Genetic Analysis by Using Partial Diallel Crossing of Maize In High Plant Densities (Estimation GCA, SCA and Some Genetic Parameters)

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Abstract

The experiment was carried out at the Field Crops Research Station, College of Agricultural Engineering Sciences - University of Baghdad in Jadriyah, with the aim of evaluating the performance of partial diallel hybrids and inbred lines of maize and estimating general combining ability (GCA), specific combining ability (SCA) and some genetic parameters. The experiment was conducted in two seasons, spring and fall 2020. Eight inbred lines of maize were used in the study (B19/834, BSW18, LW/5 L8/844, ZA17W194, Z117W, Z117W9, Z17W4), numbered (1,2,3,4,5,6,7,8), and it was sowed in the spring season and entered into a cross-program according to a partial diallel crossing system to obtain twelve partially cross-hybrids, and it was compared with its eight parents in a comparison experiment in the fall season using a Randomized Complete Block Design (RCBD) with split plots arrangement with three replication. The plant densities of 70 and 90 thousand plants ha⁻¹ represented the main plots, while the partial diallel hybrids and their parents represented the secondary plots. The results of the study showed that the ratio between GCA and SCA (GCA/SCA) It was more than 1 for yield traits, ear length, number of rows and number of row grains in both low and high densities, which indicates the control of the additive genetic action on these traits. While the ratio was less than one for the traits of the ear diameter under the low density, which indicates the control of dominance genes on this trait in the mentioned density, while the trait of the number of ear grains, the ratio between the general and specific combining abilities was less than one in the high density. Inbred line 8 had the highest effect for the general ability to combine under low density, which amounted to 11.075, while inbred line 2 was superior by giving the highest effect to the general ability to combine at low density, which amounted to 17.80, followed by inbred 8.

Keywords: Plant densities, Additive gene action, Maize, GCA, SCA.

1. Introduction

The maize crop (Zea mays L.) is characterized by its high genetic and phenotypic variance, and understanding the nature of genetic actions that control the inheritance of traits helps to choose the appropriate method of breeding, as the maize crop is an excellent model for studying genetic regulation because it has a wide genetic base available for testing and then adapting it to environmental conditions [1]. Despite the increase in the area planted in Iraq with this crop from (572,500) thousand hectares in 2015 to (1013.50) thousand hectares in 2020 [2], the local production rate of grain does not exceed (4,054 tons hectare⁻¹). The low productivity in Iraq is attributed to several reasons, including the adoption of the cultivation of synthetic and open-pollinated varieties and the lack of local genetic resources in breeding and improvement programs [3]. Combining viability testing of inbred lines is important and necessary for the purpose of determining their ability to produce economically superior hybrids or the desired trait, and that information on the relative importance of additive and non-additive genetic action is important for plant breeders to develop an efficient cross-breeding program [4], [5], indicated in his study of six pure inbred lines of maize and fifteen hybrids that resulted from the half diallel-crossing that the values of the specific combining ability component are higher than the values of the general combining ability component of the ear length characteristic and the ratio between their variance was less than one, and four inbred lines gave the combining ability negative, while the rest gave positive values, the highest of which was 1.389 for inbred line 4, while six crosses showed a specific negative ability to combine towards reducing the length of the ear, and the others of the crosses gave positive values, the highest of which was 1.85 for hybrid (4 × 6). [6], obtained positive values of general and specific combining ability for the maize inbred lines and hybrids used in the study, with the highest being 2.477. [7], found that when ten genotypes of maize were introduced into full diallel crossing, the ratio of the average squares of the general to specific ability of the
combination was less than one for the trait of ear length and diameter, which indicates the importance of the non-additive genetic action. [8], emphasized on the existence of highly significant differences for the variance of the general and specific combining ability of the ear diameter, and this indicates the participation of the additive and non-additive genetic action in the inheritance of this traits. [9], crossed twelve pure inbred lines of maize and found that the mean squares of general and specific combining ability were highly significant for ear diameter trait. [10], showed in his study of fifteen hybrids resulting from crossing between three testers and five female inbred lines(mothers), there are significant differences in the mean squares of the general and specific combining ability of the ear diameter.

The highest value of the effect of the general combining ability was 0.16, while the highest effect of the specific combining ability appeared in the hybrid (4x8), which amounted to 0.59. [11], showed that when they performed a partial diallel crossing of nineteen inbred lines, the highest positive general combining ability of inbred line 1 was 0.016, and the lowest value for strain 7 was -0.003 for the ear length trait, while the two inbred lines B and C gave a positive coupling to the ear diameter trait that amounted to 0.019 and 0.022 respectively. The lowest value for inbred line was -0.002. The mean squared ratio of GCA to SCA was less than one. [12-14], found that when they were full diallel crossing between five inbred lines of maize, the ratio between the general to specific combination ability variance was less than one, indicating the dominance of non-additive genetic action. In showing the trait of the number of rows in the ear, the number of row grains, and the number of maize grains, [15], concluded that the inheritance of the number of rows in the ear and the number of its grains is under the influence of the non-additive genetic action based on the ratio of the variance of the general to specific combining ability, which amounted to 0.04 and 0.06 respectively.

[16], when studying nineteen inbred lines that were introduced by partial diallel crossing and produced 90 single hybrids, found significant differences in the mean squares of the genotypes for the trait of grain weight and yield, as well as positive and negative values for the effects of the general and specific combing abilities. The additive control over the heritability of these traits gave inbred line B, I and 8 the highest values of the general combining ability to grain weight and yield, and the lowest value for inbred line I. Whereas the hybrid (Bx1) outperformed by giving the highest values of the specific combining ability to these two traits. The study aimed to evaluate the performance of the inbred lines and their partial hybrids and test them under two plant densities, assess the general and specific combining ability and some genetic parameters, determine the genetic action, genetic, environmental and phenotypic variation, the degree of dominance and heritability in the broad and narrow sense, to find out the appropriate method of breeding in the appropriate plant density and determine the best inbred line which produced the best hybrids under the influence of increasing plant density to be included in breeding programs to obtain the desired genotypes.

2. Methods and Materials

A field experiment was carried out in the fields of experiments of the College of Agricultural Engineering Sciences, University of Baghdad in Jadriyah for the spring and fall seasons 2020. Eight inbred lines were planted (B9/834, BSW18, LW5, L8/844, ZA17W194, Z117W, ZI17W9, ZI7W4), code (1, 2,3,4,5,6,7,8) were subjected to partial diallel crossing to obtain twelve partial cross-hybrids, and were compared with their eight parents in a comparison experiment in the fall season using a randomized complete block design. (RCBD) In the order of the split plots in three replications, the plant densities were 70 and 90 thousand plants ha⁻¹ as the main plots, while the partial exchange hybrids and their parents represented the secondary plots. The performance of the parents and their individual crosses was evaluated, as well as the assessment of the vigor of the crosses relative to the best parents, according to the method of [17], in the spring season of the year (2020). The land of the experiment was prepared from plowing, smoothing, leveling and tamping afterwards the seeds of pure inbred lines were planted on farrows, the length of the farrow is 6 meters, and the distance between them is 0.8 m, by planting six lines for one breed, and in the holes at a distance of 0.25 m between one hole and another on 17, March 2020, compound fertilizer (18% nitrogen and 46% phosphorous pentoxide) was used when planting with an amount of 240 kg.ha⁻¹, while urea fertilizer was used with an amount of 360 kg.ha⁻¹ divided into two batches, the first one month after planting and the second at the beginning of the flowering stage. As for potassium fertilizer, it was used with an amount of 200 kg.ha⁻¹. In the form of potassium sulfate when planting [18], a preventive dose of granulated diazinon was added at a concentration of 10% and at a rate of 6 kg. ha⁻¹ was placed in the middle of the plant to prevent maize stalk borer in two batches, the first in stage 4-5 leaves, and the second 15 days after the first batch [19].

All operations necessary to serve the crop were also carried out, such as irrigation, mulching and weeding, as needed. Upon reaching the flowering stage, the possible cross-breeds were carried out according to the partial cross-hybridization proposed by [20], by adopting three samples of crosses S=3 and the number of the resulting hybrids was 12 partially single hybrids, it was compared with its parents in the fall season, when the seeds of single partial hybrids and their parents were planted, which are 20 genotypes, on 7-21-2020 using the Randomized Complete Block Design (RCBD) with three replications. In the order of the split plots, the plant densities represented 70 and 90 thousands plants ha⁻¹ of the main plots, while the genotypes represented the secondary plots. The planting was carried out in farrows, with a distance of (0.8) m between the farrows and 13.88 and 17.85 cm between the holes for the two mentioned densities, and at the rate of two seeds per hole, it was thinned to
one plant. Five randomly guarded plants were taken from each experimental unit, and the data of the following traits were recorded: ear length (cm), ear diameter (cm), number of rows per ear, number of grains per row, number of ears, and grain yield in grams for individual plant. The data were placed in tables and were statistically analyzed according to the design used, and the arithmetic means were compared using the least significant difference L.S.D, with a significance level of 0.05, using the Excel and Gensate2018 programs. The vigor of the hybrid was estimated according to the following equation:

\[
\text{Calculate the sum of squares of the general and specific combining ability and some genetic parameters.}
\]

\[
\text{Find the sum of the squares of the deviations for the general combining ability:}
\]

\[
\text{SS}_{G.C.A} = \sum g_i Q_i
\]

\[
\text{Finding the sum of the squares of the deviations of the special combing ability:}
\]

\[
\text{SS}_{S.C.A} = \text{SScrosses} - \text{SS}_{G.C.A}
\]

The significance of the general ability effects on the coalition was tested by estimating the standard error

\[
\text{Average of Variance}(g_i - g_j) = 2 \left[ \frac{na^0}{n-1} - \frac{1}{25(n-1)} \right] \left[ \sigma^2 + \frac{\sigma^2 e}{r} \right]
\]

2.1 Phenotypic Variance Components

The additive, \( \sigma^2_A \) dominance \( \sigma^2_D \) and environmental variance \( \sigma^2_E \) were estimated based on the expected mean variance EMS from the analysis table of variance according to partial cross-hybridization analysis.

\[
\sigma^2_A = 2\sigma^2_{G.C.A}
\]

\[
\sigma^2_D = \sigma^2_{S.C.A}
\]

\[
\sigma^2_e = \text{MSe}
\]

The genetic \( \sigma^2_G \) and phenotypic \( \sigma^2_P \) variances were estimated through the following equations

\[
\sigma^2_G = \sigma^2_A + \sigma^2_D
\]

\[
\sigma^2_P = \sigma^2_G + \sigma^2_E
\]

2.2 Genetic parameters

Heritability broad sense estimated according following equation:

\[
h^2_{bs} = \frac{\sigma^2_G}{\sigma^2_P} \times 100 = \frac{\sigma^2_A + \sigma^2_D}{\sigma^2_A + \sigma^2_D + \sigma^2_E} \times 100
\]

The ranges were adopted for heritability in the broad sense, according to what was stated in them [21]. And as follows:

Less than 40% low
And between 40-60% average
More than 60% high

The heritability ratio was estimated in the narrow sense(Narrow Sense Heritability): For the studied traits according to the following equation:

\[
h^2_{ns} = \frac{\sigma^2_A}{\sigma^2_P} \times 100 = \frac{\sigma^2_A}{\sigma^2_A + \sigma^2_D + \sigma^2_E} \times 100
\]

The ranges suggested by [22], were adopted as follows:

Less than 20% low
And between 20- 50% average
More than 50% high.

2.3 Average Degree of Dominance

According to the average degree of dominance, as in the equation:
\[
\overline{a} = \sqrt{\frac{2 \sigma^2_D}{\sigma^2_A}}
\]

Indicates the dominance not existence. \(0 \leq \overline{a} \leq 1\)

\(\overline{a} < 1\) indicates the presence of partial dominance
\(\overline{a} = 1\) indicates the existence of complete dominance.

3. Results and Discussion

3.1 Ear length

It was found through the results of the genetic analysis for the characteristic of ear length (Tables 1 and 2) that the differences between the mean squares of the ability did not rise to the level of significance except for the general ability (GCA) under the high plant density only. Table (3) indicates the significance of the effect of the general combining ability for the ear length in high density, as the parents 1, 2, 6 and 7 were able to pass on the increase in the length of the ear to their partial crosses, and the values of their effects ranged between 0.133 to 1.00, while the other of the parents showed a negative effect of the general combining ability towards reducing the ear length. The values ranged from -0.167 to -1.05. Indicating the contribution of the mentioned parents to a great effectiveness in raising or lowering the average trait in their crosses compared to the general performance of all crosses.

3.2 Ear diameter

The results of the genetic analysis in Tables 1 and 2 for the ear diameter trait indicate the significant differences in the mean squares of the general and specific combining ability under the high and low plant densities. Table 3 reviews the values of the effects of both the general and specific combining ability of the parents and the specific crosses of partial diallel crosses of the ear diameter trait if parents 1, 2, 4, 7 and 8 bequeath an increase in ear diameter to their hybrids, and the highest value was 1.408 for parent 4 under low density, while in high density, parents 6,7 and 8 were able to give positive values that reached the highest value of 2.174 for parent 8. for the specific combining ability partial hybrids (SCA) to the traits of the ear diameter under low density, which is shown in the same table, they showed the two hybrids (1×5) and (5×8) (positive values were 2.612 and 0.069 respectively, while the hybrids showed (1×4), (3×6) and (2×7), and (1×6) have positive values under high density of 3.769, 3.597, 1.086 and 0.503, respectively.

3.3 Number of rows ear

Based on the results of genetic analysis (Tables 1 and 2), the variance of the mean squares of the general combining ability was significant under high and low plant densities, while the variance of the means of specific combining ability did not reach significant in both densities. Which indicates the great contribution of the additive action in the inheritance of the trait number of rows per ear. The results of Table 3 indicate that Parent 8 showed the highest positive and significant value for the effect of the general combining ability(1.15), while Parent 3 recorded the lowest negative and significant values (-0.158), as it was clear that parents 2 and 6 were single with a value of zero in the low density. As it is clear from the same table for the general combining ability high density, four parents showed a positive effect of increasing the number of ear rows ranging from 0.009 to 1.505, while 3, 4, 5 and 6 parents recorded negative values for their effects that ranged between -0.005 and -1.80.

3.4 Number of grain ear

The results of the genetic analysis (Tables 1 and 2) showed clear significant differences between the means of the squares of both general and specific combining ability for the trait of the number of grains of the row due to the effect of high plant density, as indicated by the participation of both additive and non-additive genetic action in the inheritance of the trait. The genetic behavior of their partial hybrids differs significantly under low plant densities. The results of Table 3 of the effect of the general combining ability (GCA) for the trait of the number of row grains showed the ability of parents 6, 7 and 8 in inheriting the trait of increasing the number of row grains to their partial hybrids in low density. Parent 8 achieved the highest positive value of 3.000, but at high density it was parents 2, 4, 6 and 8 achieved...
positive values, the highest of which was 2,799 for parent 2. It was also shown from the same table that the specific combining ability (SCA) for the number of grains of the row did not reach the level of significance, and the two crosses (2×5) and (5×8) gave positive values of 0.822 and 1.274 respectively for the low density. The direction of reducing the number of row grains ranged from -1.05 to -0.967.

3.5 Grains number ear\(^1\)

The results of the genetic analysis of the number of grains ear\(^1\) (Tables 1,2) indicated that the additive effect (GCA) under the two densities was significant, while the non-additive effect (SCA) of the genes was not significant. Table 3 shows the results of the effect of the general combining ability of the parents (GCA) and the specific (SCA) to partial hybrids of the number of grains ear\(^1\). Parents 2, 3, 4, 7 and 8 were able to inherit the increase in the number of grains per ear to most of their crosses, and the highest value of the effect was 50,967 for parent 2 in low density while parents 1, 2, 6 and 8 were able to achieve positive values, the highest value was 70,069 for parent 8 in high density. As for the effect of SCA, it did not rise to the significance under the influence of both low and high densities. This agrees with the results of [14-17].

3.6 Grain yield Plant\(^2\)(gm)

The results of the genetic analysis of the plant yield trait from tables 1 and 2 indicate the significant effect of additive and non-additive (GCA) for genes under the two plant densities. Table 3 shows the effect of the general to combining ability of the parents (GCA) and the specific combining ability of the hybrids (SCA) to the trait of the plant yield. Parents 6, 7 and 8 were able to inherit the increase in plant yield to most of their hybrids, and the highest response was 11,075 to parent 8 for low density(table,3). When the plant density was increased, parents 1, 2, 4 and 8 were able to inherit the increase in plant yield. Parent 2 was able to obtain the highest response of 17,803, followed by parent 8, which reached 11,253. As for the specific combining ability (SCA) for partial hybrids, 25% of the hybrids were able to obtain positive values (2×5), (2×6) and (5×8) under low density, and the maximum response reached 5,131 for the hybrid (5×8). Under the influence of high plant density, 91.66% of the hybrids were able to obtain positive values, corresponding to one hybrid with a negative value of -0.370 for the hybrid (4×8), while the highest positive value was 161,410 for the hybrid (3×7).

3.7 Genetic parameters

3.7.1 Ear length

The results shown in Table 4 indicated that the ratio of variance for the general combining ability to the specific combining ability of the ear length trait in low and high density and its passed from parents to their partial hybrids, and the results of the same table indicated that the percentage of heritability in the broad sense of this trait was low, reaching 21.55% and 32.66%, as well as the percentage of heritability in the narrow sense was low, as it reached 18.53% and 26.59%. The decrease in the percentage of wide and narrow heritability is due to the high value of phenotypic variance, and that the increase in phenotypic variance was due to the high value of environmental variance. Therefore, the plant breeder must conduct the selection method among the breeding methods to obtain genotypes characterized by increased ear length in both densities. The increase in the value of the additive variance and the decrease in the value of the dominance variance was reflected in the average degree of dominance, which was less than one, as it reached 0.570 and 0.676, and this indicates the control of the additive genes on the inheritance of the ear length trait in low and high density. As for the effect of SCA, it did not rise to the significance under the influence of both low and high densities. This agrees with the results of [14-17].

3.7.2 Ear diameters (cm)

The results shown in Table 4 indicated that the ratio of the variance of the general susceptibility to the general to the susceptibility to the special union GCA/SCA was 0,142 for the trait of the ear diameter in the low density, while it rose to 1.073 in the high density. The great role of the dominance genes was in their influence on the inheritance of the ear diameter traits in the low density and its passed from the parents to their partial diallel hybrids. The results of the same table indicated that the percentage of heritability in the broad sense of this trait was high, reaching 77.667%. This increase came as a result of the high value of genetic variance and that the percentage of heritability in the narrow sense of this trait was low, reaching 17.223%. The decrease in the additive variance led to an increase in the rate of the degree of dominance, as it was greater than one, reaching 2.649, and this indicates the control of the overdominance genes on the inheritance of the trait of
increasing the diameter of the ear in the low density. The percentage of heritability in the broad sense to 39.89% and the increase of the percentage of heritability in the narrow sense to 27.20% As a result of the high additive effect in the high density, and thus the appropriate selection method among the breeding methods in the increasing densities of this trait. The degree of dominance decreased to 0.964, and this indicates the dominance of additive genes for this trait in high density, and this confirms the results of [21], whose results showed a genetic act of dominance in the low density and additive in the increasing densities of the ear diameter trait. As for the value of the expected genetic improvement, it was low, reaching 0.798 and 0.905 in the two densities, respectively, while the percentage of genetic improvement was 2.001% and 2.209%, respectively.

3.7.3 Number rows ear

The results shown in Table 4 indicated that the ratio of the variance of the general combining ability and the specific combining ability SCA/GCA was 0.423 for the trait of the number of rows in the low density, while it rose to 11.478 in the high density. This indicates a change in the genetic action by increasing the number of plants per unit area from dominance to The additive role of the dominant genes was in their effect on the inheritance of the number of rows in the low density and its transmission from the parents to the resulting single hybrids.

The results of the same table indicated that the percentage of heritability in the broad sense of this trait amounted to 35.60% and that the percentage of heritability in the narrow sense of this trait was low, reaching 16.33%. This decrease is due to the decrease in the value of the additive variance in the low density. Thus, the plant breeder must cross-breed to obtain hybrids characterized by an increase in the number of rows in low density. This increase was reflected in the dominance variance and the decrease in the additive variance on the average degree of dominance, as it was greater than one, reaching 1.536, and this indicates the control of the genes of the superior dominance over the inheritance of the trait of increasing the number of rows in the density above. As for the high density, the genetic action changed to the dominance in its effect on the trait of the number of rows. The percentage of heritability in the broad sense decreased to 34.37% due to the decrease in the dominance variance and the increase in the environmental variance, while the percentage of heritability in the narrow sense increased to 32.96% due to the high value of the additional variance in the high density. Therefore, the appropriate selection method is among the breeding methods in high densities of this trait. The degree of dominance decreased to 0.293, and this indicates the dominance of additional genes for this trait in high density, and this confirms the results of [11], whose results showed a genetic action of dominance for the trait of the number of rows. As for the value of the expected genetic improvement, it was low, as it reached 0.348 and 0.734 for the two densities, respectively, while the percentage of genetic improvement was 2.458% and 5.140%, respectively.

3.7.4 Grain number row

The results shown in Table 4 indicated that the ratio of the variance of the general combining ability special combining ability GCA / SCA was 18.732 and 8.875 for the trait of the number of row grains sequentially, and this indicates that the genetic action did not change by increasing the number of plants per unit area and continued further, but its value decreased. The great role of the additive genes in their effect on the inheritance of the trait of the number of row grains in the low and high densities and its transmission from the parents to the resulting single hybrids.

The results of the same table indicated that the percentage of heritability in the broad sense of this trait was 55.84% and 67.27% was medium due to the high value of genetic variance, and that the percentage of heritability in the narrow sense of this trait was high, reaching 54.39% and 63.68%, and this increase is due to the high value of additive variance in low and high densities. Therefore, the plant breeder must choose the method of selection to obtain genotypes characterized by an increase in the number of row grains in both densities. This increase was reflected in the additive variance and the decrease in the dominance variance on the average degree of dominance, as it was less than one, reaching 0.231 and 0.336. This indicates the control of the degree of dominance. This confirms the results of [19], whose results showed an additive genetic activity in both densities. As for the expected genetic improvement value, it was 2.475 and 1.980 for the two densities respectively, while the percentage of genetic improvement was 6.472% and 5.56 respectively for the two densities.

3.7.5 Number of grains ear

The results shown in Table 4 showed that the variance ratio of the general combining ability to the specific combining ability GCA / SCA was 1.005 for the trait of the number of corn grains in the low density, while it decreased to 0.149 in the high density. This indicates a change in the genetic action by increasing the number of plants per unit area from additive to dominance, as the additive genes had a great role in their influence on the inheritance of the trait of the number of corn grains in the low density and its transmission from parents to single hybrids.
The results of the same table indicated that the percentage of heritability in the broad sense of this trait was high, reaching 97.74%, and this increase was due to the high value of genetic variance, and that the percentage of heritability in the narrow sense of this trait was high, reaching 65.11%, and this rise is due to the high value of the additive variance in the low density. Therefore, the plant breeder must choose the method of selection to obtain genetic structures characterized by an increase in the number of corn grains in low density. This increase was reflected in the additive variance and the decrease in the dominance variance on the average degree of dominance, as it was less than one, reaching 0.997. As for the high density, the genetic action changed from the additive to the dominance in its effect on the trait of the number of grains of the ear. The percentage of heritability in the broad sense decreased to 76.280% due to the high value of environmental variance, and the percentage of heritability in the narrow sense decreased to 17.494% due to the decrease in the value of additional variance and the increase in the value of environmental variance. The cross-breeding method is among the appropriate breeding methods in the increasing densities of this trait. The average degree of dominance was high, reaching 2.592. This indicates the dominance of the dominant genes for this trait in the high density, and this confirms the results of [1,6], whose results showed an additive genetic action for this trait. As for the expected genetic improvement value, it was high, as it reached 86,860 in low density and decreased to 21,056 in high density. As for the percentage of genetic improvement, it was high at low density and amounted to 16.132% and decreased at high density and reached 4.120%.

### 3.7.6 Plant yield (gm)

The results shown in Table 4 showed that the variance ratio of the general combining ability to the specific combining ability GCA/SCA was 1.027 for the trait of individual plant yield at low density, while it increased to 2.640 in high density. The genetic action did not change by increasing the number of plants per unit area and continued further. The significant role of the additive genes was in their effect on the inheritance of the trait of the yield of the plant in the low and high densities and its transmission from the parents to the resulting single hybrids. The results of the same table indicated that the percentage of heritability in the broad sense was low, reaching 17.17%, and this decrease came as a result of the decrease in the value of genetic variance and the increase in the value of environmental variance, and that the percentage of heritability in the narrow sense was low at 11.55%: This decrease is due to the high value of the environmental variance in the low density, so the plant breeder must conduct selection to obtain genotype characterized by an increase in the plant yield in the low density. This decrease was reflected in the dominance variance and the increase in the additive variance on the average degree of dominance, as it was less than one, reaching 0.986, and this indicates the control of the additive genes on the inheritance of the trait of the plant yield in the low density. As for the high density, the genetic action did not change and continued to have an additive effect on the trait of the plant yield. The percentage of heritability in the broad sense increased to 51.10% as a result of the high value of genetic variance and the decrease in the value of environmental variance. The percentage of heritability in the narrow sense has increased to 42.88% as a result of the increase in the value of the additive variance and the decrease in the value of the environmental variance. Thus, the appropriate selection method is among the methods of breeding in the increasing densities of this trait. The rate value of the degree of dominance decreased to 0.623, and this indicates control of the additive genes in the high density, and this confirms the results of [21], whose results showed an additive genetic action of the plant yield. As for the expected genetic improvement value, it was 3.567 for the low density and it rose to 12.53 for the high density. As for the percentage of genetic improvement, it was 2.592%, and it rose to 8.34% for high density.

### Table 1. Analysis of variance for general and specific combining ability of the studied traits according to the method of Kempthorne and Curnow (1961) for partial diallel crossing -analysis under the influence of low plant density in maize.

| Sources of variations | Degree of freedom | Ear length | Ear diameter | Number of rows ear⁻¹ | Number of grain row⁻¹ | Number of grains ear⁻¹ | Grain yield plant⁻¹ |
|-----------------------|------------------|------------|--------------|-----------------------|-----------------------|-----------------------|---------------------|
| Rep                   | 2                | 1.864      | 1.986        | 0.143                 | 6.101                 | 1659.383              | 118.141             |
| Crosses               | 11               | 2.483**    | 17.057**     | 2.371*                | 12.164**              | 14308.762**           | 411.977*            |
| GCA                   | 7                | 2.968**    | 18.732**     | 2.706*                | 17.263**              | 19553.515**           | 461.926*            |
| SCA                   | 4                | 1.633**    | 14.125**     | 1.785**               | 3.242**               | 5130.443**            | 324.565*            |
| Error                 | 22               | 1.465      | 1.549        | 0.941                 | 2.951                 | 3059.895             | 255.244             |
| Total                 | 35               |            |              |                       |                       |                       |                     |
Table 2. Analysis of variance for general and specific combining ability of the studied traits according to the method of Kempthorne and Curnow (1961) for partial diallel crossing -analysis under the influence of high plant density in maize.

| Sources of variations | Degree of freedom | Ear length | Ear diameter | Number of rows ear⁻¹ | Number of grain row⁻¹ | Number of grains ear⁻¹ | Grain yield plant⁻¹ |
|-----------------------|------------------|------------|--------------|-----------------------|------------------------|-----------------------|---------------------|
| Rep                   | 2                | 3.001      | 0.840        | 0.963                 | 1.260                  | 3325.980              | 955.658             |
| Crosses              | 11               | 3.098**    | 6.986**      | 2.724*                | 20.871**               | 6274.485**            | 492.508*            |
| GCA                  | 7                | 3.764**    | 8.351**      | 3.464*                | 23.659**               | 9139.313*             | 658.368*            |
| SCA                  | 4                | 1.932**    | 4.596**      | 1.430**               | 15.990**               | 1261.036**            | 202.252*            |
| Error                | 22               | 1.202      | 2.150        | 1.050                 | 1.021                  | 3591.287              | 135.065             |
| Total                | 35               |            |              |                       |                        |                       |                     |

Table 3. The effect of general and specific combining ability to some traits in partial diallel crossing under the influence of plant density in maize.

| Genotypes | Ear length | Ear diameter | Number of rows ear⁻¹ | Number of grain row⁻¹ | Number of grains ear⁻¹ | Grain yield plant⁻¹ |
|-----------|------------|--------------|-----------------------|------------------------|-----------------------|---------------------|
|           | 70         | 90           | 70                    | 90                     | 70                    | 90                  |
|           |            |              | General combining ability (GCA) |                         |                       |                     |
|           |            |              |                        |                        |                       |                     |
| 1         | 0.144      | 0.950        | 0.925                 | 1.417                  | -0.258                | 1.307               | -0.292              | -0.534               | -52.015              | 41.636               | -12.433              | 3.832               |
| 2         | 0.173      | 1.000        | 0.775                 | 0.247                  | 0.000                 | 0.157               | -0.667              | 2.799                | 50.967               | 44.322               | -6.225               | 17.803              |
| 3         | 0.706      | 1.050        | 1.075                 | 1.438                  | -0.158                | -0.663              | -0.675              | -1.105               | 49.475               | -42.828              | -2.483               | -4.693              |
| 4         | 1.144      | 0.167        | 1.408                 | 0.709                  | -0.183                | -1.800              | -0.800              | 1.612                | 21.567               | -44.480              | -0.392               | 9.419               |
| 5         | 0.440      | 0.717        | 0.642                 | 0.667                  | -0.925                | -0.764              | -2.492              | -1.617               | -50.722              | -51.493              | -2.567               | -19.368              |
| 6         | 0.277      | 0.133        | 2.458                 | 0.503                  | 0.000                 | -0.005              | 0.933               | 1.283                | -49.993              | 19.765               | 8.308                | -7.297              |
| 7         | 0.377      | 0.717        | 0.392                 | 1.678                  | 0.375                 | 0.009               | 0.992               | -3.388               | 26.782               | -46.659              | 4.717                | -11.826             |
| 8         | 1.073      | 0.300        | 0.675                 | 2.174                  | 1.150                 | 1.505               | 3.000               | 0.962                | 3.940                | 70.069               | 11.075               | 11.253              |
| Standard error |          |              |                       |                        |                       |                     |                     |                     |                     |                     |                     |                     |
| 1x4       | 1.420      | 0.807        | 1.217                 | 3.769                  | -0.878                | -0.706              | -1.824              | -9.647               | -55.018              | -4.109               | -11.935              | 6.252               |
| 1x5       | 0.565      | 0.910        | 2.612                 | 0.900                  | 0.562                 | -0.840              | -0.762              | -7.734               | 29.106               | 855.632              | -0.734               | 7.013               |
| 1x6       | 0.408      | 0.887        | 2.699                 | 0.503                  | -0.665                | -0.829              | -0.010              | -9.601               | -52.465              | 344.267              | -3.405               | 59.330              |
| 2x5       | 0.625      | 0.310        | 0.113                 | 0.905                  | -0.203                | -0.561              | 0.822               | -5.687               | 2.629                | 1377.60              | 3.208                | 1.827               |
| 2x6       | 0.614      | 0.806        | 0.690                 | 1.038                  | -0.230                | -0.082              | -1.826              | -9.481               | -14.837              | 510.519              | 0.437                | 3.527               |
| 2x7       | 0.909      | 0.465        | 0.687                 | 1.086                  | -0.297                | -0.712              | -1.387              | -6.996               | 7.024                | 380.537              | -12.861              | 6.129               |
| 3x6       | 1.143      | 0.261        | 2.177                 | 3.597                  | -0.549                | -0.586              | -1.731              | -7.781               | -13.034              | 448.979              | -10.705              | 59.330              |
| 3x7       | 1.120      | 0.403        | 1.557                 | 0.262                  | -0.449                | -0.684              | -1.825              | -1.057               | -14.994              | 1574.12              | -4.103               | 161.410             |
| 3x8       | 0.183      | 0.597        | 1.134                 | 0.252                  | -0.260                | -0.553              | -0.370              | -9.414               | 1.943                | 120.859              | -0.461               | 1.879               |
| 4x7       | 0.548      | 0.746        | 0.634                 | 0.885                  | -0.620                | 1.049               | -1.244              | -7.739               | -7.410               | 2754.49               | -0.313               | 18.496              |
| 4x8       | 1.277      | 0.985        | 0.010                 | 0.833                  | 0.469                 | -0.724              | -1.288              | -8.590               | 28.479               | 234.917               | -6.537               | -0.370              |
| 5x8       | 0.775      | 0.993        | 0.069                 | 0.026                  | 0.176                 | -0.386              | 1.274               | -8.530               | -44.729              | 843.884               | 5.131                | 0.048               |
| Standard error |          |              |                       |                        |                       |                     |                     |                     |                     |                     |                     |                     |
| Si;j-sik( |            |              |                        |                       |                       |                     |                     |                     |                       |                       |                     |                     |
| 0.802     | 0.082      | 3.478        | 0.069                 | 0.026                  | 0.176                 | -0.386              | 1.274               | -8.530               | -44.729              | 843.884               | 5.131                | 0.048               |

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Table 4. Genetic parameters of some traits in partial hybrids under the influence of two plant densities in maize.

| Genetic parameters | Plant density thousands ha⁻¹ | Plant density thousands ha⁻¹ | Plant density thousands ha⁻¹ | Plant density thousands ha⁻¹ | Plant density thousands ha⁻¹ | Plant density thousands ha⁻¹ |
|--------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
|                    | 70                            | 90                            | 70                            | 90                            | 70                            | 90                            |
| σ²GCA              | 0.173                         | 0.237                         | 0.597                         | 0.48                          | 0.11                          | 0.26                          |
| σ²SCA              | 0.056                         | 0.108                         | 4.192                         | 0.45                          | 0.28                          | 0.02                          |
| σ²E                | 1.465                         | 1.202                         | 1.549                         | 2.15                          | 0.94                          | 1.05                          |
| σ²A                | 0.346                         | 0.475                         | 1.194                         | 0.97                          | 0.23                          | 0.52                          |
| σ²D                | 0.056                         | 0.108                         | 4.192                         | 0.45                          | 0.28                          | 0.02                          |
| σ²G                | 0.402                         | 0.583                         | 5.386                         | 1.42                          | 0.52                          | 0.55                          |
| H'bs               | 21.55                         | 32.664                        | 77.66                         | 39.8                          | 3.57                          | 1.60                          |
| H'as               | 18.53                         | 26.594                        | 17.22                         | 27.2                          | 3.27                          | 1.60                          |
| α                  | 0.570                         | 0.676                         | 2.649                         | 0.96                          | 1.53                          | 0.29                          |
| ΔG                 | 0.446                         | 0.625                         | 0.798                         | 0.90                          | 0.34                          | 0.73                          |
| ΔG%                | 2.214                         | 3.230                         | 2.001                         | 2.20                          | 2.45                          | 5.14                          |

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