J. of Plant Production, Mansoura Univ., Vol. 15 (3): 111 - 117, 2024

Journal of Plant Production

Journal homepage & Available online at: www.jpp.journals.ekb.eg

Estimation of Heterosis, Combining Ability, and Gene Action Using Diallel Analysis for some Inbred Lines of Yellow Maize

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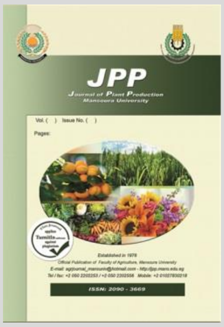

ABSTRACT

A half-diallel cross among five yellow maize inbred lines was made in 2019. Parental inbred lines and F_1 crosses along with three yellow commercial hybrids were evaluated to research the best parental inbred lines that give better hybrids and create high-yielding new yellow single crosses. Mean squares of genotypes, parents, crosses, and parents against crosses were shown to be significant or extremely significant. Both general and specific combining ability mean squares were significant or highly significant for most of the studied traits, suggesting that the inheritance of these qualities was influenced by both additive and non-additive forms of gene effects. For every characteristic under investigation, the GCA/SCA ratio was less than unity, suggesting that non-additive genetic influences were more significant and largely responsible for the inheritance of every traits under investigation. The best combiners were: Inb-27, Inb-69 and Inb-309 for silking date and plant height; Inb-27 for ASI and ear leaf area; Inb-309 for Kernels/ear; and Inb-69 and Inb-309 ear yield plant^{-1}. The most effective cross-combinations were: five crosses for silking date and eight crosses for ears yield/plant. All studied crosses manifested positive and highly significant heterosis over mid and better parents (ranged from 49.06% for cross P1 X P2 to 651.54% for cross P1 X P4 over mid parents and from 32.12% for cross P1 x P2 to 529.70% for cross P1xP4 over better parent. Therefore, it can be recommended to use the P1×P4 hybrid in the yellow maize breeding program to increase productivity and earliness.

***Keywords*: Maize, diallel, combining ability, heterosis.**

INTRODUCTION

Among the grains, maize occupies a unique position and is utilized in industry, animal husbandry, and human nutrition (Keskin *et al.*, 2005). The most expensive and time-consuming stage in the production of maize hybrids is identifying parental inbred lines that produce better hybrids. The grain yield of maize hybrids is not predicted by the inbred lines' performance (Hallauer and Miranda, 1981). In order to extract GCA and SCA information from maize populations for genetic diversity assessment, inbred line selection, heterotic pattern categorization, heterosis calculation, and hybrid production, combining ability analyses are frequently utilized in maize breeding programmes (Fan *et al.*, 2002; Melani and Carena, 2005; and Barata and Carena, 2006). In the United States, heterosis maize hybrids were planted on around 1% of all farmed land in 1933. By 1953, the percentage of maize hybrids with heterosis had increased to 96% (Sprague, 1962). Based on the aforementioned data, the most effective breeding programme may be selected (Liao 1989, Pal and Prodham 1994). Important markers of potential usefulness for inbred lines in hybrid combinations are the impacts of general combing abilities (GCA) and specific combing abilities (SCA). Differences in GCA effects have been attributed to additive, the interaction of additive x additive, and higher-order interactions of additive genetic effects in the base population, whereas variations in SCA effects have been attributed to non-additive genetic variance (Falconer, 1981). In genetic research, parallel crossings have been used to select superior parents for hybrid or cultivar production as well as to determine the inheritance of a characteristic among a range of genotypes (Yan and Kang, 2003). According to Kanchao *et al.* (2020), heterosis was shown to be more positively and significantly connected with SCA than GCA. This suggests that SCA may be used in commercial maize breeding to anticipate heterosis and produce potential hybrids. Large collections of parental lines with genotypic data may also be shared and used in international hybrid breeding initiatives by employing an open-source breeding strategy. Habiba *et al.* (2022) concluded that the majority of the lines under study demonstrated extremely general combiners, and the superior crossings resulted from a good × good combiner for the majority of characteristics that make up yield components. According to Kamal *et al.* (2023), it was discovered that additive gene action was more important for the number of days to 50% silking and tasseling, whereas SCA variations for grain yield, plant height, cob height, number of grains per row, cob girth, and cob length were greater than GCA variances. These findings highlight the significant role of non-additive genes in the inheritance of these traits. Our study aimed to ascertain the heterosis and combining capacity of five inbred lines of maize in order to identify superior single-cross hybrids that were generated from the new inbred lines that were being studied.

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DOI: 10.21608/jpp.2024.274077.1314

MATERIALS AND METHODS

The present investigation compares the performance of some experimental maize inbred lines and their F1 single crosses, which derived from crossing mad between different inbred lines developed by ARC, to examine the variability among five inbred lines of corn (*Zea mays*, L.) and its crosses, assess the impacts of combining ability for five inbred lines, determine the kind of gene action governing the inheritance of the variables under study, and pinpoint superior crossings and inbred lines to enhance maize breeding programmes' yielding capacity.

Five inbred lines of maize with different genetic backgrounds served as the genetic ingredients for this investigation. Table 1 displays the sources of these paternal inbred lineages.

Table 1. Names and sources of the maize parental inbred lines.

NO.	Name	Grain color	Source
P1	Inb. 27	Yellow	Locally developed, ARC, Egypt
P2	Inb. 48	Yellow	Locally developed, ARC, Egypt
P3	Inb. 69	Yellow	Locally developed, ARC, Egypt
P4	Inb. 103	Yellow	Locally developed, ARC, Egypt
P5	Inb. 309	Yellow	Locally developed, ARC, Egypt

Using a half-diallel crosses mating design, 10 single crosses were produced by crossing the five parental inbred lines of maize in all feasible combinations, with the exception of reciprocals, during the 2019 growing season. Parents and their F_1 single crosses (10) and three checks (SC 168, SC 3084 and SC 3444) were evaluated through 2020 growing season. The experiment arranged in a Randomized Complete Blocks Design (RCBD) with 3 replications. The plot size was one ridge, 3 meters long and 70 cm wide. Experiments of 2019 and 2020 growing seasons were conducted at the Mansoura University Faculty of Agriculture's Experimental Farm of Agronomy Department, El-Dakahlia Governorate.

Maize seed were hand sown on 15th May and 1st June in 2019 and 2020 seasons, respectively. Two grains were sown per hill at 25 cm spacing. Following seedling emergence, hills were trimmed to ensure one plant per hill. The experiment was twice hoed before to the initial and subsequent watering. When preparing the seedbed, 200 kg/feddan of phosphorus in the form of calcium superphosphate (15.5% P_2O_5) was added to the soil. After thinning, 50 kg/fed of potassium sulphate (48% K_2O) was applied. Additionally, before the first and second irrigations, nitrogen was given in the form of urea (46.5% N) at a rate of 120 kg N/fed in two equal split doses. Other farming techniques were used as advised.

The following measurements were noted:

A- Flowering and morpho-physiological traits: Days to 50% anthesis, Days to 50% silking, anthesis-silking interval, ASI (day), ear leaf area (cm^2), which calculated by the following formula: maximum length x maximum width x 0.75 (Sticker, 1964), and plant height (cm)

B-Yield traits: Number of kernels/ear and ears yield per plant (g)

Statistical analyses:

Plot mean analysis was used to examine the data. Snedecor and Cochran (1977) state that all collected data were statistically analysed using a randomised full block design in order to examine variations across different genotypes. According to Gomez and Gomez (1984), the least significant differences values (LSD) at the 5% and 1% probability levels were used to compare treatment means.

Diallel analysis:

1-Assessment of combining ability:

To assess the general (GCA) and particular (SCA) combining abilities, the data were analysed using Griffing's (1956) method 2 model 1. It was thought that the parents were fixed. Table 2 displays the analysis of variance for every characteristic. The following statement reflects the relative weight of GCA over SCA:

$$K^2_{GCA} / k^2_{SCA} = \frac{MS_{GCA} - MS_e / P + 2}{MS_{SCA} - MS_e}$$

Where, **P is the number of parents, K^2 is the average square of the effects, and MS stands for mean squares.**

Table 2. Variance analysis for the combining ability.

S.O.V	D.F.	SS	M.S	E.M.S
GCA	(p-1)	Sg	Mg	$\sigma^2 e + (P+2)/(1/P-1)\sum gi^2$
SCA	p(p-1) / 2	Ss	Ms	$\sigma^2 e + 2/(P/P-1)\sum i \sum j S^2 ij$
Error	(c-1)(r-1)	Se	Me	$\sigma^2 e$

Where, **Me: The primary randomised full block design's error mean squares divided by the number of replications (Me = Me/r), p: The total number of parents**

2-Assessment of Heterosis:

Heterosis was determined for each cross as the percentage divergence of the F1 means from the means of the tick variety, mid-parents (MP), and better parent (BP), in accordance with Mather and Jinks' (1982) suggestion. The following percentages were used to report the results:

1- Mid-parents heterosis % ($\bar{MP}$) = [($\bar{F}_1 - \bar{MP}$)/ $\bar{MP}$] x 100

2- Better-parent heterosis % ($\bar{BP}$) = [($\bar{F}_1 - \bar{BP}$) / $\bar{BP}$] x 100

3- Check-variety heterosis % ($\bar{CV}$) = [($\bar{F}_1 - \bar{CV}$) / $\bar{CV}$] x 100

Where $\bar{F}_1$ is the first generation's mean value, $\bar{MP}$ is the mid-parent's mean determined by averaging the means of the two parents, $\bar{BP}$ is the better parent's mean value, and $\bar{CV}$ is the better check variety's mean value.

The following formula was used to determine the importance of heterosis impact for values of F_1 from the better and mid-parents:

LSD for mid-parents heterosis = $t_{0.05}$ x $(3MS_e/2r)^{1/2}$

LSD for better parent or check variety heterosis = $t_{0.05}$ x $(2MS_e/r)^{1/2}$

Where: t: The tabulated (t) value for the experimental error degree of freedom at a given level of probability, r: The number of replicates, and MSe: The mean squares of the experimental error from the analysis of variance

RESULTS AND DISCUSSION

1-Analysis of variance:

Table 3 displays the analysis of variance for yield, morpho-physiological, and blooming characteristics. The findings made it abundantly evident that, for every variable under study, there was considerable or highly significant difference in the mean squares of the genotypes, parents, crosses, and parents versus crossings, except each of; parents for anthesis-silking interval (ASI) and plant height; parents versus crosses for anthesis date, and crosses for kernels no. /ear. Similar results were obtained by Chaudhary *et al.* (2000), Abd El-Aty and Katta (2002), Nawar *et al.* (2002), Barakat *et al.* (2003), Gautam (2003), Singh (2005) and Machado *et al.* (2009), Habiba *et al.* (2022) and Kamal *et al.* (2023).

Table 3. Mean squares of all flowering and morpho-physiological characteristics in maize, as well as genotypes, parents, crosses, and parents against crosses during 2020 season.

S.O.V	DF	Anthesis date, day	Silking date, day	ASI, day	Ear leaf area, cm^2	Plant height, cm	Kernels no./ear	Ears yield $plant^{-1}$, g
Reps.	2	1.27	0.16	1.49	3245.21	40.956	2184.09	0.62
Genotypes	14	15.72**	23.31**	22.21**	31981.80**	3498.546**	52808.55**	127775.31**
Parents	4	22.40**	29.07**	5.83	42077.78**	80.733	35650.00**	3995.50**
Crosses	9	14.23**	22.30**	29.57**	8199.83*	788.578*	10816.24	81518.85**
P V Cross	1	2.50	9.34**	21.51*	205635.6**	41559.5**	499373.51**	1039202.7**
Error	28	2.93	0.23	3.01	3079.02	293.146	5884.95	23.00
TOTAL	44	6.93	7.57	9.05	12282.91	1301.583	20646.96	40670.45

***, ** significant at 0.05 and 0.01 level of probability, respectively.**

2-Mean performance of parents and its F_1 crosses:

Results in Table 4 showed that the earliest parents were P_4 (51.33 day) in anthesis date; P3, P4 and P5 in silking date (58.00 day); P5, P1 and P3 in the anthesis-silking interval (4.00 - 4.67 days). For crosses, the earliest crosses were P1 x P4 (52.00 day) in anthesis date; P1 x P3 (55.00 day) in silking date; P1 X P3 and P1 X P5 ASI (0.33 and 2.00 days).

The highest parents and crosses were P1 and P3 and crosses P1 x P2 (581.0 cm^2), P1 X P3 (571.5 cm^2) in ear leaf area; P2 (126.00 cm), P4 (120.33), crosses P1 x P4 (206.33 cm), P2 X P3 (201.00 cm) and P2 X P5 (196.67 cm) in plant height. The maximum values of Kernels No./ear were recorded by P5 (566.00 kernels/ear) followed by P1 (426.67 kernels/ear) and P3 (374.00 kernels/ear). And the greatest values of Kernels No./ear were 709.33, 690.67 and 684.00 kernels/ear for crosses P2 x P3, P3 x P4 and P1 x P2, respectively. The maximum values of ears yield/plant were recorded by P5 (165.33 g/plant) followed by P3 (130.33 g/plant) and P1 (110.00 g/plant), with significant differences among them. And the greatest values of ears yield/plant were 692.67, 612.67, 530.00, 511.33 and 482.00 g/plant for crosses P1 x P4, P2 x P5, P3 x P5, P1 x P3 and P2 x P3, respectively, with significant differences among them, as shown in Table 4.

Table 4. Average performance of five parental inbred lines of maize and the F1 crosses between them and three commercial single crosses for earliness, morpho-physiological and yield traits during 2020 season.

Trait Genotype	Anthesis date, day	Silking date, day	ASI, day	Ear leaf area, cm^2	Plant height, cm	Kernels No./ear	Ears yield/ plant, g
Parents							
P1 (Inb. 27)	57.00	61.33	4.33	554.50	114.67	426.67	110.00
P2 (Inb. 48)	58.00	65.00	7.00	294.00	126.00	298.67	85.00
P3 (Inb. 69)	53.33	58.00	4.67	359.00	114.00	374.00	130.33
P4 (Inb. 103)	51.33	58.00	6.67	269.00	120.33	308.00	74.33
P5 (Inb. 309)	54.00	58.00	4.00	282.75	114.67	566.00	165.33
LSD 5%	0.91	0.25	0.92	29.35	9.06	40.57	2.54
LSD 1%	1.22	0.34	1.24	39.59	12.22	54.73	3.42
Crosses							
P1 x P2	54.67	58.00	3.33	581.00	160.33	684.00	145.33
P1 x P3	54.67	55.00	0.33	571.50	176.00	570.67	511.33
P1 x P4	52.00	59.00	7.00	500.25	206.33	629.33	692.67
P1 x P5	55.00	57.00	2.00	453.00	162.33	576.00	354.00
P2 x P3	55.00	59.00	4.00	525.50	201.00	709.33	482.00
P2 x P4	59.00	62.00	3.00	427.50	191.67	552.00	413.00
P2 x P5	55.00	59.00	4.00	484.00	196.67	620.00	612.67
P3 x P4	53.00	59.00	6.00	476.50	172.00	690.67	358.67
P3 x P5	58.00	62.00	4.00	498.25	185.67	541.33	530.00
P4 x P5	54.00	63.00	9.00	435.00	172.00	608.00	254.00
LSD 5%	1.28	0.36	1.30	41.50	12.81	57.38	3.59
LSD 1%	1.73	0.48	1.75	55.99	17.28	77.40	4.84
SC. 168	59.00	62.00	3.00	662.50	166.33	857.33	835.33
SC. 3084	60.00	63.00	3.00	667.50	223.00	676.00	461.67
SC. 3444	58.00	62.00	4.00	648.50	183.00	588.00	456.33

3-Combining ability analysis:

Both general and particular combining abilities are long-standing concepts. It has long been known that the relative effectiveness of individuals in a similar group of organisms when crossed with a heterogeneous tester serves as a good predictor of general combining ability. When the "specific combining ability" first appeared in the context of plant breeding, it meant how well the progeny of a given cross performed in comparison to other comparable crossings. It was stated that the excellence or inferiority of the cross resulted from strong or low specific combining capacity, and that a particular parental combination was particularly desired or undesirable.

Table 5 results demonstrated that, for every tested vegetative, yield, and earliness trait—aside from kernels no./ear for GCA—both the conventional (GCA) and specialised (SCA) combination abilities mean squares were considerable or very considerable. The inheritance of these qualities was shown to be influenced by both additive and non-additive forms of gene effects. In all evaluated earliness, vegetative, and yield parameters, the GCA/SCA (baker ratio) ratio was fewer than unity. These outcomes suggest that non-additive genetic influences were extra substantial and were primarily responsible for the inheritance of all characteristics under investigation. Comparable outcomes were attained by Singh (2005), Machado *et al.* (2009), Habiba *et al.* (2022) and Kamal *et al.* (2023)

General combining ability effects (gi)

All examined traits would be interested in high positive GCA effects, with the exception of earliness traits (anthesis date, silking date, and ASI) and plant height, where negative GCA effects would be beneficial from a breeder's perspective.

Table 5. Mean squares for all of the earliness, vegetative, and yield qualities, as well as the general and SCA combining ability and GCA/SCA ratio during 2020 season.

S.O.V	DF	Anthesis date	Silking date	ASI	Ear leaf area	Plant height	Kernels no./ear	Ears yield/plant
GCA	4	7.01**	7.77**	8.82**	16238.71**	105.80	3086.81	2734.73**
SCA	10	4.53**	7.77**	6.84**	8429.36**	1590.34**	23409.27**	58534.58**
ERROR	28	0.98	0.08	1.00	1026.34	97.72	1961.65	7.67
Baker ratio	-	0.76	0.67	0.72	0.79	0.12	0.21	0.09

Parental inbred line P4 (Inb. 103) had extremely negative significant GCA effects, according to findings of GCA effects for anthesis date in Table 5, suggesting that it could be an excellent common combiner for earliness. Furthermore, inbred lines of P1 (Inb. 27), P3 (Inb. 69), and P5 (Inb. 309) had negative and important or highly considerable GCA effects for silking date, according to Table 6's results of GCA effects. This suggests that these inbred lines might be regarded as effective general combiners for earliness. Comparable outcomes were attained by Surya and Ganguli (2004); Singh (2005); Sultan *et al*. (2011), Habiba *et al.* (2022) and Kamal *et al.* (2023).

Results in Table 6 show that parental inbred line P1 (Inb. 27) had a higher negative and highly significant GCA effects for Anthesis-Silking Interval, indicating that this parent P1 (Inb. 27) was the favorable general combiner for earliness trait.

Estimates of GCA effects for ear leaf area (Table 6) cleared that P1 (Inb. 27) had highly significant positive GCA effects, indicated that P1 (Inb. 27) might be considered the most effective general combiner for the area of the ear leaf. Additionally, Table 5's outcomes of the GCA effects for height of plant indicate that the inbreds of P1 (Inb. 27), P3 (Inb. 69), and P5 (Inb. 309) had negative GCA effects, though they did not reach a statistically significant level, indicating that these inbred lines are the most effective general combiners for shortness of plant. Parental inbred lines P2 (Inb. 48) and P4 (Inb. 103) on the other hand, had positive GCA effects, advising that these lines are the most effective general combiners for increasing the tallness of plant. Comparable outcomes were attained by Gautam, (2003); Surya and Ganguli, (2004); Singh, (2005); *EL-Shenawy et al. (2009)* and Habiba *et al.* (2022).

Table 6 presents the results of the GCA effects for Kernels No./ear. These findings indicate that the parental inbred line P5 (Inb. 309) reported significant and favorable GCA effects, and that this inbred line might be the greatest general combiner for raising kernels No./ear. Comparable outcomes were mentioned by Gautam, (2003); Surya and Ganguli, (2004); Singh, (2005); Rakesh *et al.*, (2006); EL-Shenawy *et al.*, (2009) and Habiba *et al.* (2022).

As shown in Table 6, P3 (Inb. 69) and P5 (Inb. 309) were the strongest general combiners for boosting ear yields per plant; they showed highly substantial and favorable GCA impacts for ear yields. The weakest general combiners for ear yield were P1 (Inb. 27), P2 (Inb. 48), and P4 (Inb. 103), where they showed highly substantial and unfavorable GCA effects for ear yield/plant. Comparable outcomes were reported by Surya and Ganguli, (2004); Singh, (2005); Rakesh *et al.*, (2006); EL-Shenawy *et al* (2009), Sultan *et al.* (2011); Habiba *et al.* (2022) and Kamal *et al.* (2023).

Table 6. Effects of GCA for all the parental maize inbred lines for e earliness, vegetative and yield traits during 2020 season.

	Anthesis date	Silking date	ASI	Ear leaf area	Plant height	Kernels No./ear	Ears yield/plant
P1 (Inb. 27)	0.28	-0.98**	-1.26**	75.72**	-4.45	7.35	-6.30**
P2 (Inb. 48)	1.32**	1.64**	0.31	-11.24	5.17	-14.17	-20.64**
P3 (Inb. 69)	-0.44	-0.79**	-0.35	15.01	-0.40	-0.27	25.03**
P4 (Inb. 103)	-1.39**	0.35**	1.74**	-43.92**	2.46	-23.70	-14.35**
P5 (Inb. 309)	0.23	-0.22*	-0.45	-35.56**	-2.78	30.78*	16.27**
LSD gi 5%	0.68	0.19	0.69	22.18	6.85	30.67	1.92
LSD gi 1%	0.92	0.26	0.94	29.93	9.23	41.37	2.59
LSD gi-gj 5%	1.77	0.49	1.79	57.28	17.67	79.19	4.95
LSD gi-gj 1%	2.39	0.66	2.42	77.27	23.84	106.83	6.68

Specific combining ability effects (Sij)

The most desirable crosses were those showing the highest positive SCA effects for all the studied traits, except the flowering traits (days to 50% anthesis, days to 50% silking and ASI), plant height, where favorable specific combining ability (SCA) effects should be lowest negative ones.

Table 7 presents the results of the effects of SCA for ten F1 crossings. Of these, three crosses (P1 X P2, P1 X P4, and P2 X P5) exhibited substantial negative SCA effects for the anthesis date. These crosses are therefore the best combinations for earliness of anthesis. Five cross combinations were shown to have negative and extremely significant SCA effects for silking date: P1 X P2, P1 X P3, P1 X P5, P2 X P3, and P2 X P5. These cross combinations are therefore the best options for early silking. Three crosses—P1 X P3, P1 X P5, and P2 X P4—had negative and very significant SCA effects for the Anthesis-Silking Interval (ASI), suggesting that these cross combinations are the most effective at shortening the time between anthesis and silking.

Six of the ten F1 crosses that were studied — P1XP2, P2XP3, P2XP5, P3XP4, P3XP5, and P4XP5 —had positive and significant or highly significant SCA effects for ear leaf area, according to Table 7's results. This suggests that these cross combinations are the best combinations for maximizing Ear leaf area. The majority of the examined crossings (six out of 10) shown highly significant positive SCA effects for plant height, according to Table 7 results, suggesting that these crosses are the most effective cross combinations for plant tallness. On the other hand, one cross, P1xP2, shown negative SCA effects on plant height, suggesting that this cross would be the most advantageous combination for small plants.

Four of the ten crosses that were studied — P1XP2, P1XP4, P2XP3, and P3XP4 — had extremely significant and favorable SCA effects, according to estimates of SCA effects for kernels No./ear (Table 7). This suggests that those cross combinations are the most effective cross-combinations for raising kernels No./ear. The best SCA effects were very substantially positive for all tested crossings, with the exception of two crosses (P1xP2 and P4xP5), suggesting that these cross combinations are the most effective at boosting ears yield/plant. Similar outcomes were attained by Welcker *et al.*, (2005); Muraya *et al.*, (2006); Amaregouda and Kajidoni, (2007); Aliu (2008), Fan *et al.*, (2009), Habiba *et al.* (2022) and Kamal *et al.* (2023).

Table 7. Effects of SCA for all the studied maize F_1 crosses for Earliness, vegetative and yield traits during 2020 season.

Trait / Cross	Anthesis date	Silking date	ASI	Ear leaf area	Plant height	Kernels No./ear	Ears yield/plant
P1 X P2	-2.00**	-2.08**	-0.08	69.07**	-1.30	147.17**	-155.63**
P1 X P3	-0.24	-2.65**	-2.41**	33.32	19.94**	19.94	164.70**
P1 X P4	-1.95**	0.21	2.16**	21.00	47.41**	102.03**	385.41**
P1 X P5	1.43*	-3.22**	-4.65**	-34.61	8.65	-5.78	16.13**
P2 X P3	-0.95	-1.27**	-0.32	74.29**	35.32**	180.13**	149.70**
P2 X P4	4.00**	0.59**	-3.41**	35.21	23.13**	46.22	120.08**
P2 X P5	-1.62*	-1.84**	-0.22	83.36**	33.37**	59.75	289.13**
P3 X P4	-0.24	0.02	0.25	57.96*	9.03	170.98**	20.08**
P3 X P5	3.14**	3.59**	0.44	71.36**	27.94**	-32.83	160.79**
P4 X P5	0.10	3.44**	3.35**	67.04**	11.41	57.27	-75.83**
LSD Sij 5%	1.40	0.39	1.42	45.28	13.97	62.61	3.91
LSD Sij 1%	1.89	0.52	1.91	61.09	18.85	84.45	5.28
LSD sij-sik 5%	2.65	0.74	2.69	85.92	26.51	118.79	7.43
LSD sij-sik 1%	3.58	1.00	3.63	115.91	35.76	160.24	10.02
LSD sij-skl 5%	2.42	0.67	2.45	78.44	24.20	108.44	6.78
LSD sij-skl 1%	3.27	0.91	3.31	105.81	32.65	146.28	9.15

Heterosis Studies:-

The success of breeding programs in many other crops, including the commercial maize sector, can be attributed in large part to heterosis. The genetic underpinnings of heterosis have been partially understood, but the biochemical, physiological, and molecular underpinnings of this phenomenon are still largely unknown. We go over the explanation of heterosis in this review. Scientists started planning tests to figure out the mechanism of heterosis in the early 1900s. Most scientists have linked heterosis to dominance or over-dominance over the years, but more recently, researchers have revealed that linkage and epistasis play significant roles. Throughout the past century, there has been a recurring theme that no single hypothesis of heterosis has proven to be accurate for every experimentation (Leyla Cesurer *et al.*, 2002).

Table 8's results showed that seven cross-combinations had negative extremely significant heterosis relative to the best check variety for anthesis date, two cross-combinations (P1XP2 and P1XP4) showed negative extremely significant heterosis over mid parents, and only one cross-combination (P1xP2) exhibited negative very significant heterosis relative to better parent. These outcomes correspond with the findings of Abd El-Aty and Katta (2002) and Saleh *et al.*, (2002).

Furthermore, seven cross-combinations showed negative extremely significant heterosis relative better parent, six cross-combinations showed negative exceedingly significant heterosis relative to mid-parents, and seven cross-combinations displayed negative extremely significant heterosis relative to the best check variety for the date of silking. These findings are consistent with those of Abd El-Aty and Katta (2002) and Saleh *et al.* (2002).

Specifically, two crosses (P1 x P3 and P1 x P5) had negative highly significant heterosis (-89.00 and 166.67 %) over check variety for anthesis-silking interval (ASI), and seven cross-combinations showed negative exceedingly significant heterosis relative to mid-parents, eight cross-combinations showed negative extremely significant heterosis relative to better parent.

Table 8. Percentage of heterosis above mid (MP), better parent (BP) and the best commercial variety (CV) in F1 crosses of the studied maize for earliness traits during 2020 season.

	Anthesis date			Silking date			ASI		
	MP	BP	CV	MP	BP	CV	MP	BP	CV
P1 X P2	-4.93**	-4.09**	-5.74**	-8.18**	-10.77**	-6.45**	-41.18**	-52.38**	11.00**
P1 X P3	-0.91	2.50	-5.74**	-7.82**	-10.33**	-11.29**	-92.59**	-92.86**	-89.00**
P1 X P4	-4.00**	1.30	-10.34**	-1.12**	-3.80**	-4.84**	27.27**	5.00**	133.33**
P1 X P5	2.70*	5.56**	-1.72	-7.82**	-10.33**	-11.29**	-148.00**	-146.15**	-166.67**
P2 X P3	-1.20	3.13*	-5.17**	-4.07**	-9.23**	-4.84**	-31.43**	-42.86**	33.33**
P2 X P4	7.93**	14.94**	1.72	0.81*	-4.62**	0.00	-56.10**	-57.14**	0.00
P2 X P5	-1.79	1.85	-5.17**	-4.07**	-9.23**	-4.84**	-27.27**	-42.86**	33.33**
P3 X P4	1.27	3.25*	-8.62**	1.72**	1.72**	-4.84**	5.88**	-10.00**	100.00**
P3 X P5	8.07**	8.75**	0.00	6.90**	6.90**	0.00	-7.69**	-14.29**	33.33**
P4 X P5	2.53*	5.19**	-6.90**	8.62**	8.62**	1.61	68.75**	35.00**	200.00**
LSD 5%	2.48	2.86	2.86	0.69	0.80	0.80	2.51	2.90	2.90
LSD 1%	3.35	3.86	3.86	0.93	1.07	1.07	3.39	3.92	3.92

Table 9's results showed that no crosses had positive heterosis relative to check variety for ear leaf area, and all examined crosses showed positive and non-significant heterosis throughout mid parents (ranging from 8.21% to 67.84%). Eight cross-combinations showed positive and non-significant heterosis above better parent (ranging from 3.07% to 64.63%).

All of the crosses that were studied showed positive and significant or extremely significant heterosis relative to the mid-parents (ranged from 33.24% to 75.60%), nine cross-combinations showed positive and extremely significant heterosis relative the better parent (ranged from 41.57% to 71.47%), and no crosses showed significant positive or negative heterosis above the best check variety for plant height. These results are included in Table 9. P1 x P2 and P1 x P5 were the only two crosses that showed desired negative heterosis (-3.61% and -2.41%) above the control variety for plant height, but not at a level that was statistically significant.

With respect to kernels no./ear, Table 10 displays the results of the study. It indicates that all of the crosses that were examined showed positive and non-significant heterosis over mid parents (ranging from 15.18% for cross P3 X P5 to 110.90% for cross P2 X P3), nine crosses showed non-significant and positive heterosis over better parent (ranging from 1.77% for cross P1 x P5 to 89.66% for cross P2 x P3), and none of the crosses showed desirable positive and significant heterosis over check variety for kernel percentage/ear. Abd El-Aty and Katta (2002), Reddy and Ahuja (2004), Pilar *et al.* (2006), and Shalim *et al.* (2006) concur with the results.

Table 9. Percentage of heterosis above mid (MP), better parent (BP) and the best commercial variety (CV) in F1 crosses of the studied maize for ear leaf area and plant height traits during 2020 season.

	Ear leaf area, cm^2			Plant height, cm		
	MP	**BP**	**CV**	**MP**	**BP**	**CV**
P1 X P2	36.95	4.78	-12.96	33.24*	27.25	-3.61
P1 X P3	25.12	3.07	-14.38	53.94**	53.49**	5.81
P1 X P4	21.49	-9.78	-25.06	75.60**	71.47**	24.05
P1 X P5	8.21	-18.30	-32.13	41.57**	41.57**	-2.41
P2 X P3	60.95	46.38	-21.27	67.50**	59.52**	20.84
P2 X P4	51.87	45.41	-35.96	55.62**	52.12**	15.23
P2 X P5	67.84	64.63	-27.49	63.43**	56.08**	18.24
P3 X P4	51.75	32.73	-28.61	46.80**	42.94**	3.41
P3 X P5	55.28	38.79	-25.36	62.39**	61.92**	11.63
P4 X P5	57.68	53.85	-34.83	46.38**	42.94**	3.41
LSD 5%	80.37	92.81	92.81	24.80	28.64	28.64
LSD 1%	108.42	125.19	125.19	33.45	38.63	38.63

In terms of ear yield/plant, Table 10's results demonstrate that all examined crosses showed positive and highly significant heterosis over mid and better parents (a range spanning from 49.06% for P1 X P2 to 651.54% for P1 X P4 over mid parent and from 32.12% for P1 x P2 to 529.70% for P1 x P4 over better parent), with no crosses exhibiting desirable positive and significant heterosis over check variety. Weidong and Tollenaar (2009), Abdel-Moneam *et al.* (2009), Abd El-Aty and Katta (2002), and Amanullah *et al.* (2011) all reported similar outcomes.

Table 10. Percentage of heterosis over mid (MP), better parent (BP) and the best commercial variety (CV) in F1 crosses of the studied maize for Kernels No./ear and ear yield/plant traits during 2020 season.

	Kernels No./ear			Ears yield/plant (g)		
	MP	**BP**	**CV**	**MP**	**BP**	**CV**
P1 X P2	88.60	60.31	-20.22	49.06**	32.12**	-82.60**
P1 X P3	42.55	33.75	-33.44	325.52**	292.33**	-38.79**
P1 X P4	71.32	47.50	-26.59	651.54**	529.70**	-17.08**
P1 X P5	16.05	1.77	-32.81	157.14**	114.11**	-57.62**
P2 X P3	110.90	89.66	-17.26	347.68**	269.82**	-42.30**
P2 X P4	81.98	79.22	-35.61	418.41**	385.88**	-50.56**
P2 X P5	43.41	9.54	-27.68	389.48**	270.56**	-26.66**
P3 X P4	102.54	84.67	-19.44	250.49**	175.19**	-57.06**
P3 X P5	15.18	-4.36	-36.86	258.51**	220.56**	-36.55**
P4 X P5	39.13	7.42	-29.08	111.96**	53.63**	-69.59**
LSD 5%	111.11	128.30	128.30	6.95	8.02	8.02
LSD 1%	149.89	173.08	173.08	9.37	10.82	10.82

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تقدير قوة الهجين والقدرة على التآلف والفعل الجيني باستخدام التهجين نصف الدائري لبعض سلالات الذرة الشامية الصفراء

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الملخص

تم إجراء التهجين نصف دائري بين خمس سلالات نقية من الذرة الصفراء في صيف موسم 2019. وتم تقييم السلالات الأبوية وهجن الجيل الأول بالإضافة إلى ثلاثة هجن تجارية صفراء للمقارنة هي، SC 168، SC 3084 وSC 3444، وذلك في تصميم القطاعات الكاملة العشوائية في ثلاث مكررات في المزرعة البحثية بقسم المحاصيل، كلية الزراعة، جامعة المنصورة، محافظة الدقهلية، مصر. وذلك بهدف دراسة القدرة على التآلف وقوة الهجين للتعرف على السلالات الأبوية الأكثر تفوقاً والتي تنتج هجناً متفوقة وتطور هجن فردية صفراء جديدة عالية الإنتاجية. أشارت النتائج إلى أن متوسط مربعات التراكيب الوراثية والآباء والهجن والآباء مقابل الهجن كانت معنوية أو عالية المعنوية في معظم الصفات المدروسة. كان متوسط مربعات القدرة العامة على التآلف (GCA) والقدرة الخاصة على التآلف (SCA) معنوية أو عالية المعنوية لمعظم الصفات المدروسة، مما يشير إلى أن كلا النوعين من الفعل الجيني الإضافي وغير الإضافي من التأثيرات الجينية كان لهما دور في وراثة هذه الصفات. وكانت نسبة GCA/SCA أقل من الوحدة لجميع الصفات المدروسة مما يدل على أن التأثيرات الجينية غير التجميعية (السيادية) كانت أكثر أهمية ولعبت الدور الأكبر في توريث جميع الصفات المدروسة. كانت أفضل الآباء قدرة عامة على التآلف هيInb-27 :، Inb-69وInb-309 لصفة ميعاد طرد الحريرة (التبكير) وارتفاع النبات (قصر النبات)؛ Inb-27 لصفتي الفترة بين اللقاح والحريرة ومساحة ورقة الكوز؛ Inb-309 لصفة عدد الحبوب بالكوز؛ و Inb-69 و Inb-309 لصفة محصول الكيزان/نبات. كانت أفضل هجن الجيل الأول قدرة خاصة على التآلف هي: خمسة هجن لميعاد طرد الحريرة، وثمانية هجن لمحصول الكيزان/نبات. أظهرت جميع الهجن المدروسة قوة هجين موجبة ومعنوية بالنسبة لمتوسط الأبوين وأفضل الأبوين، وتراوحت قوة الهجين من 49.06% للهجين P1 X P2 إلى 651.54% للهجين P1 X P4 على متوسط الأبوين ومن 32.12% للهجين P1 x P2 إلى 529.70% للهجين P1 × P4 على أفضل الأبوين. لذلك يمكن التوصية باستخدام الهجين P1 × P4 في برنامج تربية الذرة الشامية الصفراء لزيادة الإنتاجية والتبكير في النضج.