanguines P2 et P6 pour la hauteur des plantes et des épis, et ces lignées consanguines seraient de bons combinateurs pour la reproduction d'hybrides courts et le placement des oreilles basses. Les croisements (P1xP9 et P3xP4) ont eu des effets SCA souhaitables et ont nettement dépassé les deux contrôles.

Mots Clés : Effets génétiques additifs, capacité de combinaison

INTRODUCTION

Maize (*Zea mays* L.)is one of the most important cereal crop in Egypt; occupying and area of about 2.8 million feddan (equivalent to 1.18 hectares). The national maize research programme of Egypt has an optimistic plan to release early hybrids to avoid irrigation water and yet provide high grain yields. Yellow maize is one of the important sources of animal feed in Egypt, where the country imports more than five million metric tonnes per year. The national programmer mainly uses conventional crop breeding methodology, which depends upon the development inbred lines of maize from open pollinated varieties or other heterogeneous sources.

Diallel mating design method is used to analyses crosses or parents with crosses for general combining ability (GCA), due to the additive type of gene action; and specific combining ability (SCA), due to non-additive type of gene action (Griffing, 1956). Hallauer and Miranda (1981) stated that both GCA and SCA effects should be taken into consideration when planning for maize breeding programmes to produce and release new inbred lines and crosses. Several researchers studied the general and specific combining ability; and their roles in the inheritance of grain yield and other agronomic characters. Sedhom *et al.* (2007) and Sibiya *et al.* (2011) found out that GCA was more important in determining grain yield, days to mid silking, and plant and ear height than SCA. On the contrary, Werle *et al.* (2014) and Bertagna *et al.* (2018) reported that SCA played a major role in the inheritance of grain yield and other agronomic traits. The objective of this study was to assess the general and specific combining ability for yellow maize inbred lines and their crosses for grain yield and other morphological traits under Egyptian conditions.

MATERIALS AND METHODS

Nine yellow maize inbred lines (Table 1) were crossed in a-half diallel fashion, excluding the reciprocals, during the summer season of 2020 at Gemmeiza Research Station, ARC, Egypt. The resulting 36 F_1 crosses, along with two commercial checks i.e., SC168 and Pioneer SC 3444, were evaluated at three locations; namely Gemmeiza (Gm), Sids (Sd) and Mallawy (Mal) Research Stations in 2021 season. The experiment was laid out in a randomised complete block design (RCBD), with three replications. Each replication contained 38 plots and each plot consisted of one ridge with 6 m long and spacing of 0.25 m between hills within each ridge; and 0.80 m between ridges. Data were recorded on

TABLE 1. Codes, name and origin of nine yellow maize inbred lines used in the study

Code	Name	Origin
P_1	Gm.6038	Gm. Y. Pop.
P_2	Gm.2032	Pop. 31- 69 (Cimmyt)
P_3	Gz.656	Cargill-922
P_4	Gm.2022	Gm. Y. Pop.
P_5	Gm.6052	Pool -18-627M
P_6	Gm.6013	Gm. Y. Pop.
P_7	Gm.6674	Pool -18-627M
P_8	Gm.646	Pop. 59 F
P_9	Gm.689	Pop. 59 F

number of days to 50% silking, plant height, ear height; and grain yield, adjusted to 15.5% grain moisture (estimated in kg plot^{-1} and converted to ardab per feddan (ard/fed) (ardab = 140 kg and feddan = 4200 m^2). The General combining ability (GCA) and Specific combining ability (SCA) were estimated according to Griffings (1956). Diallel cross analysis was designed as method 4 model 1 (fixed model). Analysis of variance for randomised complete block design according to the method outlined by Snedecor and Cochran (1980) was used for each locations. Combined analysis of variance across the three locations was carried out whenever homogeneity of variance was detected (Snedecor and Cochran 1980).

RESULTS AND DISCUSSION

The analysis of variance for the four traits and their combined data are presented in Table 2. Locations mean squares were highly significant (P< 0.01) for all the studied traits, indicating that the three locations differed in their environmental conditions. Crosses mean squares (G) were also highly significant for all the studied traits, indicating that the crosses used in this study are widely diverse at all locations and for their combined data. Mean squares due to interaction between crosses and locations were highly significant for all studied traits, revealing that the performance of the crosses was affected by change of locations. These results are in agreement with those of Sadek *et al.* (2001) and Barakat and Osman (2008), who reported that mean squares of crosses x locations were significant for most traits.

Mean performance. Mean performance for 36 F1 crosses, along with the two commercial check hybrids are presented in Table 3. For number of days from planting to 50% silking, the results showed that 27 crosses at Gemmeiza, 16 crosses at Sids, 14 crosses at Mallawy and 28 crosses for combined data were earlier than the early check SC 3444. Similarly, 8 crosses (P1 x P3, P1 x P4, P1 x P6, P2 x P3, P2 x P5, P2 x P6, P3 x P8 and P4 x P5) were significant for earliness than SC 3444 under all locations and combined data (Table 3). Therefore, the parents of these hybrids can be used to improve this trait in maize breeding programmes.

For plant height, nine crosses (P1 x P3, P1 x P6, P2 x P3, P2 x P5, P2 x P6, P2 x P7, P3 x P6, P6 x P8 and P8 x P9) at Gemmeiza location, three crosses (P1 x P3, P2 x P6 and P8 x P9) at Sids location, five crosses (P1 x P6, P2 x P3, P2x P6,P2 x P8 and P4 x P5) at Mallawy location and for nine crosses (P1 x P3, P1 x P6, P2 x P3, P2 x P5, P2 x P6, P2 x P7, P3 x P6, P4 x P5 and P8 x P9) at the combined data, showed significant values of short plants compared to the shorter check SC 168. These results indicated that, the inbred lines for these short crosses were useful for improving short plant trait.

The shortest and desired crosses for ear height were observed in five crosses (P2 x P3, P2x P5, P2 x P6, P3 x P6 and P8 x P9) at Gemmeiza location; three crosses(P2 x P6, P3 x P6 and P8 x P9) at Sids location; four crosses (P1 x P3, P1x P6, P2x P5 and P2x P6) at Mallawy location; and ten crosses (P1 x P3, P1 x P6, P2 x P3, P2 x P5, P2 x P6, P2 x P7, P3 x P6, P4 x P7, P7 x P8 and P8 x P9) for the combined data (Table 3). This means

TABLE 2. Analysis of variance of four traits of yellow maize at three locations and for their combined data in Egypt

S.O.V	d.f.		Days to 50 % silking				Plant height (cm)			
	Single	Comb	Gm	Sd	Mal	Comb.	Gm	Sd	Mal	Comb.
Location (Loc.)	-	2	-	-	-	1796.892**	-	-	-	14979.76**
Rep/loc.	2	6	4.08	55.19	8.48	22.586	386.29	550.69	187.58	374.855
Crosses (Cr.)	35	35	16.97**	10.98**	13.77**	33.267**	1423.75**	870.18**	166.69**	1797.419**
Cr x Loc.	-	70	-	-	-	4.225**	-	-	-	331.597**
Error	70	210	1.179	2.29	3.85	2.44	73.38	135.93	25.59	78.30
CV %	-	-	1.84	2.31	3.37	2.56	3.65	5.44	2.37	4.01

** significant at 0.01 level of probability

S.O.V	d.f.		Ear height (cm)				Grain yield (ard/fad.)			
	Single	Comb	Gm	Sd	Mal	Comb.	Gm	Sd	Mal	Comb.
Location (Loc.)	-	2	-	-	-	12328.08**	-	-	-	1395.400**
Rep/loc.	2	6	130.03	964.58	132.29	408.966	5.20	11.45	3.63	6.764
Crosses (Cr.)	35	35	631.47**	458.33**	61.97**	764.020**	89.14**	43.64**	26.35**	93.940**
Cr x Loc.	-	70	-	-	-	193.877**	-	-	-	32.489**
Error	70	210	47.352	122.20	19.90	63.15	9.86	7.66	4.92	6.900
CV %	-	-	5.44	10.13	4.17	6.96	13.07	9.07	9.03	10.37

** significant at 0.01 level of probability

TABLE 3. Mean performance of 36 F_1 crosses and two check yellow maize hybrids for grain yield and other traits at three locations and for combined data in Egypt

Crosses	Days to 50 % silking				Plant height (cm)			
	Gm	Sd	Mal	Comb.	Gm	Sd	Mal	Comb.
$P_1 x P_2$	59	65	58	61	229.0	208.3	213.0	216.8
$P_1 x P_3$	55	65	56	58	213.3	191.7	207.3	204.1
$P_1 x P_4$	55	65	57	59	231.3	213.3	209.7	218.1
$P_1 x P_5$	61	68	60	63	253.7	235.0	217.0	235.2
$P_1 x P_6$	55	63	56	58	202.3	210.0	204.7	205.7
$P_1 x P_7$	54	64	56	58	242.3	221.7	218.0	227.3
$P_1 x P_8$	60	66	60	62	266.0	251.7	238.3	252.0
$P_1 x P_9$	60	67	60	62	280.7	246.7	231.7	253.0
$P_2 x P_3$	55	64	55	58	201.0	201.7	204.3	202.3
$P_2 x P_4$	60	66	55	60	228.7	210.0	213.3	217.3
$P_2 x P_5$	57	63	57	59	204.3	203.3	208.7	205.4
$P_2 x P_6$	54	62	55	57	195.0	180.0	199.0	191.3
$P_2 x P_7$	59	66	56	60	199.0	195.0	210.7	201.6
$P_2 x P_8$	61	68	57	62	233.7	210.0	206.3	216.7
$P_2 x P_9$	60	66	61	62	265.3	246.7	216.3	242.8
$P_3 x P_4$	62	69	60	64	272.7	240.0	213.3	242.0
$P_3 x P_5$	60	65	59	62	264.7	236.7	214.0	238.4
$P_3 x P_6$	57	66	56	59	209.3	193.3	213.3	205.3
$P_3 x P_7$	58	65	59	61	238.3	200.0	208.0	215.4
$P_3 x P_8$	59	65	56	60	226.0	221.7	207.0	218.2
$P_3 x P_9$	60	66	58	61	255.7	230.0	217.3	234.3
$P_4 x P_5$	57	63	56	58	226.3	201.7	206.3	211.4
$P_4 x P_6$	59	66	58	61	256.3	213.3	207.0	225.6
$P_4 x P_7$	60	66	59	61	228.3	211.7	212.3	217.4
$P_4 x P_8$	62	67	62	64	230.0	198.3	215.0	214.4
$P_4 x P_9$	63	69	60	64	239.7	221.7	216.0	225.8
$P_5 x P_6$	60	66	61	62	236.3	208.3	216.0	220.2
$P_5 x P_7$	59	64	59	61	235.7	228.3	215.7	226.6
$P_5 x P_8$	58	63	59	60	247.3	206.7	217.0	223.7
$P_5 x P_9$	58	66	57	61	242.3	208.3	216.0	222.2
$P_6 x P_7$	61	67	61	63	242.0	211.7	219.7	224.4
$P_6 x P_8$	61	64	60	62	212.0	223.3	217.3	217.6
$P_6 x P_9$	61	69	61	64	242.3	205.0	214.3	220.6
$P_7 x P_8$	62	69	61	64	246.0	218.3	223.3	229.2
$P_7 x P_9$	60	68	61	63	231.3	221.7	220.7	224.6
$P_8 x P_9$	58	63	59	60	211.3	190.0	208.0	203.1
Checks SC 168	63	69	61	64	239.7	211.6	214.6	222.0
SC 3444	62	68	61	63	234.3	233.3	218.3	228.7
LSD 0.05	1.8	2.5	3.2	1.0	14.0	19.0	8.2	8.3
0.01	2.3	3.3	4.2	2.0	18.5	25.2	10.9	10.8

TABLE 3. Contd.

Crosses	Ear height (cm)				Grain yield (ard/fad.)			
	Gm	Sd	Mal	Comb.	Gm	Sd	Mal	Comb.
$P_1 x P_2$	126.3	115.0	102.7	114.7	24.633	29.700	25.200	26.528
$P_1 x P_3$	121.0	101.7	99.3	107.3	23.667	29.067	23.200	25.312
$P_1 x P_4$	131.0	113.3	101.7	115.3	22.167	23.767	22.300	22.726
$P_1 x P_5$	134.7	126.7	108.3	123.2	24.467	33.067	27.400	28.298
$P_1 x P_6$	111.3	106.7	100.3	106.1	23.967	32.300	18.667	24.994
$P_1 x P_7$	134.7	118.3	110.3	121.1	22.700	31.500	27.333	27.167
$P_1 x P_8$	133.7	131.7	118.3	127.9	24.133	37.367	24.333	28.612
$P_1 x P_9$	141.7	128.3	116.0	128.7	34.733	34.567	32.767	34.021
$P_2 x P_3$	99.0	98.3	101.7	99.7	13.233	27.933	22.467	21.224
$P_2 x P_4$	128.0	106.7	108.3	114.3	30.467	34.500	26.233	30.401
$P_2 x P_5$	94.3	95.0	100.7	96.7	13.233	28.000	22.400	21.224
$P_2 x P_6$	106.3	80.0	99.3	95.2	26.900	28.233	25.133	26.737
$P_2 x P_7$	121.3	96.7	106.7	108.2	27.500	31.867	21.200	26.856
$P_2 x P_8$	129.0	115.0	105.0	116.3	26.867	36.167	26.267	29.753
$P_2 x P_9$	135.0	116.7	109.7	120.4	26.067	30.067	23.033	26.375
$P_3 x P_4$	161.0	130.0	108.3	133.1	36.867	37.567	29.000	34.489
$P_3 x P_5$	133.0	126.7	106.0	121.9	37.867	33.100	25.800	32.256
$P_3 x P_6$	106.7	90.0	105.3	100.7	20.733	27.333	24.267	24.104
$P_3 x P_7$	127.3	105.0	106.0	112.8	19.133	24.100	24.633	22.632
$P_3 x P_8$	127.3	113.3	106.3	115.7	25.667	27.333	22.333	25.100
$P_3 x P_9$	125.0	113.3	109.7	116.0	24.100	27.767	20.867	24.259
$P_4 x P_5$	129.0	106.7	103.7	113.1	20.400	28.933	23.700	24.333
$P_4 x P_6$	139.3	110.0	101.7	117.0	26.967	34.100	25.500	28.851
$P_4 x P_7$	120.7	106.7	103.0	110.1	18.667	23.100	21.800	21.182
$P_4 x P_8$	143.3	110.0	105.0	119.4	18.900	27.200	26.267	24.125
$P_4 x P_9$	148.0	120.0	109.0	125.7	25.833	34.933	29.667	30.140
$P_5 x P_6$	134.7	108.3	108.3	117.1	22.767	30.233	27.200	26.731
$P_5 x P_7$	141.0	120.0	109.3	123.4	28.400	35.267	20.133	27.928
$P_5 x P_8$	133.7	101.7	109.7	115.0	19.833	28.067	27.233	25.055
$P_5 x P_9$	130.7	100.0	107.3	112.7	17.900	32.667	25.600	25.403
$P_6 x P_7$	127.7	101.7	111.7	113.7	26.200	31.000	23.600	26.933
$P_6 x P_8$	114.0	108.3	112.3	111.6	19.167	34.267	24.867	26.093
$P_6 x P_9$	134.7	108.3	109.3	117.4	25.000	26.900	26.933	26.262
$P_7 x P_8$	113.3	103.3	113.7	110.1	18.833	26.900	26.167	23.980
$P_7 x P_9$	118.0	116.7	109.7	114.8	21.867	32.867	21.733	25.494
$P_8 x P_9$	95.3	80.0	103.7	93.0	25.333	26.867	19.733	23.976
Checks SC 168	138.0	110.0	109.6	119.2	27.094	35.318	29.854	30.756
SC 3444	122.3	123.3	108.6	118.1	26.579	32.245	25.183	28.002
LSD 0.05	11.2	18.0	7.3	7.5	5.1	4.5	3.6	2.57
0.01	14.9	23.9	9.6	9.7	6.8	6.0	4.8	3.32

that, the parents of these crosses were good combiners to improve low ear placement traits.

For grain yield, the three crosses, namely P1 x P9, P3 x P4 and P3 x P5, exhibited significantly higher grain yield compared to the best check hybrid (S.C 168) at Gemmeiza location. On the other hand, three crosses (P_1 x $P_{8,}$ P_2 x P_8 and P_3 x P_4) and one cross P_1 x P_9 were not significantly out-yielded by the best check SC 168 at Sids and Mallawy locations,. Two crosses (P_1 x P_9 and P_3xP_4) highly out-yielded the best check hybrid (SC 168) for combined data. These two promising crosses and the parents of these crosses can be used to improve grain yield trait in national maize programme.

Combining ability. Analysis of variance for combining ability in each location and their combined data for four traits are shown in Table 4. The mean squares associated with general combining ability (GCA) and specific combining ability (SCA) were significant and highly significant for all traits under all locations and combined data, except (GCA) for grain yield at Sids location, indicating that both additive and non-additive gene effects were important in the inheritance of these traits.

The mean squares of the interactions between GCA x locations and SCA x locations were highly significant for all traits under combined data, meaning that both of additive and non-additive gene action were affected by change of locations. The ratio of GCA/SCA was above unity for number of days to 50% silking, plant height and ear height at all locations and combined data, indicating that additive gene effects played a major role in the inheritance of these traits. On the other hand, non-additive gene effects were predominant and played an important role in the inheritance of grain yield at all locations and combined data. Also, Table 4 shows that the additive gene effects affected by change of locations more than non-additive gene effects for days to 50% silking, plant height and ear height; while the reverse was obtained for grain yield. These results are in agreement with Irshad El-Hag *et al.* (2010), Werle *et al.* (2014), Gamea *et al.* (2018) and El-Shahed *et al.* (2020); who found that non-additive gene effects were more important expressions for grain yield; while, Yousef *et al.* (2003) and Abd El-Hadi *et al.* (2005) reported that additive and additive x additive gene effects played an important role in the inheritance of this trait.

General combining ability effects. The estimates of general combining ability effects (gi) of the parental inbred lines for the four studied traits are presented in Table 5. These estimates, either positive or negative, indicate that a given inbred is much better or much poorer than the average of the group with which it is involved in the diallel crossing. The three (P1, P2 and P3) inbred lines at Gemmiza location, two (P2 and P5) inbred lines at Sids location, two (P2 and P3) inbred line at Mallawy location and three (P1, P2 and P3) inbred line for the combined data, possessed significant and negative estimates of GCA effects for days to 50% silking. This indicated that the three inbred lines could be considered as good combiners for developing early maturity genotypes. The parental inbred lines (P2 and P6) at Gemmeiza ,Sida, Mallawy and their combined data, as well as parental inbred lines (P3and P4) at Mallawy location exhibited significant and highly significant negative effects of GCA for plant height.

Ear height, parental inbred line P2 at Gemmeiza, Sida, Mallawy and their combined data exhibited significant effects, indicating that this inbred line (P2) is a good combiner for developing genotypes characterised with short plants and low ear placements. Similarly, inbred lines P6 at Gemmeiza and Sida locations, and their combined data; and P8 at Gemmeiza location, had desirable and negative significant of GCA effects for this trait. These parents can be used to improve this trait in maize breeding programme.

For grain yield, inbred line P3 and P4 can be considered as good combiners at Gemmeiza

TABLE 4. Analysis of variance of combining ability for four traits at three locations and for combined data in Egypt

S.O.V	d.f.		Days to 50 % silking				Plant height (cm)			
	Single	Comb	Gm	Sd	Mal	Comb.	Gm	Sd	Mal	Comb
GCA	8	8	8.28**	4.09**	7.87**	5.14**	608.24**	282.24**	96.14**	257.723**
SCA	27	27	4.88**	3.53**	3.62**	3.27**	434.98**	292.38**	43.54**	182.525**
GCA x Loc.	-	16	-	-	-	7.55**	-	-	-	364.450**
SCA x Loc.	-	54	-	-	-	4.38**	-	-	-	294.185**
Error term	70	210	0.39	0.76	1.28	0.81	24.46	45.31	8.53	26.101
GCA/SCA	-	-	1.70	1.16	2.18	1.57	1.40	0.99	2.21	1.412
GCA x Loc. / SCA x Loc.	-	-	-	-	-	1.72	-	-	-	1.239

** significant at 0.01 level of probability

S.O.V	d.f.		Ear height (cm)				Grain yield (ard/fad.)			
	Single	Comb	Gm	Sd	Mal	Comb.	Gm	Sd	Mal	Comb.
GCA	8	8	291.04**	215.28**	32.49**	107.789**	10.99**	4.39	4.35*	4.100*
SCA	27	27	186.62**	134.26**	17.15**	78.107**	35.26**	17.56**	10.10**	12.300**
GCA x Loc.	-	16	-	-	-	215.513**	-	-	-	8.069**
SCA x Loc.	-	54	-	-	-	129.962**	-	-	-	25.178**
Error term	70	210	15.78	40.73	6.63	21.050	3.29	2.55	1.64	2.300
GCA/SCA	-	-	1.56	1.61	1.89	1.380	0.31	0.25	0.43	0.285
GCA x Loc. / SCA x Loc.	-	-	-		-	1.658	-	-	-	0.320

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

TABLE 5. Estimates of general combining ability (GCA) effects of the nine inbred lines for the four studied traits at three locations and for combined data

Parents	Days to 50 % silking				Plant height (cm)			
	Gm	Sd	Mal	Comb.	Gm	Sd	Mal	Comb.
P_1	-1.83**	-0.44	-0.67	-0.981**	6.17**	9.13**	4.21**	6.501**
P_2	-0.73**	-0.73*	-1.91**	-1.123**	-17.07**	-8.49**	-5.51**	-10.356**
P_3	-0.87**	-0.25	-1.05**	-0.727**	0.79	0.08	-3.65**	-0.928
P_4	0.79**	0.75*	0.04	0.527**	5.41**	-0.63	-2.46*	0.771
P_5	0.08	-1.02**	0.19	-0.250	5.03**	1.98	0.06	2.358*
P_6	-0.44	-0.25	0.23	-0.155	-11.40**	-9.92**	-2.70*	-8.007**
P_7	0.22	0.70*	0.61	0.511**	-1.78	-0.87	2.59*	-0.023
P_8	1.60**	-0.06	1.14**	0.892**	-0.45	0.79	3.16**	1.168
P_9	1.17**	1.32**	1.42**	1.305**	13.31**	7.94**	4.30**	8.517**
LSD_{gi} 0.05	0.45	0.62	0.81	0.37	3.52	4.79	2.08	2.09
0.01	0.59	0.82	1.07	0.48	4.67	6.35	2.76	2.71
LSD $(_{gi-gj})$ 0.05	0.67	0.93	1.21	0.55	5.27	7.18	3.11	3.14
0.01	0.89	1.24	1.60	0.72	7.00	9.53	4.14	4.07

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

Parents	Ear height (cm)				Grain yield (ard/fad.)			
	Gm	Sd	Mal	Comb.	Gm	Sd	Mal	Comb.
P_1	3.29**	9.76**	0.29	4.446**	1.173	1.029	0.649	0.949**
P_2	-10.29**	-7.14**	-2.99**	-6.808**	-0.480	0.333	-0.675	-0.273
P_3	-1.57	0.71	-1.76	-0.871	1.287*	-1.419*	-0.585	-0.234
P_4	12.71**	4.29	-2.04*	4.986**	1.144	-0.005	1.115*	0.748*
P_5	2.81*	1.67	-0.23	1.414	-1.056	0.743	0.401	0.031
P_6	-5.24**	-8.57**	-0.95	-4.919**	-0.080	0.033	-0.070	-0.044
P_7	-1.05	-0.71	2.20*	0.145	-1.280*	-1.076	-1.437**	-1.263**
P_8	-3.10*	-1.43	2.72**	-0.601	-1.932**	0.005	0.077	-0.617
P_9	2.43	1.43	2.77**	2.208*	1.225	0.357	0.525	0.703*
LSD_{gi} 0.05	2.81	4.54	1.83	1.88	1.28	1.14	0.91	0.65
0.01	3.75	6.02	2.43	2.44	1.71	1.50	1.21	0.84
LSD $(_{gi-gj})$ 0.05	4.24	6.81	2.75	2.82	1.93	1.70	1.37	0.97
0.01	5.63	9.04	3.65	3.65	2.57	2.26	1.81	1.26

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

and Mallawy locations, respectively. On the other hand, inbred lines P1, P4 and P9 showed desirable and positive significant of GCA effects for grain yield for combined data; hence these inbred lines could be considered as good combiner parents to improved grain yield trait.

Specific combining ability effects. Estimates of the specific combining ability (SCA) effects of the 36 single crosses for all the studied traits at the three locations and their combined data are presented in Table 6. For days to 50% silking, the results illustrated that there were three single crosses; namely P1 x P6, P1 x P7 and P4 x P5 at all locations; and combined data had negative and desirable significant of SCA effects towards earliness, indicating that these single crosses are the best cross combinations for earliness. Also, other 7, 2, 2 and 8 single crosses at Gemmeiza, Sids, Mallawy and combined data, respectively showed negative significant of SCA effects for this trait.

For plant height, 17, 7, 8 and 20 crosses had desirable values for SCA effects (negative and significant) towards short plants at Gemmeiza, Sids, Mallawy and combined data, respectively. The best crosses in all locations and combined data were P1 x P3, P2 x P6, P4 x P5 and P8 x P9. Regarding ear height (towards lower ear placement) elven crosses; P1 x P3, P1 x P4, P1 x P6, P2 x P3 , P2 x P5, P3 x P6, P4 x P5, P4 x P7, P7 x P8, P7 x P9 and P8 x P9 at Gemmeiza location; five crosses; P1 x P3, P2 x P6, P3 x P6, P5 x P9 and P8 x P9 at Sids location; three crosses namely P1 x P3, P1 x P6 and P8 x P9 at Mallawy location; and eleven crosses, P1 x P3, P1 x P4, P1 x P6, P2 x P3, , P2 x P5, P2 x P6, P3 x P6, P4 x P5, P4 x P7 , P5 x P9 and P8 x P9 for their combined data exhibited negative and desirable significant of SCA effects for low ear height.

For grain yield, these crosses may find prime importance in breeding programmes for the traditional breeding procedures. It is notable that the crosses showed high SCA effects for grain yield. For this study, nine crosses (P1 x P9, P2 x P4, P2 x P6, P2 x P7, P2 x P8, P3 x P4, P3 x P5, P5 x P7 and P6 x P7) at Gemmeiza location, ten crosses (P1 x P8, P2 x P4, P2 x P8, P3 x P4, P3 x P5, P4 x P6, P4 x P9, P5 x P7 P6 x P8 and P7 x P9) at Sids location, seven crosses (P1 x P7, P1 x P9, P2 x P8, P3 x P4, P4 x P9, P5 x P6 and P7 x P8) at Mallawy location; and nine crosses (P1 x P9, P2 x P4, P2 x P7, P2 x P8, P3 x P4, P3 x P5, P4 x P9, P5 x P7 and P6 x P7) for their combined data, which showed significant of SCA effects for grain yield. The best crosses for SCA effect of grain yield which had desirable values in all locations and their combined data were P1 x P9, P2 x P4, P2 x P8, P3 x P4 and P3 x P5. These crosses could be used as good hybrids in maize breeding programme.

Superiority percentages. Superiority percentages related to two checks; SC168 and SC 3444 for the 36 F_1's crosses under combined data are presented in Table 7. Regarding days to 50% silking, most the crosses expressed superiority parentage for earliness relative to SC 168 and SC 3444; the best crosses from them were P1 x P3, P1 x P6, P1 x P7, P2 x P6 and P4 x P5.For plant height, data in Table 6 showed that, nine crosses (P_1 x P_3, P_1 x P_6, P_2 x P_3, P_2 x P_5, P_2 x P_6, P_2 x P_7, P_3 x P_6, P_4 x P_5 and P_8 x P_9) showed superiority for shortness relative to SC 168 ,while, 18 crosses showed superiority for shortness relative to SC 3444 i.e.(P_1 x P_2, P_1 x P_3, P_1 x P_4, P_1 x P_6, P_2 x P_3, P_2 x P_4, P_2 x P_5, P_2 x P_6, P_2 x P_7 , P_2 x P_8, P_3 x P_6, P_3 x P_7, P_3 x P_8, P_4 x P_5 , P_4 x P_7 , P_4 x P_8 , P_6 x P_8 and P_8 x P_9).Concerning ear height, ten crosses showed superiority for low ear position relative to SC 168 and SC 3444, i.e. (P_1 x P_3, P_1 x P_6, P_2 x P_3, P_2 x P_5, P_2 x P_6, P_2 x P_7, P_3 x P_6, P_4 x P_7, P_7 x P_8 and P_8 x P_9). While value of cross (P_6 x P_8) relative to the check SC 168 was only significant.

For grain yield, two single cross (P_1x P_9 and P_3x P_4) were the best crosses for superiority relative to SC 168 and SC 3444,

TABLE 6. Estimates of specific combining ability (SCA) effects for 36 F_1 crosses for the four studied traits at three locations and for combined data

Crosses	Days to 50 % silking				Plant height (cm)			
	Gm	Sd	Mal	Comb.	Gm	Sd	Mal	Comb.
$P_1 x P_2$	2.33**	0.87	1.95	1.718*	5.46	-6.61	0.52	-0.206
$P_1 x P_3$	-1.52**	-0.27	-0.91	-0.901*	-28.06**	-31.85**	-7.00**	-22.302**
$P_1 x P_4$	-3.19**	-0.94	-0.67	-1.599*	-14.68**	-9.46	-5.86*	-10.000**
$P_1 x P_5$	3.86**	3.49**	2.52*	3.290**	8.04	9.58	-1.05	5.524*
$P_1 x P_6$	-1.62**	-2.27**	-2.19**	-2.028**	-26.87**	-3.51	-10.62**	-13.667**
$P_1 x P_7$	-2.95**	-1.56*	-2.57**	-2.361**	3.51	-0.89	-2.57	0.016
$P_1 x P_8$	1.33*	0.54	1.24	1.036*	25.85**	27.44**	17.19**	23.492**
$P_1 x P_9$	1.76**	0.16	0.62	0.845	26.75**	15.30*	9.38**	17.143**
$P_2 x P_3$	-1.95**	-0.99	-0.33	-1.091*	-17.15**	-4.23	-0.29	-7.222**
$P_2 x P_4$	1.38*	0.35	-1.43	0.099	5.89	4.82	7.52**	6.079*
$P_2 x P_5$	-0.91	-1.23	0.10	-0.679	-18.06**	-4.46	0.33	-7.397**
$P_2 x P_6$	-3.38**	-2.32**	-1.62	-2.440**	-10.96*	-15.89**	-6.57*	-11.143**
$P_2 x P_7$	0.62	0.39	-1.33	-0.107	-16.58**	-9.94	-0.19	-8.905**
$P_2 x P_8$	1.57**	2.82**	-0.19	1.401**	16.75**	3.39	-5.10*	5.016
$P_2 x P_9$	0.33	0.11	2.86**	1.099*	34.65**	32.92**	3.76	23.778**
$P_3 x P_4$	2.86**	2.87**	3.05	2.925**	32.04**	26.25**	5.67*	21.317**
$P_3 x P_5$	2.24**	0.63	1.91	1.591**	24.42**	20.30**	3.81	16.175**
$P_3 x P_6$	-0.91	0.54	-1.48	-0.615	-14.49**	-11.13*	5.90*	-6.571*
$P_3 x P_7$	-0.24	-1.08	1.14	-0.060	4.89	-13.51*	-4.71	-4.444
$P_3 x P_8$	-0.95	-0.66	-2.71**	-1.440**	-8.77*	6.49	-6.29*	-2.857
$P_3 x P_9$	0.48	-1.04	-0.67	-0.409	7.13	7.68	2.90	5.905*
$P_4 x P_5$	-3.10**	-2.37**	-2.86**	-2.774**	-18.54**	-13.99*	-5.05*	-12.524**
$P_4 x P_6$	-0.57	0.20	-0.24	-0.202	27.89**	9.58	-1.62	11.952**
$P_4 x P_7$	-0.24	-1.42	0.05	-0.536	-9.73*	-1.13	-1.57	-4.143
$P_4 x P_8$	1.05	0.35	2.19**	1.194**	-9.39*	-16.13**	0.52	-8.333**
$P_4 x P_9$	1.81**	0.96	-0.10	0.893*	-13.49**	0.06	0.38	-4.349
$P_5 x P_6$	1.81**	1.63*	1.95	1.798**	8.27	1.96	4.86	5.032
$P_5 x P_7$	0.14	-0.99	-0.43	-0.425	-2.01	12.92*	-0.76	3.381
$P_5 x P_8$	-2.24**	-1.23	-0.62	-1.361**	8.32	-10.42	0.00	-0.698
$P_5 x P_9$	-1.81**	0.06	-2.57**	-1.440**	-10.44*	-15.89**	-2.14	-9.492**
$P_6 x P_7$	2.00**	0.92	1.52	1.480**	20.75**	8.15	6.00*	11.635**
$P_6 x P_8$	1.29*	-1.32	0.67	0.210	-10.58*	18.15**	3.10	3.556
$P_6 x P_9$	1.38*	2.63**	1.38	1.798**	5.99	-7.32	-1.05	-0.794
$P_7 x P_8$	1.29*	3.06**	1.29	1.877**	13.80**	4.11	3.81	7.238**
$P_7 x P_9$	-0.62	0.68	0.33	0.131	-14.63**	0.30	0.00	-4.778
$P_8 x P_9$	-3.33**	-3.56**	-1.86	-2.917**	-35.96**	-33.04**	-13.24**	-27.413**
L S D S_{ij} 0.05	1.08	1.51	1.96	0.89	8.54	11.63	5.05	5.08
0.01	1.44	2.00	2.60	1.16	11.35	15.44	6.70	6.59
$S_{ij}-S_{ki}$ 0.05	1.64	2.28	2.96	1.36	12.92	17.58	7.63	7.68
0.01	2.17	3.03	3.93	1.76	17.15	23.35	10.13	9.96

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

TABLE 6. Contd.

Crosses	Ear height (cm)				Grain yield (ard/fad.)			
	Gm	Sd	Mal	Comb.	Gm	Sd	Mal	Comb.
$P_1 x P_2$	6.92*	3.21	-1.50	2.877	-0.09	-2.18	0.64	-0.525
$P_1 x P_3$	-7.13	-17.98**	-6.07**	-10.393**	-2.83	-1.06	-1.45	-1.781*
$P_1 x P_4$	-11.42**	-9.88	-3.45	-8.250**	-4.18	-7.77**	-4.05**	-5.348**
$P_1 x P_5$	2.15	6.07	1.41	3.210	0.32	0.78	1.77	0.941
$P_1 x P_6$	-13.13**	-3.69	-5.88*	-7.567**	-1.16	0.72	-6.49**	-2.288**
$P_1 x P_7$	6.01	0.12	0.98	2.369	-1.23	1.03	3.54**	1.105
$P_1 x P_8$	7.06*	14.17*	8.45**	9.893**	0.86	5.82**	-0.98	1.903*
$P_1 x P_9$	9.54**	7.98	6.07**	7.861**	8.30**	2.66	7.01**	5.993**
$P_2 x P_3$	-15.56**	-4.40	-0.45	-6.806**	-11.61**	-1.50	-0.86	-4.645**
$P_2 x P_4$	-0.85	0.36	6.50	2.004	5.77**	3.66*	1.21	3.550**
$P_2 x P_5$	-24.61**	-8.69	-2.98	-12.091**	-9.26**	-3.59*	-1.91	-4.910**
$P_2 x P_6$	-4.56	-13.45*	-3.60	-7.202**	3.43*	-2.65	1.30	0.678
$P_2 x P_7$	6.25	-4.64	0.60	0.734	5.23**	2.09	-1.27	2.016*
$P_2 x P_8$	15.96**	14.40*	-1.60	9.591**	5.25**	5.31**	2.28*	4.266**
$P_2 x P_9$	16.44**	13.21*	3.02	10.893**	1.29	-1.14	-1.40	-0.430
$P_3 x P_4$	23.44**	15.83**	5.26*	14.845**	10.40**	8.47**	3.89**	7.598**
$P_3 x P_5$	5.35	15.12**	1.12	7.194**	13.60**	3.26*	1.40	6.083**
$P_3 x P_6$	-12.94**	-11.31*	1.17	-7.694**	-4.51**	-1.80	0.34	-1.995*
$P_3 x P_7$	3.54	-4.17	-1.31	-0.647	-4.91**	-3.92**	2.07	-2.248**
$P_3 x P_8$	5.58	4.88	-1.50	2.988	2.28	-1.77	-1.74	-0.426
$P_3 x P_9$	-2.27	2.02	1.79	0.512	-2.44	-1.69	-3.66**	-2.586**
$P_4 x P_5$	-12.94**	-8.45	-0.93	-7.440**	-3.72*	-2.32	-2.40*	-2.822**
$P_4 x P_6$	5.44	5.12	-2.21	2.782	1.87	3.56*	-0.13	1.771*
$P_4 x P_7$	-17.42**	-6.07	-4.02	-9.171**	-5.23**	-6.34**	-2.46*	-4.680**
$P_4 x P_8$	7.30*	-2.02	-2.55	0.909	-4.34	-3.32*	0.49	-2.382**
$P_4 x P_9$	6.44	5.12	1.41	4.321	-0.57	4.06**	3.44**	2.313**
$P_5 x P_6$	10.68**	6.07	2.64	6.464**	-0.13	-1.06	2.29*	0.367
$P_5 x P_7$	12.82**	9.88	0.50	7.734**	6.70**	5.08**	-3.41**	2.783**
$P_5 x P_8$	7.54*	-7.74	0.31	0.036	-1.21	-3.20*	2.17	-0.735
$P_5 x P_9$	-0.99	-12.26*	-2.07	-5.107*	-6.30**	1.05	0.09	-1.707
$P_6 x P_7$	7.54*	1.79	3.55	4.290	3.53*	1.53	0.53	1.863*
$P_6 x P_8$	-4.08	9.17	3.69	2.925	-2.85	3.71**	0.28	0.378
$P_6 x P_9$	11.06**	6.31	0.64	6.004**	-0.18	-4.01**	1.90	-0.773
$P_7 x P_8$	-8.94*	-3.69	1.88	-3.583	-1.99	-2.55	2.94**	-0.517
$P_7 x P_9$	-9.80**	6.79	-2.17	-1.726	-2.11	3.07*	-1.94	-0.323
$P_8 x P_9$	-30.42**	-29.17**	-8.69**	-22.758**	2.01	-4.01**	-5.45**	-2.486**
L S D S_{ij} 0.05	6.86	11.03	4.45	4.56	3.13	2.76	2.21	1.57
0.01	9.11	14.64	5.91	5.92	4.16	3.67	2.94	2.04
S_{ij}-S_{ki} 0.05	10.38	16.67	6.73	6.90	4.74	4.17	3.35	2.38
0.01	13.78	22.14	8.93	8.95	6.29	5.54	4.44	3.08

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

TABLE 7. Percentages of superiority for 36 yellow single cross relative to checks (SC 168 and SC 3444) for the four studied traits under combined data

Crosses	Days to 50 % silking		Plant height (cm)		Ear height(cm)		Grain yield (ard./fad.)	
	SC 168	SC 3444	SC 168	SC 3444	SC 168	SC 3444	SC 168	SC 3444
P_1 x P_2	-4.69**	-3.17**	-2.34	-5.20**	-3.78	-2.88	-13.75**	-5.26
P_1 x P_3	-9.38**	-7.94**	-8.06**	-10.76**	-9.98**	-9.14**	-17.70**	-9.61*
P_1 x P_4	-7.81**	-6.35**	-1.76	-4.63*	-3.27	-2.37	-26.11**	-18.84**
P_1 x P_5	-1.56	0.00	5.95**	2.84	3.36	4.32	-7.99	1.06
P_1 x P_6	-9.38**	-7.94**	-7.34**	-10.06**	-10.99**	-10.16**	-18.73**	-10.74*
P_1 x P_7	-9.38**	-7.94**	2.39	-0.61	1.59	2.54	-11.67*	-2.98
P_1 x P_8	-3.13**	-1.59*	13.51**	10.19**	7.30*	8.30**	-6.97	2.18
P_1 x P_9	-3.13**	-1.59*	13.96**	10.63**	7.97*	8.98**	10.62*	21.49**
P_2 x P_3	-9.38**	-7.94**	-8.87**	-11.54**	-16.36**	-15.58**	-30.99**	-24.21**
P_2 x P_4	-6.25**	-4.76**	-2.12	-4.98**	-4.11	-3.22	-1.15	8.57*
P_2 x P_5	-7.81**	-6.35**	-7.48**	-10.19**	-18.88**	-18.12**	-30.99**	-24.21**
P_2 x P_6	-10.94**	-9.52**	-13.83**	-16.35**	-20.13**	-19.39**	-13.07**	-4.52
P_2x P_7	-6.25**	-4.76**	-9.19**	-11.85**	-9.23**	-8.38**	-12.68**	-4.09
P_2x P_8	-3.13**	-1.59*	-2.39	-5.25**	-2.43	-1.52	-3.26	6.25
P_2 x P_9	-3.13**	-1.59*	9.37**	6.17**	1.01	1.95	-14.24**	-5.81
P_3 x P_4	0.00	1.59*	9.01**	5.82**	11.66**	12.70**	12.14**	23.17**
P_3 x P_5	-3.13**	-1.59*	7.39**	4.24*	2.27	3.22	4.88	15.19**
P_3 x P_6	-7.81**	-6.35**	-7.52**	-10.23**	-15.52**	-14.73**	-21.63**	-13.92**
P_3x P_7	-4.69**	-3.17**	-2.97	-5.82**	-5.37	-4.49	-26.41**	-19.18**
P_3x P_8	-6.25**	-4.76**	-1.71	-4.59*	-2.94	-2.03	-18.39**	-10.36*
P_3 x P_9	-4.69**	-3.17**	5.54**	2.45	-2.68	-1.78	-21.12**	-13.37**
P_4 x P_5	-9.38**	-7.94**	-4.77**	-7.56**	-5.12	-4.23	-20.88**	-13.10**
P_4 x P_6	-4.69**	-3.17**	1.62	-1.36	-1.85	-0.93	-6.19	3.03
P_4x P_7	-4.69**	-3.17**	-2.07	-4.94**	-7.63*	-6.77*	-31.13**	-24.36**
P_4x P_8	0.00	1.59*	-3.42	-6.25**	0.17	1.10	-21.56**	-13.85**
P_4x P_9	0.00	1.59*	1.71	-1.27	5.45	6.44*	-2.00	7.64
P_5 x P_6	-3.13**	-1.59*	-0.81	-3.72	-1.76	-0.85	-13.09**	-4.54
P_5 x P_7	-4.69**	-3.17**	2.07	-0.92	3.52	4.49	-9.19*	-0.26
P_5 x P_8	-6.25**	-4.76**	0.77	-2.19	-3.52	-2.62	-18.54**	-10.52*
P_5 x P_9	-4.69**	-3.17**	0.09	-2.84	-5.45	-4.57	-17.40**	-9.28*
P_6 x P_7	-1.56*	0.00	1.08	-1.88	-4.61	-3.73	-12.43**	-3.82
P_6 x P_8	-3.13**	-1.59*	-1.98	-4.85**	-6.38*	-5.50	-15.16**	-6.82
P_6 x P_9	0.00	1.59*	-0.63	-3.54	-1.51	-0.59	-14.61**	-6.21
P_7 x P_8	0.00	1.59*	3.24	0.22	-7.63*	-6.77*	-22.03**	-14.36**
P_7 x P_9	-1.56*	0.00	1.17	-1.79	-3.69	-2.79	-17.11**	-8.96*
P_8 x P_9	-6.25**	-4.76**	-8.51**	-11.19**	-21.98**	-21.25**	-22.04**	-14.38**
L.S.D. 0.05	1.0		8.3		7.5		2.566	
0.01	2.0		10.8		9.7		3.32	

also (P_2 x P_4 and P_3 x P_5) had superiority percentage for grain yield relative to SC 3444.

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