Gene Action, Heterosis and Combining Ability in Maize Hybrids
A- Using Half Diallel Analysis

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https://doi.org/10.36077/kjas/2021/130203

Received: 9/11/2021

Accepted: 28/12/2021

Abstract

A diallel cross comprising of eight pure lines of maize, ZP-505, IK58, HS, DK-17, ZP-430, ZP-595, U,N44052, and POL-158, 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 per300-grain grain weight, and grain yield per plant, to identify the combining ability effects, nature of gene action heterosis. The results revealed that the mean square for all genotypes was highly significant for all which's that is an indication of the genetic diversity between parentcausesch cause significant differences between single crosses among them. Also, it was shown that the mean square due to general and specific combining abilities was highly significant for all traits indicated the presence of additive and dominant gene effects controlling the effect of all traits. The ratio of general combining ability components to the specific combining ability components was less than one for all traits indicated that the dominance gene effects were more prominent for all studied traits. The line ZP-595 and POL-158 were the best general combiners for larger number of traits including grain yield per plant, and the crosses (ZP-505 x UN44052) and (HS x DK-17) showing highly significant specific combining ability effects and heterosis for larger number of traits and could be utilized for developing high yielding hybrid varieties as well as for exploiting hybrid vigor. The narrow sense heritability was low for all traits and ranged from 3.23% for 300 grain weight and 23.13% for number of days to silking.

Keywords: Pure lines, Heterosis, Combining ability, Gene action

Introduction

Maize (*Zea mays* L.) is an important cereal crop belonging to the Maydeae tribe, and of the Poaceae family, and it is the main crop worldwide, for being a diversified crop and is used for various purposes, for example, it is an important component of food security, providing food, fodder and bioenergy (FAO, 2012; Oliveira et al, 2020; Brash et al, 2015). It is also the most important staple food crop upon which much of the world's population depends (9 and 17).

The maize yield in developing countries is much lower than in developed ones, for example, in Africa and some countries in Asia, the average yield of maize ranged between 1.4 - 1.7 tons/ha, compared to the average of 4.9 tons/ha (10); Shiferaw *et al*, (27); Rwasimitana *et al*.,(24). Despite the great expansion in the cultivation and production of maize in most countries of the world, its production rate per unit area is still low in Iraq, and the existing hybrids approved for agriculture in Iraq are all introduced and imported in hard currency and this is done annually, so work on the production of local hybrids with good production specifications was needed, and this work constantly requires information about the genetic mechanism that controls the inheritance of different traits in this crop. However, with improved agricultural practices as well as the use of genetically improved varieties, it is possible to obtain high tons/ha yields in developing countries. It is noted that such taxa are rarely available in many eloping countries (11, 24 and 26).

Therefore, the development of hybrid varieties of maize in developing countries is an urgent need, and their success depends on the selection of parents that are distinguished in their performance to obtain hybrids that are strong in their characteristics (13 and 19).

Heterosis and combining ability are essential conditions for developing good economically viable maize hybrids (15). The technique of combining ability analysis is useful in assessing the susceptibility of pure lines and also helps in determining the nature of the gene action responsible for the inheritance of different quantitative traits, and this information is useful for plant breeders in formulating hybrid breeding programs. In maize, the perceivable ratio of heterosis for yield and the combining ability has been studied by many researchers such as Paul and Debnath (22) and Rokadia and Kaushik (23), Oppong *et al* (21), and Elmyhun *et al*,(8). A wide range of biomaterials is available to breeders to characterize the genetic control of economically important traits as a guide for deciding on an appropriate breeding methodology for use in cross-breeding. There are various genetic experimental designs such as diallel cross, line x tester, and others, through which reliable information on the effects of the general and specific abilities of parental lines and their cross-compatibility can be provided. These designs have been widely used in maize by several researchers such as Kumar *et al.* (2014), Abdel-Moneam et al. (2) ,and Ruswandi *et al*., (24) and are still applied in studies related to quantitative genetics and at different patterns of agricultural operations.

The aim of the current study in which diallel mating design was used between eight pure lines is to determine the nature and size of the gene action and the heterosis (measured as the deviation of the hybrid from mid and best parents) for grain yield and some other important traits in maize.

MATERIALS AND METHODS

Maize pure lines (1) ZP-505 (2) IK58 (3) HS (4) DK-17 (5) ZP-430 (6) ZP-595 (7) UN44052 and (8) POL-158 conducted in a half diallel crosses according to the second method proposed by Griffing (12), when planted in first of March 2020 in a field of College of the Agricultural Engineering Sciences, Duhok University, and obtained seeds of 28 first-generationn hybrid. The eight pure lines and their hybrid were planted in the tenth of March 2021 in the same location, by adopting randomized complete block design with three replications. The experimental unit contained one row 3 meters long, the distance between the rows wewas.75 m and the plants inside the row were 0.25 m apart .Compound fertilizer NPK (27:27:27) was added by 100 kg per ha during the preparation of the cultivation land, and urea by 200 kg per ha, 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. 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). Genotypes (parent & hybrids) data were analyzed, each trait according to the experimental design method used by Al-Zubaidy and Al-Falahy, (3A), and the sum squares of genotypes was divided into general and specific combining abilities according to method 2, fixed model proposed by Griffing (12), 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 = F1 - MP] and better parents (BP) by the equation [H = F1 - BP], and its significant was tested by t - test.

(2) The effects of the general combining ability (GCA) for parents and specific combining ability (SCA) for hybrids and their significance tested by adopting the t-test, as stated in Al-Zubaidy and Al-Juboury (4B).

(3) The components of the phenotypic (σ^2P) variance, additive (σ^2A), dominance (σ^2D) and environmental (σ^2E), based on the expected variance of the Griffing analysis (fixed model), and their significance from zero were tested in the manner explained by Kempthorne (16).

(4) The broad (h^2_{BS}) and narrow (h^2_{NS}) sense heritability.

(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 percentage of the mean of each trait using the following equation: GA% = [(h^2)(σP)(i) / character over all mean](100), where h^2, σP and i mean narrow sense heritability, phenotypic deviation and intensity of selection (which

equals 1.76 when 10% of plants are selected), respectively.

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

Results and Discussion

Table 1 shows the analysis of variance results for genotypes (parents and F_1’), general combining ability and specific combining ability for the studied traits, and it is noted that the mean square of all these three sources was highly significant for all traits. The highly significant of genotypes, indicate that there is a genetic divergence between the parental lines

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	7.444	4.333	75.593	8.787	4.454	0.006	2.898	96.405	45.259
genotypes	35	18.01**	19.09**	2334.4**	589.4**	24842.8**	5.579**	66.61**	408.15**	4019.56**
GCA	7	22.84**	26.91**	1962.6**	125.5**	34472.9**	1.507**	28.41**	109.75**	1564.53**
SCA	28	16.80**	17.13**	2427.4**	705.4**	22435.3**	6.567**	75.78**	482.75**	4636.33**
Error	70	1.330	0.286	7.688	1.435	316.187	0.015	0.289	21.97	2.766
σ^2gca/ σ^2sca		0.139	0.158	0.081	0.018	0.154	0.023	0.037	0.019	0.034

(**) Significant at 0.01 probability level.

used in the study, which caused a greater divergence between the resulting hybrids, therefore, given the significance of the differences between the genotypes of all traits, the subsequent genetic analysis of the combining ability and the nature of the genes action is necessary in order to identify the genetic mechanism that controls the inheritance of different traits, and thus choose the method that suits the breeding of the crop within the limits of the genetic materials approved in the study and naming the best parents and hybrids for future programs. As for the high significance of the mean squares of both general and special combining abilities indicates that the additive and dominant genetic influences are important in controlling the inheritance of all traits. The ration of σ^2gca/ σ^2sca was less than one for all studied traits indicating that the dominant gene action was more important than the additive one in controlling the inheritance of these traits. Zare et al. (2010) concluded from their study that the largest genetic effects were additive for number of rows per ear and non-additive for grain yield per plant, while Choukan and Mosavat (7) show the existence of additive and non-additive genetic effects for grain yield per plant and number of rows per ear.

Tables (2 and 3) show, respectively, the means of the parental lines and their general combining ability effects for different traits, and it is noted for NDT and NDS that the parental lines 6 was more early in maturity than other (81 days) and (82.33 days) respectively, and at the same time it showed a general combining ability, negative (desirable) and significant, so it is considered the best in its general combining ability for these two traits. For the traits of PH, LA, NGR, 300GW and GYP, line 8 gave the highest means of (194.67 cm, 747.00 cm^2, 36.000 grain, 44.503 and 1.578 gm) respectively, and at the same time, it gave desirable highly significant general combining ability effects for these five traits, and therefore it is the most efficient in improving these traits. The line 4 had the highest mean for EH (93.33 cm) and NRE

(14.367 row), but its general combining ability effect was significant non-desirable for the first and desirable for the second. It is noted in general that the lines 6 and 8 showed a significant

Table 2. Means of parents for studied traits in maize.

hybrids	traits								
	NDT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
1	83.67c	86.67c	143.00e	81.00b	662.33b	13.200c	28.333ef	35.590c	65.493f
2	84.00c	86.00c	134.00f	91.00a	578.00d	14.067a	27.333f	41.017ab	61.090g
3	84.67bc	87.67b	176.00c	82.00b	602.33c	12.733d	29.000e	40.523ab	71.510d
4	87.67a	89.33a	155.00d	71.00c	527.00e	13.700b	30.667d	39.620bc	60.507h
5	85.0bc	86.67c	176.00c	93.33a	662.33b	14.367a	28.333ef	40.490ab	69.840e
6	81.00d	82.33e	182.00b	81.00b	530.67e	14.067a	32.000c	38.080bc	76.010c
7	86.00b	89.00a	182.33b	73.33c	528.67e	13.600c	34.000b	40.167ab	79.517b
8	81.00d	84.67d	194.67a	91.00a	747.00a	14.233a	36.000a	44.503a	80.633a
P means	84.125	86.542	167.875	82.958	604.792	13.746	30.708	39.999	70.757
H means	84.500	86.988	220.048	138.238	679.226	16.321	38.214	64.856	141.792
G means	84.417	86.889	208.454	98.176	662.685	15.743	36.546	59.332	125.818

- Values followed by the same letter for each trait are not significantly different from each other.
- P = parents , H = Hybrids and G = All genotypes (parents and hybrids)

Table 3. GCA effects of parents for studied traits in maize.

hybrids	traits								
	NBT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
1	-1.08**	-0.73**	-12.94**	-0.158	33.08**	-0.29**	0.442**	-3.22**	-6.34**
2	0.458*	0.233*	-10.31**	1.642**	-41.25**	-0.24**	-1.43**	-1.611*	-12.1**
3	-1.08**	-1.20**	-2.48**	-0.56**	10.683**	-0.15**	1.508**	0.770	2.158**
4	0.625**	0.47**	1.33**	-1.29**	10.983**	0.187**	-1.19**	0.184	-5.03**
5	0.058	0.00	4.36**	-1.29**	-5.050	0.003	0.142	0.847	0.493
6	-0.08**	-1.07**	7.49**	3.841**	-27.82**	0.337**	-0.29**	-1.156	6.197**
7	1.23**	1.50**	2.93**	-2.79**	-35.82**	0.197**	0.042	1.323	6.073**
8	0.56**	0.80**	9.63**	0.608**	54.550**	-0.037	0.775**	2.864**	8.554**
SE	0.197	0.091	0.474	0.205	3.037	0.021	0.092	0.801	0.285

(**) Significant at 0.01 probability level. SE = Standard Error

Significant and desirable effect of general combining ability for largest number of traits included GYP coupled with good mean performance, followed line 3, and this is evidence of the possibility of using these lines in breeding programs to improve GYP and its components. From previous studies, Abdel-Moneam *et al.* (2) and Ruswandi *et al.*(24) obtained different effects of general combining ability in maize lines for GYP and some of its components of other traits.

Table (4) shows the mean performance of single crosses for the studied traits, and it is clear through Duncan's multiple range test that the differences between them were significant for all traits indicative of the large genetic differences between them, as a result of genetic differences between the lines that produced them. It is noted that the best NDT and NDS were 79.00 and 79.33 days respectively in the hybrid (3x4), which showed the earliest hybrid in flowering.

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

hybrids	Traits NDT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
1x2	81.33jk	84.00 h	176.00l	101.00d	578.0 j	14.600j	33.00 l	49.89f	66.55m
1x3	82.33h-k	85.33fg	203.33j	110.00c	664.0gh	14.600j	42.00c	53.88ef	101.08l
1x4	83.67f-j	87.0cde	207.67ij	91.00 f	724.33cde	16.000g	36.00 i	58.71c-f	123.91j
1x5	82.67g-k	84.67gh	210.67ghi	95.00 e	608.33ij	16.700c	45.00a	64.12a-d	169.56b
1x6	84.67d-h	86.00ef	230.67c	131.00a	744.33cd	17.333b	40.33de	68.51abc	186.23a
1x7	80.33kl	84.33gh	210.00hi	91.00 f	677.00fg	16.700c	39.67efg	71.57a	158.46c
1x8	86.67a-d	90.00 b	222.33de	101.00d	974.33a	16.47de	40.67d	63.91a-d	134.08i
2x3	83.00f-j	84.67gh	203.33j	81.00 h	761.33c	16.60cd	42.00c	69.63ab	168.83b
2x4	86.67a-d	90.00 b	191.67k	85.00 g	608.67ih	16.067g	42.33bc	61.2b-e	122.71j
2x5	84.33d-i	86.67de	250.00a	110.00c	596.33 j	16.000g	33.33 l	57.04def	110.30k
2x6	85.00c-g	87.00cde	230.67c	131.00a	587.00 j	15.267i	30.67m	62.26a-e	138.74h
2x7	87.67ab	90.00 b	221.67de	115.00b	608.33ij	16.63cd	39.00g	64.03a-d	141.10gh
2x8	88.333a	90.00 b	231.67 c	95.000e	656.00gh	16.100g	39.7efg	71.78a	142.72g
3x4	79.000l	79.33 i	221.67de	110.00c	745.67cd	17.300b	36.33 i	64.05a-d	132.08i
3x5	81.33jk	84.67gh	207.33ij	101.00d	634.00hi	14.667j	43.00b	72.537a	149.28e
3x6	84.67d-h	87.33cd	222.33de	101.00d	745.33cd	18.767a	40.67d	65.41a-d	159.52c
3x7	86.67a-d	88.00 c	210.67ghi	101.00d	677.33fg	16.700c	42.00c	64.69a-d	145.83f
3x8	82.67g-k	85.33fg	230.67 c	110.00c	638.67hi	16.133g	40.0def	70.45ab	156.59c
4x5	84.00e-i	87.00cde	241.67 b	101.00d	745.00cd	16.667c	35.67ij	72.253a	144.17fg
4x6	82.67g-k	86.67de	250.00 a	110.00c	692.33efg	17.400b	35.0jk	60.79c-e	134.14i
4x7	88.00 ab	90.000b	233.33 c	115.00b	677.33fg	16.63cd	34.67k	67.38abc	138.27h
4x8	86.67a-d	88.000c	233.33 c	116.67b	826.67 b	16.17fg	35.67ij	72.193a	167.55b
5x6	84.67d-h	87.00cde	215.67fg	91.000f	687.67fg	16.000g	41.67c	63.94a-d	124.43j
5x7	88.00ab	90.67 ab	217.33ef	91.000f	710.33def	17.367b	35.67ij	69.19ab	149.05e
5x8	85.33b-f	88.00 c	225.00 d	95.000e	607.33ij	15.667h	39.33fg	62.40a-e	153.09d
6x7	82.00ijk	84.67gh	222.67de	101.00d	530.00 k	16.17fg	37.33h	61.25b-e	149.92e
6x8	86.00a-e	88.00 c	215.0fgh	95.000e	638.00hi	16.067g	36.33i	64.11a-d	151.17de
7x8	87.33abc	91.333a	225.00 d	95.000e	674.67fg	16.33ef	33.00 l	68.78abc	153.26d
H means	84.500	86.988	220.048	138.238	679.226	16.321	38.214	64.856	141.792
G means	84.417	86.889	208.454	98.176	662.685	15.743	36.546	59.332	125.818

- Values followed by the same letter for each trait are not significantly different from each other.
- H = hybrids G = All Genotypes (parents + hybrids).

and with a significant difference from all other hybrids except (2x7 and 2x4 and 5x7) for NDT and (5x7) for NDS. The highest means were 250.0 cm for plant height in the two hybrids (2x5 and 4x6), 131.0 cm for EH in the two hybrids (1x6 and 2x6), 974.33 cm^2, 18.767 row, 45.0 grain and 186.23 gm for traits LA, NRE, NGR and GYP, in hybrids (1x8), (3x6), (1x5) and (1x6) respectively, with a significant difference from most other hybrids, while for the 300GW, the hybrids (1x7, 2x8, 3x5, 4x5 and 4x8) outperformed the highest means.

The results of special combining ability of hybrids for studied traits are shown in Table (5), and it seems that some hybrids showed significant effects in the desired direction for each trait, as the number of hybrids with significant desirable effects was 6 for NDT, 8 for NDS, 15 for PH, 14 for EH, 11 for LA, 15 for NRE, 12 for NGR, 12 for 300GW and 17 for GYP. It is noted that the hybrids (1x7), (2x3), (2x7) and (3x4) were characterized by significant and desirable effects for largest number of traits (seven) including GYP, and at the same time had high

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

hybrids	Traits								
	NDT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
1x2	-2.47**	-2.39**	-9.20**	1.341*	-76.52**	-0.619**	-2.56**	-4.6.6	-41.03**
1x3	0.067	0.378	10.29**	12.54**	-42.45**	-0.702**	3.504**	-3.001	-20.77**
1x4	-0.300	0.378	10.83**	-5.73**	17.58	0.358**	0.204	2.412	9.256**
1x5	-0.733	-1.49**	10.79**	-1.73**	-82.39**	1.243**	7.870**	7.159**	49.38**
1x6	2.100**	0.911**	27.66**	29.14**	76.38**	1.541**	3.637**	13.56**	60.35**
1x7	-4.23**	-3.32**	11.56**	-4.23**	16.414	1.048**	2.637**	14.14**	32.69**
1x8	4.167**	4.289**	-22.37**	-14.5**	157.5**	-0.911**	-6.19**	-12.36**	-42.02**
2x3	-0.800	-1.26**	7.662**	-18.3**	129.2**	1.238**	5.370**	11.14**	52.76**
2x4	1.167*	2.411**	-7.80**	-13.5**	-23.75**	0.365**	8.404**	3.296	13.83**
2x5	-0.600	-0.456	47.59**	11.47**	-20.05**	0.481**	-1.93**	-1.527	-4.11**
2x6	0.900	0.944**	25.03**	27.34**	-6.619	-0.585**	-4.16**	5.699*	18.63**
2x7	1.567*	1.378**	20.59**	17.97**	22.08*	0.922**	3.837**	4.986*	21.11**
2x8	1.567*	0.722*	-29.94**	-15.9**	-22.17*	-0.59**	-2.59**	-3.895	-20.47**
3x4	-4.97**	-6.82**	14.36**	13.67**	61.31**	1.515**	-0.529	3.767	8.937**
3x5	-2.07**	-1.02**	-3.00*	4.675**	-34.32**	-0.935**	4.804**	11.59**	20.16**
3x6	2.100**	2.711**	8.863**	-0.459	99.78**	2.832**	2.904**	6.463**	25.14**
3x7	2.100**	0.811**	1.763	6.174**	39.15**	0.905**	3.904**	3.261	11.58**
3x8	1.167	2.022**	-12.44**	-3.29**	-170.9**	-2.14**	-9.39**	-12.87**	-38.97**
4x5	-1.100	-0.356	27.53**	5.407**	76.38**	0.725**	0.170	11.89**	22.69**
4x6	-1.60**	0.378	32.73**	9.274**	46.48**	1.125**	-0.063	2.436	6.955**
4x7	1.733**	1.144**	20.63**	20.91**	38.85**	0.498**	-0.729*	6.544**	11.21**
4x8	3.067**	1.356**	-42.17**	-5.42**	-59.2**	-2.16**	-3.96**	-10.27**	-17.43**
5x6	0.967	1.178**	-4.637**	-9.73**	57.85**	-0.092	5.270**	4.913*	-8.28**
5x7	2.300**	2.278**	1.596	-3.09**	87.88**	1.415**	-1.06**	7.691**	16.46**
5x8	0.767	0.089	-38.61**	-4.75**	-95.1**	-1.44**	-6.63**	-12.18**	-39.14**
6x7	-2.87**	-2.66**	3.796**	1.774**	-69.69**	-0.118	1.037**	1.747	11.63**
6x8	0.267	-1.04**	-52.01**	11.96**	-127.8**	-2.34**	-4.66**	-15.87**	-52.01**
7x8	0.267	1.256**	-27.97**	-2.81**	-71.1**	-2.12**	-6.99**	-16.56**	-46.04**
SE	0.604	0.279	1.452	0.627	9.309	0.064	0.281	2.454	0.871

(**) and (*) Significant at 0.05 and 0.01 probability level respectively. SE = Standard Error.

performance means for these traits (Table 4), followed by hybrids (1x5), (1x6), (3x5), (3x6), (4x5), (4x6), (4x7) and (6x7) which each had a significant and desirable effect for six traits, including GYP, in addition to giving good means performance for these traits. From previous studies, Izhar and Chakraborty (15), Ruswandi *et al*. (24) and Oppong *et al*. (21) obtained desirable significant effects of the special combining ability shown by some hybrids for GYP and its components of other traits. It is noted that most of the hybrids with significant desirable specific effects for a specific trait had at least one of their parents gave a desirable significant general effect for that trait.

Tables (6 and 7) show the results of heterosis based on the deviation of hybrid mean from mid and best parents, respectively. It is noted that all hybrids gave a significant desirable heterosis for PH, NRE, 300GW and traits, and the highest heterosis values for these traits, respectively, were when measured as deviation from mid parents: 103.7, 8.15 and 36.25 in the hybrid (3x5), and as deviation from better parents 68.0, 14.07, 32.01 and 110.2 in the hybrid

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
1x2	-2.50*	-2.33**	37.50**	15.00**	-42.17*	0.97**	5.17**	11.59*	3.26
1x3	-1.83	-1.83**	43.83**	28.50**	31.67	1.63**	13.33**	15.82**	32.58**
1x4	-2.00	-1.00	58.67**	15.00**	129.7**	2.55**	6.50**	21.10**	60.91**
1x5	-1.67	-2.00**	51.17**	7.83**	-54.00**	2.88**	16.67**	26.08**	101.9**
1x6	2.33	1.50*	68.17**	50.00**	147.8**	3.70**	10.17**	31.68**	115.5**
1x7	-4.50**	-3.50**	47.33**	13.83**	81.50**	3.30**	8.50**	33.69**	85.96**
1x8	4.33**	4.33**	53.50**	15.00**	269.7**	2.75**	8.50**	23.87**	61.02**
2x3	-1.33	-2.17**	48.33**	-5.50**	171.7**	3.20**	13.83**	28.86**	102.5**
2x4	0.83	2.33**	47.17**	4.00**	56.17**	2.18**	13.33**	20.88**	61.92**
2x5	-0.17	0.33	95.00**	17.83**	-23.83	1.78**	5.50**	16.29**	44.84**
2x6	2.50	2.83**	72.67**	45.00**	32.67	1.20**	1.00	22.72**	70.19**
2x7	2.67	2.50**	63.50**	32.83**	55.00**	2.80**	8.33**	23.44**	70.80**
2x8	5.83**	4.67**	67.33**	4.00**	-6.50	1.95**	8.00**	29.02**	71.86**
3x4	-7.17**	-9.17**	56.17**	33.50**	181.0**	4.08**	6.50**	23.98**	66.08**
3x5	40.83**	41.83**	103.7**	56.17**	347.0**	8.15**	21.17**	36.25**	73.71**
3x6	1.83	2.33**	43.33**	19.50**	178.8**	5.37**	10.17**	26.11**	85.76**
3x7	1.33	-0.33	31.50**	23.33**	111.8**	3.53**	10.50**	24.34**	70.32**
3x8	-0.17	-0.83	45.33**	23.50**	-36.00	2.65**	7.50**	27.94**	80.52**
4x5	-2.33	-1.00	76.17**	18.83**	150.3**	2.63**	6.17**	32.19**	78.99**
4x6	-1.67	0.83	81.50**	34.00**	163.5**	3.52**	3.67**	21.95**	65.88**
4x7	1.17	0.83	64.67**	42.83**	149.5**	2.98**	2.33**	27.49**	68.26**
4x8	2.33	1.00	58.50**	35.67**	189.7**	2.20**	2.33**	30.13**	96.98**
5x6	1.67	2.50**	36.67**	3.83**	91.17**	1.78**	11.50**	24.65**	51.51**
5x7	2.50*	2.83**	38.17**	7.67**	114.8**	3.38**	4.50**	28.87**	74.38**
5x8	2.33	2.33**	39.67**	2.83*	-97.33**	1.37**	7.17**	19.91**	77.86**
6x7	1.00	1.17*	34.33**	15.00**	-108.8**	2.02**	3.33**	19.96**	71.60**
6x8	5.33**	4.50**	26.67**	9.00**	-0.83	1.92**	2.33**	22.82**	72.85**
7x8	3.83**	4.50**	36.50**	12.83**	36.83*	2.42**	-2.00**	26.44**	73.19**

(**) and (*) Significant at 0.01 and 0.05 probability level respectively.

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

hybrids	Traits								
	NBT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
1x2	-2.33	-2.00**	33**	11.00**	-84.33	0.53**	4.67**	8.88	1.06
1x3	-1.33	-1.33*	27.33**	28.00**	1.67	1.40**	13.00**	13.36*	29.57**
1x4	0.00	0.33	52.67**	100.00**	62.00	2.30**	5.33**	19.09**	58.42**
1x5	-1.00	-2.00**	34.67**	1.67	-54.00	2.30**	16.67**	23.63**	99.72**
1x6	3.67*	3.67**	48.67**	50.00**	82.00	3.27**	8.33**	30.43**	110.2**
1x7	-3.33*	-2.33**	27.67**	10.00**	14.67	3.10**	5.67**	31.44**	78.94**
1x8	5.67**	5.33**	27.67**	10.00**	227.33**	2.23**	4.67**	19.41**	53.45**
2x3	-1.00	-1.33*	27.33**	-10.00**	159.00**	2.53**	13.00**	28.61**	97.32**
2x4	2.67	4.00**	36.67**	-6.00**	30.67	14.07**	11.67**	20.18**	61.62**
2x5	0.33	0.67	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**	143.33**	3.60**	5.67**	23.53**	60.57**
3x5	-3.33*	-2.00**	31.33**	7.67**	-28.33	0.30**	14.00**	32.01**	77.58**
3x6	3.67*	5.00**	40.33**	19.00**	143.00**	4.70**	8.67**	24.89**	83.51**
3x7	2.00	0.33	28.33**	19.00**	75.00**	3.10**	8.00**	24.16**	66.31**
3x8	1.67	0.67	36.00**	19.00**	-108.3**	1.90**	4.00**	25.95**	75.96**
4x5	-1.00	0.33	65.67**	7.67**	82.67**	2.30**	5.00**	31.76**	74.33**
4x6	1.67	4.333**	68.00**	29.00**	161.67**	3.33**	3.00**	21.18**	58.13**
4x7	2.00	1.00	51.00**	41.67**	126.0**	2.93**	0.67	27.22**	58.76**
4x8	5.67**	3.33**	38.67**	25.67**	79.67**	1.93**	-0.33	27.69**	86.92**
5x6	3.67*	4.67**	33.67**	-2.33	25.333	1.63**	9.67**	23.45**	48.42**
5x7	3.00*	4.00**	35.00**	-2.33	48.00*	3.00**	1.67*	28.70**	69.54**
5x8	4.33**	3.33**	30.33**	1.67	-139.7**	1.30**	3.33**	17.90**	72.46**
6x7	1.00	2.33**	40.33**	20.00**	-0.67	2.10**	3.33**	21.08**	70.41**
6x8	5.33**	5.67**	20.33**	4.00*	-109	1.83**	0.33	19.60**	70.54**
7x8	6.33**	6.67**	30.33**	4.00*	-72.33**	2.10**	-3.00**	24.27**	72.63**

(**) and (*) Significant at 0.01 and 0.05 robability level respectively.

(4x6), (2x4), and (3x5). For the traits NDT, NDS, EH, LA, NGR and GYP the number of hybrids that gave a significant desirable heterosis were 3, 6, 27, 17, 26 and 27, when measured by deviation from mid parents and 3, 7, 22, 10, 23 and 27 when measured by deviation from better parents respectively. In general, it is noted that the hybrids (1x7) and (3x4) were distinguished by giving a significant desirable heterosis for all traits by the two measurement methods, except for LA in the first hybrid on the basis of the best parents, and at the same time, they had highly significant desirable effects of specific combining ability for most traits, including grain yield per plant. followed in importance by hybrids (1x3), (1x8), (2x3), (3x6), (3x7), (4x5) and (4x6), which gave significantly desirable heterosis for all traits by both measurement methods, except for the number of days to flowering. These results indicate the possibility of using these hybrids in breeding programs to develop new hybrid varieties of maize. From previous studies, other researchers obtained a significant and desirable hetrosis grain yield of maize per plant and some of its components from other traits compared to the mid or best parents, including those done by Kumar *et al.* (18), Abdel-Moneam *et al.* (2), Oppong *et al*. (21) and Elmyhun *et al.* (8).

Table (8) 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, indicating their importance in controlling the inheritance of these traits. It is noted that the values of dominance variance were greater than those of additive for all traits, indicating that the dominance genetic effects were more important for these traits. For this reason, it is noted that the values of heritability in narrow sense were much lower than in the broad sense for all traits, as the values of narrow heritability was low for all traits and ranged from 3.23% for 300GW and 23.13% for NDS, which means the inappropriateness of selection for additive genetic influences between the lines under study, while the values of broad sense heritability

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

	Traits								
	NBT	NDS	PH	EH	LA	NRE	NGR	300GW	GYP
σ^2A	1.434 ± 0.508	1.775 ± 0.598	130.329 ± 43.614	8.273 ± 2.789	2277.11 ± 766.068	0.099 ± 0.0335	1.875 ± 0.6313	5.852 ± 2.445	104.118 ± 34.767
σ^2D	5.157 ± 1.448	5.615 ± 1.474	806.569 ± 208.917	234.652 ± 60.710	7373.05 ± 1931.01	2.184 ± 0.565	25.165 ± 6.522	153.592 ± 41.566	1544.52 ± 399.032
σ^2E	1.330 ± 0.222	0.286 ± 0.048	7.689 ± 1.281	1.435 ± 0.239	316.187 ± 52.698	0.015 ± 0.003	0.289 ± 0.048	21.971 ± 3.662	2.766 ± 0.461
σ^2p	7.921	7.675	944.586	244.359	9966.35	2.298	27.328	181.416	1651.41
h^2_{BS}	0.8321	0.9628	0.9919	0.9941	0.9683	0.9935	0.9894	0.8789	0.9983
h^2_{NS}	0.1810	0.2313	0.1379	0.0339	0.2285	0.0433	0.0686	0.0323	0.0631
$\bar{a}$	2.682	2.515	3.518	7.532	2.545	6.642	5.181	7.245	5.446
GA	0.897	1.127	7.463	0.931	40.145	0.115	0.631	0.765	4.509
GA%	1.062	1.297	3.580	0.949	6.058	0.733	1.7269	1.289	3.584

were high for all traits and ranged between 83.21% for NBT and 99.83% for GYP. The average degree of dominance is greater than one for all traits indicative of the presence of over-dominance, which may be due to the distribution of linked genes between parents, so partial dominance appears as over-dominance (Hayman, 1954). From previous studies, many researchers obtained different results regarding the gene action that controls the inheritance of different traits of maize, for example, Abadi et al. (2011) found the importance of the additive genetic effect for plant height, while Petrovic (1998) indicated the importance of the non-additive gene effects in controlling plant height. 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 (Konak et al., 1999). Finally, it is noted that the expected genetic improvement in the next generation as a percent was low for all traits, as it ranged between 0.949% for EH and 6.058% for LA.

It is concluded from foregoing that it is possible to benefit from the two lines 6 and 8 due to their significant and desirable effect of general combining ability for largest number of traits included GYP coupled with good mean performance, followed by line 3, and the two hybrids (1x7) and (3x4) followed by the hybrids (1x3), (1x8), (2x3), (3x6), (3x7), (4x5) and (4x6), due to their significant desirable specific effects and heterosis for the greatest number of traits, in developing high yielding hybrid varieties as well as for exploiting heterosis phenomenon

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