Estimation of General Combining, and Genetic Parameters in Maize (Zea mays L.) by Using Line x Tester Crosses

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Abstract

This study was conducted in the fields of a farmer in the city of Ramadi - Anbar Governorate - Iraq, during the spring and fall seasons of (2020), where the seeds of eight pure lines of maize were planted (NadH26, Zm.69, Sy.52, Inb. 23, Am.63, NadH.52, MGW-16, Zm.6). Then the lines hybridized with each other by the method (Line x Tester) to produce 15 hybrids. Parental seed and individual hybrids planted in the fall season (2020) were compared according to the R.C.B.D with three replications, for the purpose of estimating the effects of combining ability of lines, hybrids, some genetic parameters and Hybridization for studied traits are: Number of days from planting to 50% to Silking, leaf area, dry plant weight, number of rows, number of grains per row, weight of 300 grains and plant yield. The results of the study showed significant differences between parents and their hybrids for all the studied traits, Tester (Zm.69) was superior by showing the highest effect of general combining in the desired direction for most of the traits, while the line (Am.63) showed the highest effect of general combining with the positive direction of most of the studied traits. The hybrid (Zm.69 X Zm.6) gave the highest effect of specific combining ability of the weight 300-grain and the plant yield was 3.65 and 44.15, respectively. The ratio between the variance of general and specific combining ability was less than one for most of the traits, and the dominance variance was large than the additive variance for most of the traits. The heritability broad sense was high for most of the studied traits, while the heritability narrow sense was low for all traits except for the two traits of leaf area and dry weight of the plant, and degree of dominance was large than one for most of the traits, which indicates the control of the genes of super-dominance over the inheritance of these traits. The expected genetic advance is low for all traits. The results also showed that the hybrid (MGW-16 X Sy.52) gave the highest positive hybrid compared to the best parents for the characteristics of the number of rows in ear, the number of grains per row, and plant yield, which reached (17.78%, 7.18% and 24.24%) respectively. It is concluded from this study the possibility of using some of the superior parents in their to derive individual hybrids with a specific combining ability for the production of high yield as most of their traits were under the influence of genes of superior dominance.

1. Introduction

(Zea mays L.) is one of the important summer field grain crops because it is of high nutritional value, and comes in third place in terms of cultivated area and production after wheat and rice, and it has many uses as it is used in human and animal nutrition, and is used in many industries such as plastic industry and dyes and in the production of ethanol (biofuels). This crop provides financial income to millions of people in many countries [1,2]. Increasing the productivity of the maize crop became necessary due to the increase in population density, and in Iraq, the production quantity of this crop is low, reaching 2,025 ton.ha−1 compared to the world production rate of 4.222 ton. ha−1 [3, 4]. The reason for this decline is due to the farmers’ dependence on local varieties and to move away from superior single hybrids with high productivity due to the difficulty of importing them. That is why many researchers have been interested in breeding and improving this crop, especially the Hybridization process between genetic diversity lines, which helped plant breeders to produce varieties and hybrids that superior local varieties by devising pure lines that are superior in their performance and their combining ability and selecting the best ones to obtain individual hybrids and high-production synthetic varieties. For the purpose of estimating several pure lines to produce high yield hybrids after crossing them with other lines, by (Line * Tester) analysis was used [5, 6, 7] and in
order to know the combining ability, must be on selecting suitable lines that have the combining ability to combine with other lines that are genetic different to produce hybrids, as it gives a clear picture of the ability of the line to produce a superior hybrid by crossing it with another line, [8, 9, 10]. The aim of the study in order to identify the genetic behavior, the components of the total genetic variation are divided into the additive and dominance genetic variation and the inheritance broad and narrow since, as well as degree of dominance through which one can know the type of gene action that controls the studied traits to determine the appropriate breeding method and improve it.

2. Materials and Method

The Lines were introduced into the crossing program (Line × Tester) according to the method [11]. This study was carried out in one of the fields to a farmer in the city of Ramadi - Iraq, with two agricultural seasons, spring and fall for the year (2020), where the land used was prepared to cultivate by conducting all agricultural operations on it, including plowing, smoothing, leveling and dividing according to the research requirements. The field was fertilized with compound fertilizer (NPK) at a rate of 300 kg.ha⁻¹ when preparing the soil, and urea fertilizer 46% nitrogen was added at a rate of 160 kg N. ha⁻¹ in two batches, the first during cultivation and the second at the beginning of the flowering phase. Eight pure lines of maize were used in this study Lines (1-3) were used as Testers and (4-8) Lines according to the hybridization method (Line × Tester) proposed by [11] to obtain the first-generation hybrids and their number (15) Single crosses, and self-pollination of Inbred line was conducted, so that the number of genotypes became (23) genotypes resulting from cross between (3 Testers x 5 Lines) = 15 hybrids + 8 pure lines. Then these genotypes were planted in the fall season (2020) and the area of one experimental unit was (3 x 3) m. The experimental unit consisted of (4) line with a distance of (0.75) m between the lines and (0.25) between hole and at a rate of (3) Seeds per hole were reduced to a single plant, according to a randomized complete block design (RCBD) with three replications. After the completion of the maturation process of the plant, ten plants were randomly taken from each experimental unit for the purpose of studying the following characteristics: Days to 50% to Silking day, leaf area cm², dry plant weight g plant⁻¹, number of rows in ear, number of grains in a row, weight of 300 grains g, yield of plant g.plant⁻¹.

Table 1. Lines of mays used in the study:

| No. Lines | Line symbol | Origin          |
|-----------|-------------|-----------------|
| 1         | NadH.26     | Locally devised |
| 2         | Zm.69       | Locally devised |
| 3         | Sy.52       | Locally devised |
| 4         | Inb.23      | Locally devised |
| 5         | Am.63       | Locally devised |
| 6         | NadH.52     | Locally devised |
| 7         | MGW-16      | Locally devised |
| 8         | Zm.6        | Locally devised |

2.1 Phenotypic data were collected

The computer Gene Stat program was used to analyze the averages using the lest significant difference (L.S.D) at 0.05 probability level. Then, statistical and genetic analysis was performed to estimate the combining ability, some genetic parameters, and Hybridization using the following as mentioned [12]: The effect of general gi for Lines to be evaluated was estimated according to the following equation

\[ \hat{g}_i = (X_{i.} - tr) - (X_{...} / Ltr) \]

The effect of general gt to parents used as Testers was estimated according to the following equation:

\[ \hat{g}_t = (X_{j..} / Lr) - (X_{...} / Ltr) \]

As for the effect of specific combining ability of each Si’j hybrid, it was estimated according to the following equation:

\[ \hat{S}_{ij} = (X_{ij} - r) - (X_{i.} / tr) - (X_{j..} / Lr) + (X_{...} / Ltr) \]
The standard errors of general combining ability for lines and tester and specific combining ability were estimated from the following equations:

\[
\text{S.E. (} \overline{g_i} - g_i \text{) Testers} = \sqrt{\frac{2 \cdot \text{Mse}}{rL}}
\]

\[
\text{S.E. (} \overline{g_i} - g_i \text{) Lines} = \sqrt{\frac{2 \cdot \text{Mse}}{rt}}
\]

\[
\text{S.E. (} S_{ij} - \overline{skj} \text{)} = \sqrt{\frac{2 \cdot \text{Mse}}{r}}
\]

The phenotypic variance values were obtained from the following laws:

\[
\delta^2A = 2 \delta^2gca
\]

\[
\delta^2D = \delta^2Sca
\]

\[
\delta^2G = \delta^2D + \delta^2A
\]

\[
\delta^2P = \delta^2G + \delta^2E
\]

The heritability was estimated with its broad sense (% h²b.s), narrow (% h²n.s), the degree of dominance (\(\hat{a}\)) and the expected genetic improvement (GΔ%) according to the following:

\[
\%\text{h}²\text{b.s} = \left(\frac{\delta^2G}{\delta^2P}\right) \times 100
\]

\[
\%\text{h}²\text{n.s} = \left(\frac{\delta^2A}{\delta^2P}\right) \times 100
\]

\[
\hat{a} = \frac{\sqrt{2 \delta^2D}}{\delta^2A}
\]

\[
\Delta G = \left(\frac{\Delta G}{\overline{Y}}\right) \times 100\%
\]

The Hybridization was according to the following

Heterosis (%H) = \(\frac{\overline{Y}_h - \overline{Y}_b}{\overline{Y}_b}\) \times 100

Where

BP = best parents

3. Results and discussion

The results of Table (2) showed that there were significant differences for the Mean of square for genotypes, parents and parents against hybrids, hybrids, lines, tests and (lines x tests) for all the studied traits. This is consistent with that reached by [2,6,13]. Table 3 represents the average of the studied traits where tester (Sy.52) is earlier in the traits Days to 50% to Silking, number of rows per ear and the weight of 300 grains, reaching (54.67 days, 16.53 row, 75.33 g) respectively. While the tester (Zm.69) superior in the dry weight of the plant, number of grains per row, and the plant yield, where it came with the highest average for these characteristics, which was (224.33g, 34.27 grain.row-1, 225.11 g.plant-1). As for the lines, line (Am.63) superior in the traits Days to 50% to Silking, reached 55.00 days. The same line also superior Leaf area of the plant and the plant yield was (477.4 cm², and 272.42 g.) respectively. The hybrid (NadH.26 X Inb.23) earliest to 50% to Silking an average 54.67 days. While the hybrid (Zm.69 X NadH.52) superior an average of 518.6 cm² for leaf area trait, the hybrid (Sy.52 X NadH.52) showed the highest average dry weight of the plant, which was 247.67 g, and the hybrid (Sy.52 X MGW-16) outperformed the number of rows ear with an average of 19.47 row. The hybrid (Zm.69 X MGW-16) gave the highest mean number of grains per row with 35.60 grain. In the weight of 300 grains, the hybrid (Sy.52 X Inb.23) showed the highest mean for the trait, which was 86.67 g, and the hybrid (Sy.52 X Am.63) was superior in the plant yield, as it gave the highest average for this characteristic of 298.40 g. Table (4) shows the of positive and negative effects for general combining ability, where the tester (Zm.69) showed the best effect of general combining in the desired direction of the characteristics of the number of rows in ear, the number of grains per row and the plant yield, which reached (0.38, 0.25, 50.80), respectively. As for the lines, the line (Am.63) showed the best effect of the general combining of the dry weight of the plant and the number of grains per row and the weight of 300 grains was (7.84, 1.73 and 6.02) respectively. The line (Inb.23) also gave the best effect of the general combining in the desired direction of the two traits leaf area and the number of rows in the ear was (9.54, 0.38) respectively. This indicates the ability of these two lines to transfer their desired genes to the individuals resulting from them when. These results were in agreement
with [13, 14, 15]. The results of Table (5) showed the effects of the specific combining ability for the studied traits, where eight hybrids showed a specific desired effect of the Days to 50% to Silking and the best hybrid in this trait (Zm.69 X MGW-16) was (-1.04). While the other hybrids gave Positive effect for specific ability in the opposite direction, it reached a maximum of 1.35 in the hybrid (NaH.26 X Inb.23), and this hybrid gave the highest desirable positive effect for the specific combining ability of the leaf area was (46.49). Eight hybrids showed a positive effect for specific combining, with a highest of 0.87 in the hybrid (Zm.69 X MGW-16) for the number of rows in ear. The hybrid (Zm.69 X Am.63) showed the highest desirable positive effect for the specific combining ability of the leaf area was (46.49). Eight hybrids showed a positive effect for specific combining, with a highest of 0.87 in the hybrid (Zm.69 X MGW-16) for the number of rows in ear. The hybrid (Zm.69 X Am.63) showed the highest desirable positive effect for the number of grains per row, which was 2.56. Whereas, the hybrid (Zm.69 X Zm.6) showed the maximum effect with the desired direction of the specific combining of the two grains 300 weight and plant yield was respectively 3.65 and (44.15). These results indicate that there is a variation between hybrids in their specific combining ability. This is similar to the results of [16, 17, 18].

The results of Table (6) indicate that the ratio between the variance of general and specific Combining ability was less than one for the traits Days to 50% to Silking, number of rows per ear, number of grains per row, weight of 300 grains, and plant yield, and this indicates the dominance of gene action control of these traits Whereas the ratio between the variance to the leaf area and dry weight was greater than one. And that heritability broad sense was high for all the studied traits, and this is due to the high value of genetic variation and the low environmental variation for all traits. As for the heritability narrow sense, it was low in most of the studied traits, with the except of the and dry weight characteristic. The reason for this is due to the decrease in the values of additive variance, and the improvement of these traits is through hybridization. The average for the degree of dominance was larger than one for most of the traits, indicating the control of the genes of over dominance inheritance of these traits. The expected genetic advance was low for all the studied traits, as it ranged between (0.11% and 3.37%) for the number of rows ear and leaf area. This is due to the low heritability in the narrow sense. These results were consistent [3, 19, 20].

The results in Table (7) indicated positive and negative significant values of the Heterosis for all traits studied for the best parents. The highest Heterosis of leaf area was 15.68% in the hybrid (Zm.69 X NadH.52), and the dry weight of the plant the hybrid (Sy.52 X NadH.52) Gave highest positive and significant hybridization of 10.89%. The hybrid (Sy.52 X MGW-16) also superior the number of rows in ear, as it gave the highest positive and significant hybridization of 17.78%. In the number of grains row, the hybrid (Sy.52 X MGW-16) showed the highest positive and significant hybridization, reaching 7.18% . Fourteen hybrids gave positive and significant values for a 300-grain weight trait, with a maximum of 15.05% in the hybrid (Sy.52 X Inb.23). While the hybrid (NadH.26 X Inb.23) gave a negative and significant value for the hybridization of 2.70% for this characteristic. As the results showed the superiority of the hybrid (Sy.52 X MGW-16), as it gave the highest positive and significant hybridization for the plant grain yield of (24.24%) These results were in agree with [4, 18, 21].

Table 2. Analysis of variance, Mean of sum square of the studied traits:

| S.O.V            | Days to 50% to Silking (day) | Leaf area (cm²) | Dry Weight (g. plant⁻¹) | No. of rows per ear | No. of grains per ear | 300 kernel weight (g) | Yield. Plant (g. plant⁻¹) |
|------------------|------------------------------|-----------------|--------------------------|---------------------|----------------------|----------------------|--------------------------|
| Replication      | 2                            | 41.78           | 3608.23                  | 3.30                | 0.88                 | 21.19                | 3.56                     | 4173.61                  |
| Genotypes        | 22                           | *1.72           | *2906.82                 | *225.07             | *1.91                | *10.02               | *76.52                   | *4760.32                  |
| Parents          | 7                            | *0.83           | *3550.93                 | *41.32              | *3.11                | *4.46                | *25.52                   | *4126.01                  |
| Parent×crosses   | 1                            | *5.53           | *4902.26                 | *3054.44            | *0.01                | *8.22                | *700.48                  | *15318.13                 |
| Crosses          | 14                           | *1.89           | *2442.23                 | *114.85             | *1.44                | *12.94               | *57.45                   | *4323.34                  |
| Lines            | 4                            | *1.64           | *613.08                  | *370.64             | *1.10                | *15.03               | *160.36                  | *7895.41                  |
| Testers          | 2                            | *1.35           | *5089.73                 | *22.75              | *2.49                | *0.80                | *24.88                   | *2344.89                  |
| Line×Tester      | 8                            | *0.43           | *26.81                   | *0.97               | *1.35                | *1.79                | *14.14                   | *3031.92                  |
| Experiment Error | 44                           | 0.03            | 0.59                     | 3.30                | 0.07                 | 0.09                 | 4.29                     | 122.43                   |

* At 0.05 Significant ** At 0.01 High-Significant
Table 3. Mean of the of the studied traits:

| Genotypes     | Traits                  | Days to 50% to Silking (day) | Leaf area (cm²) | Dry Weight (g. plant⁻¹) | No. of rows per ear | No. of grains per ear | 300 kernel weight (g) | Yield. Plant (g. plant⁻¹) |
|---------------|-------------------------|------------------------------|-----------------|--------------------------|---------------------|-----------------------|-----------------------|--------------------------|
| NadH.26       |                         | 57.67                        | 518.7           | 223.00                   | 15.40               | 33.73                 | 74.00                 | 184.45                   |
| Zm.69         |                         | 55.67                        | 448.3           | 224.33                   | 16.33               | 34.27                 | 74.33                 | 225.11                   |
| Sy.52         |                         | 54.67                        | 400.9           | 222.00                   | 16.53               | 29.73                 | 75.33                 | 173.41                   |
| Inb.23        |                         | 55.33                        | 426.2           | 223.67                   | 15.46               | 31.87                 | 71.33                 | 262.33                   |
| Am.63         |                         | 55.00                        | 477.4           | 223.67                   | 15.86               | 34.27                 | 71.00                 | 272.42                   |
| NadH.52       |                         | 56.33                        | 428.4           | 223.33                   | 15.00               | 36.27                 | 74.00                 | 210.40                   |
| MGW-16        |                         | 55.33                        | 462.9           | 227.00                   | 16.53               | 30.60                 | 72.79                 | 201.30                   |
| Zm.6          |                         | 55.33                        | 427.4           | 228.67                   | 17.13               | 33.73                 | 73.10                 | 225.40                   |
| NadH.26 X Inb.23 |                   | 54.67                        | 437.5           | 230.67                   | 14.46               | 31.20                 | 72.00                 | 143.61                   |
| NadH.26 X Am.63 |                    | 55.33                        | 449.8           | 233.33                   | 15.53               | 32.40                 | 74.14                 | 179.54                   |
| NadH.26 X NadH.52 |                 | 56.33                        | 454.6           | 236.33                   | 15.50               | 31.80                 | 78.10                 | 165.30                   |
| NadH.26 X MGW-16 |                    | 55.67                        | 456.5           | 234.33                   | 15.00               | 34.27                 | 83.67                 | 218.47                   |
| NadH.26 X Zm.6 |                         | 55.33                        | 455.8           | 233.33                   | 15.80               | 33.13                 | 82.33                 | 157.45                   |
| Zm.69 X Inb.23 |                         | 55.00                        | 443.4           | 238.00                   | 15.73               | 29.20                 | 81.67                 | 170.10                   |
| Zm.69 X Am.63 |                         | 54.67                        | 408.8           | 240.67                   | 15.40               | 29.53                 | 82.00                 | 188.40                   |
| Zm.69 X NadH.52 |                        | 56.33                        | 518.6           | 235.33                   | 15.86               | 32.80                 | 80.67                 | 257.14                   |
| Zm.69 X MGW-16 |                         | 55.67                        | 429.0           | 242.67                   | 15.73               | 35.60                 | 81.67                 | 198.47                   |
| Zm.69 X Zm.6  |                         | 55.00                        | 438.6           | 242.33                   | 17.26               | 33.33                 | 82.33                 | 212.40                   |
| Sy.52 X Inb.23 |                         | 56.33                        | 484.9           | 243.67                   | 18.23               | 32.53                 | 86.67                 | 221.40                   |
| Sy.52 X Am.63 |                         | 56.67                        | 468.9           | 245.33                   | 17.89               | 33.60                 | 77.33                 | 298.40                   |
| Sy.52 X NadH.52 |                        | 56.33                        | 469.7           | 247.67                   | 18.26               | 31.27                 | 85.33                 | 212.40                   |
| Sy.52 X MGW-16 |                         | 56.33                        | 488.0           | 245.00                   | 19.47               | 32.80                 | 84.33                 | 250.10                   |
| Sy.52 X Zm.6  |                         | 56.00                        | 415.3           | 245.67                   | 13.93               | 33.07                 | 83.00                 | 196.40                   |
| Average       |                         | 55.70                        | 452.59          | 234.35                   | 16.19               | 32.65                 | 78.31                 | 209.76                   |
| L.S.D 5%      |                         | 0.288                        | 0.5104          | 2.998                    | 0.439               | 0.505                 | 3.416                 | 18.249                   |

Table 4. Effects of a General Combining Ability for parents:

| Parents      | Days to 50% to Silking (day) | Leaf area (cm²) | Dry Weight (g. plant⁻¹) | No. of rows per ear | No. of grains per ear | 300 kernel weight (g) | Yield. Plant (g. plant⁻¹) |
|--------------|------------------------------|-----------------|--------------------------|---------------------|-----------------------|-----------------------|--------------------------|
| NadH.26      | 0.31                         | 16.24           | -6.37                    | 0.04                | -0.05                 | -1.42                 | -4.05                    |
| Zm.69        | -0.02                        | 3.77            | -5.93                    | 0.38                | 0.25                  | -3.86                 | 50.80                    |
| Sy.52        | -0.28                        | -20.01          | -0.71                    | -0.42               | -0.20                 | -3.34                 | -7.96                    |
| S.E. (Testers) | 0.04                        | 0.07            | 0.46                     | 0.06                | 0.07                  | 0.53                  | 2.85                     |
| Inb.23       | 0.51                         | 9.54            | 5.17                     | 0.38                | 0.17                  | 2.61                  | -12.49                   |
| Am.63        | 0.06                         | -2.46           | 7.84                     | -0.26               | 1.73                  | 6.02                  | -26.30                   |
| NadH.52      | -0.37                        | -3.87           | -1.42                    | 0.33                | -0.55                 | -1.08                 | -0.85                    |
| MGW-16       | 0.28                         | 7.20            | 0.71                     | -0.39               | 0.42                  | -0.33                 | 12.91                    |
| Zm.6         | -0.48                        | -10.41          | 0.71                     | -0.06               | -1.77                 | 1.42                  | -12.05                   |
| S.E. (Lines) | 0.05                         | 0.10            | 0.60                     | 0.08                | 0.10                  | 0.69                  | 3.68                     |
Table 5. Effects of Specific Combining ability for Hybrids:

| Crosses               | Days to 50% to Silking (day) | Leaf area (cm²) | Dry weight (g. plant⁻¹) | No. of rows per ear | No. of grains per ear | 300 kernel weight (g) | Yield. Plant (g. plant⁻¹) |
|-----------------------|------------------------------|----------------|--------------------------|---------------------|----------------------|-----------------------|---------------------------|
| NadH.26 X Inb.23      | 1.35                         | 46.49          | 1.31                     | -0.72               | 1.20                 | 0.53                  | -7.68                     |
| NadH.26 X Am.63       | -0.75                        | -20.09         | 0.08                     | 0.18                | -0.36               | -3.50                 | -5.41                     |
| NadH.26 X NadH.52     | -0.53                        | 29.61          | -0.6                     | 0.03                | -0.12               | -0.77                 | 10.16                     |
| NadH.26 X MGW-16      | 0.02                         | 3.58           | -0.04                    | -0.29               | -1.67               | 0.003                 | -14.18                    |
| NadH.26 X Zm.6        | -0.15                        | 14.91          | 1.17                     | -1.15               | -0.44               | -2.05                 | -35.45                    |
| Zm.69 X Inb.23        | -0.53                        | -34.02         | 1.53                     | -0.01               | -2.12               | 0.30                  | 13.96                     |
| Zm.69 X Am.63         | 0.02                         | 3.57           | -2.57                    | 0.11                | 2.56                | 1.41                  | -13.74                    |
| Zm.69 X NadH.52       | 0.24                         | -18.96         | -0.82                    | 0.70                | 1.63                | 0.80                  | 22.57                     |
| Zm.69 X MGW-16        | -1.04                        | -35.03         | -1.82                    | 0.87                | -2.64               | -0.64                 | -12.49                    |
| Zm.69 X Zm.6          | 0.17                         | 22.88          | -1.04                    | 0.11                | 1.64                | 3.65                  | 44.15                     |
| Sy.52 X Inb.23        | -0.08                        | 4.05           | -0.35                    | 0.44                | -1.19               | 1.24                  | 12.87                     |
| Sy.52 X Am.63         | -0.31                        | -11.45         | 0.51                     | -0.14               | 1.43                | 0.11                  | 20.18                     |
| Sy.52 X NadH.52       | 0.57                         | -2.78          | 0.95                     | -0.29               | -1.27               | -0.15                 | -38.73                    |
| Sy.52 X MGW-16        | 1.06                         | 4.40           | -0.93                    | -0.01               | 2.33                | 0.46                  | -24.13                    |
| Sy.52 X Zm.6          | -0.04                        | -7.16          | 2.62                     | 0.18                | -0.88               | -1.42                 | 27.92                     |
| S.E.                  | 0.10                         | 0.17           | 1.04                     | 0.15                | 0.17                | 1.19                  | 6.38                      |

Table 6. Genetic parameters of the studied traits

| Parameters        | Days to 50% to Silking (day) | Leaf area (cm²) | Dry weight (g. plant⁻¹) | No. of rows per ear | No. of grains per ear | 300 kernel weight (g) | Yield. Plant (g. plant⁻¹) |
|-------------------|------------------------------|----------------|--------------------------|---------------------|----------------------|-----------------------|---------------------------|
| δ²Gca              | 0.01                         | 31.49          | 3.70                     | 0.003               | 0.12                 | 1.53                  | 45.65                     |
| δ⁶Sca              | 0.13                         | 8.90           | 2.22                     | 0.42                | 0.56                 | 3.28                  | 969.83                    |
| δ⁶Gca/δ⁶Sca        | 0.12                         | 3.53           | 1.66                     | 0.007               | 0.22                 | 0.46                  | 0.04                      |
| δ²A                | 0.03                         | 62.98          | 7.41                     | 0.006               | 0.25                 | 3.06                  | 91.31                     |
| δ²D                | 0.13                         | 8.90           | 2.22                     | 0.42                | 0.56                 | 3.28                  | 969.83                    |
| δ²G                | 0.16                         | 71.89          | 9.63                     | 0.43                | 0.82                 | 6.34                  | 1061.14                   |
| δ²E                | 0.03                         | 0.09           | 3.30                     | 0.07                | 0.09                 | 4.29                  | 122.43                    |
| δ²P                | 0.19                         | 71.98          | 12.94                    | 0.50                | 0.91                 | 10.63                 | 1183.57                   |
| %H² b.s           | 84.57                        | 99.89          | 74.47                    | 85.91               | 89.77                | 59.65                 | 89.65                     |
| %H² n.s           | 17.06                        | 87.49          | 57.28                    | 1.29                | 28.08                | 28.78                 | 7.71                      |
| a                  | 2.81                         | 0.53           | 0.77                     | 11.41               | 2.09                 | 1.46                  | 4.60                      |
| %ΔG                | 0.28                         | 3.37           | 1.81                     | 0.11                | 1.69                 | 2.46                  | 2.60                      |
Table 7. Heterosis values based on the best parents for the studied traits

| Crosses               | Days to 50% to Silking (day) | Leaf area (cm²) | Dry weight (g. plant⁻¹) | No. of rows per ear | No. of grains per ear | 300 kernel weight (g) | Yield (g. plant⁻¹) |
|-----------------------|------------------------------|-----------------|-------------------------|---------------------|-----------------------|----------------------|---------------------|
| NadH.26 X Inb.23      | -1.192                       | -15.654         | 3.129                   | -6.468              | -7.500                | -2.70                | -45.25              |
| NadH.26 X Am.63       | 0.6                          | -13.283         | 4.318                   | -2.080              | -5.456                | 0.19                 | -34.09              |
| NadH.26 X NadH.52     | 0                            | -12.357         | 5.820                   | 0.649               | -12.324               | 5.54                 | -21.43              |
| NadH.26 X MGW-16      | 0.614                        | -11.991         | 3.229                   | -9.255              | 1.600                 | 0.13                 | 8.85                |
| NadH.26 X Zm.6        | 0                            | -12.126         | 2.037                   | -7.764              | -1.778                | 11.25                | -30.14              |
| Zm.69 X Inb.23        | -0.596                       | -1.093          | 6.093                   | -3.674              | -14.794               | 9.87                 | -35.15              |
| Zm.69 X Am.63        | -0.6                        | -14.369         | 7.283                   | -5.695              | -13.831               | 10.31                | -30.84              |
| Zm.69 X NadH.52      | 1.185                        | 15.681          | 4.903                   | -2.878              | -9.567                | 8.52                 | 14.22               |
| Zm.69 X MGW-16       | 0.614                        | -7.323          | 6.903                   | -4.839              | 3.881                 | 9.87                 | -11.83              |
| Zn.69 X Zm.6         | -0.596                       | -2.163          | 5.973                   | 0.758               | -2.742                | 10.76                | -5.76               |
| Sy.52 X Inb.23       | 3.034                        | 13.772          | 8.941                   | 10.284              | 2.070                 | 15.05                | -15.60              |
| Sy.52 X Am.63       | 3.658                        | -1.780          | 9.683                   | 8.227               | -1.955                | 2.65                 | 9.536               |
| Sy.52 X NadH.52     | 3.036                        | 9.640           | 10.898                  | 10.465              | -13.785               | 13.27                | 0.95                |
| Sy.52 X MGW-16      | 3.036                        | 5.422           | 7.929                   | 17.785              | 7.189                 | 11.94                | 24.24               |
| Sy.52 X Zm.6        | 2.432                        | -2.831          | 7.434                   | -18.680             | -1.956                | 10.18                | -12.86              |
| S.E                  | 0.045                        | 0.080           | 0.469                   | 0.069               | 0.079                 | 0.535                | 2.857               |

4. Conclusion
As a result of the differences between the lines, it was found that parent (Am.63) is the best parent, and he also recorded the highest seed yield (272.42 g. Plant⁻¹). In addition, hybrid (Sy.52 X Am.63) achieved a rate of (298.40 g), which superior the others of the hybrids in this trait. While the hybrid (Sy.52 X MGW-16) was the best in its record of the highest value of the hybridization, which was (24.24%), and parent (Zm.69) record the highest positive effect of general combining ability in the seed yield, which was (50.80). While the best effect of specific combining ability was in the hybrid (Zm.69 X Zm.6) and it reached (44.15). Therefore, these lines can be relied to develop hybrids that are superior in quantitative and qualitative.

References
[1] Abuali, A. I., Abdelmulla, A.A., Khalafalla, M.M., Idris, A.E. & Osman, A.M. 2012. Combining ability and heterosis for yield and yield components in maize (Zea mays L.). Australian Journal of Basic and Applied Sciences, 6(10), 36-41.
[2] Akula, D., Patil, A.P., Zaidi, P.H., Kuchanur, P., Vi-nayan, M.T. & Seetharam, K. 2018. Line x testers analysis of tropical maize inbred lines under heat stress for grain yield and secondary traits. Maydica, 61(1), 4.
[3] Al-Hazemawi, A. K. H. 2018. The combining ability and genetic diversity of maize inbred lines grown under planting dates using Simple Sequence Repeat (SSR) markers. Adissertation of Doctorate, Departement of Biology, Al.anbar University / Iraq.
[4] AL-Hazemawi, A. K. H., & Hassawi, D.S. 2020. Combining Ability Analysis of Yield and Yield Components in Maize (Zea mays L.) Using Line X Tester Method Under Heat Stress. Journal of Education and Scientific Studies, 4(15), 231-254.
[5] Al-Naggar, A.M.M., Shabana, R., Hassanein, M.S., Elewa, T.A., Younis, A.S.M. & Metwally, A.M.A. 2017. Estimation of genetic parameters controlling inheritance of maize quantitative traits under different plant densities using Line× Tester analysis. Asian Journal of Advances in Agricultural Research, 1-12.
[6] Dar, Z.A., Lone, A.A., Khuroo, N. S., Ali, G., Abidi, I., Ahangar, M.A. & Yousuf, N. 2017. Line x tester analysis in Maize (Zea mays L.) for various morpho-agronomic traits under temperate conditions. Int. J. Curr. Microbiol. App. Sci., 6(7), 1430-1437.

[7] Darshan, S. S., & Marker, S. 2019. Heterosis and combining ability for grain yield and its component characters in quality protein maize (Zea mays L.) hybrids. Electronic Journal of Plant Breeding, 10(1), 111-118.

[8] Hussain, M.A., & Mohamad, M.O. 2017. Estimation of some genetic parameters, correlation and heritability in various maize traits. Science Journal of University of Zakho, 5(1), 70-74.

[9] Hussain, M.A.H., Saaed, R.I.S., Askandar, H.S.A. & Khcther, A.A.K. 2019. Estimation of some genetic parameters and heterosis in maize by using half diallel cross. Journal of Duhok University, 22(2), 37-48.

[10] International Institute of Tropical Agriculture. 2001. Seeding the quarterly newsletter of genetic resources action international.

[11] Kempthorne, O. 1957. An Introduction to Genetic Statics, John Willey and Sons, New York.

[12] Kumar, S., Chandel, U., Guleria, S.K. & Devlash, R. 2019. Combining ability and heterosis for yield contributing and quality traits in medium maturing inbred lines of maize (Zea mays L.) using line x tester. IJCS, 7(1), 2027-2034.

[13] Kuselan, K., Manivannan, N., Ravikesavan, R. & Paranidharan, V. 2017. Combining ability analysis for yield and its component characters in maize (Zea mays L.). Electronic Journal of Plant Breeding, 8(2), 591-600.

[14] Mutlag, N.A., Fayyad, S.A., AbdulHamed Z.A., & Ibraheem, M.M. 2018. Estimation of hybrid vigor, combining ability and gene action using (line x tester) analysis in maize. The Iraqi Journal of Agricultural Science, 49(5), 740.

[15] Nataraj, V., Shaha, J.P. & Vandana, D. 2014. Estimates of variability, heritability and genetic advance in certain inbreds of maize (Zea mays L.). Int. J. of Applied Biol. and Pharmaceutical Tech., 5(1): 242-254.

[16] Nawar, A.A. 1984. Genetic analysis of earliness and yielding in maize by diallel crossing. Minufiya Journal. 9:171-189.

[17] Ramadan, A.S.A.A., Ghadeer, M.A. & Muhammad, A.A. 2020. Estimation of combining ability and gene action of maize (zea mays l.) Lines using line× tester crosses. Biochemical and Cellular Archives, 20 (1),1769-1775.

[18] Salami, H.A., Sika, K.C., padonou, W., Aiy, D., Yallou, C., Adjanojoun, A., Kotchoni, S. & Baba, L. 2016. Genetic diversity of maize accession (Zea mays L.) cultivated from benin using microsatellites markers. American J. of Molecular Bio., 6, 12-24.

[19] Singh, R.K & Chaudhary, B.D. 2007. Biometrical Methods in Quantitative Genetic Analysis. Kalyani publishers, New Delhi- Ludhiana, India. Pp: 318.

[20] Sprague, G.F. & Tatum L.A. 1942. General vs specific combining ability in single crosses of corn. J. American Soc. Agron., 34, 923-952.

[21] Wuhiab, K.M., Hadi, B.H. & Hassan, W.A. 2016. Hybrid vigor, heterosis, and genetic parameters in maize by diallel cross analysis. International Journal of Applied Agricultural Sciences, 2(1), 1-11.