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COMBINING ABILITY ESTIMATES AND GENE EFFECTS FOR GRAIN YIELD AND YIELD COMPONENTS IN MAIZE (*ZEA MAYS L.*)

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Abstract:

Nine inbred lines of maize were used in this study, which entered in crosses according to the method of factorial mating system, where the lines DK, OH40 and ZP-607 used as females and lines ZM47R, G105, ZM51, ZM49R, Inbreed2 and G54 used as male parents. The parents and the first generations of their single crosses planted through autumn season of 2013 at Al-Hawija, Kirkuk Province using randomized complete block design with three replications, then data recorded for characters, plant height, main ear height, number of ears per plant, ear length, ear diameter, number of rows per ear, number of grains per row, number of grains per ear, 300 grain weight and grain yield per plant. The results showed that there are highly significant differences between genotypes (parents and hybrids) for all characters. The two lines OH40 and G54 given desirable significant effects of general combining ability for the largest number of characters. The hybrids showed variation in their effects of specific combining ability for different characters, and the hybrids (OH40 x ZM51), (ZP-607 x G549) and (DK x G105) characterized by desirable specific combining ability for the largest number of characters including grain yield per plant. Additive genetic variance appeared largest in its value than dominance one for plant height, main ear height, ear length, ear diameter, number of grains per row and number of grains per ear, and vice versa for the rest of characters. Average degree of dominance was less than one for main ear height and number of grains per ear, indication of a partial dominance, and was more than one for the rest of the characters indicating over dominance. The broad sense heritability ranged between 57.834% for number of grains per ear and 95.565% for main ear height, and in narrow sense between 21.053% for number of ears per plant and 67.218% for main ear height.

Keywords: Wheat And Rice, Grains, Leaves, Stems And Silk

INTRODUCTION

Maize is the most important cereal crop in the world after wheat and rice, and is characterized by great production potential and has achieved a leading position among cereals on the basis of production and productivity (Keskin et al., 2005), and progress in maize genomics, breeding and production plays a major role in the lives of a large proportion of the world populations (Xu and Crouch, 2008). Each part of the plant in maize has an economic value, as the grains, leaves, stems and silk are used in production of hundreds of food and non-food products. The main purpose of maize breeding is to develop new pure lines and hybrids that are superior to the existing ones with respect to a number of traits, and in working towards this goal, special attention is given to the grain yield trait, as is the case of most of the economically important traits of maize (Vasic et al., 2001), where grain yield is a complex quantitative trait that depends on a number of factors that are inherited in a quantitative manner (Zivanovic et al., 2007), which as a quantitative trait, it is largely influenced by environmental conditions, has a complex gene action and low heritability (Bovanski et al., 2009), as well as influenced by a number of components, including the number of rows per ear, the number of grains per row, and others. Distinguishing the parental pure lines that can be used to develop surpassed crosses is the most costly and time consuming stage in the development of hybrid maize, and the performance of the pure maize lines by itself does not predict the performance of the crosses for grain yield (Hallauer and Miranda, 1988). Predictions of single cross values or hybrid vigor between parental pure lines can for this reason increase the efficiency of hybrids breeding programs (Betran et al., 2003). The main objective of maize breeding is to obtain new hybrids with high genetic potential for production and positive characteristics that exceed the existing commercial hybrids (Secanski et al., 2005), and for this reason analysis of the combining ability is an important way for the deduction of gene action, and it is often used by crop breeders in choosing parents with high general combining ability and hybrids with high specific combining ability (Yingzhong, 1999). The variance of the general combining ability is related to the additive genetic effects, while that of the specific combining ability includes the non-additive genetic effects caused by the dominance and epistatic deviations with regard to some traits. In any systematic breeding program, it is necessary to identify surpassed parents to cross between them in order to expand the genetic variations that help in selecting distinct genotypes (Hallauer and Miranda, 1988), and the first basic steps in the development of hybrids is to test the pure lines in terms of their general combining ability effects, and in the field of plant breeding, different mating systems are used, including the factorial mating system (in which a group of lines that use as females are mated with another group that used as males) to test the combining ability for parental lines in order to identify surpassed parents for use in hybrid development programs (Fry, 2004). The combining ability has been tested by many maize breeders, including (Glover et al., 2005, Dawod et al., 2009, Sibiya et al., 2012, El-Badawy, 2013, Al-Falahy et al., 2014, Zhang et al., 2016, Sadalla et al., 2017, Al-Fahad et al, 2020 and Fayyad and Hammadi, 2021). Also, by identifying the gene action and some important genetic parameters such as heritability and the average degree of dominance of the grain yield and its components in maize, useful information can be obtained in the breeding programs of this crop, as the breeder wants to know the amount of variations in the crop that is due to the genetic factor, and to which range is this variation is inherited, because the efficiency of selection depends mainly on additive genetic variance, the effect of the environment and the interaction between the genotype and the environment (Novoselovic et al., 2004). Many studies have been conducted in this field on maize crop, including those carried out by Ojo et al. (2007), Dawud and Abdullah (2011), Khodarahmpour (2011), Al-Falahy et al. (2012), Al Qaisi (2013) and Al Bayati (2013).

The aim of the current study is to evaluate the effects of general and specific combining abilities for nine pure lines of maize and their single crosses, as well as other genetic parameters, including the average degree of dominance and heritability of grain yield and some of its components of other traits using factorial mating design in order to identify surpassed breeding lines and hybrid combinations.

MATERIALS AND METHODS

Nine pure lines of maize were planted in Sharqat (sallahuddin Governorate) during the spring season of 2013 and the single crosses were carried out among them according to the method of the factorial mating system proposed by Comstock and Robinson (1948 and 1952), where the lines were used: (1) DK, (2) OH40 and (3) ZP-607 as Females and the lines (4) ZM47R, (5) G105, (6) ZM51, (7) ZM49R, (8) $Inbreed_2$ and (9) G54 as males. On July 18, 2013 the seeds of the parents and crosses (nine Parents and 18 single crosses) were sown in Hawija (Kirkuk governorate) using a randomized complete block design with three replications, and the planting was on rows of 3 m length, and the distance between them 0.75 m And a distance of 0.3 m between plants and a distance of 0.30 m between plants. The service operations related by weeding and thinning were carried out, and phosphate fertilizer P_2O_5 was added at a rate of 200 kg per hectare during planting, and nitrogen fertilizer (urea 46% N) at a rate of 200 kg per hectare after a month of planting. The data were recorded on the basis of the individual plant (ten plants from each experimental unit) on the traits: plant height (cm), main ear height (cm), number of ears per plant, ear length (cm), ear diameter (cm), number of rows per ear, number of grains per row, number of grains per ear 300 grains weight (gm) and grain yield per plant (gm).

The data of all genotypes, parents and crosses were analyzed separately according to the method of experimental design used, and the differences between the mean of any of them were tested by Duncan's Multiple Range Test (Al-Zubaidy and Al-Falahy (2016), then the crosses data were analyzed according to the method of the factorial mating system according to the steps explained by Al-Zubaidy and Al-Gubory (2016). The fixed model was adopted to implement the following statistical and genetic procedures:

(1) Estimate the effects of the general combining ability for males ($\hat{g}_i$) and females ($\hat{g}_j$) from the two equations: $\hat{g}_i = \bar{y}_{i..} - \bar{y}_{...}$ and $\hat{g}_j = \bar{y}_{.j.} - \bar{y}_{...}$, where $\bar{y}_{i..}$ and $\bar{y}_{.j.}$ and $\bar{y}_{...}$ the mean of the male i, the mean of the female j, and the general mean of the trait, respectively.

(2) Estimate the effects of the specific combining ability for each hybrid ($\hat{S}_{ij}$) from the equation: $\hat{S}_{ij} = \bar{y}_{ij.} - \bar{y}_{i..} - \bar{y}_{.j.} + \bar{y}_{...}$, since $\hat{S}_{ij}$ is the mean of the hybrid ij for the trait, and the significance of the general and specific effects was tested from zero through standard error (SE), which was estimated as: SE($\hat{g}_i$ or $\hat{g}_j$) = $\sqrt{2\sigma^2 e/r}$ and SE($\hat{S}_{ij}$) = $\sqrt{4\sigma^2 e/r}$, respectively, where σ^2e means the variance of the effect of experimental error and estimated by dividing the mean square error (MSe) divided by the number of replicates (r).

(3) Estimate the components of phenotypic variance σ^2p (additive genetic σ^2A, dominant genetic σ^2D and environmental σ^2E) based on the expected mean square from the analysis of variance according to the factorial mating system (fixed model), as:

$$\sigma^2A = \sigma^2m + \sigma^2f \quad ; \quad \sigma^2D = \sigma^2mf \quad ; \quad \sigma^2E = \sigma^2e = MSe/r,$$

Since σ^2m, σ^2f, σ^2mf and σ^2e are the variance of the effect of males, females, the male x female interaction, and the experimental error respectively. The total genetic variance σ^2G and phenotypic variance σ^2p were calculated from the following equations:

$$\sigma^2G = \sigma^2A + \sigma^2D \ ; \ \sigma^2p = \sigma^2G + \sigma^2E = \sigma^2A + \sigma^2D + \sigma^2E$$

The significance of the variances from zero was tested by the method shown by Kempthorne (1957).

(4) Estimate heritability in its two senses, broad (h^2_{bs}) and narrow (h^2_{ns}), average degree of dominance (ā) and genetic advance as a percentage of the trait mean (GA%) as follows:

$h^2_{bs} = \sigma^2G/\sigma^2p$; $h^2_{ns} = \sigma^2A/\sigma^2p$; $\bar{a} = \sqrt{2\sigma^2D/\sigma^2A}$; $GA\% = [(i\ \sigma p\ h^2_{ns})/\bar{y}...]\ x100$,

i = means the selection intensity and is equal to 1.75 at the selection rate of 10% of plants, and σp is the phenotypic deviation (which is the root squared of phenotypic variance). The limits of heritability were adopted in the broad sense according to Ali (1999) (less than 40% low, 40-60% medium and more than 60% high) and narrow according to Al-Adary (1999) (less than 20% low, 20-50% medium and above 50% high) and genetic advance according to Agarwal and Ahmad (1982) (less than 10% low, between 10-30% medium and more than 30% high).

All statistical and genetic analysis were performed using the two available programs, Statistical Analysis System (SAS) and Microsoft Office Excel 2003.

RESULTS AND DISCUSSION

The analysis of variance results of all kinds appear in Table (1). For all genotypes, parents, or hybrids, it appears that the mean squares was significant at 1% probability level for all traits, except for ear diameter and number of rows per ear (it was significant at the probability level of 5%) and, plant height, number of ears per plant and ear length (it did not reach the significant limit) in case of parents, and that related to all parents verse hybrids was not significant for the two traits, main ear height and number of rows per ear, significant at the probability level of 5% for number of ears per plant and at a probability level of 1% for other traits. These results indicate that there are genetic variations between the nine lines of maize approved in the study, indicating the genetic divergence between them, and greater variations between the resulting single crosses. As a result of the highly significant mean squares of the genotypes for all traits, it becomes necessary to continue studying the genetic behavior of all traits to identify the gene action that controls them. In order to implement this, an analysis of variance was conducted for the hybrids using the factorial mating design method, and its results presented in the same table indicated that the mean squares of each of males, females and the interaction between them was highly significant for all traits, except number of ears per plant and number of grains per ear in case of males (significant in them at the level of Probability 5%), number of ears per plant and grains yield per plant in case of females and number of grains per ear in case of male x female interaction (not significant in it), and that related to males verse females was not significant number of grains per ear and highly significant for the other traits. Table (2) shows the means of the nine lines (females and males) and their general combining ability effects for the studied traits under. For females, it is noted that the differences between the means of

the lines for the two traits of, number of ears per plant and grain yield per plant are not significant, and that the line OH40 gave the highest means for the two traits (1.136 ear and 236.018 g), and at the same time, the same line showed a non-significant desirable general combining ability effects for the two traits. The line OH40 surpassed by highest means for traits: plant height, ear length, number of rows per ear, number of grains per row and number of grains per ear, and at the same time it showed desirable effects for the general combining ability for these traits, reaching the significant limit for plant height and ear length, while the line ZP-607 surpassed by highest means for plant height and 300 grains weight (4.818 cm and 128,468 g, respectively), and also showed desired general combining ability effects which was significant for plant height trait only. It is noted from the comparison between the male parental lines and their general combining ability effects (Table 2), that the line G54 gave the highest means for plant height, main ear height, number of ears per plant, ear length and number of rows per ear (199.508 cm, 131,906 cm, 1,246, 21.539 cm and 16,492 rows, respectively), as well as the significant and desirable general combining ability effects for ear diameter and number of grains per ear. The line ZM49R surpassed by highest means for number of grains per row and ear (37.180 and 572.05 grains, respectively), and its general combining ability effects were desirable but not significant for the two traits. The pure line ZM51 surpassed by highest means for the two traits, 300 grains weight and grain yield per plant (137,564 and 256.00 gm, respectively), but its general combining ability effects for the two traits were not significant. Finally, the $Inbreed_2$ line was surpassed by highest mean for ear diameter of 5.080 cm, with a significant difference from all other lines, and at the same time it showed a desirable significant general combining ability effect. The previous results indicate the possibility of benefiting from the distinguished lines with their mean performance general combining ability effects in the breeding programs to transfer the traits that characterized them, especially the two lines OH40 and G54. From previous studies, other researchers obtained similar results on means performance and general combining ability effects in some of the lines approved in their studies, including: Glover et al. (2005), Dawod et al. (2009), Sibiya et al (2012), EL-Badawy (2013) and Al-Falahy et al. (2014). The comparison between the general performance means foe females and males indicates that those related to females was significantly higher for all traits, except number of ears per plant and number of rows per ear, where the two means were close. Table (3) shows the means of single crosses for studied maize traits, and it is noted for the trait of plant height that the hybrid (1 x 9) had the highest mean of 200.28 cm with a non-significant difference from the hybrids (2 x 9), (3 x 5), (3 x 6), (3 x 7) and (3 x 9), and the main ear height ranged between 99.523 and 138.61 cm, with a significant superiority of the hybrid (2 x 9) over all other hybrids, except for the two hybrids (1 x 9) and (2 x 5), as the highest number of ears per plant was 1,273 in the hybrid (3 x 9) with a significant difference from the hybrid (3 x 5) only. For the ear length, the highest mean reached 21,863 cm in the hybrid (2 x 5), with a non-significant difference from most of the other crosses. The ear diameter of the crosses ranged between 4.543 cm and 5.327 cm, with significant superiority of the hybrid (2 x 8) over all other crosses. The two hybrids (1 x 6) and (2 x 4) had the highest number of rows per ear, reaching 17.00 and 17.267 rows, respectively, and the differences between them and most other crosses were significant. For the number of grains per row, the hybrid (2 x 7) surpassed by giving the highest mean of 38,507 grains with a non-significant difference from most of the crosses. The highest means of the number of grains per ear were 582.48, 590.24, 588.67 and 566.04 grains in hybrids (1 x 7), (2 x 4), (2 x 9) and (3 x 7) respectively, and its differences were significant with all other hybrids. The weight of 300 grains ranged between 111.51 gm in the hybrid (2 x 9) and 142.39 gm in the hybrid (2 x 6), with a significant superiority of the latter over some other hybrids. Finally, the hybrid (2 x 6) had the highest grain yield per plant of 303.89 g, with significant surpass over all other hybrids, and with an increase of 78.235% over the lowest yield in the hybrid (2 x 4). In general, it is noted that the two hybrids (2 x 5) and (2 x 9) had good performance means for the largest number of traits reached seven, followed by the hybrid (1 x 9) with good performance means for six traits, and the single hybrid (2 x 6) only had the best mean

Table (1): Analysis of variance results for all genotypes, parents and hybrids using factorial mating method for ten traits in maize.

Source		df	Mean square for traits:									
			Plant height (cm)	Main ear height (cm)	Number ears per plant	Ear length (cm)	Ear diameter (cm)	Number rows per ear	Number grains per row	Number grains per ear	300 grains weight (gm)	Grain yield per plant (gm)
Reps.		2	5927.53	4279.34	0.434	36.951	1.671	39.360	228.916	115213.2	3960.25	7599.48
Genotypes		26	431.75**	384.56**	0.023*	2.902**	0.116**	1.446**	32.307**	9178.35**	425.66**	2657.27**
Parents		8	322.37	358.93**	0.005	1.427	0.053*	1.414*	38.527**	14033.34**	337.57**	2657.27**
Crosses		17	453.71**	417.50**	0.028**	2.564**	0.106**	1.517**	16.992**	3643.51**	480.27**	2599.13**
Parents vs Crisses		1	930.72**	29.585	0.047*	20.452**	0.782**	0.510	236.65**	64430.53**	199.711	7187.61**
Males ♂		(5)	698.36**	734.88**	0.039*	4.201**	0.213**	1.614**	29.800**	7311.69*	532.23**	3237.69**
Females ♀		(2)	982.39**	859.59**	0.004	3.880**	0.020**	0.758**	24.669**	6938.38**	362.09**	300.351
Males vs Females		1	212.61**	57.701**	0.001	4.753**	0.023*	0.109	20.584**	3430.93**	1127.5**	3567.77**
Males x Females		(10)	225.74**	170.39**	0.028**	1.482**	0.070**	1.619**	9.052**	1150.45	477.92**	2739.59**
Error	genotypes	52	88.225	46.481	0.013	0.734	0.020	0.517	4.835	2222.58	71.233	485.153
	parents	16	188.18	56.649	0.005	0.946	0.024	0.595	5.717	1528.58	50.562	320.907
	crosses	34	13.454	8.445	0.006	0.225	0.005	0.159	1.540	844.917	28.122	181.380
GCA/SCA components			0.918	1.186	0.250	0.769	0.553	0.200	0.884	5.189	0.249	0.203

(**) and (*) significant at 1% and 5% probability levels respectively.

Table (2): Means of parents (females and males) and their general combining ability effects for ten traits in maize.

Parents		traits									
		Plant height (cm)	Main ear height (cm)	Number ears per plant	Ear length (cm)	Ear diameter (cm)	Number rows per ear	Number grains per row	Number grains per ear	300 grains weight (gm)	Grain yield per plant (gm)
females											
1- DK	mean	c 174.996	106.736 b	1.108 a	20.372 b	4.754 b	15.955 ab	34.901 a	544.16 ab	127.420 a	230.730 a
	effect	-7.664	-8.005	-0.014	-0.222	-0.038	0.040	0.312	6.312	2.048	-0.846
2- OH40	mean	183.294 b	118.869 a	1.136 a	21.127 a	4.804 ab	19.097 a	35.572 a	553.55 a	120.229 b	236.018 a
	effect	0.634	4.128	0.014	0.533	0.012	0.182	0.983	15.702	-5.143	4.442
3- ZP-607	mean	a 189.736	118.592 a	1.123 a	20.282 b	4.818 a	15.693 b	33.294 b	515.81 b	128.468 a	227.981 a
	effect	7.076	3.851	0.001	-0.312	0.026	-0.222	-1.295	-22.008	3.096	-3.595
Males											
4- ZW47R	mean	176.112 c	109.088 cd	1.110 b	20.320 b	4.688 c	15.899abc	34.75 bc	546.42 ab	117.277 d	209.94 b
	effect	-6.548	-5.563	-0.012	-0.274	-0.104	-0.016	0.161	8.572	-8.095	-21.636
5- G105	mean	179.847 bc	114.992 b	1.119 ab	21.349 a	4.669 c	15.413 c	35.560 ab	536.86 ab	130.21 ab	235.85 a
	effect	-2.813	0.251	-0.003	0.755	0.123	-0.502	0.971	-0.988	4.836	4.274
6- ZM51	mean	180.642 bc	113.46 bc	1.056 b	20.101 b	4.481 b	16.158 ab	32.076 d	508.07 b	137.564 a	256.00 a
	effect	-2.018	-1.277	-0.066	-0.493	-0.311	0.243	-2.513	-29.778	12.192	24.424
7- ZM49R	mean	184.062 b	113.037abc	1.080 b	19.886 b	4.744 bc	16.086abc	37.180 a	572.05 a	120.55 cd	239.92 a
	effect	1.402	-1.704	-0.042	-0.708	-0.048	0.171	2.591	34.202	-4.822	8.344
8- Inbred₂	mean	175.789 c	105.961 d	1.123 ab	20.368 b	5.080 a	15.442 bc	33.03 bc	501.36 b	126.95 bc	207.63 b
	effect	-6.871	-8.780	0.001	-0.226	0.288	-0.473	-1.560	-36.488	1.580	-23.946
9- G54	mean	199.508 a	131.906 a	1.246 a	21.539 a	4.719 bc	16.492 a	34.94 bc	562.33 a	119.68 cd	240.11 a
	effect	16.848	17.165	0.124	0.945	0.073	0.577	0.350	24.482	-5.689	8.534
SE for Effect		2.995	2.373	0.063	0.387	0.058	0.326	1.013	23.733	4.329	10.996
Females means		179.437	116.593	1.062	20.121	4.622	15.556	32.199	493.96	137.843	227.85
Males means		173.843	112.425	1.076	19.231	4.561	15.792	30.678	470.05	124.133	203.465
crosses means		182.66	114.741	1.122	20.594	4.792	15.915	64.589	537.848	125.372	231.576

- The mean values for each of females and males followed by the same letter for each trait are not significantly different from each other.

Table (3): Single crosses means for ten traits of maize.

Single crosses	Traits									
	Plant height (cm)	Main ear height (cm)	Number ears per plant	Ear length (cm)	Ear diameter (cm)	Number rows per ear	Number grains per row	Number grains per ear	300 grains weight (gm)	Grain yield per plant (gm)
1 x 4	fg 166.44	101.39 f	1.220ab	g 18.810	d-g 4.693	bcd 15.52	a-35.447d	540.72c	a-e 126.00	bcd 244.55
1 x 5	g 158.01	99.523 f	1.163ab	a-e 20.908	efg 4.687	15.033d	ab 38.240	564.25b	a 141.41	bcd 251.11
1 x 6	fg 167.09	99.617 f	1.000 b	b-g 20.190	c-f 4.810	17.00 a	29.810f	501.04d	ab 133.99	bcd 239.33
1 x 7	cde 181.33	107.33ef	1.000 b	c-g 20.000	c-g 4.787	abc 16.65	abc 36.283	582.48a	de 112.59	b-e 216.44
1 x 8	def 176.81	102.44 f	1.043ab	a-f 20.553	bc 4.977	bcd 15.527	c-33.373f	514.82d	a 138.34	b-e 221.39
1 x 9	a 200.28	130.28ab	1.220ab	ab 21.773	fg 4.570	a-16.00d	a-36.250d	561.67b	de 112.19	c-f 211.55
2 x 4	ef 174.26	111.29de	1.000 a	a-e 20.970	d-g 4.703	17.267a	b-34.227e	590.24a	95.15f	f 170.50
2 x 5	ab 190.69	130.54ab	1.193ab	a 21.863	g 4.543	a-16.04d	a-35.400d	548.0bc	a-e 124.47	b-e 221.33
2 x 6	cde 185.25	120.50cd	1.000 b	a-d 21.073	b-e 4.910	bc 15.387	a-35.667d	532.00c	a 142.39	a 303.89
2 x 7	cde 182.58	111.72de	1.167ab	a-g 20.260	d-g 4.713	a-15.99d	38.507a	567.63b	b-e 118.48	d 257.78
2 x 8	fg 166.72	100.55 f	1.193ab	a-e 20.950	a 5.327	15.200d	c-33.667f	494.76d	a-d 129.38	def 209.50
2 x 9	a 199.99	138.61 a	1.243ab	ab 21.647	fg 4.627	abc 16.70	a-35.967d	588.67a	e 111.51	bcd 253.11
3 x 4	bcd 187.64	114.58de	1.110ab	a-d 21.180	efg 4.667	14.91 d	a-34.577e	508.3cd	abc 130.68	b-e 214.78
3 x 5	abc	114.62de	1.000 b	abc	c-g	15.167d	c-33.040f	498.33d	a-e	b-e

	190.83			21.277	4.777				124.75	235.11
3 x 6	abc 189.58	120.28cd	1.167ab	fg 19.040	c-f 4.803	a-16.087d	30.750ef	491.17d	a 136.32	b-e 224.78
3 x 7	a-d 188.28	120.05cd	1.053ab	efg 19.397	d-g 4.733	bcd 15.617	abc 36.75	566.04a	abc 130.58	bcd 245.55
3 x 8	cde 183.83	114.89de	1.133ab	d-g 19.600	bcd 4.937	bcd 15.60	def 32.047	494.50d	cde 113.13	ef 192.00
3 x 9	ab 198.25	126.83bc	1.273 a	a-d 21.197	b 5.080	ab 16.777	c-32.600f	536.67c	ab 135.35	bc 255.67
Crosses means	182.66	114.741	1.122	20.594	4.792	15.915	34.589	537.848	125.372	231.576

- (1) DK, (2) OH40, (3) ZP-607, (4) ZM47R, (5) G105, (6) ZM51, (7) ZM49R, (8) Inbreed2, (9) G54.
- The values followed by the same letter for each trait are not significantly different from each other.

Table (4): Specific combining ability effects for single and ten traits of maize.

Single crosses	Traits									
	Plant height (cm)	Main ear height (cm)	Number ears per plant	Ear length (cm)	Ear diameter (cm)	Number rows per ear	Number grains per row	Number grains per ear	300 grains weight (gm)	Grain yield per plant (gm)
1 x 4	-2.008	0.307	0.124	-1.288	0.043	-0.419	0.385	-12.012	6.675	35.456
1 x 5	-14.173	-7.464	0.058	-0.219	0.056	-0.420	2.368	21.078	9.154	16.106
1 x 6	-5.888	-5.842	-0.042	0.311	0.367	0.802	-2.578	-13.342	-5.622	-15.824
1 x 7	4.932	2.298	-0.066	0.336	0.081	0.524	-1.209	4.118	-10.008	-22.634
1 x 8	8.685	4.484	-0.066	0.407	-0.065	0.045	0.032	7.148	9.340	14.606
1 x 9	8.436	6.379	-0.012	0.456	-0.111	-0.532	0.999	-6.972	-9.541	-27.714
2 x 4	-2.486	-1.926	-0.124	0.117	0.003	1.186	-1.506	28.118	-16.984	-43.882
2 x 5	10.209	11.420	0.060	-0.019	-0.138	0.445	-1.143	-4.562	-0.595	-18.962
2 x 6	3.974	2.908	-0.070	0.439	0.417	-0.953	2.608	8.228	9.969	43.448
2 x 7	-2.116	-5.445	0.073	-0.159	-0.043	-0.278	0.344	-20.122	3.073	13.418
2 x 8	-9.703	-9.539	0.056	0.049	0.235	-0.424	-0.345	-22.302	7.571	-2.572
2 x 9	-0.152	2.576	-0.017	-0.425	-0.104	0.026	0.045	10.638	-3.030	8.558
3 x 4	4.452	1.641	-0.001	1.172	-0.047	-0.767	1.122	-16.102	10.307	8.435
3 x 5	3.907	-4.226	-0.120	0.240	0.082	-0.024	-1.225	-16.522	-8.554	2.855
3 x 6	1.862	2.965	0.110	-0.749	0.296	0.151	-0.031	5.108	-4.340	-27.625
3 x 7	-2.858	3.162	-0.028	-0.177	-0.037	-0.247	0.865	15.998	6.934	9.225
3 x 8	0.965	5.078	0.009	-0.456	-0.169	0.380	0.313	15.148	-16.918	-12.035
3 x 9	-8.334	-8.927	0.026	-0.030	0.335	0.507	-1.044	-3.652	12.571	19.155
SE	4.235	3.356	0.089	0.548	0.082	0.461	1.433	33.564	6.123	15.551

- (1) DK, (2) OH40, (3) ZP-607, (4) ZM47R, (5) G105, (6) ZM51, (7) ZM49R, (8) Inbreed2, (9) G54.

formance for grain yield per plants, in addition to the traits, ear length, number of grains per row and 300 grains weight. The effects of the specific combining ability of single crosses appear in Table (4), and from it, is noted that the hybrids (1 x 7), (1 x 8), (1 x 9), (2 x 5) and (3 x 4) showed significant specific combining ability effects in the desired direction for plant height. For the main ear height, significant desirable specific combining ability effect was observed in the hybrids (1 x 8), (1 x 9), (2 x 5) and (3 x 8). A significant, desirable specific effect was shown for each of number of ears per plant and ear length in only one cross, which is for each of them, respectively (3 x 6) and (3 x 4). The hybrids (1 x 6), (2 x 6), (2 x 8), (3 x 5), (3 x 6) and (3 x 9) gave a significant desired effect of specific combining ability for ear diameter trait. There was a significant and desirable increase for the trait of number of rows per ear in the hybrids (1 x 6), (1 x 7), (2 x 4) and (3 x 9) and for number of grains per row in the two hybrids (1 x 5) and (2 x 6), and for 300 grains weight in the hybrids (1 x 4), (1 x 5), (1 x 8), (2 x 6), (2 x 8), (3 x 4), (3 x 7) and (3 x 9), and for grain yield per plant in hybrids (1 x 4), (1 x 5), (2 x 6) and (3 x 9), as for the number of grains per ear, no significant specific effects appeared in the desired direction in any of the hybrids, while it was desirable non-significant in nine crosses. It is noted, in general, that the hybrid (2 x 6) was surpassed by showing a specific combining ability, desirable for the largest number of traits, which reached eight, and reached the significant limit in four of them: ear diameter, number of grains per row, 300 grains weight and grain yield per plant, followed by the hybrid (3 x 9). Which achieved a desirable increase in five traits and it was significant in the four traits: ear diameter, number of rows per ear, 300 grains weight and grain yield per plant, then the hybrid (1 x 5), which was surpassed by its specific combining ability in six traits that reached the significant limit in three of them, which is number of grains per row, 300 grains weight and grain yield per plant. It is clear from the foregoing that there is a variation between the hybrids in their specific combining ability effects, and that the values of the specific effects were not always related to the values of the general combining ability for both parents, as surpassed hybrids may appear in their specific effect for a trait, at a time when they are arising from two parents having low values of general combining ability or may include one parent with high general combining ability value, nor is it required that the two parents with high general combining ability produce a hybrid with high value for specific combining ability effect for different traits, Singh and Gupta (1969) indicated that the crosses with high values of specific combining ability included one parent with a high value of the general combining ability, and Muhammad et al. (1988) decided that a number of parents with high general combining ability effects gave hybrids with high specific combining ability when crossed with parents with low general combining ability. It is also noted that most of the crosses that were characterized by a significant desired general combining ability had good mean performance for all traits. In view of the fact that the grain yield trait occupies a great importance in breeding programs, the best hybrids were identified on the basis of grain yield per plant with its specific combining ability effects in Table (5), among which the hybrid (2 x 6) record the highest grain yield per plant (303.89 gm), followed by the hybrid (2 x 7) with a mean of 257.78 gm, while the last hybrid (1 x 4) with a mean

Table (5): The best hybrids in their mean performance for grain yield and their specific effect.

sq	Single cross	Grain yield	GCA effect for parents	SCA effect for crosses	Other traits with a significant specific combining ability
1	2 x 6	303.89 a	high x high	43.447*	ear diameter, number of grains per row and 300 grains weight
2	2 x 7	257.78 b	high x low	13.418	--------
3	3 x 9	255.67 bc	low x low	19.155*	ear diameter, number of grains per row and 300 grains weight
4	2 x 9	253.11 bcd	high x low	8.558	--------
5	1 x 5	251.11 bcd	low x low	16.106*	number of grains per row and 300 grains weight
6	3 x 7	245.55 bcd	low x low	9.225	300 grains weight
7	1 x 4	244.55 bcd	low x low	35.456*	300 grains weight

of 244.55 gm. It is noted that the surpassed hybrid in its performance of the grain yield (2 x 6), also gave a significant and desirable effect of the specific combining ability for the same trait, and that the two parents who made it had an effect of general combining ability high x high, while the surpassed hybrid in its performance for the trait, (3 x 9).), which had a high specific combining ability effect came from parents with general combining ability low x low, and the result was a high specific combining ability, which may lead to high heterosis. The possibility of a hybrid resulting from two parents low x low in their general combining ability is due to the interaction between the dominant alleles of one parent and the recessive alleles of the other parent (Senthil and Bharathi, 2009), although there are other crosses characterized by the high grain yield and its specific combining ability effect was not significant, and perhaps in an undesirable direction, including (2 x 7), (2 x 9) and (3 x 7), and this also indicates that the specific combining ability is a characteristic of the hybrid, perhaps high in some crosses and low in others, and for this reason, evaluation of the characteristic of the hybrid is a must, and in this regard the superior hybrid (2 x 6) can be used as a strong single cross and to test more other crosses.

Table (6) shows the estimates of genetic parameters for the different traits, and from 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, and it is noted that the additive genetic variance values were greater than those of the dominant for plant height, main ear height, ear length and diameter, and number of grains per row and ear, and for this reason it is noted that the values of narrow sense heritability were higher, while it was the opposite for the rest of the traits. the narrow sense heritability ranged from 21.053% for number of ears per plant to 67.218% for main ear height, and it was high for plant height, main ear height, ear length and number of grains per row and ear, which means the appropriateness of selection for additive genetic effects between the lines under study, and it was moderate for the other traits, while the broad sense heritability values ranged between 57.834% for number of grains per ear and 95.565% for main ear height, that is, it was moderate for number of grains per ear and high for other traits. The average degree of dominance was less than one for main ear height and number of grains per ear, indicating the presence of partial dominance, and greater than one for the rest of the traits indicative of over dominance, and these over dominant values, which ranged between 1,044 for plant height and 2,234 for number of rows per ear, and its reason may be due to the distribution of linked genes between parents, and for this, partial dominance appears as over dominance (Hayman, 1954). From previous studies, many researchers reached different results regarding the gene action that controls the inheritance of different traits of maize, for example, Chakraborty et al. (2012) found that the additive genetic variance was more important than the dominant genetic variance in the inheritance of plant height and grain yield traits, and El-Badawy (2013) indicated that the additive gene action was more important for number of rows per ear, while the dominant gen action was more important for the number of grains per row, 100 grains weight and grain yield per plant. Al-Qaisi (2013) showed that both additive and dominant genetic variances differed from zero for grain yield and all its components, except ear length trait, and the values of the dominant variance were higher than the values of the additive variance for all traits, except 300 grains weight, and this indicates the greater importance of the dominant gene action in the inheritance of the studied traits. These differing results can be attributed to differences in genetic material approved in different studies and to differences in environmental conditions, or to the adoption of different methods for estimating genetic parameters. Finally, it is noted that the expected genetic advance in the next generation as a percentage was moderate for main ear height and low for other traits, as it ranged between 2.338% for number of rows per ear and 14.147% for main ear height.

Table (6): Variance components and some genetic parameters for ten traits in maize.

Variance components and genetic parameters	Traits									
	Plant height (cm)	Main ear height (cm)	Number ears per plant	Ear length (cm)	Ear diameter (cm)	Number rows per ear	Number grains per row	Number grains per ear	300 grains weight (gm)	Grain yield per plant (gm)
Additive genetic variance	129.930 ± 80.073	128.001 ± 77.414	0.004 ± 0.003	0.645 ± 0.402	0.024 ± 0.013	0.195 ± 0.126	4.425 ± 2.739	1057.056 ± 707.605	74.566 ± 45.847	346.199 ± 204.385
Dominant genetic variance	70.762 ± 30.738	53.982 ± 23.197	0.007 ± 0.004	0.419 ± 0.202	0.022 ± 0.010	0.487 ± 0.221	2.504 ± 1.238	101.844 ± 170.019	149.933 ± 65.074	852.737 ± 373.083
Environmental variance	13.454 ± 3.171	8.445 ± 1.991	0.006 ± 0.002	0.225 ± 0.053	0.005 ± 0.001	0.159 ± 0.037	1.540 ± 0.363	844.917 ± 199.149	28.122 ± 6.628	181.38 ± 42.752
Total genetic variance	200.692	181.983	0.011	1.064	0.046	0.682	6.929	1158.900	224.498	1198.936
Phenotypic variance	214.146	190.428	0.017	1.289	0.051	0.841	8.469	2003817	252.621	1380.316
Average degree of dominance	1.044	0.918	2.031	1.139	1.345	2.234	1.064	0.439	2.005	2.219
Broad sense heritability	93.717	95.565	64.474	82.542	90.121	81.085	81.816	57.834	88.868	86.859
Narrow sense heritability	60.674	67.218	21.053	50.032	47.311	23.191	52.249	52.752	29.517	25.081
Genetic advance	15.538	16.233	0.048	0.994	0.186	0.372	2.661	41.324	8.210	16.307
Genetic advance as percent	8.806	14.147	4.267	4.827	3.887	2.338	7.693	7.683	6.549	7.042

It is concluded from the above the possibility of benefiting from the distinguished lines with their mean performance and general combining ability effects in the breeding programs to transfer the traits that characterized them, especially the two lines OH40 and G54, and the hybrids: (OH40 x ZM51) distinguished by showing a desirable specific combining ability for largest number of traits (eight traits) and reached to the significant limit in four of them: ear diameter, number of grains per row, 300 grains weight and grain yield per plant, and (ZP-607 x G54), which achieved a desirable increase in five traits and was significant in the following four traits: ear diameter, number of rows per ear, 300 grains weight and grain yield per plant, and (DK x G105), which was distinguished by its specific combining ability in six traits, that reached the significant limit in three of them, namely number of grains per row, 300 grains weight and grain yield per plant, in developing highly productive hybrid varieties as well as exploiting the phenomenon of hybrid vigor.

REFERENCES

1. Agarwal, V. and Z. Ahmad (1982). Heritability and genetic advance in triticale. Indian J. Agric. Res. 16:19-23.
2. Al-Adari, A. H. M. (1999). Fundamentals of Genetics. Ministry of Higher Education and Scientific Research. University of Mosul.
3. Al-Bayati, H. A. H. (2013). Inheritance of single crosses traits in different mating systems of pure lines of maize (Zea mays L.). Ph. D thesis. Department of Field Crops, College of Agriculture and Forestry, University of Mosul, Iraq.
4. Al-Fahad, A. C., H. J. Hammadi and M. R. Azzam (2020). Effect of Sodium Azide Mutagen on Genetic
5. Parameters in Maize (Zea mays L.). Indian Journal of Ecology (2020) 47 Special Issue (10), 181-184.
6. AL-Falahy, M. A. H., K. M. Dawod and A. S. A. Mohammad (2012). Gene action and combining ability studies in single cross hybrids of maize. J. Duhok Univ., 15(1): 63-71.
7. AL-Falahy, M. A. H., K. M. Dawod and A. S. A. Mohammad (2014). Estimation of combining ability for yield and its components using triallel crosses in maize. Int. J. Pure Appl. Sci. Technol., 20(1): 1-11.
8. Ali, A. A. A. (1999), Heterosis and gene action in maize (Zea mays L.), Ph. D thesis, College of Agriculture and Forestry, University of Mosul, Iraq,
9. Al-Qaisi, I. Kh. Kh. (2013). Estimation of gene action on some field traits in maize (Zea mays L.).Ph. D thesis, Department of Field Crops, College of Agriculture and Forestry - University of Mosul, Iraq.
10. Al-Rawi, K. M. and A. M. Khalaf Allah (2000). Design and analysis of agricultural experiments, Dar Al-Kutub Institution for Printing and Publishing, University of Mosul.
11. Betran, F. J., J. M. Ribaut, D. Beck and Gonzalez Deleon D (2003) .Genetic diversity, specific combining ability, and heterosis in tropical maize under stress and non-stress environments. Crop Sci. 43:797-806.
12. Bovanski, J., Z. Sreckov and A. Nastastic (2009). Genetic and phenotypic relationship between grain yield and components of grain yield of maize (*Zea mays* L.). Genetika 41(2):145-154.
13. Comstock, R. E. and H. F, Robinson (1948). The components of genetic variance in populations of
14. biparental progenies and their use in estimating the average degree of dominance. Biometric 4: 254-266.
15. Comstock, R. E. and H. F, Robinson (1952). Estimation of average dominance of genes heterosis. Iowa State College Press. 494-516.
16. Dawod, Kh. M. and A. H. Abdullah (2011). Combining ability analysis based on single and three way crosses for protein and oil traits. The Fifth Scientific Conference of the Faculty of Agriculture, Tikrit University, for the period from 26 to 27 April 2011.
17. Dawod, K. M., A. S. A. Mohamad and kh. H. Kanosh (2009) . Inheritance of grain yield in half diallel maize population . J. of Tikrit Univ. for Agri. Ecie., 9(3): 412-418.
18. EL-Badawy, M. EL. M. (2013). Heterosis and combining ability in maize using diallel among seven new inbred lines. Asian J. of Crop Sci., 5(1): 1-13.
19. Fayyad, H. F., H. F and H. J. Hammadi (2021). Estimation of Combining Ability and Gene Action for Yield and Yield Components in Maize (Zea mays L.). Earth and Environmental Science, 761: 1-7.
20. Fry, J. D. (2004). Estimation of genetic variances and covariances by restricted maximum likelihood using PROC MIXED. pp. 7-39. In A. R. Saxton (ed.). Genetic analysis of complex traits using SAS. Books by Users Press, SAS Inst., Cary, NC.
21. Glover, M, D. Willmot, L. Darrah, B. Hibbard and X. Zhu (2005). Diallel analysis of agronomic traits using Chines and U.S. maize germplasm. Crop Sci. 45(3):1096-1102.
22. Hallauer, A. R. and J. B. Miranda (1988). Quantitative Genetics In Maize Breeding. 2nd ed. Iowa State University Press. Ames, IA.
23. Hayman, B. I. (1954). The analysis of variance of diallel tables. Biometrics 10:235-244.
24. Kempthorne, O. (1957). An Introduction to Genetic Statistics. John Wiley and sons, New York, U S A.
25. Keskin, B., I. H. Yilmaz and O. Arvas (2005). Determination of some yield characters of grain corn in eastern Anatolia region of Turkey. J. Agron. 4(1):14-17.
26. Khodarahmpour, Z. (2011). Gene action studies of different traits in maize (*Zea mays* L .) under and heat normal condition. J. of American. Sci. 7 (5) : 442 – 448.
27. Mohammed, A. A., F. Abd-Alqadir and Kh. M. Dawud (1988). Combining ability analysis and heterosis using diallel cross among local varieties of maize. Mesopotamia J. of Agriculture 20(2): 201-218.

28. Novoselovic, D., M. Baric, G. Drezner, J. Gunjaca and A. Lalic (2004). Quantitative inheritance of some wheat plant traits. Gen. Mol. Biol. 27(1):92-98.
29. Ojo, G. O. S., D. K. Adedzwa and L. L. Bello (2007). Combining ability estimates and heterosis for grain yield and yield components in maize (*Zea mays* L.). J. Sustain. Develop. Agric. Environ. 3:49-57.
30. Sadalla, H.A, M. O. Barznji and S. A. Kakarash (2017). Full diallel crosses for estimation of genetic
31. parameters in maize. The Iraqi J. of Agri. Sci. 48, (special Issue):30-40.
32. Secanski, M., T. Zivanovic and G. Todorovic (2005). Components of genetic variability and heritability of the number of rows per ear in silage maize. Biotechnol. Anim. Husb. 21(1-2):109-121.
33. Senthil, K. P. and P. Bharthi (2009). Studies on relationship between gca and sca effects in maize
34. (*Z.mays* L.), Elect.J.Plant Breed., 1:24-27.
35. Sibiya, J., P. Tongoona; J. Derera and Nv. Rij (2012). Genetic analysis and genotype x environment (G x E) for grey leaf spot disease resistance in elite African maize (*zea mays* L.) germplasm. Euphytica, 185:349-362.
36. Singh, K. B. and V. B. Gupta (1969). Combining ability in wheat. Indian J. Genet. And Pl. Breed.,
37. 29:53-61.
38. Singh, R. K. and B. D. Chaudhary (2007). Biometrical Methods In Quantitative Genetic Analysis.
39. Kalyani Publishers, New Delhi, 304p.
40. Vasic, N., M. Ivanovic, L. Peternelli, D. Jockovic, M. Stojakovic and J. Bocanski (2001). Genetic relationships between grain yield and yield components in a synthetic population and their implications in selection. Acta Agronomica Hungarica 49(4):337-342.
41. Xu, J. Y. and H. Crouch (2008). Genomics of tropical maize, a stable food and feed across the world. pp.333-370. In Genomics of Tropical Crop Plants, P. H. Moore and R. Ming (eds.). Springer, London, UK.
42. Yingzhong, Z. (1999). Combining ability analysis of agronomic characters in sesame. The Institute of Sustainable Agriculture (IAS), CSIC.
43. Zhang, Y. D., X. M. Fan, W. Yao, H. P. Piepho and M. S. Kang (2016). Diallel analysis of four
44. maize traits and a modified heterosis hypothesis. Published in Crop Sci. 56, 1115-1126.
45. Zivanovic, T., M. Secanski and M. Filipovic (2007) .Combining abilities for the number of kernel rows per ear in silage maize. Plant breeding and seed production, 13(3-4):13-19.

تقديرات القدرة على الاتحاد والتأثيرات الجينية لحاصل الحبوب ومكوناته في الذرة الصفراء (*Zea mays L.*)

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الخلاصة

استخدمت في الدراسة تسعة سلالات نقية من الذرة الصفراء، ادخلت في تهجينات وفق طريقة النظام التزاوجي العاملي، حيث استخدمت السلالات DK وOH40 وZP-607 بوصفها امهات والسلالات ZM47R وG105 وZM51 وZM49R و Inbreed2 وG54 بوصفها آباء ذكور. زرعت الآباء والاجيال الاولى لهجنها الفردية خلال الموسم الخريفي لعام 2013 في قضاء الحويجة، محافظة كركوك بتصميم القطاعات العشوائية الكاملة بثلاثة مكررات، ثم سجلت البيانات عن صفات ارتفاع النبات وارتفاع العرنوص الرئيسي وعدد العرانيص بالنبات وطول العرنوص وقطر العرنوص وعدد الصفوف بالعرنوص وعدد الحبوب بالصف وعدد الحبوب بالعرنوص ووزن 300 حبة وحاصل الحبوب بالنبات. اظهرت النتائج ان هناك اختلافات معنوية عالية بين التراكيب الوراثية (أباء وهجن) للصفات جميعها. اعطت السلالتين OH40 وG54 تأثيرات مرغوبة معنوية للقدرة العامة على الاتحاد لاكبر عدد من الصفات، واظهرت الهجن تبايناً في تأثيراتها للقدرة الخاصة على الاتحاد للصفات المختلفة، وتميزت الهجن (ZM51 x OH40) و(9G54 x ZP-607) و(G105 x DK) بقدرة خاصة على الاتحاد مرغوبة لاكبر عدد من الصفات بضمنها حاصل الحبوب بالنبات. ظهر التباين الوراثي الاضافي اكبر في قيمته من التباين الوراثي السيادي لصفات ارتفاع النبات وارتفاع العرنوص الرئيسي وطول وقطر العرنوص وعدد الحبوب بالصف وبالعرنوص والعكس لبقية الصفات. وقل معدل درجة السيادة عن واحد لصفتي ارتفاع العرنوص الرئيسي وعدد الحبوب بالعرنوص دلالة على وجود السيادة الجزئية وكان اكبر من واحد لبقية الصفات دلالة على السيادة الفائقة. تراوح التوريث بالمعنى الواسع بين 57.834% لعدد الحبوب بالعرنوص و95.565% لارتفاع العرنوص الرئيسي، وبالمعنى الضيق بين 21.053% لصفة عدد العرانيص بالنبات و67.218% لارتفاع العرنوص الرئيسي.