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EVALUATION OF SOME YELLOW MAIZE HYBRIDS FOR GRAIN YIELD AND EARLINESS

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ABSTRACT

During the summer growing season of 2021, seven elite yellow maize inbred lines were crossed in a half-diallel mating design at Gemmeiza Research Station. The resulting21 F_1 crosses plus two check hybrids i.e., SC168 and SC3444 were assessed at three Agricultural Research Stations, Gemmiza, Ismailia and Sids, using a randomized complete block design (RCBD) with three replications in 2022 summer growing season. Data were recorded on number of days to 50% silking, plant height, ear height and grain yield. Mean squares owing to locations (L), crosses (C) and their interaction (C×L) were significant ($P \leq 0.01$) for all traits under study. The mean squares resulting from general combining ability (GCA), specific combining ability (SCA) and their interactions with locations were significant for most traits under study. Both additive and non-additive gene effects were important in the inheritance of traits under study. However, additive gene effects were more important in the inheritance of most studied traits. The best inbred lines for GCA effects were Gm97 and Gz666 for grain yield. Compared to the checks; the three hybrids (Gm97 × Gz666), (Gz666 × Gm1002) and (Gm19 × Gm97) showed high grain yield and earliness. These hybrids could be used in the National Maize Breeding Program.

Key words: ***Zea mays, Hybrids, GCA, SCA, Additive, Non-Additive, Gene effects.***

INTRODUCTION

Maize (*Zea mays* L.) is regarded as one of the world's main cereal crops due to its high yield, rich diversity and vital nutrients. But finding inbred lines that produce superior hybrids is time-consuming and expensive process (Keskin *et al* 2005 and Mohammed *et al* 2014). In hybrids breeding program, the selection of germplasm as the basic population is crucial to determine the availability of superior parents. These parents, derived from superior genetic materials, should possess optimal agronomic traits and should have high general combining ability (GCA) and specific combining ability (SCA) (Takdir *et al* 2007). Diallel crosses have been widely utilized in genetic research to examine the inheritance of traits among a group of genotypes, particularly to assess the GCA and SCA of inbred lines to identify superior parents for use in hybrid development program (Malik *et al* 2004). An account the additive type of gene effects for GCA and the non-additive type of gene effects for SCA are considered in four methods (Griffing 1956). According to Hallauer and Miranda (1981), both GCA and SCA effects should be considered when planning maize breeding programs to produce new inbred lines and crosses. The functions of GCA and SCA in the inheritance of qualitative and quantitative traits have been extensively studied. Numerous studies demonstrated that non-additive gene effects influenced the inheritance of silking date, grain yield, plant height and ear height (Nawar *et al* 1980, El-Shamarka 1995, El-

Shenawy *et al* 2002 and Mosa *et al* 2024b), however other studies, showed that the inheritance of silking date, grain yield, plant height and ear height were largely determined by additive gene effects (Al-Naggar 1991, Mosa 2003, Keimeso and Abakemal 2020 and Mosa *et al* 2023). Generally, these two categories of genetic effects, GCA and SCA are important in plant breeding program. GCA describes the average performance of a genotype across a range of hybrid populations, while SCA measure the performance of a specific genotype in a particular cross (Yingzhong 1999, Sharief *et al* 2009 and de Faria *et al* 2022). The purposes of this research were to estimate the GCA and SCA effects for inbred lines and their crosses for traits under study and to identify superior hybrids for grain yield and earliness compared with two commercial hybrids.

MATERIALS AND METHODS

Plant materials included, seven outstanding yellow maize inbred lines, which were selected from different sources and regions. The inbred lines Gm1, Gm21, Gm19, Gm97, Gm1002, Sk11 and Gz666 which were developed at Gemmiza (Gm), Sakha (Sk) and Giza (Gz) Agricultural Research Stations. A half diallel was created by crossing between these seven inbred lines during 2021 summer growing season at Gemmiza Research Station. The resulting 21 F_1 hybrids and two commercial hybrids (SC168 and Pioneer SC3444), were evaluated at Gemmiza, Ismailia and Sids Agricultural Research Stations using a randomized complete block design (RCBD) with three replications during the summer growing season of 2022. Each plot consisted of one row, 6 m long, with a spacing of 0.8 m between rows and 0.25 m between hills. All the suggested agronomic practices were implemented at the appropriate times. The data were recorded on number of days to 50% silking, plant height (cm), ear height (cm) and grain yield in ardab per feddan (ard/fed) adjusted at 15.5% grain moisture (ardab = 140 kg and feddan = 4200 m^2). Using the Statistical Analysis System (SAS 2008) computer application, a combined analysis was conducted across the three locations after performing a homogeneity test, as outlined by Snedecor and Cochran (1989). The general and specific combining abilities (GCA and SCA), as well as their interactions with locations, were computed according to Method-4 Model-1 (Griffing 1956), using the AGD-R Software (Analysis of Genetic Designs in R for windows) version 5.0 Statistical Software according to Rodríguez *et al* (2015). The ratio between GCA and SCA was calculated using the procedure developed by Baker (1978), which was later modified by Hung and Holland (2012), which formula: $2K^2$ GCA/($2K^2$ GCA + K^2 SCA), where K^2 GCA is the variance effects derived from the mean squares of GCA and K^2 SCA is the variance effects derived from the mean squares of SCA. Since the total genetic variance among F_1 hybrids is equal twice the GCA plus SCA component. The superiority percentage of 21 crosses for grain yield was estimated according to Singh *et al* (2004), expressed as the percentage deviation of the mean performance of the F_1 compared to the two commercial hybrids.

RESULTS AND DISCUSSION

For all studied traits, the mean squares sowing to locations (L) were highly significant (Table1), revealing that there were differences existed between the various locations. Similar results were reported by Ismail *et al* (2023), Abd-Elaziz *et al* (2024) and Mosa *et al* (2024a). The mean squares due to crosses (C) were highly significant for all traits under study, suggesting that there were variations among the tested crosses. Additionally, the mean squares due to the interaction between crosses and locations (C×L) were highly significant for all traits, indicating that the crosses were influenced by changes in their locations. Similar results were reported by Abd El-Azeem *et al* (2021), Akhi *et al* (2023), Ismail *et al* (2023), Abd-Elaziz *et al* (2024) and Mosa *et al* (2024a).

Table 1. Mean squares due to locations, crosses and their interaction for four studied traits.

SOV	df	Number of days to 50% silking	Plant height	Ear height	Grain yield
Locations (L)	2	545.53**	27526.38**	2966.48**	168.72**
Rep/L	6	35.54	818.48	214.91	26.61
crosses (C)	22	24.46**	1380.22**	544.32**	76.02**
C×L	44	3.37**	358.94**	142.13**	27.38**
Error	132	1.62	158.47	70.18	7.93

** indicate significant at 0.01 level of probability.

Mean performances of twenty-one of single crosses along with two check hybrids for number of days to 50% silking, plant height, ear height and grain yield across various locations are presented in Table (2).

Table 2. Mean performance of 21 crosses along with two check hybrids for traits under study as combined across three locations.

Cross	Number of days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (ard/fed)
Gm1 × Gm21	58.44	208.33	100.67	26.95
Gm1 × Gm19	58.33	199.22	97.89	21.31
Gm1 × Gm97	59.44	226.56	110.89	25.76
Gm1 × Sk11	59.89	230.44	110.44	25.67
Gm1 × Gz666	59.33	237.56	113.00	24.88
Gm1 × Gm1002	58.89	220.11	110.67	24.01
Gm21 × Gm19	58.56	206.56	98.00	25.13
Gm21 × Gm97	58.22	193.78	96.33	22.29
Gm21 × Sk11	57.89	206.22	106.44	24.88
Gm21 × Gz666	58.89	204.00	104.00	22.10
Gm21 × Gm1002	59.00	204.22	97.89	18.79
Gm19 × Gm97	59.22	222.89	109.22	29.05
Gm19 × Sk11	59.33	212.56	100.89	23.29
Gm19 × Gz666	63.00	220.78	108.44	21.98
Gm19 × Gm1002	59.67	222.33	102.11	25.45
Gm97 × Sk11	58.44	213.33	102.67	21.63
Gm97 × Gz666	61.89	229.22	119.78	31.98
Gm97 × Gm1002	58.56	225.89	109.11	24.13
Sk11 × Gz666	58.89	223.44	115.11	25.46
Sk11 × Gm1002	59.67	236.67	116.78	26.60
Gz666 × Gm1002	60.56	234.22	120.11	29.14
Check SC168	63.44	228.11	123.11	26.33
Check SC3444	63.33	225.11	104.11	26.10
LSD 0.05	1.19	11.74	7.81	2.63
0.01	1.57	15.51	10.32	3.47

For number of days to 50% silking, the crosses ranged from 57.89 days for (Gm21 × Sk11) to 63.44 days for (SC168). For plant height, the crosses ranged from 193.78 cm for (Gm21 × Gm97) to 237.56 cm for (Gm1 × Gz666), nine crosses *i.e.*, (Gm1 × Gm21, Gm1 × Gm19, Gm21 × Gm19, Gm21 × Gm97, Gm21 × Sk11, Gm21 × Gz666, Gm21 × Gm1002, Gm19 × Sk11 and Gm97 × Sk11) were significantly shorter than the shortest check hybrid SC3444. For ear height, the crosses varied from 96.33 cm for (Gm21 × Gm97) to 123.11 cm for (SC168), one cross (Gm21 × Gm97) showed lower ear placement than the best check hybrid SC3444.The crosses for grain yield ranged from 18.79 ard/fed for (Gm21 × Gm1002) to 31.98 ard/fed for (Gm97×Gz666), the cross (Gm97 × Gz666) had the highest grain yield, followed by (Gz666 × Gm1002) and (Gm19 × Gm97).

Superiority percentages of 21 hybrids relative two commercial hybrids (SC168 and SC3444) for grain yield and number of days to 50% silking are shown in Table (3). The results indicated that, all crosses except the cross (Gm19 × Gz666) were significantly earlier than the two check hybrids SC168 and SC3444, the best crosses from them were (Gm21 × Gm1002) followed by (Gm1 × Gm19). The three crosses (Gm19 × Gm97), (Gm97 × Gz666) and (Gz666 × Gm1002) were greatly out-yielded the two checks, SC168 and SC3444, also showed better earliness compared to the two check hybrids. So, these three hybrids will be further evaluated on a larger scale in the hybrids registration program in Egypt.

Table 4 shows that the mean squares due to GCA and SCA were highly significant for all studied traits, indicating that the additive gene effects (GCA) and non-additive gene effects (SCA) have a considerable impact on the inheritance of all studied traits. The mean squares due to the (GCA×L) interaction were significant or highly significant for all studied traits, except for number of days to 50% silking, indicating that the GCA of inbred lines was altered by the environmental conditions. On the other hand, the mean squares sowing to the (SCA× L) interaction was highly significant for number of days to 50% silking, plant height and grain yield, suggesting that the specific hybrid combinations were not stable under locations for these traits.

Table 3. Superiority percentages of 21 crosses relative to the two commercial hybrids SC168 and SC3444 for grain yield and number of days to 50% silking, as combined across three locations.

Cross	Number of days to 50% silking		Grain yield (ard/fed)	
	SC168	SC3444	SC168	SC3444
Gm1 × Gm21	-7.88**	-7.72**	2.38	3.27
Gm1 × Gm19	-8.06**	-7.89**	-19.05**	-18.35**
Gm1 × Gm97	-6.30**	-6.14**	-2.16	-1.30
Gm1 × Sk11	-5.60**	-5.44**	-2.51	-1.66
Gm1 × Gz666	-6.48**	-6.32**	-5.51	-4.68
Gm1 × Gm1002	-7.18**	-7.02**	-8.79	-8.00
Gm21 × Gm19	-7.71**	-7.54**	-4.57	-3.74
Gm21 × Gm97	-8.23**	-8.07**	-15.35**	-14.61**
Gm21 × Sk11	-8.76**	-8.60**	-5.49	-4.67
Gm21 × Gz666	-7.18**	-7.02**	-16.07**	-15.34**
Gm21 × Gm1002	-7.01**	-6.84**	-28.62**	-28.00**
Gm19 × Gm97	-6.65**	-6.49**	10.33*	11.29*
Gm19 × Sk11	-6.48**	-6.32**	-11.55*	-10.78*
Gm19 × Gz666	-0.70	-0.53	-16.51**	-15.79**
Gm19 × Gm1002	-5.95**	-5.79**	-3.35	-2.50
Gm97 × Sk11	-7.88**	-7.72**	-17.84**	-17.12**
Gm97 × Gz666	-2.45*	-2.28*	21.45**	22.51**
Gm97 × Gm1002	-7.71**	-7.54**	-8.36	-7.56
Sk11 × Gz666	-7.18**	-7.02**	-3.31	-2.47
Sk11 × Gm1002	-5.95**	-5.79**	1.02	1.90
Gz666 × Gm1002	-4.55**	-4.39**	10.67*	11.63*
LSD 0.05	1.19		2.63	
0.01	1.57		3.47	

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

Table 4. Mean squares due to GCA and SCA and their interactions with locations for four studied traits.

SOV	df	Number of days to 50% silking	Plant height	Ear height	Grain yield
GCA	**6**	**23.68****	**3345.77****	**1192.21****	**49.64****
SCA	**14**	**9.03****	**645.39****	**179.59****	**95.77****
GCA × L	**12**	**1.79**	**344.73***	**199.39****	**48.42****
SCA × L	**28**	**3.39****	**367.17****	**90.18**	**20.00****
Error	**120**	**1.52**	**162.28**	**69.71**	**8.34**
$2K^2$ GCA/($2K^2$ GCA+K^2 SCA) (RGS)		**0.54**	**0.72**	**0.80**	**0.16**

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

Comparable outcomes were documented by Ismail *et al* (2023) and Abd-Elaziz *et al* (2024). The ratio $2K^2$ GCA/($2K^2$ GCA + K^2 SCA) (RGS), which suggested by Baker (1978). The results showed that RGS values were 0.54, 0.72 and 0.80 for number of days to 50% silking, plant height and ear height, respectively, indicating that additive gene effects are important in the inheritance of these traits. These findings are consistent with those reported by Abd El-Azeem *et al* (2021), Habiba *et al* (2022), Akhi *et al* (2023) and Abd-Elaziz *et al* (2024). However, grain yield had a (GSR) of 0.16, indicating that non-additive gene effects are controlling the inheritance of grain yield. These results are consistent with those reported by Akhi *et al* (2023) and Mosa *et al* (2024a).

Estimates of general combining ability effects of seven inbred lines for four studied traits across three locations are shown in Table (5). Positive GCA effects are desirable for improving grain yield, while negative GCA effects are desirable for selecting for earliness, shorter plant height, and ear height. The results showed that the inbred lines Gm1, Gm21, and Sk11 had negative and significant or highly significant GCA effects for number of days to 50% silking, indicating that these lines had an appropriate allele frequency for earliness.

Additionally, the two inbred lines Gm21 and Gm19 exhibited negative and highly significant GCA effects for both plant height and ear height, suggesting a tendency towards shortness. In terms of grain yield, the two inbred lines Gm97 and Gz666 had positive and highly significant GCA effects; these two inbred lines could be utilized in making hybrids that have high yielding ability. The desirable inbred lines for the various traits could be employed in the Maize Breeding Program based on the aforementioned results.

Table 5. GCA effects of seven inbred lines for traits under study as combined across three locations.

Inbred line	Number of days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (ard/fed)
Gm1	-0.34*	2.83	0.11	-0.02
Gm21	-1.01**	-17.00**	-7.93**	-1.71**
Gm19	0.42*	-4.75**	-5.29**	-0.50
Gm97	-0.05	0.71	1.00	1.23**
Sk11	-0.38*	2.91	1.87	-0.24
Gz666	1.30**	8.23**	7.49**	1.36**
Gm1002	0.06	7.07**	2.74*	-0.12
LSD g_i 0.05	0.34	3.48	2.28	0.79
0.01	0.44	4.60	3.02	1.04
LSD g_i-g_J 0.05	0.51	5.32	3.49	1.21
0.01	0.68	7.03	4.61	1.59

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

Table 6 presents estimates of specific combining ability effects of 21 crosses for studied traits across three locations. The desirable hybrids for SCA effects were (Gm1 × Gm19), (Gm1 × Gz666), (Gm21 × Gz666), (Gm97 × Gm1002) and (Sk11 × Gz666) for early maturity, (Gm1 × Gm19), (Gm21 × Gm97) and (Gm97×Sk11) for short plant height, (Gm97 × Sk11) for short ear height, (Gm1 × Gm21), (Gm21 × Gm19), (Gm21 × Sk11), (Gm19 × Gm97), (Gm97 × Gz666), (Sk11 × Gm1002) and (Gz666 × Gm1002) for grain yield. These hybrids have potential for use in maize breeding programs for various purposes.

Table 6. SCA effects of 21 crosses for traits under study as combined across three locations.

Cross	Number of days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (ard/fed)
Gm1 × Gm21	0.45	4.49	1.32	3.91**
Gm1 × Gm19	-1.08**	-16.87**	-4.10	-2.95**
Gm1 × Gm97	0.50	5.00	2.61	-0.23
Gm1 × Sk11	1.27**	6.69	1.30	1.14
Gm1 × Gz666	-0.97**	8.49*	-1.77	-1.25
Gm1 × Gm1002	-0.17	-7.80*	0.65	-0.63
Gm21 × Gm19	-0.19	10.29**	4.05	2.55**
Gm21 × Gm97	-0.06	-7.96*	-3.90	-2.01*
Gm21 × Sk11	-0.06	2.29	5.34*	2.05*
Gm21 × Gz666	-0.75*	-5.24	-2.73	-2.34*
Gm21 × Gm1002	0.61	-3.87	-4.08	-4.16**
Gm19 × Gm97	-0.48	8.91*	6.34**	3.54**
Gm19 × Sk11	-0.04	-3.62	-2.86	-0.76
Gm19 × Gz666	1.94**	-0.71	-0.93	-3.67**
Gm19 × Gm1002	-0.15	2.00	-2.50	1.28
Gm97 × Sk11	-0.46	-8.31*	-7.37**	-4.14**
Gm97 × Gz666	1.30**	2.27	4.12	4.60**
Gm97 × Gm1002	-0.79*	0.09	-1.79	-1.76*
Sk11 × Gz666	-1.37**	-5.71	-1.41	-0.46
Sk11 × Gm1002	0.65	8.67*	5.01*	2.17**
Gz666× Gm1002	-0.15	0.91	2.72	3.11**
LSD S_{ij} 0.05	0.66	6.86	4.50	1.56
0.01	0.88	9.07	5.95	2.06
LSD S_{ij}-S_{ik} 0.05	1.03	10.63	6.97	2.41
0.01	1.36	14.06	9.21	3.19
LSD $S_{ij}S_{kl}$ 0.05	0.89	9.21	6.04	2.09
0.01	1.18	12.18	7.98	2.76

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

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تقييم بعض هجن الذرة الشامية الصفراء لمحصول الحبوب والتبكير فى النضج

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تم تهجين سبع سلالات جديدة من الذرة الشامية الصفراء بنظام التزاوج النصف دائرى بمحطة بحوث الجميزة موسم 2021. تم تقييم التهجينات الناتجة وعددها 21 هجين بالإضافة إلى إثنين من الهجن التجارية للمقارنة فى محطات البحوث الزراعية بالجميزة والإسماعيلية وسدس موسم 2022 بإستخدام تصميم القطاعات الكاملة العشوائية (RCBD) فى ثلاث مكررات. وكانت الصفات التى تم دراستها هى عدد الأيام حتى ظهور حرائر 50% من النباتات – إرتفاع النبات – إرتفاع الكوز – محصول الحبوب. كان التباين الراجع للمواقع والهجن وتفاعلهما عالى المعنوية لجميع الصفات المدروسة. كان التباين الراجع لكلا من القدرة العامة والخاصة على الائتلاف وتفاعلهما مع المواقع معنوياً لمعظم الصفات المدروسة. كانت تأثيرات كلاً من الفعل الوراثى المضيف والفعل الوراثى غير المضيف مهماً فى وراثة جميع الصفات تحت الدراسة ومع ذلك كان الفعل الوراثى المضيف أكثر أهمية فى وراثة معظم الصفات. أظهرت السلالتان Gm97، Gz666 أعلى قدرة عامة على التآلف لصفة محصول الحبوب. أظهرت الثلاثة هجن (Gm97 × Gz666)، (Gz666 × Gm1002)، (Gm19 × Gm97) قدرة خاصة على الإئتلاف مرغوبة لصفة محصول الحبوب كما أنها تفوقت معنوياً على هجن المقارنة SC168، SC3444 فى محصول الحبوب والتبكير فى النضج وعليه يمكن إستخدام هذه الهجن فى برامج التربية للذرة الشامية كهجن صفراء عالية الإنتاجية ومبكرة فى النضج.