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# Performance and Heterosis for the Yield Traits and Components of Maize (*Zea mays* L.) Using the Full Diallel Cross Method

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**ABSTRACT:** For the purpose of evaluating five pure lines of maize through the diallel and reciprocal crosses that resulting from it, by estimating Heterosis on basis of deviation of the average of the first generation from the higher and mean parents in the traits of growth and yield. A field experiment was conducted in spring season to perform the full diallel crosses and the autumn season of the year 2020 to compare genotypes in a comparison experiment using RCBD. The results showed significant differences in the traits of days to 50% silking, plant height, number of ears per plant, number of grains per row, 300-grain weight, and grains yield per plant, indicating the variation of the pure lines involved in hybridization. Pure line (5) showed superiority in the number of ears per plant, number of grains per row, 300-grain weight, and grains yield per plant, pure line (3) was distinguished of days to 50% silking trait and pure line (2) in plant height trait. The cross (1×5) was the best diallel crosses at all the studied traits. Regarding the reciprocal crosses, the crosses were superiority as the following : (4×2) in traits of days to 50% silking, and cross (4×3) in the plant height and the two crosses (4×1) and (5×4) in the number of ears per plant trait and (2×1) number of grains per row trait and cross (5x2) in 300-grain weight trait, and cross (4×1) in the grains yield per plant trait. While the results of Heterosis, on basis of deviation of the average of the first generation from average parents, showed that cross in days to 50% silking, 13 crosses in plant height, 20 crosses for the number of ears per plant, and the number of grains per row, 14 crosses in 300-grain weight and 20 crosses in grains yield per plant gave Heterosis in the desired direction in diallel and reciprocal crosses, the values highest of Heterosis in grains yield per plant trait were 26.66% for the diallel cross (1×5). As for the Heterosis based on basis of deviation of the average of the first generation from higher parents was (3) crosses in days to 50% silking, 16 crosses in plant height, 19 crosses for the number of ears per plant and number of grains per row, 8 crosses in 300-grain weight and 20 crosses in grains yield per plant gave the hybrid strength in the desired direction in reciprocal and reverse hybrids, the highest values of Heterosis in grains yield per plant were 47.48% for the cross (1×5). It can be concluded that Heterosis depends on the diversity between the pure lines, which was clear in the pure lines (1) and (5).

**Key words**: maize, evaluation, Heterosis, full Diallel cross, (*Zea mays* L.).

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## INTRODUCTION

Maize (*Zea mays* L.) is an important strategic crop in many regions of the world and ranks third after wheat and rice in terms of cultivated area and production. Its grains consume as human food and as a concentrated diet for poultry and animals because it contains carbohydrates, starch, and some vitamins in addition to the use of its vegetative parts as animal food. (Sweed and Al-Jumaily, 2017). Therefore, plant breeders were interested in production increasing and improving the quality of this economic crop, in terms of exploiting the heterosis phenomenon (Hamdalla, 2011). Every part of the maize plant has economic importance such as the grains, leaves, stems and silking that used to produce hundreds of food and non-food products. The main purpose of plant breeding is to develop pure lines and hybrid pure lines that surpass the parents in some important traits (Dawod *et al.*, 2012). A diallel cross between different parent is one of the important mating systems Through which it was possible to reach conclusions about the nature of the genes work and general and specific combining ability with an estimation of some genetic parameters through which it is possible to determine the best method for crop breeding, in addition to benefit of the phenomenon of heterosis, that garnered attention the interest of the breeder of this crop. Many researchers and plant breeders have used pure lines of maize in full diallel cross programs such as Ibraheem and Hamadi (2010), Ramadan (2010), Rovaris *et al.* (2017). Ramadan *et al.* (2020) studied the full diallel cross between six pure lines of maize, the study indicated that heterosis, calculated on basis of deviation of the average of the first generation from the higher parents, had positive and negative values for all the studied traits of diallel and reciprocal crosses except the number of ears per plant and grains yield per plant gave positive values in reciprocal crosses. Similarly, Ahmed and Al- Hamadany (2014) studied the method of a complete diallel cross between eight pure lines of maize and obtained heterosis with positive and negative values calculated on basis of deviation of the average of the first generation on higher and mean parents in the studied traits. Also, Wuhiab *et al.* (2016a), studied five pure lines of maize using the full diallel cross and found that heterosis on the basis of the best parents had positive and negative values for diallel and reciprocal crosses for the traits of the number of ears per plant, 100-grain weight, and grains yield per plant. Ishola (2016) used the full diallel cross of eight pure lines of maize and confirmed that heterosis values calculated on the basis of average and best parents were positive and negative values for diallel and reciprocal crosses of grains yield per plant trait. Abed *et al.* (2017), tested the full diallel cross on five pure lines of maize, the study found that heterosis on the basis of the highest parents was positive and negative values for traits of plant height and grains yield per plant. Yuwono *et al.* (2017), conducted a study on the full Diallel cross, obtained negative and positive heterosis values for days to 50% silking and plant height compare to the best parents in diallel crosses, Al-Obaidi (2018), when used the full Diallel cross of six pure lines of maize, found that diallel and reciprocal crosses gave positive and negative heterosis on the basis of the best parents for studied traits of plant height, grains yield per plant, number of grains per row, 300-grain weight, and grains yield per plant.

Sugiharto *et al.* (2018), when using the full diallel cross between 7 pure lines of maize, found that heterosis calculated on the basis of best parents had positive values for both diallel and reciprocal crosses in grains yield per plant trait. Amoon (2019), used a five pure lines of maize,

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mentioned that heterosis calculated on the basis of the best parents was positive and negative values for all the studied traits except for the two traits of plant height and number of grains per row which were positive values, while number of ears per plant was not significant. Ali *et al.* (2020) indicated when using eight pure lines of maize by using full diallel cross that heterosis was positive values in diallel and reciprocal crosses of the plant height traits on basis an higher and mean parents in the number of grains in the row were positive and negative values on basis an higher and mean parents, except for reciprocal crosses, it's had positive values based on the basis of the average parents, while in 100 grain weight trait, they had positive and negative values, except for diallel crosses, which had positive values on the basis of average parents. The aim of this study was to introduce a group of pure lines (five pure line) in a full diallel cross program in order to estimate heterosis on basis of deviation of average of the first generation from best parents and general and specific combining ability.

## MATERIALS AND METHODS

A field experiment was carried out in AL-Anbar Governorate/ city of Ramadi- the village of Albu Shaban in the spring and autumn seasons of 2020 using five pure lines of maize, namely ART-B-17, Zm-1, SYn-33, Inb-27, and Zm-5, which provided by the Department of Agricultural Research/ Abu Ghraib Research Station, soil service operations were conducted, included plowing, smoothing, leveling, and fertilization. The fertilization rate was as the following N: P (18:18) at the rate of 400 kg/h. The seeds of pure lines were planted in the spring season on 20/3/2020. The spacing between two adjacent furrows and pits were 0.75 and 0.25 m respectively, at the rate of 2-3 seed per pit, urea fertilizer (46% N) was applied with the rate of 400 kg.h-1, split into two batches, the first was applied after 30 days of emergence and the second at flowering. Weeds control was carried out after the first irrigation and before germination, for this purpose, Atrazine was used at a concentration of 80% at a rate of 3.2 kg/ ha. During the growing season, the crop service operations were conducted such as irrigation, weeding, and hoeing, and the maize leg borer insect (*Sesamia Criteca*) was controlled using the granulated diazinon pesticide 10% topically applied twice using feeding method, the first treatment was at the 6-leaf stage and the second was after 20 days from the first control, these processes were in both seasons. When the female inflorescences appeared and before the emergence of silking, it was covered with paper bags to avoid open pollination and to ensure access to the required crosses, while the male was covered with paper bags a day before the start of the pollination process and after the release of pollen grains, the hybridization process continued until all the required crosses between the five pure lines were completed, at a rate of five ears for each cross to ensure that sufficient seeds would be obtained for planting in the comparison experiment.

the full diallel cross was carried out between pure lines in two directions diallel and reciprocal crosses, using the approach of Griffing method 1 with the fixed model, so the number of genotypes is the result is equal to $p^2$. The seeds of the pure lines were propagated by self-pollination, and at the end of the season, the plantains produced from the pure lines and crosses were dried and squandered separately for the purpose of using them in a comparison experiment that included the pure lines and first-generation F1 hybrids (diallel and reciprocal crosses). Pure lines and Single crosses seed were planted on 27/7/2020 in the comparison experiment, which

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consisted of 10 diallel single crosses and 10 reciprocal single crosses, the space between the two adjacent furrows was 0.75 m while the space between the two adjacent pits was 0.25 m. Two lines with 7 m length for every single cross with three replications according to Randomize Complete Block Design (R.C.B.D) were used taking into account all agricultural operations to serve the soil and crop. The data for each of the traits under study were taken i.e., days to 50% silking, plant height (PLH), number of ears per plant (NEPP), number of grains per row (NGPR), 300-grain weight (300 GW), and grains yield per plant (GY) after weight adjustment to 15.5% moisture content (wolf *et al.* 2000). Statistical analysis of each trait was carried out according to a randomized complete block design (RCBD) according to the fixed territory model mentioned by Steel and Torri (1980). The arithmetic means of the hybrids in the studied traits were tested using the least significant difference (L.S.D) with probability levels 0.05 and 0.01. Owing to the presence of significant differences between the genetic crosses, the data for each trait of the study were analyzed genetically according to the approach of Griffing method 1 with the fixed model

heterosis of diallel and reciprocal crosses was estimated based on the basis of the average and best parents (diallel and reciprocal), according to the following equation: (Singh and Chaudhary, 2007):

$$\text{Heterobeltiosis}\ \% = \overline{\text{F1}} - \overline{\text{BP}}/\overline{\text{BP}} \times 100$$

$$\text{Heterosis}\ \% = \overline{\text{F1}} - \overline{\text{MP}}/\overline{\text{MP}} \times 100$$

**Results and Discussion**

The results of the analysis of variance for the studied traits of mean squares of genotypes, which includes the pure lines, diallel and reciprocal crosses were significant at a significance level of 1% for all studied traits, this indicates differences between the genotypes under study as a result of having different genes for the studied traits, consequently, this difference allows us to conduct the genetic analysis for these traits to determine the superior pure line, diallel and reciprocal crosses and include it in breeding and improvement programs. Table (1) indicates that the average trait in pure lines and diallel and reciprocal crosses in days to 50% silking trait was 67.24 days, and the pure line (1) took the longest period reached 69.33 days, while the pure line (3) took the least period reached 68.01 days, this great genetic variation between the pure lines in days to 50% silking trait led to significant differences in these traits for diallel and reciprocal crosses, it was found that cross (1×5) was the earliest hybrids which took 64.09 days, while cross (1×3) was late in days to silking took 69.28 days, while in reciprocal crosses, cross (4×2) was the earliest reciprocal crosses, which took 65.12 days, while cross (3×2) was late in days to silking took 70.46 days, and this difference in days to 50% silking shows the role of cytokinesis and interaction between it and nuclear genetics in controlling inheritance of this trait. Pure line (2) gave the highest average in plant height trait, reached 198.96 cm, while pure line (1) gave the lowest average for this trait, which was 168.56 cm. The genetic divergence between the pure lines was clearly reflected in diallel and reciprocal crosses resulting from it, the diallel cross (1×5) gave the highest average for the trait was 191.52 cm, while the cross (1×4) gave the lowest values reached 174.05 cm, whilst the reciprocal cross (4×3) gave the highest averages reach 189.18 cm and the reciprocal cross (4×2) gave the lowest values reach 177.84 cm. the number of

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ears per plant is one of the main components of the yield of maize, and the number of ears per plant differs according to the types and varieties used, the genotypes present in Iraq are not from a multi-group of ears (Elsahookie, 1990). As pure line (5) gave the highest average for the trait of 1.44 ear/ plant, while pure line (4) gave the lowest averages for the trait reached 1.00 stem/plant. The genetic divergence between the strains was clearly reflected in the diallel and reciprocal crosses resulting from it, as the cross (1×5) gave the highest number of ears per plant, which reached 1.44, while the reciprocal crosses (4×1) and (5×4) gave the highest number of ears per plant was 1.31 ear/ plant, while the lowest number of ears per plant was shown by the crosses (2×3) and (4×5), reaching 1.12 ear/ plant, and for the reciprocal cross (4×3) reached 1.08 ear/ plant. So as to the number of grains per row, pure line (5) showed the highest average reached 38.54 grains/ row, while the pure line (1) gave the lowest average for the trait reached 30.53 grains/ row, while the cross (1×5) showed the highest average for the trait reached 49.05 grain/row. In reciprocal crosses, the cross (2×1) gave the highest average of the trait, reached 46.24 grain/ row, while the lowest averages in diallel crosses were shown by the cross (1×2) reached 32.65 grain/ row, and in the reciprocal crosses the cross (5×3) gave the lowest average was 42.55 grain/ row.

Whereas, in the 300-grain weight trait, pure line (5) had the highest mean for the trait, reaching 89.16 for the two pure lines, while pure line (2) gave the lowest average for the trait was 72.45. These significant differences between the pure lines were reflected in the resulting hybrids, the cross (1×5) gave the highest average reach 90.17 g, while the reciprocal cross (5×2) gave the highest average reach 86.25 g, and the lowest average for the cross was shown by the cross (1×2) was 81.16 g and the reciprocal cross (3×1) was 81.08 g.

**Table (1) value means of pure lines and crosses (diallel and reciprocal) of the studied traits in maize by full diallel cross method 2020**

| Traits / Genotype | DTS | PLH | NEPP | NGPR | 300 GW | GY |
|---|---|---|---|---|---|---|
| **1** | 69.33 | 168.56 | 1.12 | 30.53 | 75.24 | 121.33 |
| **2** | 68.09 | 198.96 | 1.01 | 36.54 | 72.45 | 134.93 |
| **3** | 68.01 | 182.06 | 1.01 | 32.43 | 82.35 | 126.73 |
| **4** | 68.57 | 172.56 | 1.00 | 34.63 | 84.65 | 130.84 |
| **5** | 75.01 | 168.60 | 1.14 | 38.54 | 89.16 | 156.73 |
| **1x2** | 67.14 | 176.87 | 1.23 | 38.65 | 81.16 | 157.24 |
| **1x3** | 69.28 | 182.93 | 1.28 | 44.76 | 83.75 | 161.35 |
| **1x4** | 66.11 | 174.05 | 1.33 | 46.72 | 85.09 | 174.10 |
| **1x5** | 64.09 | 191.52 | 1.44 | 49.05 | 90.17 | 231.15 |
| **2x3** | 65.13 | 182.54 | 1.12 | 44.74 | 83.46 | 163.76 |
| **2x4** | 65.00 | 184.74 | 1.23 | 46.12 | 86.17 | 157.84 |
| **2x5** | 67.03 | 180.99 | 1.18 | 45.17 | 84.14 | 187.11 |
| **3x4** | 65.09 | 185.92 | 1.18 | 42.65 | 83.43 | 182.44 |
| **3x5** | 67.01 | 184.79 | 1.16 | 46.53 | 85.04 | 188.16 |
| **4x5** | 66.03 | 181.56 | 1.12 | 42.86 | 83.13 | 180.24 |
| **2x1** | 66.09 | 186.26 | 1.25 | 46.24 | 81.17 | 159.35 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| **3x1** | 67.11 | 186.84 | 1.26 | 44.35 | 81.08 | 180.54 |
| **3x2** | 70.46 | 188.96 | 1.20 | 44.07 | 82.17 | 177.23 |
| **4x1** | 66.22 | 181.74 | 1.31 | 45.08 | 81.55 | 186.35 |
| **4x2** | 65.12 | 177.84 | 1.24 | 44.26 | 84.03 | 171.65 |
| **4x3** | 67.09 | 189.18 | 1.08 | 43.85 | 85.09 | 170.26 |
| **5x1** | 70.18 | 178.86 | 1.17 | 45.75 | 82.14 | 182.36 |
| **5x2** | 66.00 | 181.96 | 1.27 | 44.26 | 86.25 | 181.09 |
| **5x3** | 66.05 | 186.75 | 1.28 | 42.55 | 82.04 | 180.43 |
| **5x4** | 65.82 | 188.54 | 1.31 | 46.13 | 83.33 | 183.66 |
| **G. Mean** | 67.24 | 182.54 | 1.20 | 42.66 | 83.13 | 169.07 |
| **L.S.D 5%** | 1.710 | 0.167 | 0.011 | 0.040 | 0.052 | 0.046 |
| **L.S.D 1%** | 2.282 | 0.223 | 0.015 | 0.054 | 0.069 | 0.061 |

In the trait of grains yield per plant, pure line (5) had the highest average of the trait was 156.73 g/ plant, while the lowest average was 121.33 g/ plant was given by the pure line (1). In diallel cross 231.15 g/ plant was given by the cross (1×5), while the lowest average for the trait in diallel crosses was 157.737 g/ plant for the cross (1×2), while diallel crosses differed from a reciprocal cross, where the highest mean of the trait was 186.35 g/ Plant for the cross (4×1), while the lowest average was 159.35 g/ plant for the cross (2×1).

**Heterosis Relative to Higher Parents:**

The results listed in Table (2) show that the Heterosis relative to the highest parents of the studied traits in maize was negative and significant values for (9) diallel hybrids and (8) reciprocal hybrids and their positive and significant values are diallel hybrid and two reciprocal hybrids, where the highest Heterosis of the significant negative early was reached in diallel Cross -4.54% for the cross (2×4), while the highest positive Heterosis was 1.87% for the cross (1×3). Regarding the reciprocal crosses, the highest positive Heterosis was significantly negative for the earliest parents in the cross (4×1). That was -7.09%, while the cross (3×2) showed the highest value in the positive significant direction for Heterosis relative to the highest parents, which was 3.60%. The hybrids that gave positive values for the strength of the hybrid indicated that the trait was under the control of the partial dominance genes of the early pure line, and the hybrids that gave a negative value for Heterosis indicated that the trait was under the control of the genes of the super-dominance. The increase in early female flowering in hybrids compared with the strains was a result of gene recombination, which includes the production of genes such as the Early Phase gene, which affects the Juvenile phase, which ends the growth period of the maize crop due to the increased rate of crop growth. These results are consistent with the results of Ibraheem and Hamadi (2010), Ramadan (2010), Ahmed and Al-Hamdani, (2014), Yuwono *et al.* (2017), Abed and Hammadi (2018), and Amoon (2019) in their attainment of positive and negative Heterosis in diallel and reciprocal crosses in days to 50% silking trait. Heterosis was of positive and negative values in diallel and reciprocal crosses of the plant height trait, Table (2) as diallel crosses were positive and negative significant in (3) crosses, as the highest positive values reached 13.59% for the cross (1×5), and in negative crosses the highest values of Heterosis were -9.03% for the cross (2×5), while in reciprocal crosses it had positive significant values in (8) crosses and negative significant values in one cross, as the highest values of Heterosis reached

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9.26% for the cross (5×4), And in a negative direction, it was -6.38% for the cross (2×1). This indicates the genetic divergence between the pure lines involved in diallel and reciprocal crosses. These results are in agreement with Ibraheem and Hamadi (2010), Ahmed and Al-Hamdani (2014), Abed *et al.* (2017), Yuwono *et al.* (2017) Al-Obaidi (2018) and Ali *et al.* (2020) in their obtaining positive and negative Heterosis in diallel and reciprocal crosses in plant height trait. Differences in trait of number of ears per plant in Table (2) between the pure lines led to the emergence of a positive Heterosis in their diallel crosses in (9) crosses and a negative Heterosis in one cross, while in reciprocal crosses it had positive significant values at all crosses, and this indicates that the dominant genes As such, was super-dominant in the crosses that gave positive values for Heterosis and partial dominance in the crosses that gave negative values for Heterosis, as the cross (1×5) gave the highest positive significant value in diallel cross reached 26.32%, while the highest positive value for Heterosis in reciprocal crosses was 22.77% for the cross (4×2), while the cross (4×5) had a negative non-significant value of Heterosis in diallel crosses reached -1.75%, while reciprocal crosses did not give any negative values. These results are in agreement with the results of Wuhiab *et al.* (2016a), Abdel-Moneam *et al.* (2014), Wuhiab *et al*. (2016b), Al-Obaidi (2018), Abed and Hammadi (2018) in obtaining positive and negative Heterosis in diallel crosses, and with Ramadan (2010) in obtaining Positive values in all reciprocal crosses in number of ears per plant trait. The nuclear and cytoplasmic genetic divergence between the pure lines in number of grains per row trait in Table (2) led to the difference in the type of the Controlling gene action on the trait within and between diallel and reciprocal crosses, as Heterosis was positive and the significant of all diallel and reciprocal crosses, which illustrates the control of the genes of the super-dominance of the higher pure line as such in all crosses. The cross (1×3) showed the highest positive value for Heterosis in diallel crosses, reaching 38.02%, while the highest positive value in reciprocal crosses was 36.76% for (3×1). These results agree with Abdel-Moneam *et al.* (2014) who reported a positive Heterosis in all crosses number of grains per row trait. The results of Table (2) indicate that (3) diallel crosses and one reciprocal cross show positive significant values for Heterosis in 300 grain weight trait, where the cross (1×2) gave the highest significant positive value for heterosis in diallel crosses reach 7.87%, while the cross (2×1) gave a positive significant value for Heterosis in reciprocal crosses, reached to 7.88%. crosses in which the mean of the trait deviated from the mean of the best parent in a negative direction was (4) diallel crosses and (5) reciprocal crosses all gave negative and significant values of Heterosis the highest value was negatively in the diallel crosses -6.76% for the cross (4×5) and the reciprocal crosses -7.99% in the cross (2×5), and these results are consistent with the results of Ibraheem and Hamadi (2010), Ramadan (2010), Ahmed and Al-Hamdani ( 2014), Abdel-Moneam *et al.* (2014), Wuhiab *et al.* (2016a), Wuhiab *et al*. (2016), Al-Obaidi (2018), Abed and Hammadi (2018), Amoon (2019), Ali *et al*. (2020) in obtaining of positive and negative Heterosis in diallel and reciprocal crosses. Also, the table shows that the values of Heterosis in grains yield per plant trait were positive and significant for all diallel and reciprocal crosses. this illustrate to control super-dominance genes of the superior pure line on the trait in these crosses, where the cross (1×5) showed the highest positive value for Heterosis in diallel crosses, at 47.48%, while the highest positive value in reciprocal crosses was 42.46% for the cross (3×2). This is in agreement with Ramadan (2010), Sugiharto *et al*. (2018),

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Ali *et al.* (2019) in having positive Heterosis in all diallel and reciprocal crosses in plant yield trait.

**Table (2) Heterosis HP% relatively to the higher parents for the studied traits in maize by full diallel cross method 2020**

| Traits / Genotype | DTS | PLH | NEPP | NGPR | 300 GW | GY |
|---|---|---|---|---|---|---|
| **1x2** | -1.40 | 4.93 | 9.82 | 5.77 | 7.87 | 16.53 |
| **1x3** | 1.87 | 0.48 | 14.29 | 38.02 | 1.70 | 27.32 |
| **1x4** | -3.59 | 0.86 | 18.75 | 34.91 | 0.52 | 23.99 |
| **1x5** | -7.56 | 13.59 | 26.32 | 27.27 | 1.13 | 47.48 |
| **2x3** | -4.26 | -8.25 | 10.89 | 22.44 | 1.35 | 21.37 |
| **2x4** | -4.54 | -7.15 | 21.78 | 26.22 | 1.8 | 16.98 |
| **2x5** | -1.56 | -9.03 | 3.51 | 17.20 | -5.63 | 19.38 |
| **3x4** | -4.29 | 2.12 | 16.83 | 23.16 | -1.44 | 28.61 |
| **3x5** | -1.47 | 1.50 | 1.75 | 20.73 | -4.62 | 20.05 |
| **4x5** | -3.70 | 5.22 | -1.75 | 11.21 | -6.76 | 15.00 |
| **2x1** | -2.94 | -6.38 | 11.61 | 26.55 | 7.88 | 18.10 |
| **3x1** | -1.32 | 2.63 | 12.50 | 36.76 | -1.54 | 42.46 |
| **3x2** | 3.60 | 3.79 | 18.81 | 35.89 | -0.22 | 31.35 |
| **4x1** | -7.09 | 5.32 | 16.96 | 30.18 | -3.66 | 42.43 |
| **4x2** | -5.03 | 3.06 | 22.77 | 27.81 | -0.73 | 27.21 |
| **4x3** | -1.35 | 3.91 | 6.93 | 26.62 | 0.52 | 30.13 |
| **5x1** | 1.23 | 6.09 | 2.63 | 18.71 | -7.87 | 16.35 |
| **5x2** | -3.07 | 7.92 | 11.40 | 14.84 | -3.26 | 15.54 |
| **5x3** | -2.94 | 2.58 | 12.28 | 10.40 | -7.99 | 15.12 |
| **5x4** | -4.01 | 9.26 | 14.91 | 19.69 | -6.54 | 17.18 |
| **SE Di.** | 0.80 | 2.22 | 2.88 | 3.11 | 1.38 | 3.00 |
| **SE Rec.** | 0.97 | 1.34 | 1.82 | 2.75 | 1.50 | 3.41 |

**Heterosis Relative to Mean Parents:**

The genetic divergence between the pure lines was reflected in heterosis of the resulting hybrids in Table (3), which shows heterosis relative to mean parents to the studied traits, wherein days to 50% silking trait, the negative and significant values were in (9) diallel and reciprocal crosses, and their positive and significant values were one diallel cross and one reciprocal cross, where the highest significant negative heterosis in diallel crosses reached -11.20% for the cross (1×5), while the positive heterosis of the diallel cross (1×3) was 0.89%, and the reciprocal crosses had the highest values of the negative heterosis Relatively of the mean of the two parents of the cross (5×4) was -8.32%, while the cross (3×2) showed a value in the positive significant direction of the heterosis reached 3.54%. The hybrids that gave positive values for the heterosis indicated that the trait was under the control of the partial dominance genes of the early pure line, and the hybrids that gave a negative value for the heterosis indicated that the trait was under the

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control of the genes of the super-dominance. These results are in agreement with the results of Ahmed and Al-Hamdani (2014) and Al-Falahy (2015) who reported positive and negative heterosis in diallel and reciprocal crosses in days to 50% silking trait.

Regarding the plant height trait, Table (3), heterosis of the diallel cross was positive and significant in (5) crosses and negative significant in two crosses, where the highest positive crosses values reached 13.61% for the cross (1×5). In negative crosses, the highest values of heterosis were -4.18% for the cross (2×3), while the reciprocal crosses had positive significant values in (6) crosses and negative significant values in one cross, where the highest values of heterosis in the positive direction reached 10.53% for the cross (5×4), and in the negative direction the significant mean was -4.26% for the cross (4×2). This indicates the genetic divergence between the pure lines involved in diallel and reciprocal crosses. These results are in agreement with Ahmed and Al-Hamdani (2014) who reported positive and negative heterosis in diallel and reciprocal crosses in plant height trait. In terms of the number of ears per plant, the heterosis was positive in all diallel and reciprocal crosses, and this indicates that the genes controlling the trait were super-dominant, where the cross (1×5) gave the highest positive significant value in diallel crosses, which reached 27.43%, whereas, the highest positive value of the hybrid strength in reverse hybrids was 23.58% for the cross (4×1), while the cross (4×5) had the lowest positive heterosis in diallel crosses reached to 4.67%, and the cross (5×1) had the lowest heterosis positive significant in reciprocal crosses was 3.54%. heterosis in the number of grains per row traits Table (3) showed the difference in the type of the genetic action that controlling the trait within and between the diallel and reciprocal crosses, where heterosis was positive and significant in all diallel and reciprocal crosses, which illustrates the control of the genes of Super dominance of the higher pure line on the trait in all crosses. The cross (1×4) showed the highest positive value for heterosis in diallel crosses reached 43.40%, and the lowest value reached 15.25% in the cross (1×2), while the highest positive value in reciprocal crosses reached 40.88% in the cross (3×1), and the lowest heterosis in the cross (5×2) was 17.90%, These results are in agreement with Al-Falahy (2015) and Ali *et al.* (2020) who obtained positive heterosis in reciprocal crosses in the number of grains per row trait. And also consent with Abdel-Moneam *et al.* (2014) in obtaining positive heterosis in diallel and reciprocal crosses in the number of grains per row trait. heterosis in 300-grain weight trait in diallel crosses was positive and significant in (7) crosses and negative significant in one cross, while in reciprocal crosses had positive significant values in (7) crosses and negative significant values in both crosses, where the cross (1×2) gave the highest significant positive value for heterosis in diallel crosses was 9.91%, while the cross (2×1) gave a positive significant value for heterosis in reciprocal crosses that reached 9.92%. The highest value in the negative direction in diallel crosses was -4.34% for the cross (4×5) and reciprocal crosses 4.33% for the cross (3×5), and these results are in accord with the results of Ahmed and Al-Hamdani (2014) Al-Falahy (2015) and Abdel-Moneam. *et al.* (2014) in their obtaining positive and negative heterosis in diallel and reciprocal crosses in 300-grain weight trait.

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**Table (3) Heterosis MP% Relatively to the Mean parents for the studied traits in maize by full diallel cross method 2020**

| Traits / Genotype | DTS | PLH | NEPP | NGPR | 300 GW | GY |
|---|---|---|---|---|---|---|
| **1x2** | -2.28 | -3.75 | 15.49 | 15.25 | 9.91 | 22.72 |
| **1x3** | 0.89 | 4.35 | 20.19 | 42.19 | 6.29 | 30.09 |
| **1x4** | -4.12 | 2.05 | 25.47 | 43.40 | 6.44 | 38.08 |
| **1x5** | -11.20 | 13.61 | 27.43 | 42.03 | 9.70 | 66.26 |
| **2x3** | -4.29 | -4.18 | 10.89 | 29.74 | 7.83 | 25.17 |
| **2x4** | -4.87 | -0.55 | 22.39 | 29.61 | 9.70 | 18.78 |
| **2x5** | -6.32 | -1.52 | 9.77 | 20.32 | 4.13 | 28.31 |
| **3x4** | -4.69 | 4.86 | 17.41 | 27.20 | -0.08 | 41.66 |
| **3x5** | -6.29 | 5.40 | 7.91 | 31.13 | -0.83 | 32.76 |
| **4x5** | -8.02 | 6.44 | 4.67 | 17.15 | -4.34 | 25.35 |
| **2x1** | -3.81 | 1.36 | 17.37 | 37.89 | 9.92 | 24.37 |
| **3x1** | -2.27 | 6.58 | 18.31 | 40.88 | 2.90 | 45.56 |
| **3x2** | 3.54 | -0.81 | 18.81 | 27.79 | 6.16 | 35.47 |
| **4x1** | -3.96 | 6.55 | 23.58 | 38.37 | 2.01 | 47.80 |
| **4x2** | -4.70 | -4.26 | 23.38 | 24.38 | 6.98 | 29.17 |
| **4x3** | -1.76 | 6.69 | 7.46 | 30.78 | 1.90 | 32.20 |
| **5x1** | -2.76 | 6.10 | 3.54 | 32.47 | -0.07 | 31.17 |
| **5x2** | -7.76 | -0.99 | 18.14 | 17.90 | 6.74 | 24.18 |
| **5x3** | -7.64 | 6.51 | 19.07 | 19.91 | -4.33 | 27.31 |
| **5x4** | -8.32 | 10.53 | 22.43 | 26.09 | -4.11 | 27.73 |
| **SE Di.** | 0.80 | 2.22 | 2.88 | 3.11 | 1.38 | 3.00 |
| **SE Rec.** | 0.97 | 1.34 | 1.82 | 2.75 | 1.50 | 3.41 |

Also, the results indicated that the values of heterosis in grains yield per plant trait were positive and significant for all the diallel and reciprocal crosses, which explains the control of the genes of Super dominance of the higher pure line on the trait in these crosses, where the cross (1×5) showed the highest positive value for heterosis in diallel crosses was 66.26%, The lowest heterosis in diallel crosses was for the cross (2×4), reached 18.78%. While the highest positive value in reciprocal crosses was 47.80% for the cross (4×1), and the lowest heterosis in reciprocal crosses was 24.18% for the cross (5×2). the results were in agreement with Ahmed and Al-Hamdani (2014) and Ishola (2016) in their obtaining positive and negative heterosis in diallel and reciprocal crosses in grains yield per plant, and with Abdel-Moneam *et al.* (2014), Al-Falahy (2015), Ali *et al.* (2019) who reported positive heterosis in diallel and reciprocal crosses in grains yield per plant.

**Conclusion:**

It can be concluded that the Heterosis depends on the diversity between the pure lines, which was evident in pure lines (1) and (5), which was reflected in diallal and reciprocal crosses.

Therefore, diallal and reciprocal crosses can be used superior in the production of double and 3-way hybrids.

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