PARTIAL DIALLEL ANALYSIS OF MAIZE INBRID LINES FOR KERNAL YIELD AND ITS COMPONENTS IN SULAIMANI-IRAQ

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ABSTRACT

This study was aimed to investigate combining ability among maize inbred lines. Randomized complete block design with three replicates was used to study the general combining ability of parents, and specific combining ability of 12 F1s. Combining ability was studied in a partial diallel cross in maize for traits yield and attribute at two locations (Qlyasan and Kanipanka) at Sulaimani Governorate. The cross 3×6 produced the highest value kernels yield and most of the attributed traits as the average of both locations. Mean squares due to crosses, GCA and SCA were highly significant for most traits as the average of both locations. The ratio of σ^2gca/ σ^2sca was found to be less than one for all traits except days to silking and rows/ ear at the first location, ears/plant, and kernels/row at the second location, and days to silking, plant height, rows/ear and kernels/row as the average of both locations which were more than one, this confirms the importance of both additive and non-additive gene effect in the inheritance of these traits. Heritability in broad-sense was found to be highest for days to tasseling and silking, ear width, kernels/row, and 300 kernels weight, while for narrow sense, it was low to moderate for different traits.

Keywords: locations, gene action, heterosis, kernel yield, heritability.
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التحليل الوراثي للجيل الأول بأستعمال التهجينات التبادلية النصفية للذرة الصفراء في بيئتين مختلفتين ضمن محافظة السليمانية– العراق

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المستخلص:

يعتبر برنامج تربية وتحسين الذرة الصفراء مهم جداً لتلبية الطلب المستمر لتزايد السكان, تم دراسة القدرة للتآلف في نظام التهجينات التبادلية الجزئية لمحصول الذرة الصفراء لحاصل الحبوب ومكوناتها. أستعمل تصميم القطاعات العشوائية الكاملة وبثلاث مكررات, لدراسة القدرة العامة للتآلف للأباء والقدرة الخاصة للتآلف لـ 12 من هجن الجيل الأول في موقعين (قلياسان وكاني بانكة) بمحافظة السليمانية. كانت متوسط المربعات الخاصة للهجن, GCA وSCA كان معنوي لمعظم الصفات المدروسة كمتوسط لكلا الموقعين. أظهر الهجين 3×6 أفضل قيمة لحاصل الحبوب ومعظم مكوناته كمتوسط لكلا الموقعين. إن نسبة σ^2gca/ σ^2sca أقل من الواحد الصحيح لجميع الصفات بأستثناء عدد الأيام للتزهير الأنثوي وعدد الصفوف/ عرنوص في الموقع الأول و كذلك عدد العرانيص/ نبات وعدد الحبوب/ صف في الموقع الثاني ,وعدد الأيام للتزهير الأنثوي , طول النبات, عدد الصفوف/ عرنوص وعدد البذور/ صف كمتوسط الموقعين حيث كانت النسبة أعلى من الواحد الصحيح لتلك الصفات وهذا يؤكد أهمية كلا الفعل الجيني الأضافي وغير الأضافي في توريث تلك الصفات. درجة التوريث في معناها العام كانت عالية للتزهير الذكري والأنثوي, قطر العرنوص, عدد الحبوب/ صف و وزن 300 حبة بينما كانت واطئة الى متوسطة في الصفات المختلفة.

كلمات مفتاحية: المواقع، الفعل الجيني، قوة الهجين، حاصل الحبوب، درجة التوريث.
***جزء من أطروحة دكتوراه للباحث الأول.**

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INTRODUCTION

Maize (*Zea mays* L.) is a diploid organism and has ten pairs of chromosomes. It has great social and economic importance for humans, animals, and industry (26). Maize is a C4 plant and can utilize solar energy more efficiently than other cereals. Maize crops can be utilized for multiple purposes like human food, poultry feed, animal fodder, and industrial raw material. Maize is one of the oldest and key cereal crops in the world. It is the highest yielding grain crop having multiple uses. A great combination of high market demand with comparatively low production cost, ready market, and high yield has generated great interest in maize cultivation. It is gaining popularity daily due to vast demand, particularly for the poultry industry (1). It is cultivated in nearly 150 Mha in approximately 160 countries, constituting 36% (782 Mt) of the global grain production (9). Maize breeders do their best to explore the genetic material to develop new maize genotypes characterized by high yielding and better quality (68). The main models of diallel analysis employed are the balanced diallel, where all the possible combinations are performed; the peculiarity of this model is the limitation of working with a large number of parents (19). The diallel mating aiming the selection of parents and hybrids has been widely used in plant breeding (50, 62, 76); moreover, according to (81), through hybrid combinations, the best parents with the highest number of favorable and complementary alleles can be identified. This mating design allows the estimation of the genetic parameters useful for genetic selection. In general terms, diallel schemes are useful to evaluate the genetic values of the genitors through their combing ability. The combining ability is the result of the alleles combination of an individual with the alleles of other individuals, and the performance of the generated progeny expresses it. (60, 59). The partial diallel involves two heterotic groups of parents, maximizing the information about the study groups with a lower number of crossings, yet the reciprocal effects are generally not estimated, allowing loss of additional information. Circulating diallel are represented in the design by the same number of crossings, still less than p-1, reducing the number of total combinations; however, losses of information occur regarding certain hybrid combinations, for being absent. A variable number of crossings represents incomplete diallel; this design results from combinations losses. In the unbalanced diallel are estimated all hybrid combinations and also the other generations are represented, but in variable frequency due to the unequal number of replicates per treatment (19). The nature and magnitude of gene action are important factors in developing an effective breeding program. Combining ability analysis is useful to assess the potential inbred lines and helps identify the nature of gene action involved in various quantitative characters. This information is helpful to plant breeders for formulating hybrid breeding programs (3). Maize breeders need information about the type, and relative amount of genetic variances component and their interaction with the environment as well as the information on heterosis is essential for developing new hybrids; therefore, heterosis has been used with plant breeders for improving the yield components and yield of different crops which could be used in hybridization programs to develop superior hybrids. This study was designed to estimate the combining abilities of inbred lines and crosses under two locations to determine the effects of environments on the expression of both GCA, SCA, and some genetic parameters.

MATERIALS AND METHODS

This experiment was conducted using partial diallel cross was implemented according to Kempthorne and Curnow 1961, using eight Zea maize inbred lines, which have been received from Baghdad University, As follow: (MGW 16, NADH 102, NADH 704, NADH 706, NADH 52, ZY 52, NADH 905, MSI 4279). The current study used 8 parents from inbred lines and their F1 crosses. The experiment was conducted between April 4 to July 28, 2020, at the Kani panka location, but at the Qlyasan location, carried out between April 7 to July 30, 2020, at the Sulaimani Governorate. The location climate is considered a semi-arid environment, cold and wet in winter, hot and dry in summer. The average temperature from July to August is between 39-43^{0}C and often reaches nearly 50^{0}C. October means high temperatures are 24-29^{0}C and slightly cooling down in November. (Kurdistan Regional Government, Director of Agriculture/Agriculture of Meteorology, Bakrajo, 2020), Mahmood and Towfiq (44). The experiment was conducted using completely randomized block design with three replicates at each location. Each genotype is planted in one row 3-meter-long 0.75 meter spacing between rows and 0.30m spacing between plants within the row.

Data were taken for the characters:

The number of days to 50% Tasseling, Number of days to 50% Silking, Plant height (cm), ear length (cm), ear diameter (mm), Number of ears/ plants, Number of rows/ears, Number of kernels/row, 300 kernels weight (g) and Kernels yield (ton/ha). Statistical analysis was performed for each character using analysis of variance. According to the significant results between genotypes for each studied character, partial diallel analysis had been performed. A random sample of crosses of the size S is analyzed, in which S is defined as less than (n-1). Both S and n should be neither odd nor even. With n lines, the total number of crosses to be analyzed in partial diallel thus is (ns/2). For sampling, a constant K is defined as k=(n+1-s)/2.

ANOVA of Combining Ability in Partial Diallel Crossing:

Source of Variation	d.f	S.S.	M.S.	E.M.S.
Replication	r-1	$\frac{\sum y^2..k}{(ns/2)} - CF$		
Crosses	(ns/2)-1	$\frac{\sum y^2 ij}{r} - CF$	$\frac{S.S. crosses}{(ns/2)-1}$	
GCA	n-1	r∑GiQi	$\frac{S.S. gca}{n-1}$	$\sigma^2e + r\sigma^2 s + \frac{rs(n-2)}{n-1}\sigma^2 g$
SCA	n(s/2-1)	Treat S.S.- gca S.S.	$\frac{S.S. sca}{n(s/2-1)}$	$\sigma^2e + r\sigma^2 s$
Error	(r-1)[(ns/2)-1]	S.S. T – S.S.t- S.S.r	$\frac{S.Se}{(r-1)[(ns/2)-1]}$	σ^2e
Total	(rns/2)-1	$\sum Y^2 ijk$ – CF		

Where: n: Parents number, r: replication number, and, s: Sample size

To obtain the analysis of variance and the adjusted means of each evaluated treatment in the field trial, the following statistical model was used:

Yijk = μ + τi + βj + θk + δiyijk + εijk

In the model above, Yijk is the value for the *i*-th treatment, in the *k*-th replications, and in *j*-th experimental group; μ is the overall mean; τi is the fixed effect of treatment i;βj is the random effect of group j; θk is the random effect of replications (k);*δ*i*γ*ij is the random effect of the interaction among groups and treatments, where *δ*i = 1 when it is a common treatment (commercial checks), or *δ*i = 0 when it is a regular treatment; and *ε*ijk is the error value.

RESULTS AND DISCUSSION

Qlyasan Location: The mean squares of variance analysis for crosses, general and specific combining ability for studied characters at Qlyasan location, are shows in Table (1). The mean squares for crosses were highly significant for all studied traits except for both no. of ears/ plant and no. of rows/ear, which were significant. Concerning the GCA mean squares for the characters, it was highly significant for all except no. of ears/plant which did not significant and no. of rows/ear which was significant. The SCA mean squares were highly significant for no. of days to 50% tasseling and no. of kernels/row, while it was significant for no. of days to 50% silking, Plant height, ear diameter, 300 kernel weight, and kernel yield. But it was not significant for the others. The mean squares for parents were highly significant for No. of days to 50% silking, no. of rows/ear, no. of kernels/row, 300 kernels weight, and kernel yield. But it was significant for no. of days to 50% tasseling, plant height, ear length, and ear width. But it was not significant for no. of ears/plant. Amanulla et al (6) revealed that mean squares for to crosses and parents were highly significant for all the traits, indicating that considerable genetic variability for various traits existed among the material under study. Turi et al (74) observed significant variability for ear length, no. of kernels/row, ear width, grain moisture content, 300 kernel weights, and kernel yield. Other researchers (67) and (32) reported significant variability for different morphological characters. The mean squares due to SCA were higher than GCA for plant height, ear height, and days to silking, which revealed the predominance of non-additive gene action for controlling these characters. The higher magnitude of GCA variance was found for days to maturity, grains per ear, and 1000-grain weight, which indicated a predominance of additive gene action (2,3).

Table 1. Mean squares of variance analysis for crosses, general, specific combining abilities and for parents in maize for studied characters at Qlyasan locations

Source of Variance	Mean squares					Mean squares		
	Replications	Crosses	GCA	SCA	$\sigma^2 e$	Replications	Parents	$\sigma^2 e$
df / Characters	2	11	7	4	22	2	7	14
No. of days to 50% Tasseling	2.527	3.367 **	3.470 **	3.187 **	0.440	0.722	0.952 *	0.299
No. of days to 50% Silking	0.861	2.794 **	3.973 **	0.732 *	0.211	0.560	6.645 **	1.481
Plant height	10.704	61.351**	64.884**	55.169 *	17.625	6.681	58.271 *	18.780
Ear length (cm)	2.511	3.984 **	4.991 **	2.223 n.s	0.813	0.621	1.524 *	0.509
Ear width (mm)	6.181	14.463 **	14.882 **	13.729 *	3.428	9.569	16.541 *	4.798
Number of ears / plant	0.003	0.205 *	0.211 n.s	0.196 n.s	0.087	0.171	0.089 n.s	0.034
Number of rows/ear	0.333	4.307 *	5.724 *	1.825 n.s	1.650	0.505	2.194 **	0.505
Number of kernels/ row	1.788	65.361 **	86.456 **	28.443 **	3.683	11.884	61.457 **	8.069
300 kernels weight	10.563	75.162**	91.295**	46.930 *	13.624	10.926	74.508 **	9.551
Kernels yield	1.982	1.860 **	1.882 **	1.820 *	0.435	4.498	1.231 **	0.285

The means of studied characters for F1 crosses at the first location (Qlyasan), is represent in Table (2). The earliest cross to 50% tasseling and 50% silking at Qlyasan location showed by the cross (2×6) and (3×6) with 52.444 and 62.333 days respectively, while the cross (2×6) produced the maximum number of kernels/ rows reached 38.822. The highest plant height and ear length was shown by the cross (3×7) 176.933 and 18.644 cm, respectively. The cross (3×6) produces maximum ear width value, 300 kernel weight, and kernel yield reached 39.043 mm, 65.380 gm, and 6.670 t/h, respectively. The highest no. of ears/plants reached 1.889, produced by the crosses (1×4) and (3×8). The higher ear diameter indicated that the grain to stover ratio might be higher. If the grain size is large, then selection could be made based on ear diameter to improve grain yield in maize (79, 74, and 35). determining performance is affected by environmental variations, and therefore, evaluation based on several years and locations is a necessary strategy to be pursued in the breeding program (79). Crosses effects were significant in almost all evaluated traits except plant height, indicating the average differences among the genotypes. These responses constituted a key element for breeding programs, justifying the partition of variance in the interest groups in the diallel analysis of variance (45). The highest grain yield per plant could be the main selection criteria to develop higher-yielding maize hybrids for highest crop production and productivity (7, 13, 28, 33, 34, 36, 46, 47, 51, 56, and 61).

Table 2. Average of studied characters for the F1 crosses at Qlyasan location

Crosses	Days to 50% Taseling	Days to 50% Silking	Plant height (cm)	Ear length (cm)	ear width (mm)	No. of Ears /plant	No. of rows/ ear	No. of Kernels/ row	300 kernels weight (gm)	Kernels yield ton/ha
1×4	53.222	65.778	166.333	15.520	32.678	1.889	18.111	21.000	52.300	4.067
1×5	52.889	64.556	172.667	16.189	37.891	1.222	18.000	31.667	54.280	5.147
1×6	54.000	64.000	165.667	16.210	34.017	1.333	17.111	35.611	60.177	4.458
2×5	53.444	62.778	160.556	14.478	34.229	1.444	17.333	31.222	47.280	3.418
2×6	52.444	63.111	167.167	16.242	37.732	1.111	16.889	38.222	59.627	4.666
2×7	54.444	63.444	166.667	16.500	36.014	1.444	16.000	34.111	56.063	4.569
3×6	54.111	62.333	166.556	17.046	39.043	1.556	17.222	34.889	65.380	6.670
3×7	52.667	62.445	176.933	18.644	36.001	1.222	15.778	29.556	52.983	5.054
3×8	55.333	64.000	163.444	16.467	34.772	1.889	14.333	36.333	54.400	4.468
4×7	55.000	63.445	168.833	15.367	35.463	1.222	15.667	27.333	50.640	4.267
4×8	55.111	64.000	163.500	14.411	32.396	1.222	16.778	29.667	51.703	4.258
5×8	55.333	64.111	162.222	16.871	38.302	1.222	14.778	30.333	59.267	4.960
LSD (.05)	1.12363	0.778308	7.1089	1.526976	3.135134	0.500161	2.175104	3.249818	6.2501	1.116472

The means of studied characters at the first location due to the parents show in Table (3), It was highly significant for the characters days to 50% silking, no. of rows/ear, no. of kernels/row, 300 kernel weight and kernels yield, but it was significant for the others except no. of ears/plant which did not significant. These results are in line with those of (27), who observed considerable variability among maize genotypes.

Table 3. Average of studied characters for Maize parents at Qlyasan location

parents	Days to 50% Tasseling	Days to 50% Silking	Plant height (cm)	Ear length (cm)	ear width (mm)	No. of Ears /plant	No. of rows/ ear	No. of Kernels/ row	300 kernels weight (gm)	Kernels yield ton/ha
1	55.222	68.111	163.222	12.817	32.683	1.111	14.444	26.167	46.253	4.605
2	54.667	67.334	158.111	13.436	32.743	1.222	14.667	32.444	41.353	4.815
3	55.444	69.111	163.889	12.797	34.819	1.222	14.111	24.333	36.347	3.969
4	54.778	65.889	164.111	13.290	31.292	1.333	13.111	25.111	38.467	3.932
5	56.000	67.778	158.889	12.214	30.231	1.333	15.333	18.167	41.693	4.304
6	55.667	69.333	157.000	13.797	33.270	1.556	14.222	25.000	43.933	4.345
7	56.222	67.000	157.222	13.641	35.547	1.000	14.667	24.889	41.003	3.695
8	55.000	65.000	151.222	14.529	37.476	1.111	16.000	31.889	52.483	5.722
LSD (.05)	0.957563	2.130957	7.589079	1.24952	3.836059	0.32169	1.243928	4.9745	5.4121	0.9353

Data represents in Table (4) illustrate the heterosis values for the crosses at Qlyasan location, estimated as the percentage of F1s deviation from mid parental values. Any combination among the parents had hybrid vigor over the parents, which might be due to dominant, over dominant, or epistatic gene action. So, the crosses showing a desirable SCA effect could be use in the future breeding program. At Qlyasan location, the percentage of heterosis for most crosses were negative; for days to tasseling, the maximum negative heterosis percentage for this trait was recorded by the cross (3×7) recording -5.67 %. All heterosis values for days to silking carried a negative charge. The highest negative heterosis value was -9.95 recorded by the cross (3×6). Concerning plant height and ear length, all crosses recorded a positive heterosis value, and the highest value was 10.20% recorded by the cross (3×7) and 41.04%, respectively. The highest plant height indicated that the respective hybrids might be used for fodder production (11). Most crosses carried a positive charge due to ear width; the highest value was 20.45% for the cross (1×5). Positive and negative heterosis represent in no. of ears/plant, the values were restricted between -20.1 to 61.94% for the crosses (2×6) and (3×8) respectively. Positive and negative heterosis recorded by no. of rows/ear, which restricted between -5.67 to 31.45% for (5×8) and (1×4) respectively. All heterosis values carried a positive charge except the cross (1×4), which showed negative heterosis with -18.09 due to the character no. of kernels /row. In contrast, maximum positive heterosis was 42.86% recorded by the cross (1×5). All crosses for the character 300 kernel weight showed positive heterosis. The maximum heterosis value was 62.88% for the cross (3×6). Positive and negative heterosis values were represented in the character kernel yield. The values were restricted between -11.80 to 60.46% for the crosses (4×8) and (3×6), respectively. Significant mid-parent heterosis and heterobeltiosis were reported for most of the F1 crosses for grain yield and its related traits (39).

Table 4. Heteroses values (percentage of F1s deviation from mid parental values) for studied characters at Qlyasan location

Crosses	Days to 50% Taseling	Days to 50% Silking	Plant height (cm)	Ear length (cm)	ear width (mm)	No. of Ears /plant	No. of rows/ ear	No. of Kernels/ row	300 kernels weight (gm)	Kernels yield ton/ha
1×4	-3.23	-1.82	1.63	18.90	2.16	54.58	31.45	-18.09	-0.14	23.47
1×5	-4.90	-4.99	7.21	29.35	20.45	-0.01	20.90	42.86	23.44	23.44
1×6	-2.61	-6.87	3.47	21.82	3.16	0.00	19.38	39.20	33.45	33.45
2×5	-3.41	-7.07	1.30	12.89	8.71	13.03	15.56	23.38	13.86	13.86
2×6	-4.94	-7.64	6.10	19.29	14.32	-20.01	16.92	33.08	31.23	39.83
2×7	-1.80	-5.54	5.71	21.88	5.47	29.98	9.09	18.99	36.15	36.15
3×6	-2.60	-9.95	3.81	28.20	14.68	12.01	21.57	41.44	62.88	62.88
3×7	-5.67	-8.24	10.20	41.04	2.32	9.99	9.65	20.09	37.00	37.00
3×8	0.20	-4.56	3.74	20.52	-3.81	61.94	-4.80	29.25	22.48	22.48
4×7	-0.90	-4.51	5.08	14.12	6.11	4.76	12.80	9.33	27.44	27.44
4×8	0.40	-2.21	3.70	3.61	-5.78	0.03	15.27	4.09	13.70	13.70
5×8	-0.30	-3.43	4.62	26.17	13.14	-0.01	-5.67	21.20	25.86	25.86
SE	0.5950	0.7124	0.701	2.7135	2.2642	6.8797	3.0560	5.0659	4.4809	3.8616

Data in Table (5) show the estimation of some genetic parameters for studied characters at Qlyasan location. The ratio of σ^2gca/σ^2sca was more than one for both days to silking and no. of rows/ear reached 2.4186 and 8.6582 respectively, Confirming the importance of additive gene effect in controlling the inheritance of these characters, while it was less than unity for the rest. The value of the average degree of dominance as represented in the same Table it was more than one for all characters except days to silking and no. of rows/ear, thus confirming the high contribution of non-additive gene effect in controlling the inheritance of these characters. Heritability in broad-sense was found to be high for most characters except plant height, no. of ears/plant, and No. of rows/ear, which was lower to moderate. Heritability in narrow-sense was found to be high for both days to silking and no. of kernels/row, while it was moderate for ear length, no. of rows/ear and 300 kernels weight and it was low for the other. Some studies have reported high, narrow-sense heritability at 73% (75) and moderate at 40.65% for yield (29). Higher narrow-sense heritability indicated that the contribution of the additive variance effect was greater in the inheritance of these characters (17, 58, and 77). Researchers suggested higher dominance as selection criteria for the developing higher-yielding maize hybrids (12, 30, 43, and 65). Almost equal role of additive and non-additive gene actions was observed for days to maturity. The additive genetic variance was preponderant for grains per ear and 1000-grain weight, and non-additive gene action was involved in plant height, ear height, days to silking, and days to maturity (3).

Table 5. Estimations of some genetic parameters for studied characters at Qlyasan location

Genetic parameters	Characters: Days to 50% Tasseling	Days to 50% Silking	Plant height (cm)	Ear length (cm)	ear width (mm)	No. of Ears /plant	No. of rows/ ear	No. of Kernels/ row	300 kernels weight (gm)	Kernels yield Ton/ha
σ^2e	0.440	0.211266	17.6254	0.813189	3.4280	0.0872	1.6500	3.683	13.624	0.4347
σ^2 gca	0.036647	0.420036	1.2593	0.358756	0.1495	0.0019	0.5055	7.520	5.751	0.0080
σ^2 sca	0.915569	0.173672	12.5147	0.469951	3.4336	0.0363	0.0584	8.253	11.102	0.4619
σ^2gca/σ^2Sca	0.0400	2.4186	0.1006	0.7634	0.0435	0.0517	8.6582	0.9112	0.5180	0.0173
σ^2A	0.073294	0.840071	2.5186	0.717512	0.2990	0.0037	1.0109	15.041	11.502	0.0160
σ^2D	0.915569	0.173672	12.5147	0.469951	3.4336	0.0363	0.0584	8.253	11.102	0.4619
$\bar{a}$	4.998359	0.643016	3.1524	1.144529	4.7922	4.3985	0.3398	1.048	1.389	7.6052
h^2 bs	0.691905	0.827539	0.4603	0.593538	0.5213	0.3145	0.3932	0.863	0.624	0.5236
h^2 ns	0.051283	0.685767	0.0771	0.358639	0.0418	0.0295	0.3718	0.558	0.317	0.0175

Kanipanka location

Regarding the Kanipanka location Table (6), the mean squares due to the crosses were highly significant for all characters except plant height, which was significant, and no. of ears/plant, which was non-significant. The mean squares for SCA due to the characters were highly significant for no. of days to 50% tasseling, no. of days to 50% silking, ear width, 300 kernels weight, and kernel yield, while it was significant for ear length and non-significant for the other. The mean squares for parents due to the characters were highly significant for all characters except ear length, which was significant only. Baktash et al (16) revealed significant differences in all the studied traits. Highly significant differences among genotypes for all characters indicated the presence of sufficient genetic variability. The magnitude of mean squares for GCA and SCA for different characters indicated significant differences among the GCA and SCA effects (14, 25). Significant estimates of GCA and SCA variances suggested the dominant role of both additive and non-additive gene effects, which is supported by others (54, 63). Other researchers (8) Confirmed highly significant differences among the genotypes for all characters, the magnitude of mean squares for general and specific combining abilities for different characters indicated significant differences among the GCA and SCA effects. The mean squares due to SCA were much higher than GCA for plant height, ear height, and days to silking, which revealed the predominance of non-additive gene action for controlling these characters. The higher magnitude of GCA variance was found for days to maturity, grains per ear, and 1000-grain weight, which indicated a predominance of additive gene action (3).

Table 6. Mean squares of variance analysis for crosses, general, specific combining abilities and for parents in maize for studied characters at Kanipanka locations.

Source of Variance	Mean squares					Mean squares		
	Replications	Crosses	GCA	SCA	σ^2e	Replications	Parents	σ^2e
df / Characters	2	11	7	4	22	2	7	14
No. of days to 50% Tasseling	0.670	3.655**	3.736**	3.515**	0.488	0.056	2.920	0.347
No. of days to 50% Silking	0.482	1.882**	2.0699**	1.554**	0.232	0.930	2.600	0.825
Plant height	372.876	180.577*	217.759*	115.509 n.s	69.209	32.673	152.307**	22.539
Ear length (cm)	3.801	5.639**	5.740**	5.462*	1.357	0.736	3.082*	0.763
Ear width (mm)	0.256	32.629**	35.543**	27.531**	1.134	9.121	14.267	1.847
Number of ears / plant	0.028	0.062n.s	0.077*	0.035 n.s	0.0312	0.005	0.190 **	0.015
Number of rows/ear	0.429	2.057**	2.559**	1.179n.s	0.631	1.792	6.793**	1.035
Number of kernels/ row	91.160	28.166*	37.809**	11.290n.s	9.646	5.838	6.188**	1.150
300 kernels weight	0.0116	99.931**	100.608**	98.746**	12.694	2.0800	34.688**	1.289
Kernels yield	0.0031	1.4209**	1.460**	1.353**	0.221	0.2678	1.451**	0.314

At Kanipanka location, the average performance of studied characters represents in Table (7). The cross (3×6) was the earliest for 50% tasseling and 50% silking, while it was the highest for 300 kernels weight showing 49.889, 59.889 days 82.830 gr, respectively. The highest value for plant height and ear length exhibited by the cross (5×8) with 197.888 and 22.100 cm, respectively. The maximum ear width was 44.185 mm produced by the cross (3×7). The maximum number of ears/plant, rows/ear, and kernels/ row were 1.778, 16.667, and 40,444 produced by the crosses (2×6), (1×6), and (3×8), respectively. The highest kernel yield reached 8.646 t/h shown by the cross (4×7) and followed by 8.455 t/h for the cross (1×4). Baktash (15) revealed a significant difference among selection cycles in grain yield and some yield components, and it was concluded that the modified mass selection could be used successfully in improving the grain yield and some yield components of synthetic corn varieties. The selection based on ear length could be improve grain production (4, 6, 40, 53and 70). It can be concluded that selection for Early and Late selection inbred lines and testers' effect have great importance in deriving hybrids of a high yield and several traits (15). High yield under fluctuation environments requires not only high yield in a unique environment, but also the stability of relatively high yield across varied environments (52). The main purpose of multi-environment experiments is to identify superior varieties based on multiple traits and mega environments. (37, 38). Sense each environment consists of a combination of various factors, in other words, cold and drought stress that influence adaptation and stability performance, it is difficult to specify all the differences between environments about these factors (18).

Table 7. Average of studied characters for the F1 crosses at Kanipanka location

Crosses	Days to 50% Tasseling	Days to 50% Silking	Plant height (cm)	Ear length (cm)	ear width (mm)	No. of Ears /plant	No. of rows/ ear	No. of Kernels/ row	300 kernels weight (gm)	Kernels yield ton/ha
1×4	50.222	60.111	191.000	18.311	35.583	1.444	16.000	36.667	72.437	8.455
1×5	51.111	60.222	193.111	19.117	38.359	1.333	15.889	34.833	75.417	7.041
1×6	51.222	60.222	182.445	17.700	36.471	1.445	16.667	39.111	67.060	7.064
2×5	52.111	61.334	192.999	17.911	32.561	1.333	15.111	31.111	74.117	7.050
2×6	50.556	60.333	181.111	20.377	36.258	1.778	15.333	39.000	77.467	7.188
2×7	51.445	60.778	171.555	16.911	31.542	1.556	16.000	34.000	76.267	6.858
3×6	49.889	59.889	178.778	18.800	37.479	1.444	14.222	41.778	82.830	7.087
3×7	52.667	61.778	180.222	18.133	44.185	1.222	14.889	37.334	69.777	6.752
3×8	51.556	61.111	183.889	19.800	36.361	1.444	14.667	40.444	79.067	7.034
4×7	53.778	62.556	186.443	18.755	40.141	1.333	16.222	39.111	64.540	8.646
4×8	52.555	61.222	177.000	19.156	35.941	1.333	14.222	36.000	81.473	6.445
5×8	51.333	60.444	197.888	22.100	35.119	1.333	16.222	37.333	80.640	6.452
LSD (.05)	1.1827758	0.8162809	14.08698	1.972745	1.8028	0.2990678	1.3452219	5.2591712	6.0329382	0.7954635

The average of studied characters for the parents was represent in Table (8), indicating that the earliest parent for days to tasseling was parent 4 50.444 days, in comparison for days to silking was 61.444 days showed by parent 1. The highest value for ear width was 38.217 mm produced by parent 3, while for kernel yield, it was 7.071t/h produced by parent 6. Parent 7 gave the maximum height for plants reached 171.444 cm. The highest value for the characters ear length, no. of ears/plant, no. of rows/ear, no. of kernels/row, and 300 kernel weight showed by parent 8 reached 19.533cm, 1.667 ears, 18.111 rows, 31.667 kernels, and 72.527 gr respectively. The hybrids with a higher 300-kernel yield indicated that the grain size could be larger or bold kernels will be produced, improving grain yield per plant (66). Sokolov and Guzhva (69) reported considerable variation for different morphological traits. Other researchers showed significant variation among morphological and agronomic traits (67, 32).

Table 8. Average of studied characters for Maize parents at Kanipanka location

parents	Days to 50% Tasseling	Days to 50% Silking	Plant height (cm)	Ear length (cm)	ear width (mm)	No. of Ears /plant	No. of rows/ ear	No. of Kernels/ row	300 kernels weight (gm)	Kernels yield ton/ha
1	52.778	61.444	158.778	17.460	37.348	1.444	14.111	29.222	65.040	5.597
2	52.222	61.889	157.889	18.093	34.356	1.000	14.222	28.556	68.603	6.314
3	52.222	63.444	166.111	18.023	38.217	1.111	14.889	29.000	67.817	6.783
4	50.444	61.667	148.778	17.430	35.993	1.000	14.556	27.889	68.047	6.028
5	52.000	62.778	155.000	18.096	32.047	1.000	13.556	30.111	61.767	4.936
6	51.889	62.111	164.889	16.205	32.832	1.222	13.222	30.889	69.900	7.071
7	53.889	63.889	171.444	18.994	33.475	1.000	14.333	27.556	70.980	6.603
8	52.889	63.444	163.333	19.533	34.259	1.667	18.111	31.667	72.527	6.564
LSD (.05)	1.0309	1.5902	8.3139	1.5296	2.3800	0.2160	1.7815	1.8781	1.9883	0.9811

Table (9) illustrates the heterosis value for the studied characters, concerning to day to silking showed positive and negative heterosis. The maximum negative value was -4.16% for the cross (3×6). Days to silking and plant height showed positive heterosis values for all crosses; the highest value was 18.49% for the cross (4×8) for days to silking and 24.33% for the cross (5×8) due to plant height. Positive and negative heterosis values were represented for the characters ear length, ear width, no. of ears/plant and no. of rows/ear, maximum positive heterosis for ear length and no. of ears/plant were 18.82 and 60.04% recorded by the cross (2×6), in comparison for ear width it was 23.26% recorded by the cross (3×7), but it was 21.95% for the cross (1×6) due to no. of rows/ear. All crosses for the character no. of kernels /row and kernel yield showed positive heterosis; the maximum value for no. of kernels/row was 41.08% for the cross (4×7), while it was 45.46% for kernel yield recorded by the cross (1×4). 300 kernels weight showed positive and negative heterosis, which restricted between -7.15% for the cross (4×7) and 20.29% for the cross (3×6). Various researchers and maize breeders have suggested grain rows per ear as the main selection criterion (23, 72). The percent standard heterosis expresses by the F1 hybrids over the commercial hybrid check variety, pacific 11 for yield, and different yield contributing characters. The degree of heterosis in F1 hybrids varied from character to character or from cross to cross (8,21 and 57). Das and Islam (20) also found significant positive heterosis for kernel weight. Several workers also reported an appreciable percentage of heterosis for grain yield in maize (21, 55 and, 64). The negative heterosis and heterobeltiosis indicate the decrease in the trait may offer in the next generation; therefore, the selection may be made to fix a decrease in specific traits to improve crop yield and productivity (4, 5,10, 22, and 24).

Table 9. Heteroses values (percentage of F1s deviation from mid parental values) for studied characters at Kanipanka location

Crosses	Days to 50% Taseling	Days to 50% Silking	Plant height (cm)	Ear length (cm)	ear width (mm)	No. of Ears /plant	No. of rows/ ear	No. of Kernels/ row	300 kernels weight (gm)	Kernels yield ton/ha
1×4	-2.69	16.47	24.21	4.97	-2.96	18.18	11.63	28.40	8.86	45.46
1×5	-2.44	14.95	23.09	7.53	10.55	9.07	14.86	17.42	18.95	33.70
1×6	-2.12	15.07	12.74	5.15	3.94	8.36	21.95	30.13	-0.61	11.53
2×5	0.00	17.70	23.37	-1.02	-1.93	33.30	8.80	6.06	13.70	25.33
2×6	-2.88	15.90	12.22	18.82	7.93	60.04	11.74	31.21	11.86	7.41
2×7	-3.04	14.55	4.18	-8.81	-7.00	55.57	12.06	21.19	9.28	6.18
3×6	-4.16	15.05	8.02	9.85	5.50	23.82	1.19	39.52	20.29	2.31
3×7	-0.73	16.44	6.78	-2.03	23.26	15.77	1.90	32.02	0.55	0.89
3×8	-1.90	16.28	11.64	5.44	0.34	3.98	-11.11	33.33	12.68	5.41
4×7	3.09	19.92	16.45	2.98	15.57	33.30	12.31	41.08	-7.15	36.90
4×8	1.72	18.49	13.42	3.65	2.32	-0.04	-12.93	25.37	15.92	2.37
5×8	-2.12	15.25	24.33	17.46	5.93	-0.04	2.46	30.58	20.10	12.20
SE	0.6081	0.4691	2.0764	2.2312	2.4155	5.8607	2.9959	2.7753	2.5280	4.4576

At this location, Table (10), confirm that the ratio of σ^2gca/σ^2sca was found to be high for no. of ears/plant and no. of kernels/row recording 4.990, and 6.273 respectively, while it was less than one for the rest. The average degree of dominance for most characters was more than one except no. of ears/plant and no. of kernels/row. Heritability in broad-sense was found to be high for days to tasseling, days to silking, ear length, ear width, 300 kernels weight, and kernel yield. But it was low to moderate for plant height, no. of rows/ear and no. of kernels/row, and it was low for no. of ears/plant. Heritability in narrow-sense was low in all characters except No. of rows/ear and no. of kernels/row, which was moderate. The broad-sense heritability and narrow-sense heritability were recorded higher for most of the traits studied. The traits plant height, ear height, ear length, ear diameter, kernels/ row, grain per plant, and grain yield per plant were controlled by the additive type of gene action (39). The nature and magnitude of gene action are important to factor in developing an effective breeding program. Combining ability analysis is useful to assess the potential inbred lines and helps identify the nature of gene action involved in various quantitative characters. This information is helpful to plant breeders for formulating hybrid breeding programs (3). The ratio of the components revealed that GCA variance was much higher than SCA variance for ear diameter, indicating a predominance of additive gene effect for this trait. A higher magnitude of non-additive gene effects was observed for most yield components like ear length, number of kernels per ear, and kernel weight. The grain yield was predominantly controlled by non-additive gene action (dominance and epistasis) (8, 25, 42, and 49). Also, Zelleke (80) reported the predominant role of non-additive gene action for kernel yield in maize. Hussain (31) confirmed the predominant role of non-additive gene action for No. of kernels/ ear in maize. In contrast, Mason and Zuber (48) indicated the predominance role of additive gene action for kernel yield. The classification of heritability stands low when it is 50 percent (71).

Table 10. Estimations of some genetic parameters for studied characters at Kanipanka location

Genetic parameters	Characters									
	Days to 50% Tasseling	Days to 50% Silking	Plant height (cm)	Ear length (cm)	ear width (mm)	No. of Ears /plant	No. of rows/ ear	No. of Kernels/ row	300 kernels weight (gm)	Kernels yield Ton/ha
σ^2e	0.4879	0.2324	69.2090	1.3573	1.1335	0.0312	0.6311	9.6463	12.6936	0.2207
σ^2 gca	0.0287	0.0669	13.2546	0.0361	1.0385	0.0055	0.1789	3.4376	0.2413	0.0138
σ^2 sca	1.0089	0.4404	15.4333	1.3681	8.7993	0.0011	0.1827	0.5480	28.6842	0.3776
σ^2 gca/σ^2Sca	0.0284	0.1520	0.8588	0.0264	0.1180	4.9895	0.9792	6.2732	0.0084	0.0364
σ^2A	0.0573	0.1339	26.5092	0.0723	2.0770	0.0110	0.3577	6.8752	0.4826	0.0275
σ^2D	1.0089	0.4404	15.4333	1.3681	8.7993	0.0011	0.1827	0.5480	28.6842	0.3776
$\bar{a}$	5.9336	2.5649	1.0791	6.1530	2.9109	0.4477	1.0105	0.3993	10.9030	5.2387
h^2 bs	0.6861	0.7119	0.3773	0.5149	0.9056	0.2802	0.4613	0.4349	0.6968	0.6473
h^2 ns	0.0369	0.1660	0.2385	0.0258	0.1729	0.2547	0.3054	0.4028	0.0115	0.0440

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