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Diallel Analysis of Seven Maize Inbred Lines for Different Characters across Locations

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ABSTRACT: Seven elite yellow maize inbred lines derived from different genetic sources were evaluated in this study to estimate combining ability, type of gene action, and superiority crosses over commercial check hybrids. In 2021 growing season, all possible combinations between these inbred lines were done, excluding reciprocals (Griffing's 1956, method 4, model 1) at Gemmeiza Agricultural Research Station, located in the center of the delta, Gharbia governorate, Egypt. In 2022 season, the resulting 21 crosses along with two commercial crosses; SC. 168 and Pioneer SC. 3444 were evaluated in a randomized complete block design (RCBD) with three replications at the three Research Stations (Locations); Gemmeiza, Mallawi and Nubaria. Recorded data were days to 50% silking, plant height, ear height and grain yield. The results showed significant differences for all the studied traits between the three locations. Mean squares of crosses and their partitions, GCA and SCA were highly significant for all studied traits, meaning that both additive and non-additive gene effects were important in the inheritance of all studied traits, however the additive gene effects played the major role in the inheritance of days to 50% silking, ear height, and grain yield, meanwhile, the non-additive gene effects were predominance for the inheritance of plant height. The parental lines Gm 6022, Gm 36 and Gz 639 had significant GCA effects for grain yield. Seven crosses (Gm 5 x Gm 36), (Gm 5 x Gz 639), (Gm 6052 x Gm 74), (Gm 6022 x Gm 15), (Gm 74 x Gm 36), (Gm 15 x Gm 10) and (Gm 10 x Gz 639) showed significant values for SCA effects for grain yield. Cross Gm 6052 x Gm 74 significantly out yielded (34.23 ard/fed) the best check SC 168 (30.87 ard/fed) and is recommended for further evaluation to be registered as new hybrid.

Keywords: *Zea mays, additive gene effects, non-additive gene effects*

INTRODUCTION

Maize (*Zea mays* L.) is one of the most strategic crops in Egypt and worldwide. It is essentially consumed for both human food and animal feed. It is used as a raw material for many industrial products (El-Hosary *et al.*, 2018). Egypt imported more than 50% of its maize grain consumption. So, maize breeders in Egypt encouraged to produce new hybrids with high yield to decrease this gap between production and consumption. Identifying the combining ability of maize genotypes is important to produce the promising hybrids. Diallel analysis provides information about the components of genetic variations and help the breeder in the selection of desirable parents for crossing program and in deciding a suitable breeding procedure for the genetic improvement of various quantitative traits. Sprague and Tatum (1942) defined general (GCA) and specific (SCA) combining ability. Melchenger *et al.* (1990), Zelleke (2000), Mosa (2006) and Mosa *et al.* (2023) found that both GCA and SCA were significant for grain yield, silking date, plant and ear height. Hence both additive and non-additive gene effects were important for these traits. However Abd El-Mottalb *et al.* (2014), Abo El-Haress (2015), El-Hosary *et al.* (2018) and Abd El-Azeem *et al.* (2021) reported that additive gene effects have the important role in inheritance of grain yield. Other researchers reported that the non-additive gene effects were the major role in the inheritance of grain yield (Attia *et al*. 2015, Kamara 2015, Wani *et al.* 2017, Murtadha *et al*. 2018 and Kamara *et al.* 2019). This investigation aimed to estimate the combining ability of some elite maize inbred lines and to identify superior hybrids to improve the yielding ability in maize breeding programs.

MATERIALS AND METHODS

Seven elite yellow maize inbred lines were used as parents in this study. The code number and names of inbreds are presented in Table (1). In 2021 growing season, all possible combinations without reciprocals crosses were made among these inbred lines in half diallel fashion to obtain 21 F_1 crosses. In 2022 growing season, the resulted 21 F_1 hybrids and two check hybrids SC168 and SC Pioneer 3444 were evaluated in three research stations represented different environments; Gemmeiza, Mallawi and Nubaria. A randomized complete block design with three replications was used. Each plot consisted of one row, 6 m long and 0.80 m width. Planting was made in hills spaced at 0.25 m with two kernels per hill, the seedlings were thinned to one plant per hill after 21 days from planting. All agricultural practices were carried out according to standard commercial recommendations for maize production.

Table (1): Code number and name of inbred lines in the current study.

Code	Name
(P_1)	Gm.5
(P_2)	Gm. 6022
(P_3)	Gm. 74
(P_4)	Gm. 36
(P_5)	Gm. 15 T2
(P_6)	Gm. 10
(P_7)	Gz. 639

Data were collected for number of days from planting to 50% silk emergence (number of days from planting to the date when 50% of the plants in a row have visible silk), plant height (Average height of 5 guarded plants in centimeters (cm) measured from soil surface to the point on stem where tassel branching begins), ear height (Average height of 5 guarded plants in centimeters (cm) measured from soil surface to the point on stem where ear leaf begins) and grain yield (ard/fed) grams of grain shelled from harvested ears adjusted to 15.5% moisture content (one ardab = 140 Kg, one feddan = 4200 m^2). The obtained data were statistically analysis according to Snedecor and Cochran (1980). The combined analysis was done when homogeneity of error mean squares for the three locations was found. General and specific combining ability were estimated according to Griffing (1956), method-4, model-1.

RESULTS AND DISCUSSION

The result of the combined analysis of variance for four studied traits across three locations is presented in Table (2). The mean squares due to locations (L), crosses (C) and their interaction (C x L) were highly significant for all traits, except for C x L for plant and ear height, meaning that the locations differed in their conditions (soil and weather). The mean squares due to GCA and SCA were highly significant for all studied traits, meaning that both GCA (additive gene effects) and SCA (non-additive gene effects) were important in the inheritance of these studied traits. All traits showed GCA/SCA ratio more than unity values except plant height, indicating that the additive gene effects played a major role in the inheritance of days to 50% silking, ear height and grain yield.

Table (2): Mean squares of locations, crosses, GCA, SCA and their interactions for the four studied traits.

SOV	d.f	Days to 50% silking	Plant height	Ear height	Grain yield
Location (L)	2	668.45**	28232.59**	16403.24**	763.09**
Rep/L	6	8.58	494.01	476.40	7.66
Crosses (C)	20	20.63**	1424.46**	943.58**	71.14**
GCA	6	33.57**	1313.95**	1275.72**	82.34**
SCA	14	15.03**	1471.81**	801.24**	66.34**
C x L	40	5.78**	216.15	171.15	12.24**
GCA x L	12	4.16**	267.09	270.56*	10.34
SCA x L	28	6.42**	194.30	128.55	13.07**
Error	120	1.83	195.66	131.85	6.08
GCA /SCA		2.23	0.89	1.59	1.24

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

Meanwhile the non-additive gene effects played the major role in the inheritance of plant height. The results obtained are in confirmation with the results obtained in maize by El-Shamarka *et al*. (2015), Karim *et al*. (2022) and Ismail *et al.* (2023). The mean squares due to GCA x L interaction were significant and highly significant for ear height and days to 50% siking, respectively. In contrast, mean squares due to SCA x L interaction were highly significant for days to 50% silking and grain yield. Abd El Mottalb and Gamea (2014) found that the additive gene action has the major role in the inheritance of days to 50% siking, plant height and ear height while the non-additive has the major role in inheritance of grain yield. Abd-Elaziz *et al.* (2021) illustrated that additive gene effect has the major role in inheritance of days to 50% silking, plant height and ear height. Meanwhile, the non-additive gene variance has a major role in the inheritance of grain yield. Ismail *et al.* (2023) and Mosa *et al.* (2023) found that the additive gene action has the major role in the inheritance of days to 50% silking, plant height, ear height and grain yield.

The performance of crosses for the four studied traits across the three locations are presented in Table (3). Fifteen crosses from the twenty one crosses exhibited earliness than the earliest check SC. 168. The best crosses were (P1 x P5), (P1 x P6), (P1 x P7) and (P3 x P6). Four crosses (P1 x P5), (P3 x P5), (P3 x P6) and (P3 x P7) were shorter than the shortest check (SC.168); their crosses could be tested in high plant density. The low ear position is favorable to immune crosses from lodging; this appears in three crosses (P3 x P5), (P3 x P6) and (P3 x P7) which had lower ear placement than the best check cross SC 3444. For grain yield, one cross P2 x P3 (34.23 ard/fed) significantly out yielded than the best check cross SC. 168 (30.87 ard/fed). In comparison, five crosses (P1 x P4), (P2 x P5), (P3 x P4), (P4 x P7) and (P6 x P7) did not significantly out yielded the best check (SC. 168). These above crosses will be evaluated in the advanced level of testing in maize breeding program.

General combining ability effects could be estimated whenever the significant of GCA mean squares for the trait is viewed. Estimates of general combining ability effects for days to 50% silking, plant height, ear height and grain yield across the three locations are presented in Table (4). Parents 1 and 3 showed favorable significant negative values for days to 50% silking. Therefore, these parents are recommended to inter earliness program. For plant and ear height, parent 3 showed negative significant GCA effects and is recommended for breeding to plant density tolerance. Parents 2, 4 and 7 showed positive significant GCA effects for grain yield so these parents are good combiners for grain yield. These results suggested the importance of these inbreds being involved in improving the maize program.

Table (3). Mean performance of 21 F_1 crosses and two checks for the four traits across the three locations.

cross	Days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (ard/fed)
P1 x P2	58.22	213.89	112.11	29.73
P1 x P3	57.11	217.00	107.11	27.18
P1 x P4	58.11	231.67	124.33	31.31
P1 x P5	56.22	207.67	109.78	22.95
P1 x P6	56.44	213.11	115.56	26.33
P1 x P7	56.78	235.11	128.67	30.02
P2 x P3	59.44	238.11	121.00	34.23
P2 x P4	57.67	217.67	114.33	29.82
P2 x P5	60.22	244.00	129.89	30.79
P2 x P6	58.56	239.44	128.89	27.95
P2 x P7	60.33	228.89	121.56	27.55
P3 x P4	57.33	234.56	125.89	30.85
P3 x P5	57.33	211.44	103.56	25.14
P3 x P6	56.44	196.67	95.33	25.15
P3 x P7	56.89	203.33	95.56	24.98
P4 x P5	56.89	216.56	117.00	26.30
P4 x P6	60.78	227.33	123.00	27.27
P4 x P7	60.78	224.89	119.56	31.12
P5 x P6	58.11	218.56	111.22	27.35
P5 x P7	60.11	219.44	119.22	28.13
P6 x P7	58.44	230.33	127.56	32.12
SC. 168	60.33	225.89	124.78	30.87
SC. 3444	62.89	228.78	116.94	30.64
LSD 0.05	1.27	13.12	10.77	2.31
LSD 0.01	1.65	17.01	13.96	3.00

Table (4). Estimates of general combining ability (GCA) effects for the seven inbred lines for the four studied traits.

Inbred	Days to 50% silking	Plant height	Ear height	Grain Yield
P1	-1.26**	-3.15	-0.55	-0.57
P2	1.05**	9.56**	5.49**	1.94**
P3	-0.93**	-6.62**	-10.37**	-0.57
P4	0.47*	3.69	4.76**	1.26**
P5	-0.06	-3.30	-1.93	-1.94**
P6	-0.09	-1.75	0.25	-0.84*
P7	0.82**	1.56	2.36	0.71*
LSDgi 5%	0.37	3.84	3.15	0.68
LSDgi 1%	0.48	4.98	4.09	0.88
LSDgi-gj5%	0.57	5.87	4.82	1.03
LSDgi-gj 1%	0.74	7.61	6.24	1.34

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

Specific combining ability effects are estimated whenever the significance of SCA mean squares is in view. SCA effects across the three locations for 21 crosses resulted from the half diallel of seven parents are presented in Table (5). Results showed that five crosses (P1 x P7), (P2 x P4), (P3 x P6), (P3 x P7), and (P4 x P5) had negative significant SCA effects for days to 50% silking toward earliness. For plant height, five crosses (P1 x P2), (P1 x P5), (P2 x P4), (P3 x P6) and (P3 x P7) showed significant negative SCA effects for short plants. Four crosses (P1 x P2), (P2 x P4), (P3 x P6) and (P3 x P7) exhibited significant negative SCA effects for ear height. For grain yield, SCA showed significant positive effects in seven crosses (P1 x P4), (P1 x P7), (P2 x P3), (P2 x P5), (P3 x P4), (P5 x P6) and (P6 x P7).

Table (5). Estimates for specific combining ability (SCA) effects for 21 crosses for the four studied traits.

Cross	Days to 50% silking Silk	Plant height	Ear height	Grain Yield
P1 x P2	0.24	-14.89**	-9.55**	-0.04
P1 x P3	1.10**	4.40	1.32	-0.08
P1 x P4	0.70	8.76*	3.41	2.22**
P1 x P5	-0.65	-8.24*	-4.46	-2.94**
P1 x P6	-0.41	-4.36	-0.86	-0.66
P1 x P7	-0.98**	14.33**	10.14**	1.49*
P2 x P3	1.13**	12.80**	9.16**	4.47**
P2 x P4	-2.05**	-17.96**	-12.64**	-1.78**
P2 x P5	1.04**	15.38**	9.61**	2.39**
P2 x P6	-0.61	9.27*	6.43*	-1.55*
P2 x P7	0.26	-4.60	-3.01	-3.50**
P3 x P4	-0.41	15.11**	14.78**	1.76**
P3 x P5	0.13	-1.00	-0.86	-0.74
P3 x P6	-0.74*	-17.33**	-11.26**	-1.84**
P3 x P7	-1.21**	-13.98**	-13.15**	-3.56**
P4 x P5	-1.72**	-6.20	-2.55	-1.42*
P4 x P6	2.19**	3.02	1.27	-1.54*
P4 x P7	1.28**	-2.73	-4.28	0.75
P5 x P6	0.06	1.24	-3.81	1.74**
P5 x P7	1.15**	-1.18	2.07	0.97
P6 x P7	-0.50	8.16*	8.23**	3.85**
LSD_{SIJ}5%	0.73	7.58	6.22	1.34
LSD_{SIJ}1%	0.95	9.82	8.06	1.73
$LSD_{SIJ-SIK}$ 5%	1.14	11.74	9.63	2.07
$LSD_{SIJ-SIK}$1%	1.47	15.22	12.49	2.68

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

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الملخص العربى

تحليل الدياليل لسبعة سلالات من الذرة الشامية لصفات مختلفة عبر المواقع

محمد عبدالعزيز عبدالنبى عبدالعزيز و محمد موسى بدوى درويش وهشام عبدالحميد ابويوسف وعبدالفتاح عفيفى محمد عفيفى و محمد رضا اسماعيل و نوره على حسن

قسم بحوث الذرة الشامية – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية – الجيزة

استخدمت فى هذه الدراسة سبعة سلالات منتخبة صفراء من الذرة الشامية مشتقة من مصادر وراثية مختلفة وذلك لدراسة القدرة الائتلافية ، طبيعة الفعل الجينى والهجن المتفوقة مقارنة بأعلى هجن المقارنة المستخدمة. حيث ان فى الموسم الزراعى 2021 تم إجراء كافة التهجينات الممكنة بين السلالات فى نظام تزاوج الدياليل النصف دائرى بإستخدام طريقة جريفينج 1956 ، طريقة –4 نموذج –1 للحصول على 21 هجين بمحطة البحوث الزراعية بالجميزة. فى الموسم الزراعى 2022 تم تقييم الـ 21 هجين بالأضافة إلى هجينين للمقارنة وهما هجين فردى 168 وهجين فردى بايونيير 3444 فى تصميم القطاعات كاملة العشوائية بثلاثة مكررات فى ثلاث محطات بحثية هى الجميزة و ملوى و النوبارية. أخذت البيانات على صفات عدد الايام حتى ظهور 50 %حريرة ، إرتفاع النبات ، إرتفاع الكوز ومحصول الحبوب أردب/فدان. أظهرت النتائج وجود إختلافات معنوية بين الثلاثة مواقع لكافة الصفات المدروسة. أظهرت النتائج أن التباينات الراجعة للهجن ومجزئاتها (القدرة العامة على للائتلاف والقدرة الخاصة على للائتلاف عالية المعنوية لكل صفات الدراسة. وهذا يشير إلى اهمية الفعل الجينى المضيف وغير المضيف فى وراثة هذه الصفات. ومع ذلك الفعل الوراثى المضيف كان اكبر اهمية فى كلا من صفات ظهور 50% حريرة وارتفاع الكوز والمحصول بينما كان الفعل غير المضيف اكثر اهمية فى وراثة ارتفاع النبات. أظهرت النتائج إلى أن أفضل السلالات فى تاثيرات القدرة العامة على الائتلاف لصفة المحصول هى السلالة 2 و السلالة 4 والسلالة 7. اظهرت سبعة هجن قدرة ائتلافية خاصة لصفة محصول الحبوب (جميزة 5 xجميزة 36 و جميزة 5 xجيزة 639 و جميزة 6022 xجميزة 74 و جميزة 6022 xجميزة 15 و جميزة 74 xجميزة 36 و جميزة 15 xجميزة 10و جميزة 10 xجيزة 639 و الهجين جميزة 74 x جميزة 6022 تفوق فى المحصول معنويا (34,21 اردب للفدان) عن افضل هجن المقارنة هجين فردى 168(30.87 اردب للفدان) ومن ثم يرشح للدخول فى تجارب التقييم على نطاق اوسع فى عدة جهات تمهيدا لتسجيله واعتماده للانتاج التجارى.