Study of Combining Ability and Hybrid Vigor in Many Maize lines Zea mays L.

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Abstract. In this study, nine pure maize lines were tested, in the analytical program (Line X Tester), during spring season 2020 to obtain individual hybrids which are 20. Parents and the resulting individual hybrid seeds were cultivated in the autumn season 2020 in accordance with random complete block design R.C.B.D. in three replicates to estimate the general and specific combining ability, some genetic parameters, and study the hybrid vigor by the best parents. The statistical analysis results showed significant differences between parents and individual hybrids for every studied character. Tester (ART-B-17) showed superiority with the highest positive effect of the general combining ability for grains number per row, weight of 300 grains and grains yield per plant where it gave 51.81, 7.71, and 45.74 respectively. The line (Zm4) has the most desired effect with regard to the general combining ability for the parameters; the height of upper cob, plant height, number of grains per row, number of cobs per plant and, weight of 300 grains, and single plant grains yield (10.53, 11.48, 2.89, 0.08, 29.28) respectively. The hybrid (Zm3 x ART-B-17) gave the highest wanted effect for the specific combining ability for the following traits; the height of upper cob, number of cobs per plant and single plant grains yield 13.34, 0.15 and 48.46 respectively. The genetic analytical results showed the presence of additive non-additive effects that control the parameters inheritance. Percentages of broad and narrow sense heritability for grains crop parameter reached 100 % and 30.95% respectively, while the average degree of dominance for the same parameter reached 2.11. the hybrid (Zm4 x S6) achieved the highest positive hybrid vigor for single plant grains yield (64.45%). In conclusion, this study showed the possibility to use some dominant parental crosses to obtain single hybrids with high grain yield because the single plant grains yield parameter was complying the effect of highly dominant genes.

1. Introduction:
Maize Zea mays L. is considered a grainy, mixed pollination crop which is easily breed and enhanced and particularly hybridized. Maize is widely cultured and comes third in economic importance following wheat and rice [1]. It's used as a human food and animal fodder due to seeds contain of starch, proteins, vitamins, oil, and minerals. In addition, it used for biofuel production [2]. The total area that has been cultured with this crop reached 57.2 thousand hectares in Iraq 2017, which produced 185.3 thousand tons with productivity average of 3.32 ton.hec⁻¹ [3].

The productivity of this crop In Iraq decreases in large areas due to the lack of understanding the important of culturing genotypes with high productivity, especially the dominant individual hybrids that suits the Iraqi environment for their difficult import, or maybe the ignorance about soil and crop maintenance processes. To improve maize productivity there is a need to determine the appropriate genetic pattern which depends on the presence of genetic database about lines ability to make specific combining and genetic features that include both broad and narrow sense heritability percentages and the average degree of dominance to make use in breeding and enhancement programs that could be measured in many breeding methods such as (line X tester) method, suggested by [4]; this method has an important role in individual hybrid production and evaluation, in addition, it’s possible to obtain assumptions about genes function and the abilities of general and specific combining that comply additive and non-additive gene effect with some genetic feature estimation, especially broad and narrow sense heritability which discloses the relative importance of genetic diversion through total morphologic diversion, then choosing the appropriate breeding method, through
which, parental structures is determined for the best hybrids production, using the hybrid vigor effect which is the most important feature in plant breeding. This feature increases plant breeders’ interest about maize crop to be the most preferred trait in improving the breeding and genetic enhancement methods due to the genetic distance among the pure lines used for hybrid production [5].

The degree of this distance would increase hybrid vigor because of the increase in combining ability, so, the plant breeders try to find the best hybrids by detecting the best parents to achieve maximum hybrid vigor. It is possible through the use of plenty pure lines to evaluate and produce best dominant hybrids in grains production and content. The study aims to determine lines and hybrids genetic behavior, studying general and specific combining abilities and their effects using (line X tester) method and recognizing the gene action that control studied characters inheritance, broad and narrow sense heritability, and average degree of dominance, in addition to study hybrid vigor for first generation members related to the best parents for the individual hybrids produced by (line X tester) method of hybridization.

2. Materials and Procedures:
This study was made in a farm in Al-Bushaaban Village on the left of Euphrates River (7km North of Rumadi city) during both spring, and autumn seasons (2020). Nine pure line of yellow maize were input in a hybridization program within (line X tester) method suggested by Kempthorne [4]. These lines are: 1- Zm5, 2- Zm1, 3- Zm2, 4- Zm3, 5- Zm4, 6- ART-B-17, 7- Syn-33, 8- S5 and 9- S6. After finishing all the soil service operations, the farm was fertilized with complex fertilizer (NPK) at a rate of 400 kg.ha⁻¹ during soil preparation. Also, urea fertilizer (46% nitrogen) was added as 160 kg N.ha⁻¹ in two loads, the first during planting process and the second at the beginning of flowering. Pure grains were manually cultivated on March 18, 2020 in rows separated by (0.75m) space, and in holes with distance of (0.25m) in between. (6) rows were planted as average for each pure line and (3) seeds per single hole, to become reduced after the plant height reached (0.2m) into one plant per hole. The crop service operations have been made when necessary. After reaching flowering age, female cob has been wrapped with paper bags before the seeds appear to obtain the wanted cross and to avoid open pollination, and male cobs were wrapped too, a day before pollination begins and after the pollen grains have been released. Next day, pollen grains were collected to pollinate the ready cobs, and with continuity, all the possible hybridizations among the nine pure lines have been made. The lines used (6 - 9) male parents (Testers) and (1 - 5) female parents (Lines) to produce 20 hybrids to obtain a total of 29 genetic structures (4 testers X 5 lines = 20 hybrids + 9 parents). By the end of the season, the cobs produced by crosses were collected, seeds spread and isolated to be cultured in a control experiment on July 20, 2020 after finishing all necessary operations for soil service using random complete block design (R. C. B. D.) in three replications where the experimental unit area was (3X4m) distributed as (4) lines per genetic structure, the row length is (4m) and the space between two rows is (75cm) with space (25cm) between holes, (3) seeds per hole and lately reduced to (1) plant per hole after germination. All the crop service operations were made to study the following characters:

1. The average of flowering days in 50% of plants.
2. The average of plant height (cm): beginning from the stem appearing from soil surface to the node that holds male Cob.
3. The average of upper cob height (cm).
4. The average of cobs number per plant.
5. The average of grains number per row.
6. The average of weight of (300) grains (g) after modifying the water content 15.5% in grains [6].
7. The average of single plant yield (g) after weight modification on the water content 15.5% in grains as said by [7].

Data were statistically analyzed, and significant differences were obtained for every studied parameter, followed by genetic analysis using R. C. B. D. in three replicates in accordance with Singh and Chaudhary [8] to make the following evaluations:
The effect of general combining ability $g_i^w$ was estimated for Lines to test according to the following equation:

$$g_i^w = (X_i.. / \text{tr}) - (X .. / L\text{tr})$$

The general combining ability $g_t^w$ was estimated for the used parents (testers) according to the following equation:

$$g_t^w = (X .. / Lr \... / \text{Ltr})$$

The specific combining ability $S_{ij}$ for each hybrid was estimated according to the following equation:

$$S_{ij} = (X_{ij}.. / \text{tr}) - (X_{i}.. / \text{tr}) - (X_{.j}.. / \text{Lr}) + (X .. / \text{Ltr})$$

Cov. H.S. average = $\frac{1}{n(2L_1-1)} \left( \frac{(t-1)\text{MS}_{\text{L}}+(t-1)\text{MS}_{\text{tr}}}{L+t-2} \right)$

$\sigma^2_{gca} = \text{Cov. H.S.} = \left( \frac{(F+1)}{4} \right) \sigma A$

$\sigma^2 A = 2 \sigma^2_{gca}$

$\sigma^2_{sca} = \left( \frac{(F+1)}{2} \right)^2 \sigma D$

$\sigma^2 D = \sigma^2_{sca}$

To estimate standard errors for the lines and testers general combining ability and hybrids specific combining ability, it's done as:

$$\text{S.E. (gi-gi) Testers} = \sqrt{\frac{2\text{Mse}}{rL}}$$

Line standard errors:

$$\text{S.E. (gi-gi) Lines} = \sqrt{\frac{2\text{Mse}}{rt}}$$

Hybrids standard errors:

$$\text{S.E. (Sij-Skj)} = \sqrt{\frac{2\text{Mse}}{r}}$$

Morphologic Contract Components Estimation:

It includes additive variance ($A \sigma^2$), non-additive or dominant contrast ($D \sigma^2$) and environmental contrast ($E \sigma^2$) and they are estimated through the estimated mean contrast EMS for stable sample as follows:

$$\sigma^2 L = (\text{MS}_L - \text{MS}_{\text{L0}}) / rt$$

additive variance = $\sigma^2 L$

$$\sigma^2 t = (\text{MS}_t - \text{MS}_{\text{L0}}) / rL$$

non-additive or dominant variance = $\sigma^2 t$

$$\sigma^2 G = \sigma^2 D + \sigma^2 A$$

genetic variance = $\sigma^2 G$
\[ \sigma^2 P = \sigma^2 G + \sigma^2 E \]  
\[ \text{phenotypic variance} = \sigma^2 P \]

Inheritance Percentage and Average Degree of Dominance:

The percentages of broad (\(h^2\) b.s \%) and narrow (\(h^2\) n.s \%) inheritance were estimated by rules mentioned by [9]:

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

While the average degree of dominance per character was estimated by the following equation:

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

Hybrid Vigor (Heterosis):

Heterosis was computed for all the studied characters compared with the best mean parent using the following equation [10]:

\[ \text{Hybrid Vigor (H\%)} = \left( \frac{F_T - H_P}{H_P} \right) \times 100 \]

3. Results and Discussion:

Table (1) shows significant differences for average squares between genetic compounds and parents, parents versus hybrids, lines versus testers, and lines with testers for every studied character which was agreed by [11] through getting significant differences for several studied characters.

Table (1) analysis of variance of hybridizing (tester*lines) for the studied parameters during spring season 2020

| Source of difference S.O.V | Degree of Freedom | Means squares M.S |
|---------------------------|------------------|------------------|
|                           |                  | Female flowering (Day) | Plant hight (cm) | Upper cob hight (cm) | Number of cobs per plant | Number of seeds per row | Wight of 300 seeds (gm) | Single plant production |
| Replicates                | 2                | 0.001             | 5633.08.4        | 241.63               | 0.0001                   | 0.005                    | 0.002                   | 0.004                   |
| Genetics                  | 28               | '10.14'           | '17617.05'       | '4018.57'            | 0.02'                    | 24.51'                   | '160.78'                | 4196.95'                |
| Parents                   | 8                | '14221.33'        | '12237.28'       | '2564.26'            | 14.65'                   | 3244.28'                 | 12188.34'              | '5327.39'               |
| Parents*hybrids           | 1                | '58344.40'        | '22734.13'       | '3101.12'            | 20.25'                   | 15073.88'                | '57822.56'              | 348601.51'              |
| hybrids                   | 19               | '2932.12'         | '19612.89'       | '4679.20'            | 0.92'                    | 608.77'                  | 2325.58'                | 11133.36'               |
| lines                     | 4                | '30.75'           | '914.07'         | 843.87'              | 0.06'                    | '50.84'                  | 222.79'                 | '4986.05'               |
| testers                   | 3                | '18495.06'        | '120770.15'      | '27558.81'           | 5.69'                    | 3683.78'                 | 13655.23'               | 49686.85'               |
| Lines*testers             | 12               | '8.50'            | '556.51'         | 237.75'              | 0.01'                    | 25.99'                   | '194.10'                | 3544.09'                |
| Error                     | 56               | 0.03              | 178.14           | 134.25               | 0.003                    | 0.0006                   | 0.0007                   | 0.0008                   |

Table (2) illustrates the superiority of tester (ART-B-17) in female flowering, plant height and upper cob height, 68.34 days, 187.63 cm and 87.34 cm respectively. while the tester (Syn-33) surpassed in parameters
of grains number per row, 300 grains weight and grains yield per plant with 28.35 grain per row, 60.29 gm and 121.43 cm, respectively. The line (Zm5) overpassed in parameters of female flowering, plant height and upper cob height as follows 70.23 days, 181.13 cm, and 83.16 cm, respectively. While the line (Zm4) surpassed in plant cob number, row grains number, 300 grains weight and grains yield per plant as 1.31 cobs a plant, 34.13 grains a row, 71.23 gm and 152.63 gm respectively. The hybrid (Zm2 X ART-B-17) exceeded in the mean parameter of female flowering days number to give 65.06 days while the hybrid (Zm4 X ART-B-17) in mean characters of plant height, upper cob height, plant cob number, 300 grains weight and grains yield per plant to reach 211.16 cm, 109.15 cm, 1.48 cobs a plant, 37.45 grains a row, 76.34 gm and 204.75 gm, respectively. It agrees with the results of [12] and [3].

| Parameters | Female flowering (Day) | Plant height (cm) | Upper cob height (cm) | Number of cobs per plant | Number of seeds per row | Weight of 300 seeds (gm) | Single plant production |
|------------|------------------------|-------------------|-----------------------|--------------------------|-------------------------|------------------------|------------------------|
| 1          | 70.23                  | 181.13            | 83.16                 | 1.17                     | 32.13                   | 64.24                  | 123.14                 |
| 2          | 73.48                  | 164.22            | 77.34                 | 1.04                     | 27.04                   | 51.05                  | 80.24                  |
| 3          | 70.84                  | 157.34            | 68.13                 | 1.1                      | 31.24                   | 59.33                  | 86.55                  |
| 4          | 72.15                  | 179.54            | 80.03                 | 1.18                     | 25.34                   | 46.14                  | 65.33                  |
| 5          | 71.03                  | 161.25            | 71.23                 | 1.31                     | 34.13                   | 71.23                  | 152.63                 |
| 6          | 68.34                  | 187.63            | 87.34                 | 1.22                     | 29.06                   | 45.13                  | 66.15                  |
| 7          | 72.44                  | 160.20            | 72.16                 | 1.20                     | 31.53                   | 60.29                  | 121.43                 |
| 8          | 71.65                  | 180.24            | 82.27                 | 1.14                     | 28.35                   | 56.43                  | 81.54                  |
| 9          | 73.06                  | 171.13            | 77.34                 | 1.18                     | 26.14                   | 53.33                  | 64.63                  |
| Parents mean | 71.46          | 171.40            | 77.66                 | 1.17                     | 29.44                   | 56.35                  | 93.51                  |
| 1x6        | 66.15                  | 198.63            | 101.14                | 1.29                     | 33.55                   | 67.45                  | 153.25                 |
| 2x6        | 69.20                  | 169.33            | 86.33                 | 1.25                     | 31.34                   | 58.23                  | 116.34                 |
| 3x6        | 65.06                  | 196.53            | 100.02                | 1.33                     | 34.61                   | 65.53                  | 119.53                 |
| 4x6        | 71.23                  | 181.43            | 92.43                 | 1.28                     | 33.54                   | 60.33                  | 100.43                 |
| 5x6        | 69.01                  | 211.16            | 109.15                | 1.48                     | 37.45                   | 76.34                  | 204.75                 |
| 1x7        | 69.33                  | 191.64            | 97.74                 | 1.27                     | 34.60                   | 68.44                  | 149.44                 |
| 2x7        | 71.16                  | 181.33            | 81.07                 | 1.22                     | 32.74                   | 64.55                  | 143.56                 |
| 3x7        | 70.16                  | 194.35            | 88.43                 | 1.29                     | 34.33                   | 62.46                  | 141.64                 |
| 4x7        | 68.23                  | 185.13            | 83.56                 | 1.25                     | 33.19                   | 66.15                  | 140.73                 |
| 5x7        | 69.14                  | 201.34            | 95.14                 | 1.31                     | 35.05                   | 70.04                  | 182.73                 |
| 1x8        | 68.14                  | 191.25            | 86.24                 | 1.26                     | 33.85                   | 67.54                  | 148.64                 |
| 2x8        | 70.06                  | 184.34            | 83.34                 | 1.2                     | 31.56                   | 61.48                  | 125.85                 |
| 3x8        | 69.23                  | 191.63            | 88.72                 | 1.25                     | 33.26                   | 64.65                  | 128.42                 |
| 4x8        | 70.26                  | 186.42            | 85.43                 | 1.20                     | 32.45                   | 60.74                  | 110.75                 |
| 5x8        | 69.38                  | 195.06            | 89.51                 | 1.35                     | 35.44                   | 72.43                  | 184.84                 |
| 1x9        | 70.02                  | 188.14            | 87.15                 | 1.27                     | 34.22                   | 67.11                  | 151.74                 |
| 2x9        | 71.26                  | 196.24            | 90.32                 | 1.22                     | 32.44                   | 58.53                  | 115.86                 |
| 3x9        | 71.01                  | 182.36            | 83.42                 | 1.29                     | 33.15                   | 65.65                  | 117.94                 |
| 4x9        | 70.15                  | 189.53            | 86.13                 | 1.25                     | 30.65                   | 59.42                  | 107.44                 |
| 5x9        | 69.51                  | 194.23            | 88.25                 | 1.30                     | 35.26                   | 69.33                  | 188.59                 |
| Hybrids mean | 69.38              | 190.60            | 90.17                 | 1.27                     | 33.63                   | 65.22                  | 141.82                 |

| L.S.D   | 0.049 | 0.043 | 0.046 | 0.008 | 0.047 | 0.046 | 0.052 |

The combining ability:

Table (3) shows the consent of the parents, as the tester (ART-B-17) gave the highest positive effect for the general combination of the number of grains per raw, the weight of 300 grains, and the yield of the single plant grains were 51.81, 7.71, and 45.74, respectively, while the tester (S_{17-0.5}) had the highest positive effect. The general combination of plant height and the height of the upper cob are 23.97 and 0.33 respectively, as for the lines. The line (Zm4) gave a desired effect, which is susceptible to the general grouping of characteristics: plant height, upper cob height, number of seeds per plant, number the whole grain, the weight of 300 grains, and the yield of the single plant grains were in the range of 11.48 and 10.53 and 0.08, 2.89, 6.10 and 29.28 respectively. This indicates the ability of these lines to transmit its gene is attributed to individuals resulting from its interbreeding with other lines, as for the lines that gave the values were negative, indicating the opposite, while the lines (Zm3) and (Zm4) gave a negative effect.
The general calculation rate for the number of days of female flowering is -2.55 and -0.26 respectively, and this is evidence to meet these two breeds, to transfer the early genes of female flowering when these genes are combined the lines, along with the other genes of the breed. These results complying with those of AL-Hazemawi [13], Bayoumi et al. [11], and Kumar et al. [14].

Table (3) The effects of the general ability of parents to combine for the studied traits in autumn season 2020.

| Parameters | Female flowering (Day) | Plant height (cm) | Upper cob height (cm) | Number of cobs per plant | Number of seeds per row | Wight of 300 seeds (gm) | Single plant production |
|------------|------------------------|-------------------|-----------------------|--------------------------|-------------------------|-------------------------|------------------------|
| Parents    |                        |                    |                       |                          |                         |                         |                        |
| 1          | 0.97                   | -8.39              | -7.13                 | -0.09                    | -0.89                   | -1.32                   | -11.88                 |
| 2          | 0.22                   | -2.47              | -6.64                 | 0.004                    | -1.38                   | -4.55                   | -13.34                 |
| 3          | 1.62                   | -6.67              | -6.34                 | -0.04                    | -1.99                   | -2.66                   | -17.47                 |
| 4          | -2.55                  | 6.55               | 7.58                  | 0.046                    | 1.37                    | 2.63                    | 13.41                  |
| 5          | -0.26                  | 11.48              | 10.53                 | 0.08                     | 2.89                    | 6.10                    | 29.28                  |
| Standard error of lines | 0.28                   | 0.25               | 0.01                  | 0.01                     | 0.06                    | 5.40                    |                        |

Table (4) showed that there were ten hybrids with specific desired effects of the number of days of female flowering, with minimum record of 1.73 that were recorded by the hybrid (Zm1 x ART-B-17). Hybrid (Zm2 x Syn-33) showed the highest positive effect of the specific combining ability of 22.43, while the hybrid (Zm3 x ART-B-17) has the highest of the specific combining ability for the height of the upper cob which was 13.34. Hybrid (Zm5 x S6) had the highest specific combining ability for the trait of number of cobs per plant which is 0.42. Hybrid (Zm1 x ART-B-17) achieved the highest improvement for number of seeds and weight of 300 seed 3.83 and 13.12, respectively. Most of the hybrids recorded a positive effect of the specific combining ability for the trait ‘yield of single plant seeds’ that was 48.36 in hybrids (Zm3 x ART-B-17).

The variance in hybrids for having positive effects, while others have negative effects of the special combination ability in the studied traits, is an evidence that there is a variance between the hybrids for the ability to combine. These results were identical with those of Andayani et al. [15], Al-Faraji [3], And Elmyhun [16].

Table (4) Effects of the specific ability to combine for each hybrid for the studied traits during autumn season 2020.

| Parameters | Female flowering (Day) | Plant height (cm) | Upper cob height (cm) | Number of cobs per plant | Number of seeds per row | Wight of 300 seeds (gm) | Single plant production |
|------------|------------------------|-------------------|-----------------------|--------------------------|-------------------------|-------------------------|------------------------|
| Hybrids    |                        |                    |                       |                          |                         |                         |                        |
| 16         | -1.18                  | 9.84              | 4.50                  | 0.04                     | 1.81                    | 6.06                    | 21.90                  |
The results of Table (5) showed that $\sigma^2_{gca}/\sigma^2_{sca}$ was more than 1 for the studied traits, this suggest the control of the genitive factor in passing on the inheritance of these traits, except for the single plant production that were under the control of a genuinely gained act, this is confirmed by $\sigma^2_{gca}/\sigma^2_{sca}$ was that was less than one for this trait. The inherit percentage, in the broad sense, was high for all the studied traits, their values ranged from 71.56% for the height of the upper cob, and 100.1 for the number of seeds per row this is due to the high value of genetic variation compared to the value of environmental variation that was low, which makes the parameters more inheritable for the new generations, this agrees with the results of [3].

For the studied traits, the highest is 98.58% for the number of female blooming, and this is imposed on the plant breeder to use the selection method to improve the studied traits, except for the trait of single plant grain yield, in which the percentage of heritability in the narrow sense is low.

The table indicates the presence of a partial pattern of genes in some genomic sites that governs the inheritance of traits because the average degree of dominance of these traits was less than one.

### Table (5) values of variance of genetic parameters for the traits studied by crossbreeding (line X tester) for autumn season 2020.

| Parameters | Female flowering (Day) | Plant height (cm) | Upper cob height (cm) | Number of cobs per plant | Number of seeds per row | Weight of 100 seeds (gm) | Single plant production |
|------------|------------------------|-------------------|-----------------------|--------------------------|-------------------------|--------------------------|-------------------------|
|            |                        |                   |                       |                          |                         |                          |                         |
| $\sigma^2_{gca}$ | 0.03 | 178.14 | 134.25 | 0.003 | 0.0006 | 0.0007 | 0.0008 |
| $\sigma^2_{sca}$ | 201.95 | 1458.24 | 337.81 | 0.006 | 48.4460 | 210.5527 | 1710.9 |
| $\sigma^2_{G}$ | 201.98 | 1663.38 | 472.06 | 0.009 | 48.44 | 210.55 | 1710.9 |
| $\sigma^2_{D}$ | 199.12 | 1299.74 | 303.31 | 0.06 | 39.78 | 145.85 | 529.53 |
| $\sigma^2_{D}$ | 2.82 | 185.50 | 34.50 | 0.005 | 8.66 | 64.70 | 1181.36 |
| $\sigma^2_{sca}$ | 99.56 | 640.87 | 151.65 | 0.030 | 19.39 | 72.92 | 264.76 |
| $\sigma^2_{G}$ | 2.82 | 185.50 | 34.50 | 0.005 | 8.66 | 64.70 | 1181.36 |
| $\sigma^2_{G}$ | 99.56 | 640.87 | 151.65 | 0.030 | 19.39 | 72.92 | 264.76 |
| $\sigma^2_{D}$ | 99.56 | 640.87 | 151.65 | 0.030 | 19.39 | 72.92 | 264.76 |
| $\sigma^2_{D}$ | 2.82 | 185.50 | 34.50 | 0.005 | 8.66 | 64.70 | 1181.36 |
| $\sigma^2_{D}$ | 99.56 | 640.87 | 151.65 | 0.030 | 19.39 | 72.92 | 264.76 |
| $\sigma^2_{D}$ | 2.82 | 185.50 | 34.50 | 0.005 | 8.66 | 64.70 | 1181.36 |
| $\sigma^2_{D}$ | 99.56 | 640.87 | 151.65 | 0.030 | 19.39 | 72.92 | 264.76 |
| $\sigma^2_{D}$ | 2.82 | 185.50 | 34.50 | 0.005 | 8.66 | 64.70 | 1181.36 |
| $\sigma^2_{D}$ | 99.56 | 640.87 | 151.65 | 0.030 | 19.39 | 72.92 | 264.76 |
| $\sigma^2_{D}$ | 2.82 | 185.50 | 34.50 | 0.005 | 8.66 | 64.70 | 1181.36 |
| $\sigma^2_{D}$ | 99.56 | 640.87 | 151.65 | 0.030 | 19.39 | 72.92 | 264.76 |
| $\sigma^2_{D}$ | 2.82 | 185.50 | 34.50 | 0.005 | 8.66 | 64.70 | 1181.36 |
| $\sigma^2_{D}$ | 99.56 | 640.87 | 151.65 | 0.030 | 19.39 | 72.92 | 264.76 |
| $\sigma^2_{D}$ | 2.82 | 185.50 | 34.50 | 0.005 | 8.66 | 64.70 | 1181.36 |
| $\sigma^2_{D}$ | 99.56 | 640.87 | 151.65 | 0.030 | 19.39 | 72.92 | 264.76 |

Hybrid vigor: Table (6) showing the vigor of the hybrids, calculated from the variation of the rate of first-generation members, from the rate of best parents. The hybrid vigor was significantly negative of sixteen crosses in terms of the number of days of female flowering, which indicates the genetically divergence of parents.
Hybrids (4x7) recorded the lowest value of the hybrid vigor in the negative direction, which was -5.43%. Four hybrids recorded positive and significant values of hybrid strength, with the highest rate of 4.22% for the hybrids (4x6).

These results indicate that the genes were super dominant in terms of early emergence of female parts in hybrids that gave negative values to the vigor of the hybrids, whereas the hybrids that gave positive hybrid vigor. The opposite effect occurred in the hybrids with the positive hybrid vigor had delayed flowering effect of the genes. Eighteen hybrid showed positive and significant values to the vigor of the hybrid for the trait of plant height. Hybrid (5x7) recorded the highest positive and significant value of the hybrid vigor 24.86%, while the hybrids (2x6) gave the lowest significantly negative value for the same trait -9.75%.

The positive values of the hybrid vigor indicate the existence of Parents’ genes superiority that have the highest plant height, while negative values of hybrid vigor indicate, the presence of partial dominance of the genes towards a reduction of height in plants, which is a desirable trait in maize. With regard to the height parameter of the upper cob, all hybrids gave significantly positive values of hybrid vigor with highest value in hybrids (5x7), that reached 31.84%, except for hybrids (2x6) which gave -1.15%.

Hybrid (5x6) had the highest hybrid vigor, for the trait of the number of sprouts in the plant was 12.97%, while the hybrid (9x5) had a significantly negative hybrid vigor of -0.76% for the same trait. All hybrids recorded positive and significant values for the number of grains per row, the highest value was 38.38% in hybrids (5x8).

Table (6) the strength of the hybrid H% based on the best parents for the traits studied by cross-hybrid method (lines X testers) for autumn season 2020.

| Parameters Tested | Female flowering (Day) | Plant height (cm) | Upper cob height (cm) | Number of cobs per plant | Number of seeds per row | Weight of 300 seeds (gm) | Single plant production |
|-------------------|------------------------|-------------------|----------------------|--------------------------|------------------------|-------------------------|------------------------|
| 1x6               | -3.20                  | 5.86              | 15.80                | 5.73                     | 4.41                   | 4.99                    | 26.67                  |
| 2x6               | -1.25                  | -9.75             | -1.15                | 2.45                     | 7.84                   | 14.06                   | 44.99                  |
| 3x6               | -4.79                  | 4.74              | 14.51                | 9.01                     | 10.78                  | 10.45                   | 38.10                  |
| 4x6               | 4.22                   | -3.30             | 5.82                 | 4.91                     | 15.41                  | 30.75                   | 51.82                  |
| 5x6               | 0.98                   | 12.54             | 24.97                | 12.97                    | 9.72                   | 7.17                    | 34.14                  |
| 1x7               | -1.28                  | 5.80              | 17.53                | 5.83                     | 9.73                   | 6.53                    | 21.35                  |
| 2x7               | -1.76                  | 10.41             | 4.82                 | 1.66                     | 3.84                   | 7.96                    | 18.22                  |
| 3x7               | -0.95                  | 21.31             | 22.54                | 7.50                     | 8.88                   | 3.59                    | 16.64                  |
| 4x7               | -5.43                  | 3.11              | 4.41                 | 4.16                     | 5.26                   | 9.71                    | 15.89                  |
| 5x7               | -2.66                  | 24.86             | 31.84                | 0.22                     | 4.10                   | -1.67                   | 19.72                  |
| 1x8               | -2.79                  | 6.69              | 3.70                 | 7.69                     | 5.35                   | 5.13                    | 20.70                  |
| 2x8               | -2.21                  | 2.27              | 1.30                 | 5.26                     | 11.32                  | 8.94                    | 54.34                  |
| 3x8               | -2.27                  | 6.31              | 7.84                 | 9.64                     | 6.46                   | 8.96                    | 48.37                  |
| 4x8               | -1.93                  | 3.42              | 3.84                 | 1.69                     | 14.46                  | 7.63                    | 35.82                  |
| 5x8               | -2.32                  | 8.22              | 8.80                 | 3.05                     | 38.38                  | 1.68                    | 21.10                  |
| 1x9               | -0.23                  | 3.87              | 4.79                 | 7.62                     | 6.44                   | 4.46                    | 24.84                  |
| 2x9               | -2.46                  | 14.67             | 16.78                | 3.38                     | 19.97                  | 9.75                    | 44.39                  |
| 3x9               | 0.23                   | 6.56              | 7.86                 | 9.32                     | 6.11                   | 7.28                    | 36.26                  |
| 4x9               | -2.77                  | 5.56              | 7.62                 | 5.93                     | 17.25                  | 11.41                   | 64.45                  |
| 5x9               | -2.13                  | 13.49             | 14.10                | -0.76                    | 3.31                   | -0.02                   | 23.56                  |
| S.E.              |                       |                   |                      |                         |                       |                         |                        |

For the weight of 300 grains parameter, a value of 30.75% was recorded in the hybrids (4x6), while the hybrid (5x7) was recorded the lowest significant negative hybrid vigor of -1.67% for the same trait. All hybrids gave significantly positive values for the hybrid vigor of single plant grains production, the highest was with hybrid (4x9) that was 64.45%. These results were in line with those of Ambikabathy et al. [17], Bartaula et al. [18], and Ibraheem and El-Ghareeb [19] for the hybrid vigor of the studied parameters.

4. Conclusions
   1. There is a genetic variance between parents and their hybrids for most traits, this is confirmed by the values of hybrid strength in all traits under the study.
2. The parents that have a good general combining ability, can be used in the production of hybrids and varieties such as the father (sy-33) and (Zm4). Crosses that have a high specific combining ability, can be used in hybrids and in selection program for the special combining ability, such as hybrid (Zm3 x ART-B-17).

3. The additive genetic act had the main role in controlling traits inheritance, this is clear from the rate of dominance degree of less than one, and the high percentage of heritability in the narrow sense for most of the studied traits.

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