International Journal of Applied Agricultural Sciences
2016; 2(1): 1-11
Published online January 22, 2016 (http://www.sciencepublishinggroup.com/j/ijaas)
doi: 10.11648/j.ijaas.20160201.11

Hybrid Vigor, Heterosis, and Genetic Parameters in Maize by Diallel Cross Analysis

Kareema Mohamad Wuhiab, Banan Hassan Hadi, Wajeeha Abed Hassan

Department of Field Crops Sciences, College of Agriculture, University of Baghdad, Baghdad, Iraq

Email address:

Kareema522@yahoo.com (K. M. Wuhiab), bhd.1970@yahoo.com (B. H. Hadi), Wa.hassan69@yahoo.com (W. A. Hassan)

To cite this article:

Kareema Mohamad Wuhiab, Banan Hassan Hadi, Wajeeha Abed Hassan. Hybrid Vigor, Heterosis, and Genetic Parameters in Maize by Diallel Cross Analysis. *International Journal of Applied Agricultural Sciences*. Vol. 2, No. 1, 2016, pp. 1-11. doi: 10.11648/j.ijaas.20160201.11

Abstract: A field experiment was conducted at the experimental farm of Field Crop Sciences Department, College of Agriculture / University of Baghdad. Five maize (*Zea mays* L.) inbred lines were tested for general and specific combining ability by using full diallel cross. Seed of inbred were planted in spring and fall season of 2013. In first season, seeds were planted, and at anthesis crossing between inbreds were done. In the fall season varietal trial for crosses and parents were conducted by using RCBD design with four replications to evaluate crosses and parents and to estimate some genetic parameters. Statistical analysis revealed high significant increases for all traits, ear height, leaves area, no of ears/plant, no. of grain/plant, grain weight, dry weight/plant and yield t/ ha. The genetic analysis showed that inbred 2 was superior and gave high grain yield (5.74 t/ha.), due to its high dry weight (207.82g/plant), and no. of grain /plant (704.49). In addition, it had positive GCA. The reciprocity cross 4×1 was superior and gave highest yield 6.98 t/ha. due to superiority in 100 grain weight (18.53g). It also had positive and higher hybrid vigor (45%) for grain yield, and positive effect of sca (1.56). All reciprocity crosses were higher than crosses; the highest one is 4 × 3, which gave 8.69 t/ha. All parent and crosses had had positive variance for yield, but all reciprocity crosses were negative. Mean square for SCA and RCA were more than GCA, and therefore the σ^2 GCA was less which made σ^2 A less than σ^2D and σ^2 Dr, so σ^2 GCA / σ^2 SCA and σ^2 GCA / σ^2 RCA became less than one and the degree of dominance was more than one, making $h^2_{n.s}$ very little. Thus, the trait was governed by non-additive gene action. We can conclude that there is a possibility of using superior inbreds to produce hybrids or use selection for it and produce synthetic varieties.

Keywords: Full Diallel, Maize, Genetic Cytoplasmic, Degree of Dominance, GCA, SCA

1. Introduction

The effective method for high yield selection requires information about the amount of genetic variation found in the population that is called combining ability and heterosis. The selection of the superior parents for crossing and hybrid production is very important in breeding and improvement program, so that performance of hybrid related to the general and specific ability of inbreds within the a crossing. Crossing between genetically unrelated parents, at least one of them has a high General Combining Ability (GCA), will produce the superior hybrid [1]. And to achieve this goal diallel mating system used, which is progeny performance analysis that can be statistically partitioned to GCA and Specific Combining Ability (SCA) components, which are considered as an important means in identified the best crosses to exploitation hybrid vigor and choose the best crosses to be used as an improved varieties, or used in another breeding programs. To know the hybrid vigor and identification parent had GCA and its crosses had SCA, which help for superior hybrid development possess favorable traits, we can use diallel analyzed. the diallel mating systems are used widely in breeding programs to estimate the genetic potentially for genotypes or populations [Alam, 2] and these systems are analysis the variance and estimate its effects for varieties within population, as well estimate heterosis and its components. The combining ability known as ability of parents or varieties to combine among them via crossing process, so the genes or desired traits move to its progenies. GCA attributable to the additive genes in their effects, while SCA attributed to genes of dominance effects or epistasis. It is necessary to obtain information on the nature of parents combining ability and their behavior and performance in crosses to select the best ones for crossing and identification of promising hybrid or varieties [3]. the production or the development of inbreds in maize become easier to test any of them to exceed than its parents in their traits [4], so parents GCA effects estimated in their crosses, and estimates SCA effect of crosses for its parents [5]. we can get high values of heterosis by using genetically divergent inbreds and possessed combining ability to produce hybrids[6], since the hybrid vigor or heterosis that increase the performance of progeny compared with homozygous parents reach to the highest levels when the combining population was complementary and heterozygous [6]. GCA gives information about inbreds that produce the best hybrids when crossing with each other, as well as giving information about the behavior of the same inbred. The control of additive gene action on trait enables us to produce synthetic varieties, either high impact for SCA means that there high and efficient heterosis to produce high yield hybrids, and that the use of diallel designs to estimate GCA and SCA for inbred and its crosses allow better knowledge and the most efficient way to the breeding and improve plants [7]. Search aimed to understand the foundations of heterosis and how to investment it in efficient and precise the estimate of breeding values and the possibility of its investment in the crosses production which possess high SCA in its behavior and performance to increase the efficiency of traits improvement in maize.

2. Materials and Methods

2.1. Field Experiment Details

A field experiment was conducted at the farm of Field Crops Sciences Department - College of Agriculture - University of Baghdad. Five maize inbred lines: ZM43W (ZE)(1), ZM60(2), ZM19(3), ZM49W3E(4) and CDCN5(5) were tested for general and specific combining ability by using full diallel cross. Seeds of inbreds were planted on 17/03/2013 to conduct crossing among them to get the seeds of F1. Soil of field has been prepared as recommended. 200 kg P_2O_5 / ha from fertilizer of calcium triple super phosphate (46% P_2O_5) was added three times, at planting, after two months of first batch and at anthesis, in two seasons of planting. In the first season, seeds of inbred planted at furrow, with length 4m and 0.75m distance between them, and 0.25 m between the hills. Female inflorescences covered, before the emergence of silk, tassel was covered day before pollination. Conducted full diallel cross between inbreds. After maturity, harvested plants each separately for planting in the subsequent season. At second season (fall) seeds of 25 genotypes (20 cross +5 parents), were planted to evaluate its performance using randomized complete block design with four replicates. At maturity, a random sample took for measured the following traits: ear height, leaves area, number of ears per plant, number of grains per plant, the weight of hundred grains, dry weight of the plant as well as yield t/ha.

2.2. Statistical Methods

The Genstate program for statistical analysis was used for analysis of variance, means were compared by using the least significant difference at the level of 5% probability. The following equation was used to calculate the hybrid vigor:

Hybrid vigor = $\{\frac{\bar{F}-\overline{BP}}{\overline{BP}}\} \times 100$ (Singh and Chaudhary, 1985) [8]

General and specific combining ability were estimated according to Griffing [9], diallel cross analysis designated as first method, Fixed model, mathematicalmodel for crosses and reciprocal crosses are:

$$Y_{ijk} = \mu + g_i + g_j + S_{ij} + R_{ik} + e_{ijk}$$

Where

y_{ijk} = the value of genotype ij in replicate k

μ = overall average to row

g_i = effect of ability parent i

S_{ij} = effect of specific combining ability for singles cross-ij

R_{ij} = effect of specific combining ability for singles reciprocal cross ij

e_{ijk} =modified experimental error effect

The variance of general combining ability ∂^2gca, and specific combining ability ∂^2sca and variance of the reciprocal effect ∂^2rca were calculated according to the following equations:

$$\partial^2 gca = \frac{MSgca-MSe}{2n}$$

$$\partial^2 sca = MSsca - MSe$$

$$\partial^2 rca = \frac{MSrca-MSe}{2}$$

$$MSe = \frac{MSe}{r}$$

The ratio between the variance of general combining ability to the Specific ∂^2 gca / ∂^2 sca and reciprocal crosses ∂^2 gca / (∂^2 rca was calculated. Estimated the effect of general combining ability (g_i) and specific for crosses (s_{ij}) and specific for reciprocal crosses (r_{ij}) according to the following equations:

$g_i = \frac{1}{2n}(y_i. + y._j) - \frac{1}{n^2}$ y.

$s_{ij} = \frac{1}{2}(y_{ij} + y_{ji}) - \frac{1}{2n}(y_i. + y._i + y_j. + y._j) + \frac{1}{n^2}$ y...

$r_{ij} = \frac{1}{2}(y_{ij} - y_{ji})$

To compare the effect of general combining ability, estimated the standard error of the difference between the effects of general combining ability g_i, according to the following equation:

Standard Error $(g_i - g_j) = \sqrt{\frac{MSe}{n}}$

To compare the effect of values of specific combining ability, estimated the standard error of the difference between the effects of specific combining ability (s_{ij}) for two crosses.

S.E $(s_{ij} - s_{ik}) = \sqrt{\frac{n-1}{n}} \times MSe$

To compare the effect of values of specific combining ability, estimated the standard error of the difference between the effects of specific combining ability (r_{ij}) for two reciprocal crosses.

S.E $(r_{ij} - r_{ik}) = \sqrt{Mse}$

estimate of the variance of general combining ability of parents $\partial^2 g_{ii}$, and variance of specific for crosses $\partial^2 s_{ij}$ and specific for reciprocal crosses ∂^2rij, for each parent, according to Singh and Chaudhary (1985) [8].

$\partial^2 g = (g_i)^2 - \frac{1}{n^2}$ MSe

$\partial^2 s_{ij} = \frac{1}{n-2} \sum s^2_{ij} \frac{MSe\ (n^2}{2n^2}$

$\partial^2 r_{ij} = \frac{1}{n-2} \sum r^2 ij \frac{MSe}{2}$

Estimate genetic parameters and gene action:

$\partial^2 A = 2\ \partial^2 gca$

$\partial^2 D = \partial^2 sca$

$\partial^2 E = MSe$

$\partial^2 G = \partial^2 A + \partial^2 D = 2\ \partial^2 gca + \partial^2 sca$

on impose of the absence of Epistasis. (Griffing, 1956) [9].

$\partial^2 p = \partial^2 G + \partial^2 E$

$h^2_{.b.s.} = \frac{\partial^2 G}{\partial^2 P} = \frac{\partial^2 A + \partial^2 D}{\partial^2 A + \partial^2 D + \partial^2 E} = \frac{2\,\partial^2 gca + \partial^2 sca}{2\,\partial^2 gca + \partial^2 sca + \partial^2 E}$

$h^2_{.b.sr} = \frac{\partial^2 G}{\partial^2 P} = \frac{\partial^2 D + \partial^2 D.r}{\partial^2 A + \partial^2 D.r + \partial^2 E} = \frac{2\,\partial^2 gca + \partial^2 rca}{2\,\partial^2 gca + \partial^2 rca + \partial^2 E}$

$h^2_{.n.s} = \frac{\partial^2 A}{\partial^2 P} = \frac{\partial^2 A}{\partial^2 A + \partial^2 D + \partial^2 E} = \frac{2\,\partial^2 gca}{2\,\partial^2 gca + \partial^2 rca + \partial^2 E}$

Rate the degree of dominance:

$\bar{a} = \sqrt{\frac{2\,\partial^2 D}{\partial^2\ A}} = \sqrt{\frac{2\,\partial^2 sca}{2\,\partial^2\ gca}} = \sqrt{\frac{\partial^2 sca}{\partial^2\ gca}}$

$\bar{a}.r = \sqrt{\frac{2\,\partial^2 D.r}{\partial^2\ A}} = \sqrt{\frac{2\,\partial^2 rca}{2\,\partial^2\ gca}} = \sqrt{\frac{\partial^2 rca}{\partial^2\ gca}}$

3. Results and Discussion

3.1. Ear Height (cm)

Table 1. *Mean of ear height (cm) for inbreds (value diameter) reciprocity crosses (values above diameter) the hybrid vigor, GCA effects, SCA for reciprocity crosses (values above diameter) RCA for revere crosses (values under diameter) and its variances, with some genetic parameters, for maize, in the fall season 2013.*

R_{ij}δ²	**S_{ij}δ²**	**G_{ii}**	**Sˆ$_{ij}$**					**parents**
			5	**4**	**3**	**2**	**1**	**iiĝ**
-6.69	3.71	-0.08	10.99	10.67	-2.65	4.15	-0.73	1
-15.06	5.40	8.16	11.87	3.67	8.52	-2.96	3.05	2
-5.50	-1.69	100.69	-1.76	2.84	10.07	-14.61	-6.86	3
-11.85	4.07	34.15	7.03	-5.90	12.77	-4.15	2.21	4
-10.88	5.37	-0.39	-0.48	-23.28	15.31	-6.20	4.64	5
Standard error			Mean squares					
Rˆ$_{ij}$	$_{ij}$ŝ	$_{ii}$ĝ			e	RCA	SCA	GCA
2.78	1.58	1.11			15.41	258.3	385.06	364.02
reciprocity crosses			Reveres crosses			Variances		
121.45	Drδ²		369.65	Dδ²		34.86	gcaδ²	
1.86	-râ		3.26	Ā		69.72	² Aδ	
92.54	$h^2_{b.s}$		96.61	$h^2_{b.s}$		0.094	gca /δ² scaδ²	
33.75	$h^2_{n.s}$		15.33	$h^2_{n.s}$		0.287	gca / δ² rcaδ²	

Table 1. *Continue.*

5	**4**	**3**	**2**	**1**	**Parents**
102.38	94.21	87.78	91.45	63.33	1
90.19	78.63	88.96	53.83	85.36	2
111.10	107.73	101.13	118.19	101.50	3
65.33	51.95	82.20	86.92	89.78	4
58.78	111.90	80.48	102.58	93.10	5
				87.94	Overall mean
				15.62	L.S.D 5 %
5	4	3	2	1	Parents
0.16	0.48	-0.13	0.44		1
0.53	0.46	-0.12		0.35	2
0.10	0.06		0.17	0.004	3
0.11		-0.19	0.61	0.42	4
	0.90	-0.20	0.74	0.47	5

Parent 3 was significantly superior in ear height (101 cm) on the rest of parents that were similar among themselves (Table 1), also it was superior on overall mean where rest parents did not reach to it. Crosses resulted from crossing among these parents were affected and differed among themselves whether it is crosses or reciprocal. Two crosses 4× 3 and 5 × 3 and reciprocal crosses 3×1 and 3×2 gave highest mean of the high 0f ear. In general, the mean of high ear for crosses was higher or close to the overall mean except 4 × 2 and 5 × 4, which was given, less than the overall mean, while the reciprocal crosses did not differ from overall mean. The hybrid vigor for crosses was mostly positive except a cross 3 × 2; the highest value to cross 5 × 2, 4 × 1, 4 × 2 and 2 × 1, whereas reciprocal crosses, 4 × 3 and 5 × 3 was the high and positive, while 4 × 5 and 2 × 4was negative. The different between genotypes with each other requires study the GCA and SCA for parents and its crosses. The effect of general combining ability for parents was negative in four of them and only parent 3 was positive indicated to the effect in increasing the height of ear more than four parents remaining, in what was the effect of SCA positive for crosses except two crosses which includes the parent 3 and their two crosses 3 × 1 and 5 × 3, while the effect of half reciprocal crosses was positive and the other half effect was negative, meaning that the reciprocal effect of the parents (by cytoplasm of maternal) is towards reducing ear height of maize. These influences reflected on variance of effects of GCA, SCA and RCA, where it was higher $\sigma^2 g_{ii}$ (100.69) for the parent 3 and had a less variance for S_{ij} (1.69-), while it was positive and close of rest of parents. The variance of the reciprocal crosses all negative towards reducing ear height. The data of table 1 illustrate that the trait was under the influence of non- additive gene action so as decreased the MS of gca and variance of additive was low and contrast high value of the variance of dominance which has a multiplier of additive variance, and this is evident from the low ratio of σ^2 GCA/ σ^2 SCA for crosses and reciprocal crosses, so the degree of dominance was more than one, as well as the h^2_{ns} was decreased. In this case, we can use crossing among parents to produce superior hybrids. Wuhaib [10] has indicated that the h^2_{ns} was 60%, making the degree of dominance less than 1 and this means that there is over dominance genes controlling the trait, suggesting the possibility of using hybridization followed by selection to improve the trait.

3.2. Leaves Area (m^2)

Parents differed among themselves significantly in leaves area for maize plants (Table 2), but any of them did not reach the overall average value. However, parent 1 achieve highest leaves area for the plant reached 0.43 m^2, despite this, some of crosses between these parents had given area more than its parents and general mean, but it did not superiority upon them significantly. Highest leaves area achieved by cross 2 × 1, 5 × 2 and 5 × 3, reciprocal cross 2 × 1 achieved higher leaves area followed by cross 4 × 1, may be due to the parent 1, which achieved the highest leaves area relative to other parents. In general, higher values of leaves area for reciprocal crosses than the crosses may be due to the role of cytoplasmic genetics for maternal shared in its production. The hybrid vigor in most crosses was positive towards increasing the leaves area, but crosses 3 × 1, 4 × 1 and 5 × 1 that were negative towards reducing the leaves area. All reciprocal crosses were positive toward increased leaves area. These data show that the use of these inbred as female have an impact in the traits because of the participation of the genes responsible for cytoplasmic heredity in increase the plants leaves area of maize. Also it demonstrated from the table that the parent 1 and 2 have a positive effect of $g_{ii,}$ while the other three parents had a negative effect. The S_{ij} effects for crosses were positive with the exception of cross 3 × 1 and 5 × 1, and versa; the reciprocal crosses were all negative except two crosses 3 × 4 and 3 × 5. $\sigma^2 S_{ij}$ were a positive, and superiority the $\sigma^2 G_{ii}$ effects. All the reciprocal variance effects were negative. Leaves area governed by genetically with evidence that value of environmental variance is very low, as the MS for SCA was double the MS of GCA and three times the MS of RCA, so we find that the value of σ^2 gca very little, so it was the σ^2 A less than σ^2 D and σ^2 Dr, and the latter turn was less than the σ^2 D. The impact of this in proportion σ^2 gca / σ^2 sca and σ^2 gca / σ^2 Rca were very few, which led to increase the degree of dominance and make it more of one. This means that trait under the influence of non -additive gene action (dominance and epistasis), Aliu et al. [11] pointed to that the ratio σ^2 gca / σ^2 sca was less than 1 and the trait is governed by non additive gene action. The decline in the influence of the additive gene action and increase the influence of the non additive gene action led to a decline in the proportion of heritability in the narrow sense, and that the high value of heritability in the broad sense refers to the control of non additive genes than the additive on the trait, in this case the appropriate breeding method to improve the trait is hybridization.

Table 2. *Mean of leaf area (cm^2) for inbreds (value diameter) reciprocity crosses (values above diameter) the hybrid vigor, GCA effects, SCA for reciprocity crosses (values above diameter) RCA for reveres crosses (values under diameter) and its variances, with some genetic parameters, for maize, in the fall season 2013.*

$R_{ij}\delta^2$	**$S_{ij}\delta^2$**	**$G_{ii}^2\delta$**	**$\hat{S}_{ij}$**					**Parents**
			5	**4**	**3**	**2**	**1**	**$I\hat{g}_i$**
-0.06	0.01	0.00	-0.03	0.04	-0.03	0.05	0.01	1
-0.02	0.04	0.00	0.03	0.02	0.00	0.03	-0.01	2
-0.01	0.02	0.00	0.04	0.04	-0.01	-0.01	-0.05	3
-0.03	0.05	0.00	0.06	-0.02	0.02	-0.03	-0.05	4
-0.03	0.03	0.00	-0.01	-0.03	0.02	-0.01	-0.06	5
Standard error			Mean squares					
$\hat{R}_{ij}$	$_{ij}\hat{s}$	$_{ii}\hat{g}$			e	RCA	SCA	GCA
0.008	0.127	0.002			0.000	0.002	0.008	0.004
reciprocity crosses			reveres crosses			Variances		
0.002	$Dr\delta^2$		0.008	$D\delta^2$		0.00	$gca\delta^2$	
1.78	-râ		4.62	Ā		0.001	$^2 A\delta$	
97.26	$h^2_{b.s}$		99.38	$h^2_{b.s}$		0.00	gca /δ^2 scaδ^2	
37.53	$h^2_{n.s}$		8.50	$h^2_{n.s}$		0.00	gca / δ^2 rcaδ^2	

Table 2. *Continue.*

5	4	3	2	1	Parents
0.34	0.40	0.34	0.50	0.43	1
0.46	0.41	0.43	0.37	0.53	2
0.47	0.46	0.36	0.46	0.44	3
0.42	0.32	0.41	0.48	0.50	4
0.31	0.47	0.43	0.49	0.45	5
				0.424	Overall mean
				0.019	L.S.D 5%
5	4	3	2	1	Parents
- 0.21	- 0.07	- 0.21	0.16		1
0.24	0.11	0.16		0.23	2
0.31	0.27		0.24	0.02	3
0.35		0.14	0.30	0.16	4
	0.52	0.19	0.32	0.05	5

3.3. Number of Ears/Plant

Parents did not differ among themselves significantly in the number of ears /plant, but the highest number of ears was the parent 3, which is not different from the overall mean significantly, but it was less of it (Table 3). Three crosses gave number of ears higher than the overall mean and higher than the highest parent, a 2 × 1, 3 × 2 and 4 × 3; the other crosses did not superior to overall mean, but were similar to it and resembled the highest parents. Two reciprocal crosses only 5 × 3 and 5 × 4 had superiority the overall mean and on the highest parents significantly, and the others were similar significantly overall mean and higher parents, whether below or above of them in their value. Most hybrid vigor for crosses was positive except across 5 × 1, cross 2 × 1 and 4 × 3 possess higher hybrid vigor followed by 3 × 2. Seven reciprocity crosses were positive for six reciprocal crosses of the highest value cross 2 × 1, 5 × 3 and 5 × 4, and was negative for four crosses, The reverse were also positive for six of them, and the highest value for the cross 4 × 3 and the remainder negative. The $\sigma^2 \hat{g}_{ii}$ for parents were a few and positive value, except parent 4 was negative, but $\sigma^2 S_{ij}$ were all positive, and also were positive for three parents, and negative for two parents of reverse crosses. The environmental variation in this trait low and unimportant in influencing trait. In spite of the approaching of MS for GCA and SCA, but the σ^2 gca was low has led to a reduction σ^2 A, which was less than the σ^2 D, which in turn is equal to σ^2 Dr, and this made the ratio σ^2 gca / σ^2 sca low (if it to reverse more than doubled to reciprocal), making the degree of dominance more than one and leading to a decline in the proportion of heritability in narrow sense, thus, the trait controlled by the non additive gene action, for this, the appropriate way to improve the trait is hybridization.

Table 3. *Mean of no.ears per plant for inbreds (value diameter) reciprocity crosses (values above diameter) the hybrid vigor, GCA effects, SCA for reciprocity crosses(values above diameter) RCA for reveres crosses (values under diameter) and its variances, with some genetic parameters, for maize, in the fall season 2013.*

$R_{ij}\delta^2$	$S_{ij}\delta^2$	$G_{ii}^2\delta$	$\hat{S}_{ij}$					Parents $I\hat{g}_i$
			5	4	3	2	1	
0.04	0.06	0.00	-0.23	0.12	-0.02	0.33	-0.03	1
0.23	0.06	0.01	-0.14	-0.19	0.19	-0.08	0.39	2
0.08	0.18	0.04	0.28	0.09	0.20	0.15	0.04	3
-0.05	0.10	-0.00	0.29	0.01	0.28	0.11	-0.26	4
-0.15	0.06	0.01	-0.10	-0.26	-0.20	0.07	-0.03	5
Standard error			Mean squares					
$\hat{R}_{ij}$	$_{ij}\hat{s}$	$_{ii}\hat{g}$			e	RCA	SCA	GCA
0.080	0.383	0.032			0.013	0.089	0.136	0.141
reciprocity crosses			reveres crosses			Variances		
0.123	$Dr\delta^2$		0.123	$D\delta^2$		0.013	$gca\delta^2$	
1.73	-râ		3.098	Ā		0.026	$^2 A\delta$	
83.12	$h^2_{b.s}$		91.98	$h^2_{b.s}$		0.106	gca /δ^2 scaδ^2	
33.40	$h^2_{n.s}$		15.86	$h^2_{n.s}$		0.342	gca / δ^2 rcaδ^2	

Table 3. *Continue.*

5	**4**	**3**	**2**	**1**	**Parents**
1.00	1.23	1.58	2.00	1.13	1
1.15	1.25	1.85	1.06	1.23	2
1.56	1.97	1.25	1.56	1.50	3
1.33	1.12	1.42	1.03	1.75	4
1.00	1.85	1.97	1.00	1.06	5
				1.39	Overall mean
				0.45	L.S.D 5%
5	4	3	2	1	Parents
- 0.12	0.09	0.26	0.77		1
0.08	0.12	0.48		0.09	2
0.25	0.58		0.25	0.20	3
0.19		0.14	- 0.08	0.55	4
	0.65	0.58	- 0.06	- 0.06	5

3.4. No. of Grains / Plant

Table 4 shows that the parent 2 has achieved the highest number of grains / plant giving 704.49 grain, has superiority the rest of parents and the overall mean and its crosses. The percentage of increase the number grain to parent 2 for parent 1 which gave less number of grains per plant was 130% and for parents 3, 4 and 5 by 37% and 69% and 30% respectively. Superiority of parent 2 attributable to give medium value of plant height and leaf area (Table 1 and 2), Permitted it obtaining a high rate of pollination and fertilization. Four reciprocal crosses achieved higher number of grains per plant than the overall mean, and only one cross (3 × 2) gave the number of grains per plant is similar the higher parent (2) for contribution of this parent in this cross. As for the reverse crosses, six of them gave grains / plant is higher than the overall mean, while three of them gave higher than the highest parents, It was top rated reverse cross (3 × 2) it also returns to the same parents involved in the reciprocal cross, Perhaps this is due to the parent 2 which was superior to the rest of the parents. Reflected the differences between parents on the values of hybrid vigor for their crosses, five of them gave positive hybrid vigor, the top rated for cross 4 × 1, with four of them have been negative toward decrease number of grains/plant. The reverse crosses was only two of them negative and the rest were positive towards increase the number of grain/plant, it was the top rated cross 4 × 1 also. I think that these parents genetically unrelated (diversity). The table also explained that the effect of the $\hat{g}_{ii}$ were positive and high for the parent 2, and positive for parent 3, and was negative for the rest of the parents. The effect $\hat{S}_{ij}$ was positive for 6 reciprocal crosses and high value for parent 3with 2 and parent 4 with 1. Reverse crosses, the highest reverse effect was positive for the parent 2 with 1, while it was negative for seven crosses. Parent 2 possess highest positive and the highest value 0.65 to cross 5 × 4 and 0.58 to cross 5 × 3 and 0.55 for cross 4 × 1, the rest were negative towards reducing the value of trait.

Table 4. *Mean of grain number for inbreds (value diameter) reciprocity crosses (values above diameter) the hybrid vigor, GCA effects, SCA for reciprocity crosses(values above diameter) RCA for reveres crosses (values under diameter) and its variances, with some genetic parameters, for maize, in the fall season 2013.*

$R_{ij}\delta^2$	**$S_{ij}\delta^2$**	**$G_{ii}{}^2\delta$**	**$\hat{S}_{ij}$**					**Parents $I_i\hat{g}$**
			5	**4**	**3**	**2**	**1**	
-205.79	-43.60	2410.3	82.79	129.08	-40.20	27.83	- 49.27	1
-274.98	-100.70	4080.8	-39.92	-35.99	130.28	64.01	41.71	2
-275.32	-27.24	127.22	-22.79	46.29	12.01	-71.41	-13.06	3
-301.47	-48.31	-14.67	46.01	-1.51	-109.82	-105.72	-11.14	4
-242.72	-106.07	620.49	-25.25	- 42.54	3.55	-54.32	0.35	5
Standard error			Mean squares					
$\hat{R}_{ij}$	${}_{ij}\hat{s}$	${}_{ii}\hat{g}$			E	RCA	SCA	GCA
14.55	3.066	5.82			423.47	**7028.33	**20356.53	**18272
reciprocity crosses			reveres crosses			Variances		
3302.43	$Dr\delta^2$		19933.06	$D\delta^2$		1784.853	$gca\delta^2$	
1.36	-râ		3.342	Ā		3569.71	${}^2A\delta$	
94.195	$h^2{}_{b.s}$		98.32	$h^2{}_{b.s}$		0.0089	$gca/\delta^2\ sca\delta^2$	
48.93	$h^2{}_{n.s}$		14.92	$h^2{}_{n.s}$		0.540	$gca/\delta^2\ rca\delta^2$	

Table 4. *Continue.*

5	4	3	2	1	Parents
613.28	671.83	514.14	688.94	306.63	1
495.19	525.46	739.55	704.49	605.52	2
572.18	551.64	515.08	882.37	540.27	3
581.38	416.25	771.27	736.89	694.11	4
542.07	666.45	565.08	603.82	612.58	5
				604.65	Overall mean
				81.90	L.S.D 5%
5	4	3	2	1	Parents
0.131	0.614	- 0.003	- 0.022		1
- 0.29	- 0.25	0.057		- 0.14	2
0.055	0.07		0.25	0.05	3
0.07		0.39	0.04	0.67	4
	0.23	0.04	-0.14	0.13	5

The effect of GCA was a positive value for the two parents only 3 and 4, and negative for remaining parents, In return was the effect of SCA positive for six crosses of the highest value cross 2 × 1, 5 × 3 and 5 × 4, and was negative for four crosses, the reciprocal were also positive for six of them, and the highest value for the cross 4 × 3 and the remainder negative. The $\sigma^2 \hat{g}_{ii}$ for parents were a few and positive value, except parent 4 was negative, but $\sigma^2 S_{ij}$ were all positive, and also were positive for three parents, and negative for two parents of reciprocal crosses. The environmental variation was very low and unimportant in influencing trait. In spite of the approaching of MS for GCA and SCA, however, σ^2 gca was low, led to a reduction σ^2 A, and that was less than the σ^2 D, which in turn was equal to σ^2 Dr, and this made the ratio σ^2 gca / σ^2 sca low (that was to reciprocal more than doubled to crosses), make the degree of dominance more than one, leading to a decline the proportion of heritability narrow sense, so, the trait under the control of non- additive gene action, hybridization, appropriate method to improve it.

3.5. The Weight of 100 Grain

Table 5 shows that parents differed among them in 100 grain weight. Parent 3 superiority and gave the highest grain weight (17.9 g), an increase of 43% and 30% and 41% and 32% for parents 1, 2, 4 and 5 respectively. In spite of it superiority, but it is not significantly different from the overall mean of grain. Five crosses gave grain weight higher than the overall mean, highest crosses were 5 × 2 and 4 × 3. The cross 3 × 1 was equal to overall mean, however, it did not exceed a parent which gave the highest weight of the grain (parent3), only two crosses gave less than the overall mean and the mean of highest parent. Five reciprocal crosses superiority overall mean, and the highest mean parents, the four of them to the parent 5 and one for parent 4, the highest one cross 5 × 2, which achieved an increase rate of 29.5% and 24.9% than overall mean and the highest mean parents respectively. Three reciprocal crosses resembled the overall mean and the highest mean of parents and only 3 × 2 decreased from them, because it gave the highest number of grains/ plant 882.37 grain (Table 3), led to increased competition among them, so weight of grain became less. These differences among parents reflected on the difference in the hybrid vigor for crosses resultant from them. Seven crosses were positive 0.45 for cross 4 × 1, and negative in three crosses to the parent 3; 3 × 1, 3 × 2 and 5 × 3. All reciprocal crosses are positive except 3 × 2 negative, the highest positive hybrid vigor 0.64 and 0.62 for cross-maternal 5 with 1 and 2. The $\hat{g}_{ii}$ effects were positive for parents 3, 4 and 5, highest value for parent 5, parents 1 and 2were positive, and the highest for the parent 2. S_{ij} effects were positive for 8 crosses, high value for cross 5 × 2, 5 × 1 and 4 × 3, two only negative 3 × 2 and 5 × 3. Most of reciprocal crosses were negative, only three were positive 4 × 1, 4 × 2 and 3 × 2 for $\hat{S}_{ij}$. The $\sigma^2 G_{ii}$ is positive for parents, only P4 was negative, while the $\sigma^2 S_{ij}$ was positive except P3, $\sigma^2 R_{ij}$ for all parents negative. Each of the three variance were different significantly. The value of environmental variance refers to a decline in its influence in trait relative to the additive and dominance variance, namely that the trait under the effect of genetic control and that is not the important role of the environment. The variance of dominance was higher than the additive, indicative that the effect of the non -additive gene action governs trait by evidence decline ratio of σ^2 GCA /σ^2 SCA for crosses and reciprocal crosses, this is clear from the high value of the degree of dominance, which also indicate that trait under the influence of non-additive gene action, enhanced by the heritability narrow sense that was very low, sign that the additive gene action no have significant impact, and the trait controlled by non- additive gene action. It can be improved by hybridization. This result Emphasizes result obtained by Wuhaib [10] when using the method Line x tester for several inbred, since found that trait governed by non -additive gene action that reduced the h^2_{ns} and degree of dominance was higher than one, also Albadawy [12] reported that the ratio σ^2 GCA /σ^2 SCA was less than one, so the largest percentage of the total genetic variation is due to non additive gene action, It did not agree result of Akber et al [13], as they found that the proportion of the σ^2 GCA /σ^2 SCA was greater than 1, and trait is governed by the additive gene action.

3.6. Dry Weight / Plant

Table 6 shows a significant difference among the plant dry weight for parents used in the diallel cross program for maize, and different from the overall mean. Parent 3 superiority and parent 2 was similar to it. parent 3 gave highest plant dry weight superior to the rest of the parents by 39%, 28%, 156.4% and 49%. Crosses and reciprocal crosses affected by different parents, it gave high weights, but did not differ from the overall mean (except cross 5 × 2 which gave less dry weight due to the lowest number of grain /ear with a decrease in other trait), highest weight was 303.21 and 300.33 for crosses 3 × 2 and 4 × 3. in general, Reciprocal crosses were higher than crosses, where the cross 5 × 2 superiority because it gave a higher Plant height 102.58 cm, high leaves area 0.49 m^2 and high grain weight 22.35g (Tables 1, 2 and 5). Hybrid vigor in seven crosses was positive toward increasing the plant dry weight, the highest 0.47 was for cross 5 × 1 followed by 0.38 for cross 4 × 1. Reciprocal crosses were positive except only one was negative, the highest positive value of hybrid vigor 0.84 for cross 5 × 4, followed by cross 5 × 2, 4 × 1 and 5 × 1, as the result of the effect of cytoplasmic genetic. Three parents possessed positive effect for ĝii, the highest value was 0.70 for parent 5, $\hat{S}_{ij}$ effect for crosses was positive except only one was negative; the highest value of positive is 43.85 for cross 4 × 1, followed by 43.44 for cross 5 × 4. Reciprocal crosses were negative except two positive; cross 5 × 1 and 4 × 3, the highest value of positive is 29.01, while the other reciprocal crosses, and was negative, with the highest value 74.57 for cross 5 × 2 and 51.99 for crosses 5×4. Negative effects resulting from the presence of negative $\sigma^2 \hat{S}_{ij}$ and $\sigma^2 R_{ij}$. σ^2 ĝii were positive for four parents and was high for parent 4 and 3, while parent 5 has negative variance for ĝii, either $\sigma^2 \hat{S}_{ij}$ and $\sigma^2 R_{ij}$ were negative for all parents towards reducing the plant dry weight, the highest value for the parent 3 for $\sigma^2 \hat{S}_{ij}$ and 5 for $\sigma^2 R_{ij}$. MS value for SCA was higher than the MS for GCA, which in turn was higher than the value of the MS for RCA. The environmental variation is very low. σ^2D was multiple the σ^2A and σ^2R, so the ratio of σ^2GCA /σ^2SCA and σ^2GCA / σ^2RCA less than 1, make the degree of dominance and the â –r greater than 1, referring to the control of the non additive gene action on trait. This is clear from the low heritability denote the decline effect the additive gene action, in which case the hybridization can be used to improve the plant dry weight. This result confirms what found by Wuhaib [10] of that dry weight is under the control of non -additive gene action resulted to low proportion of heritability (40.5% and 31%) and the high value of the degree of dominance (1.7 and 2.1) to the inbred and testers used in Line x tester cross program. However, Vacaro [14] found that σ^2GCA was the biggest of σ^2 SCA, suggesting that the trait was governed by the additive genes.

Table 5. *Mean of grain weight(100) for inbreds (value diameter) reciprocity crosses (values above diameter) the hybrid vigor, GCA effects, SCA for reciprocity crosses(values above diameter) RCA for reveres crosses (values under diameter) and its variances, with some genetic parameters, for maize, in the fall season 2013.*

$R_{ij}\delta^2$	$S_{ij}\delta^2$	G_{ii}^2	$\hat{S}_{ij}$					parents
			5	4	3	2	1	iiĝ
-0.91	1.35	0.09	2.50	0.88	0.64	0.10	-0.30	1
-0.71	0.85	0.21	3.39	0.95	-1.82	-0.46	-1.31	2
-1.18	-0.13	0.02	-1.29	2.13	0.15	0.28	-0.49	3
-0.60	1.52	- 0.00	0.65	0.04	-0.55	0.57	0.65	4
-2.74	1.73	0.32	0.57	-2.36	-2.68	-1.59	-1.50	5
Standard error			Mean squares					
$\hat{R}_{ij}$	$_{ij}\hat{s}$	$_{ii}\hat{g}$			e	RCA	SCA	GCA
0.179	0.527	0.071			0.064	**4.12	**13.19	**1.62
Reciprocity crosses			Reveres crosses			Variances		
2.029	$Dr\delta^2$		13.129	$D\delta^2$		0.155	$gca\delta^2$	
3.616	-râ		9.198	Ā		0.310	$^2A\delta$	
97.35	$h^2_{b.s}$		99.53	$h^2_{b.s}$		0.0118	gca /δ^2 $sca\delta^2$	
12.91	$h^2_{n.s}$		2.298	$h^2_{n.s}$		0.076	gca / δ^2 $rca\delta^2$	

Table 5. *Continue.*

5	4	3	2	1	Parents
18.53	18.53	17.26	15.30	12.55	1
19.17	18.36	15.41	13.73	17.91	2
14.00	19.02	17.90	14.84	18.23	3
16.16	12.74	20.13	17.22	17.23	4
13.16	20.87	19.37	22.35	21.53	5
				17.26	Overall means
				1.01	L.S.D 5%
5	4	3	2	1	Parents
0.37	0.45	-0.035	0.11		1
0.39	0.33	-0.13		0.30	2
-0.22	0.06		-0.17	0.023	3
0.23		0.13	0.25	0.35	4
	0.59	0.08	0.62	0.64	5

Table 6. *Mean of total dry matter per plant (gm) for inbreds (value diameter) reciprocity crosses (values above diameter) the hybrid vigor, GCA effects, SCA for reciprocity crosses(values above diameter) RCA for reveres crosses (values under diameter) and its variances, with some genetic parameters, for maize, in the fall season 2013.*

$R_{ij}δ^2$	**$S_{ij}δ^2$**	**$G_{ii}^2δ$**	**$\hat{S}_{ij}$**					**Parents**
			5	**4**	**3**	**2**	**1**	**Iiĝ**
-162.75	-55.88	6.14	25.36	43.85	-23.63	11.00	- 4.20	1
-181.23	-54.60	19.63	8.62	3.42	37.36	5.58	-10.34	2
-161.60	-63.89	432.66	2.51	16.32	21.08	-17.89	-41.69	3
-157.19	-39.06	524.47	43.44	-23.15	29.01	-9.70	-7.67	4
-192.72	-48.10	-11.01	0.70	-51.99	-23.04	-74.57	2.64	5
Standard error			Mean squares					
$\hat{R}_{ij}$	$_{ij}\hat{s}$	$_{ii}\hat{g}$			E	RCA	SCA	GCA
11.989	2.838	4.796			287.465	**2392.34	**3953.07	**2573.426
reciprocity crosses			reveres crosses			Variances		
1052.44	$Drδ^2$		3665.61	$Dδ^2$		228.596	$gcaδ^2$	
2.146	-râ		4.00	Ā		457.19	$^2Aδ$	
84.00	$h^2_{b.s}$		93.48	$h^2_{b.s}$		0.0623	$gca/δ^2 scaδ^2$	
25.44	$h^2_{n.s}$		10.37	$h^2_{n.s}$		0.217	$gca/δ^2 rcaδ^2$	

Table 6. *Continue.*

5	**4**	**3**	**2**	**1**	**Parents**
281.58	265.91	208.63	259.13	192.10	1
197.40	233.23	303.21	207.82	279.90	2
258.32	300.33	266.67	338.98	292.02	3
226.07	103.75	242.32	252.63	281.25	4
178.54	330.05	304.40	346.55	276.29	5
				257.08	Overall mean
				67.48	L.S.D 5%
5	4	3	2	1	Parents
0.47	0.38	-0.22	0.25		1
-0.05	0.12	0.137		0.346	2
-0.03	0.13		0.27	0.10	3
0.27		-0.09	0.22	0.46	4
	0.84	0.14	0.67	0.43	5

3.7. Yield t / h

Table 7 illustrates that yield of unit area was differed among parents. The highest yield was 5.74 t / ha for parent two, and significantly no differs from the parent 3 which gave 5.64 t / ha. Parent 1 gave less yield 2.16 t/ha. Differences between parents reflected on crosses and reciprocal crosses resulting from them. Five crosses gave yield higher than the highest parents, and two of them (4 × 1 and 5 × 1) gave higher than the overall mean. It seems from the data that parents which given yield less (1 and 4) has given high yield 6.98 t / ha for their cross. This indicates that parents may have been more genetically homozygous resulted in higher heterozygosity, which covered the harmful effects of deleterious gene and gave higher yield. Generally, reciprocal crosses was higher in yield of crosses, this is due to the influence of the cytoplasmic genetics in the trait. Nine reciprocal crosses gave yield higher than the parents except cross 3 × 1 that gave less than the highest parent 2 and 3; however, it is higher than other parents. In addition, all (except 3 × 1) gave the yield higher than the overall mean, it was the top rated cross 4 × 3. Seven crosses achieved a positive hybrid vigor, the higher was 1.03% for cross 4 × 2, the rest were negative, the higher was - 0.20 of cross 5 × 3. The hybrid vigor for reciprocal crosses were positive toward increase the yield, except cross 3× 1, which had a hybrid vigor towards reducing the yield, evidence that it gave yield less than the rest of the reciprocal crosses. The highest positive hybrid vigor for cross 4 × 1, note that parents of this cross was not distinct in higher yield, but have given less in comparison with the rest parents, in other words, yield of parents 1 and 4 was less than the rest of the parents, but the crossing between them has given highest hybrid vigor, did not that cross 1 × 4 and 4 × 1 the highest in yield only but the yield of them were higher than the highest parents and higher than the overall mean, and its yield was 7.13 tons / h while the mean of crosses 2 × 3 and 3 × 2 resulting from highest parents was 6.94 t / ha. This result agrees result of Vacaro et al. [14] where they found significant differences between the values of the hybrid vigor in yield ranged between negative and positive. Three parents possessed positive ĝii, was highest value 0.35 for the parent 2, while the other is negative, the highest value was 0.46 for the parent 1. The parent which has high $σ^2 \hat{S}_{ij}$ (parent 1 and 5) the effect of $\hat{S}_{ij}$ are negative for each a reciprocal crosses, while the only one cross was negative with parent 3, whilst it positive for seven crosses, the highest 1.56 for cross 4 × 1 followed by 1.47 for 5 × 1 and 1.14 for 4 × 3. σ

$^2 G_{ii}$ was positive for all parents, but it was low, except parent 1 and 2. $\sigma^2 S_{ij}$ was positive also, but it is higher than the values of $\sigma^2 G_{ii,}$ and the highest value of 1.11 for the parent 4 followed by 0.94 for the parent 1, this an indication of that trait is governed by the effect of non- additive gene action, either σ^2 Rij were all negative, the highest value for the parent 4 and 5, which is generally higher than the values of the effect of $\sigma^2 S_{ij.}$ The impact of environment was slightly. MS for sca three times as MS gca and the doubled MS for rca, make the σ^2 gca very few 0.091 led to a decline in variance of additive from the value of the dominance and reciprocal variance, the rate between them was less than 1, which led to the high value of the degree of dominance, referring to the control of non-additive gene action in yield of the maize plant, causing low rate of heritability narrow sense, to reach 4.45% for crosses, and 20.14% for reciprocal crosses. This result confirms what Wuhaib [10] got that the yield governed by non-additive gene action, with the proportion of heritability of 30.8% and 30%, and the degree of dominance 2.08 and 2.12 of the inbred used in the Line × tester cross. The results obtained by Jenweerawat [15] noted that the MS for GCA for parents and SCA for crosses were significant for grain yield, while the result obtained by Vacaro [14] was dispute this finding, where he found that the trait under the influence of the additive gene action, because ratio between the σ^2 GCA /σ^2 SCA was greater than 1. Therefore, the heritability rate was low 11% for grain yield as found byAkbar et al. [13]. Sedhom et al. [16] and Alamnie et al. [17] pointed to that additive gene action is responsible for inherited grain yield.

Table 7. *Mean of grain yield(ton\hectare) for inbreds (value diameter) reciprocity crosses (values above diameter) the hybrid vigor, GCA effects, SCA for reciprocity crosses(values above diameter) RCA for reveres crosses (values under diameter) and its variances, with some genetic parameters, for maize, in the fall season 2013.*

$R_{ij}\delta^2$	**$S_{ij}\delta^2$**	**$G_{ii}{}^2\delta$**	**$\hat{S}_{ij}$**					**Parents**
			5	**4**	**3**	**2**	**1**	**Iiĝ**
-0.31	0.94	0.21	1.47	1.56	-0.37	0.18	-0.46	1
-0.83	0.29	0.12	0.25	-0.05	0.51	0.35	-0.09	2
-0.99	0.20	0.02	-0.69	1.14	0.16	-0.43	-0.28	3
-1.23	1.11	0.00	0.69	0.04	-1.43	-0.85	-0.08	4
-1.25	0.57	0.01	-0.08	-1.31	-0.82	-1.12	-0.48	5
Standard error			Mean squares					
$\hat{R}_{ij}$	$_{ij}\hat{s}$	$_{ii}\hat{g}$			e	RCA	SCA	GCA
0.059	0.339	0.024			0.007	1.388	3.800	0.920
reciprocity crosses			Reveres crosses			Variances		
0.69	$Dr\delta^2$		3.793	$D\delta^2$		0.091	$gca\delta^2$	
2.75	-râ		6.446	ā		0.183	$^2 A\delta$	
0.73	$h^2{}_{b.s}$		0.94	$h^2{}_{b.s}$		0.024	gca /δ^2 scaδ^2	
20.14	$h^2{}_{n.s}$		4.45	$h^2{}_{n.s}$		0.132	gca / δ^2 rcaδ^2	

Table 7. *Continue.*

5	**4**	**3**	**2**	**1**	**parents**
6.37	6.98	4.97	5.90	2.16	1
5.31	5.41	6.51	5.74	6.08	2
4.49	5.82	5.64	7.37	5.52	3
5.26	2.66	8.69	7.11	7.13	4
4.04	7.89	6.13	7.56	7.33	5
				5.91	Overall mean
				0.22	L.S.D 5%
5	4	3	2	1	Parents
0.57	0.23	-0.13	0.03		1
-0.06	1.03	0.13		0.06	2
-0.20	0.03		0.31	-0.02	3
0.31		0.53	0.24	1.68	4
	0.95	0.09	0.32	0.81	5

Dadheech, Joshi [19], Baracat, Osman [20], and Irshad et al. [21] pointed out that the non-additive gene action was more important in the inheritance of grain yield. But Iqbal et al.[5] and Akbar et al. [13] and Hefny [22] has pointed out that the effect of each of the additive and non-additive gene action was important in gene expression in the yield of maize grain and its components. Mezmouk et al. [6] stated that getting the highest hybrid vigor is when there are combinations an integrative of mixed groups' heterotic groups thus increasing progenies performance compared with parents identical homozygous, they have also stated that there are three mechanisms to explain heterosis: Dominance, over dominance and Positive epistatic interaction.

We can conclude that inbred lines were significantly different among themselves in performance. Crosses from inbred high yield gave lowest yield, while crosses from inbred low yield gave yield higher than all crosses and overall mean, also gave positive hybrid vigor, high positive variance for specific combining ability. Crosses produced from high homozygous and un related inbreds gave high yield due to high heterozygosis, hence we can used to produce hybrids or use selection for it and produce synthetic varieties.

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