Gene Action, Heterosis and Combining Ability in Maize Hybrids

B- Using Line x Tester Analysis

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Abstract

A line x tester cross comprising eight pure lines, ZP–505, IK58, and HS, used as testers (female parents), DK-17, ZP- 430, ZP-595, UN44052, and POL-158, used as lines (male parents), was studied for nine traits (number of days to silking, number of days to tasseling, plant height, ear height, leaf area, number of rows per ear, number of grains per row, 300 grains weight and grain yield per plant, to determine the nature of gene action in parents and hybrids and estimation of heterosis. The results revealed that themean square for genotypes, parents, and hybrids was highly were significant for all traywhich that is an indication of the diversity between parents (lines and testers) causes cause significant differences between single crosses among them. Also, it was shown that mean square due to each of lines and testers was highly significant for all traits indicated the presence of additive gene effects controlling these characters, and that due to the interaction of line x tester was significant at 1% level for all traits meaning the presence of dominance gene effects controlling them. The ratio of general combining ability components to the specific combining ability components was less than one for all traitsindicatingd that dominance gene effects were more prominent for all studied traits. The tester ZP–505 and line ZP-595 were the best general combiner for largest number of traits including grain yield per plant, and the crosses (HSxDK-17), (IK58xUN44052), (HSxPOL158) and (ZP–505xZP-595) showing significant specific combining ability effects and heterosis for largest number of traits and could be utilized for developing high yielding hybrid varieties as well as for exploiting heterosis. The range of narrow sense heritability ranged from 20.98% for 300GW to 55.71% for GYP, as it was high for LA (50.68%) and GYP (55.71%), and moderate for other traits.

Keywords: Testers, Heterosis, Combining ability, Gene action

Introduction

Maize (*Zea mays* L.) is one of the world's major cereal crops, with an annual production of about 854.6 million tons on an area of 168.4 million hectares and an average yield of 5.07 tons per hectare (٤). It has gained its great importance due to the increased demand for it in food, feed and industrial use. Maize is a versatile crop with a wide genetic diversity and is able to grow successfully in a wide range of environmental conditions.

The development of new hybrid varieties of maize requires information on the genetic structure of the parental lines and their offspring. This information can be derived through the use of different mating designs, such as diallel crosses (١٠, 11, and 14), line x tester mating design (15), and others. Venkatesh *et al*. (20) used the line x tester method to evaluate the offspring of 42 top crosses (21 lines and two testers) with the aim of reducing the number of lines at the early screening stage. The line x tester mating design was used in various studies, for example, those by Menkir *et al.* (16), Wali *et al*. (21), Hefny (12), Dar *et al*.(7) and Bayoumi *et al*.(5) to estimate the effects of the general and specific combining abilities of the studied lines and their crosses. Using the effects of the combining ability of the yield. The line x tester analysis also helps in estimating the components of genetic variance and the type of genetic effects (2). By using the line x tester method, Venkatesh *et al.* (20) found a significant effect, Hussain and Aziz (13) explained that the parents with high general combining ability for any trait do not have to give the effects of the specific combining ability to be high for the same trait. Riboniesa and Efren (19) categorized the pure lines of maize into two strong groups differences between lines and testers, and the combinations between them indicates indices importance of both additive and non-additive (dominant) genetic variance in controlling grain yield. Gamea (9) reported that analysis of variance of crosses and their components, lines, testers and lines x testers showed highly significant differences for all traits, except lines x testers for days to 50% silking, and general combining ability component was larger than the specific one for all studied traits, indicating the dominance of additive gene action in the inheritance of these traits. Chokan (6) evaluated the offspring of line x tester hybrids in maize under normal and high plant densities and noted that the additive genetic variance was significant for the number of grains per row and the number of rows per ear at high plant density, and for other traits including grain yield, both additive, and dominance variances were significant in both densities. Mustafa (17) used in his study of sixteen pure lines of maize using the (line × tester) method in different environmental conditions, and concluded that the hybrids varied in their specific combining ability effects, and the hybrid (IPA4 x ATSH) had significant desirable effects for the traits of number of days to tasseling and silking, Plant height, number of plant leaves, leaf area, ear length and grain weight. In a factorial mating system using five testers as females and 16 lines as male parents in maize in two environments.

The aim of the current study is to estimate the heterosis (as deviation of $F_{1's}$ from mid and better parents), variances and effects of the general and specific combining abilities for grain yield of maize and its components from other traits using hybrids produced using the line x tester mating design.

Materials and Methods

The genetic material in the current study included eight pure lines of maize, which they are: (1) ZP–505 (2) IK 58 and (3) HS, used as testers (female parents) and (4) DK-17 (5) ZP- 430 (6) ZP-595 (7) UN44052 and (8) POL-158 used as lines (male parents). All lines were planted on first of March 2020 in the field of College of Agricultural Engineering Sciences, Duhok University, and all possible crosses were made between them according to the method of line x tester (2). The obtained first-generation hybrids (15 individual hybrids) with their parents (3 testers and 5 lines) were plante on a tenth of March 2021, at the same location using a randomized complete block design with three replications, and the plants of each experimental unit were distributed in one row of (3 m) length, the distance between them (0.75 m) and the distance between plants (0.25 m). Compound fertilizer NPK (27:27:27) was added by 100 $kg.ha^{-1}$ during the preparation of the cultivation land, and urea by 200 $kg.h^{-1a}$, in two periods, the first, one month after planting and the second before flowering, and surface irrigation and other field services during the study as needed. Thinning was performed by leaving one plant in the hole, 25 days after planting. The data on the individual plants (ten plants randomly selected from each experimental unit) were collected for the traits: number of days to silking (NDS), number of days to tasseling (NDT), plant height (PH) (cm), ear height (EH) (cm), leaf area (LA) (cm^2), number of rows per ear (NRE), number of grains per row (NGR), 300 grains weight (300GW) (gm), grain yield per plant (GYP)(gm). Data of genotypes (parent & hybrids) were analyzed for each trait according to the experimental design method used by Al-Zubaidy and Al-Falahy,(3), and the sum squares of genotypes were divided into the components according to the line x tester method, and the following parameters were estimated:

(1) Heterosis (H) was estimated based on the deviation of the first generation hybrid mean (F_1) from the mean of the mid parents by the equation [$H = F_1 - MP$] and better parents (BP) by the equation [$H = F_1 - BP$], and significance cant was tested by t-test.

(2) The effects of general combining ability (GCA) for parents and specific combining ability (SCA) for hybrids, and their significance tested by adopting t-test, as stated in Al-Zubaidy and Al-Juboury (2).

(3) The components of the phenotypic variance: additive (σ^2A), dominance (σ^2D) and environmental (σ^2E), based on the expected variance of line x tester analysis, and their significance from zero were tested in the manner explained by Kempthorne (15).

(4) The broad and narrow sense of heheritability (5) the average degree of dominance (ā) for each trait to identify the type of dominance that controls its inheritance.

(6) Genetic gain expected from selection in the next-generation as percent of the mean for each trait using the following equation: GA% = [$(h^2)(\sigma P)(i)$/character over all mean]x(100), where h^2, σP and i mean narrow sense heritability, phenotypic deviation and selection intensity (which equals 1.76 when 10% of plants are selected), respectively.

The available statistical programs, Statistical Analysis System (SAS), Minitab, and Microsoft Office Excel, 2003 were used in the implementation of statistical and genetic measures.

Results and Discussion

The analysis of variance results for the studied traits appear in Table (1), and it is noted that the mean square of all genotypes was highly significant for all traits, and when divided into its components (all parents, crosses and parents vs crosses), it is noted that the mean square of these components was highly significant for all traits, except for NDT and NDS in case of the parents vs crosses (their mean square did not reach the significant limits). These results indicate the existence of genetic divergence between the parents used in study (testers and lines), which in turn was reflected in the presence of high significant differences between single crosses resulting from them. As for the analysis of variance results for general and specific combining abilities (which is represented by dividing the mean square of genotypes into testers, lines, and the interaction between them), it is clear from the same table that the mean of squares belonging to each of the testers and lines was highly significant for all traits, indicating the presence of an additive gene effect controlling the inheritance of these traits, also the mean squares of tester x line interaction were highly significant for all traits, indicating that there is a dominant gene effect that controls their inheritance. When estimating the ratio between the components of the general combining ability to the components of the special combining ability, it is noted that it ranged between 0.172 for NGR and 0.635 for GYP, meaning that the ratio was less than one for all traits, and this indicates that the dominant gene effect is a more important additive one for all traits. These results are in agreement with those of Venkatesh *et al.* (20), and Dawod *et al.* (8), and do not agree with Gamea (9).

Table 1: Analysis of variance for genotypes and combining ability for studied traits in maize.

Source	df	MS for traits								
		NDT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
Reps	2	8.014	3.232	46.536	6.275	160.174	0.006	2.449	39.238	56.555
Genotypes	22	19.165**	20.876**	2746.03**	748.57**	28974.37**	7.153**	87.87**	506.4**	4657.7**
Parents	7	15.804**	15.708**	1367.33**	206.23**	19247.23**	0.932**	28.33**	19.34**	183.96**
P vs C	1	0.420	0.339	42490.9**	7285.8**	92607.67**	113.6**	1140.5**	1060.6**	85185.4**
Crosses	14	22.184**	24.927**	596.45**	552.8**	29292.71**	2.663**	42.45**	67.53**	1142.5**
Testers	2	52.156**	55.089**	318.29**	109.4**	68211.29**	2.189**	56.69**	65.04**	2198.5**
Lines	4	15.367**	15.856**	766.41**	840.3**	25416.09**	2.389**	18.63**	67.89**	1443.1**
T x L	8	18.100**	21.922**	581.01**	519.9**	21501.37**	2.917**	50.80**	67.96**	726.75**
Error	44	1.833	0.277	3.930	0.791	7.053	0.017	0.268**	16.53**	2.186
$\sigma^2 gca/\sigma^2 sca$		0.448	0.373	0.275	0.291	0.514	0.211	0.172	0.261	0.635

(**) Significant at 1% probability level.

Tables (2 and 3) show the means of the parents (testers and lines) for the different traits and their effects of general combining ability respectively. It is noted that the parental tester 3 and line 5 gave the lowest means for NDS and NDS of (82.87 and 84.93) and (82.78 and 85.33) days, respectively, an indication that they are more early in flowering, and at the same time, their effects of general combining ability were significant and desirable, and thus are the most efficient in improving these two traits. For the traits PH and EH, the highest means were 225.13 cm and 107.2 cm for tester 2 and 227.89 cm and 121.0 cm for line 6 respectively, but thereof the general combining ability effects were significant desirable only in line 6, which is, for this reason, the most efficient in improving these two traits. The parental tester 1 was characterized by good mean performance for traits LA, NRE, NGR, 300GW, and GYP, and at the same time had significant and desirable effects of general combining ability, for all of them except 300GW. It appears that some parental lines were characterized by highest means and at the same time with desirable significant effects of general combining ability as follows: line 6 for NRE and GYP, line 8 for LA and 300GW and line 5 for NGR, indicates that these lines considered as most efficient in improving these traits. Finally, it is noted that tester 1 and line 6 had the highest means performance in addition to desirable significant effects of general combining ability for the largest number of traits, including GYP, and this encourages their adoption in breeding program because they are the more efficient in improving important traits. From previous studies, Mustafa (17), Hefny (12) and Bayoumi *et al.* (5) can identify testers and lines with different general ability effects for GYP and some of its components in maize.

Table 2. Table 2. Means of parents (testers and lines) for studied traits in maize.

Hybrids	Traits								
	NBT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
					Testers				
1	83.60b	86.40b	216.27c	101.80c	745.67a	16.635a	40.333a	65.365ab	154.450a
2	86.40a	88.73a	225.13a	107.20a	611.27c	16.013b	37.000b	63.263b	131.116c
3	82.87c	84.93c	218.53b	104.60b	688.20b	16.713a	40.400a	67.427a	148.615b
					Lines				
4	83.11b	85.44d	207.00d	95.33c	692.89b	16.46c	38.22b	61.32b	126.24d
5	82.78b	85.33d	222.67b	102.00b	612.89d	15.68e	40.44a	64.56ab	142.27c
6	84.78a	86.78c	227.89a	121.000a	692.222b	17.122a	37.222c	65.396ab	161.498a
7	84.89a	87.44b	214.11c	102.33b	654.22c	16.68b	40.22a	66.76a	148.46b
8	85.89a	88.444a	228.22a	102.00b	756.33a	16.23d	40.11a	68.72a	144.46c
P means	84.13	86.542	167.875	82.958	604.792	13.746	30.708	39.999	70.575
H means	84.29	86.689	219.978	104.533	681.711	16.450	39.244	65.352	144.639
G means	84.23	86.638	201.855	97.029	654.957	15.496	36.275	56.533	118.499

- Values (testers or lines) followed by the same letter for each trait are not significantly different.

Table 3. GCA effects of parents (testers & lines) for studied traits in maize.

parents	NBT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
					Traits				
					Testers				
1	-0.689	-0.289	-3.711	-2.733	63.956	0.186	1.089	0.013	9.811
2	2.111	2.044	5.156	2.667	-70.444	-0.437	-2.244	-2.089	-13.523
3	-1.422	-1.756	-1.445	0.067	6.489	0.263	1.156	2.075	3.976
SE	0.408	0.148	0.458	0.133	0.703	0.028	0.132	1.218	0.646
					Lines				
4	-1.178	-1.245	-12.978	-9.2	11.178	0.006	-1.022	-4.032	-18.403
5	-1.511	-1.356	2.689	-2.533	-68.822	-0.775	1.199	-0.788	-2.371
6	0.489	0.089	7.911	16.467	10.511	0.672	-2.022	0.044	16.859
7	0.600	0.756	-5.867	-2.2	-27.489	0.228	0.978	1.411	3.825
8 4	1.600	1.756	8.244	-2.533	74.622	-0.217	0.867	3.362	-0.175
SE	0.527	0.191	0.591	0.172	0.907	0.037	0.170	1.573	0.834

The means of lines x testers hybrids and their specific combining ability effects for different traits are presented in Tables (4 and 5), and it seems that a limited number of hybrids showed a significant specific combining ability effects in the desired direction for each trait (Table, 5), as the number of hybrids with significant desired effects reached four for each of NDT and NDS, six for each of PH, NRE and 300GW, seven for each of EH, LA, and NGR, and eight for NGP. It is noted that the hybrid (3x4) was distinguished by the desired significant effects for seven traits: NDT, NDS, PH, EH, LA, NRE, and GYP, and the hybrid (2x7) for six traits: PH, EH, LA, NRE, NGR, and GYP. At the same time, these two hybrids had a good average performance for these traits, especially the hybrid (3x4)

Table 4. Means of hybrids for studied traits in maize.

hybrids	NDT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
					Traits				
1x4	83.67cde	87.00bcd	207.67de	91.00f	724.33c	16.00e	36.00g	58.71d	123.91h
1x5	82.67def	84.67f	210.67d	95.00e	608.33h	16.70c	45.00a	64.12a-d	169.56b
1x6	84.67bcd	86.00de	230.67b	131.00a	744.33b	17.33b	40.33de	68.51abc	186.23a
1x7	80.33fg	84.33f	210.00de	91.00f	677.00d	16.70c	39.67ef	71.57a	158.46c
1x8	86.67abc	90.00a	222.33c	101.00d	974.33a	16.47d	40.67d	63.91a-d	134.08g
2x4	86.67abc	90.00a	191.67f	85.00g	608.67h	16.07e	42.33bc	61.20cd	122.71h
2x5	84.33cd	86.67cd	250.00a	110.00c	596.33i	16.00e	33.33h	57.04d	110.30i
2x6	85.00bcd	87.00bcd	230.67b	131.00a	587.00j	15.27f	30.67i	62.26bcd	138.74f
2x7	87.67ab	90.00a	221.67c	115.00b	608.33h	16.63cd	39.00f	64.03a-d	141.10f
2x8	88.33a	90.00a	231.67b	95.00e	656.00e	16.10e	39.67ef	71.78a	142.72ef
3x4	79.00g	79.33g	221.67c	110.00c	745.67b	17.30b	36.33g	64.05a-d	132.08g
3x5	81.33efg	84.67f	207.33e	101.00d	634.00g	14.67g	43.00b	72.54a	149.28d
3x6	84.67bcd	87.33bc	222.33c	101.00d	745.33b	18.77a	40.67d	65.41a-d	159.52c
3x7	86.67abc	88.00b	210.67d	101.00d	677.33d	16.70c	42.00c	64.69a-d	145.83de
3x8	82.67def	85.33ef	230.67b	110.00c	638.67f	16.13e	40.00de	70.45ab	156.59c
H means	84.289	86.689	219.978	104.533	681.711	16.450	39.244	65.352	144.639
G means	84.232	86.638	201.855	97.029	654.957	15.496	36.275	56.533	118.499

- Values followed by the same letter for each trait are not significantly different.

Table 5. Specific combining ability effects of hybrids for studied traits in maize.

Hybrids	Traits								
	NDT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
1x4	1.245	1.845	4.378	-1.6	-32.512	-0.6413	-3.3111	-6.2665	-12.137
1x5	0.578	-0.378	-8.287	-4.267	-68.512	0.7254	3.467	-18.298	16.706
1x6	0.578	-0.489	6.489	12.733	-11.845	0.025	2.022	1.935	14.924
1x7	-3.867	-2.8222	-0.4	-8.6	-41.178	-0.1635	-1.6444	3.641	0.184
1x8	1.467	1.844	-2.178	1.733	154.044	0.048	-0.533	20.019	-20.193
2x4	1.44479	2.511	-20.489	-13	-13.778	0.048	6.356	-28.404	10.000
2x5	-0.556	-0.711	22.178	5.333	53.888	0.648	-4.867	17.631	-19.223
2x6	-1.889	-1.822	-2.377	7.333	-34.778	-1.4189	-4.3111	26.091	-9.2321
2x7	0.667	0.511	2.401	10	24.555	0.392	1.022	-2.3355	6.1613
2x8	0.333	-0.489	-1.711	-9.667	-29.889	0.303	1.800	-11.953	11.778
3x4	-2.689	-4.356	16.112	14.6	46.289	0.581	-3.045	-20.275	1.871
3x5	-0.023	1.089	-13.889	-1.067	14.622	-1.386	1.400	-3.845	2.253
3x6	1.31139	2.311	-4.1114	-20.067	46.6221	1.381	2.289	22.816	-5.957
3x7	3.20029	2.311	-1.9996	-1.4	16.6221	-0.241	0.622	10.437	-6.611
3x8	-1.7997	-1.356	3.8893	7.933	-124.15	-0.363	-1.267	-8.324	8.149
SE	0.91258	0.330	1.023	0.298	1.5709	0.063	0.295	2.725	1.445

(Table, 4), and they were followed in specific combining ability effects by hybrids (3x8) and (1x6), which had a significant and desirable effect for 5 and 4 traits respectively, including GYP, in addition to giving good performance means for these traits. From previous studies, Menkir *et al.* (16), Wali *et al.* (21), Hefny (12), Dar *et al.* (7) obtained significant specific combining ability effects which some crosses showed for GYP and its components of other traits. It is noted that most of the hybrids with desired significant effects for a specific trait, was at least one of their parents gave a desirable significant general combining ability effect for that trait. It appears from the results of Table (5) that many of the hybrids had non-significant specific combining ability effects (whether positive or negative) among the 15 hybrids.

The results of heterosis expressed as mean deviation of the hybrid from mid and better parents and for studied traits presented in Tables (6 and 7) respectively. It is noted that all hybrids gave a significant desirable heterosis for PH, EH, NRE, NGR, 300GW and GYP traits when measured on the basis of mid parents, and for the PH, NRE, 300GW and GYP traits when measured on the basis of the better parents. On the basis of the mid parents, a significant and desirable heterosis appeared for the traits NDT, NDS and LA in a number of hybrids that were respectively 3, 4 and 11, while on the basis of the better parents, a significant and desirable hybrid heterosis appeared for the traits NDT, NDS, EH, LA and NGR in a number of crosses reached 2, 4, 13, 10 and 14., respectively. It is noted that the three hybrids (1x7), (3x4) and (3x5) gave a significant desirable heterosis measured on the basis of mid parents for all studied traits, followed by the hybrids (1x4), (1x6), (1x8), (2x4), (2x6), (2x7), (3x6) and 3x7, each of them had a significant desirable heterosis for seven traits, including GYP. But when measured on the basis of better parents, the hybrid (3x4) gave a significant desirable heterosis for all studied traits, followed by the two hybrids (1x7), (3x5), each of them had a significant desirable heterosis for eight traits, and the hybrids (1x4), (1x6), (1x8), (2x7), (3x6) and (3x7), each gave a significant desirable hybrid strength for seven traits. These results identify hybrids with good behavior in improving grain yield in maize, which are needed to be tested in different locations and environments.

Table 6. Heterosis based on deviation of F_1 from mid parents for studied traits in maize.

hybrids	Traits								
	NDT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
1x4	-2.00	-1.000	58.667**	15.00**	129.67**	2.55**	6.50**	21.11**	60.91**
1x5	-1.667	-2.00**	51.167**	7.833**	-54.00**	2.88**	16.67**	26.08**	101.89**
1x6	2.333	1.500*	68.167**	50.00**	147.83**	3.70**	10.17**	31.68**	115.48**
1x7	-4.50**	-3.50**	47.333**	13.83**	81.50**	3.30**	8.50**	33.69**	85.96**
1x8	4.333**	4.333**	53.500**	15.00**	269.67**	2.75**	8.50**	23.87**	61.02**
2x4	0.833	2.333**	47.167**	4.000**	56.17**	2.18**	13.33**	20.88**	61.92**
2x5	-0.167	0.333	95.000**	17.83**	-23.83**	1.78**	5.50**	16.29**	44.84**
2x6	2.500	2.833**	72.667**	45.00**	32.67**	1.20**	1.00**	22.72**	70.19**
2x7	2.667	2.500**	63.500**	32.83**	55.00**	2.80**	8.33**	23.44**	70.80**
2x8	5.833**	4.667**	67.333**	4.000**	-6.50*	1.95**	8.00**	29.02**	71.86**
3x4	-7.17**	-9.17**	56.167**	33.50**	181.00**	4.08**	6.50**	23.98**	66.08**
3x5	-3.500*	-2.50**	31.333**	13.33**	1.67**	1.12**	14.33**	32.03**	78.42**
3x6	1.833	2.333**	43.333**	19.50**	178.83**	5.37**	10.17**	26.11**	85.76**
3x7	1.333	-0.333	31.500**	23.33**	111.83**	3.53**	10.50**	24.34**	70.32**
3x8	-0.167	-0.833	45.333**	23.50**	-36.00**	2.65**	7.50**	27.94**	80.52**

(**) and (*) Significant at 1% and 5% probability level respectively.

Table 7. Heterosis based on deviation of F_1 from better parent for studied traits in maize.

hybrids	Traits								
	NDT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
1x4	0.000	0.333	52.67**	10.00**	62.00**	2.30**	5.33**	19.09**	58.42**
1x5	-1.000	-2.00**	34.67**	1.667	-54.00**	2.30**	16.67**	23.63**	99.72**
1x6	3.667*	3.67**	48.67**	50.00**	82.00**	3.27**	8.33**	30.43**	110.2**
1x7	-3.333	-2.33**	27.67**	10.00**	14.67**	3.10**	5.67**	31.41**	78.94**
1x8	5.67**	5.33**	27.67**	10.00**	227.3**	2.23**	4.67**	19.41**	53.45**
2x4	2.667	4.00**	36.67**	-6.00**	30.67**	2.00**	11.67**	20.18**	61.62**
2x5	0.333	0.667	74.00**	16.67**	-66.00**	1.63**	5.00**	16.02**	40.46**
2x6	4.00**	4.67**	48.67**	40.00**	9.00*	1.20**	-1.33*	21.25**	62.73**
2x7	3.67**	4.00**	39.33**	24.00**	30.33**	2.57**	5.00**	23.01**	61.59**
2x8	7.33**	5.33**	37.00**	4.00**	-91.00**	1.87**	3.67**	27.28**	62.09**
3x4	-5.67**	-8.33**	45.67**	28.00**	143.3**	3.60**	5.67**	23.53**	60.57**
3x5	-3.33*	-2.00**	31.33**	7.67**	-28.33**	0.300	14.00**	32.01**	77.22**
3x6	3.67*	5.00**	40.33**	19.00**	143.0**	4.70**	8.67**	24.89**	83.51**
3x7	2.00	0.333	28.33**	19.00**	75.00**	3.10**	8.00**	24.16**	66.31**
3x8	1.67	0.667	36.00**	19.00**	-108.3**	1.90**	4.00**	25.95**	75.96**

(**) and (*) Significant at 1% and 5% probability level respectively.

From previous studies, other researchers obtained a significant and desirable heterosis for grain yield of maize and some of its components from other traits compared to the mid or better parents, including those done by Ogo *et al*. (18) and Alam *et al*. (1).

Table (7) shows the estimates of genetic parameters for the different traits, and it is clear that the additive and dominance genetic variances were significant from zero for all traits, an indication of their importance in controlling the inheritance of these traits. It is noted that the values of dominance variance were greater than those of the additive for traits of NDT, NDS, PE, EH, NRE, NGR and 300GW, indicating that the dominant genetic effects were more important in the inheritance of these treats, while it was the opposite for LA and GYP, For this reason, it is noted that the values of narrow sense heritability were much lower than in the broad sense of these traits. The values of narrow sense heritability ranged between 20.98% for 300GW to 55.71% for GYP, as it was high for LA (50.68%) and GYP (55.71%), and moderate for other traits. The broad sense heritability was high for all traits and ranged between 61.21% for 300GW to 99.95% for LA. The average degree of dominance is greater than one for all traits indicative of the presence of over-dominance, and these over-dominance values, which ranged between 1.255 for GYP and 2.409 for NGR, may be due to the distribution of linked genes between parents, so partial dominance appears as over-dominance (11). From previous studies, many researchers obtained different results regarding the gene action that controls the inheritance of different traits in maize, for example, Chokan (6) noted that additive genetic variance was significant for the NGR and NRE, and for other traits including grain yield, both additive and dominance variances were significant. Venkatesh *et al*. (20) reported the importance of both additive and non-additive (dominant) genetic variance in controlling grain yield. Gamea (9) pointed out the dominance of additive gene action in the inheritance of maize traits in his study. These divergent results can be attributed to differences in genetic material approved in different studies and differences in environmental conditions, or to the adoption of different methods for estimating genetic parameters. Finally, it is noted that the expected genetic improvement in the next generation as a percent was moderate for the

Table 8: Variance components and genetic parameters for studied traits in maize.

	Traits								
	NDT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
σ^2A	4.859 ± 0.907	5.385 ± 0.944	105.667 ± 34.945	100.519 ± 38.136	7370.18 ± 1379.71	0.408 ± 0.111	5.802 ± 1.054	8.942 ± 3.176	306.523 ± 69.869
σ^2D	5.423 ± 2.701	7.215 ± 3.268	192.360 ± 86.612	173.502 ± 77.502	7164.77 ± 3205.24	0.966 ± 0.435	16.844 ± 7.573	17.145 ± 10.196	241.521 ± 108.337
σ^2E	1.833 ± 0.382	0.277 ± 0.058	3.930 ± 0.819	0.791 ± 0.165	7.053 ± 1.471	0.017 ± 0.004	0.261 ± 0.056	16.529 ± 3.447	2.186 ± 0.456
σ^2p	12.114	12.877	301.968	274.347	14542	1.392	22.914	42.616	550.230
h^2_{BS}	0.8487	0.9785	0.9869	0.9971	0.9995	0.9877	0.9883	0.6121	0.9960
h^2_{NS}	0.4011	0.4182	0.3499	0.3664	0.5068	0.2934	0.2532	0.2098	0.5571
ā	1.494	1.637	1.908	1.858	1.394	2.176	2.409	1.958	1.255
GA	2.457	2.641	10.703	10.681	107.567	0.609	2.133	2.411	22.999
GA%	2.917	3.048	5.302	11.008	16.424	3.932	5.881	4.264	19.408

Grain yield per plant EH, LA and GYP and low for other traits, as it ranged between 2.917% for NDT and 19.408% for GYP.

It is concluded from foregoing that it is possible to benefit from the tester ZP–505 and line ZP-595 due to their desirable significant general combining ability for the largest number of traits, including grain yield per plant, and hybrids (HSxDK-17), (IK58xUN44052), (HSxPOL158) and (ZP–505xZP-595) due to their desirable significant effects and heterosis for most traits in developing high yielding hybrid varieties as well as for exploiting the phenomenon of hybrid vigor.

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