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# Determination of Combining Ability and Type of Gene Action Using Half-Diallel Cross Among Seven $S_6$ White Maize Inbred Lines

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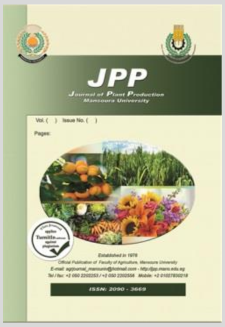



## ABSTRACT

Seven $S_6$ white maize inbred lines were derived from selfing of $S_4$ inbred lines of two populations; three way cross-324 and Giza-2 were used as parents of a 7 x 7 half-diallel cross and were obtained on 21 $F_1$ crosses. These 7 $S_6$ inbred lines and their 21 $F_1$ crosses along with the 2 checks i.e., SC-128 and SC-129 were evaluated at Experimental Farm, Faculty of Agriculture, Al-Azhar University, Assiut Branch in 2021. Highly significant differences were detected among genotypes, parents, crosses, parents vs. crosses, general and specific combining abilities for all traits. $\sigma^2$GCA/$\sigma^2$SCA was less than the unity for all traits. The 4 crosses; $P_4$ x $P_7$, $P_5$ x $P_6$, $P_5$ x $P_7$ and $P_6$ x $P_7$ possessed desirable significant positive heterotic effects for increasing grain yield/plant relative to the checks SC-128 and SC-129, and among them the 3 crosses; $P_5$ x $P_6$, $P_5$ x $P_7$ and $P_6$ x $P_7$, also possessed significant negative desirable standard heterotic effects for tasseling and silking earliness relative to both the checks. The 2 parents; $P_6$ and $P_7$, which derived from Giza-2 population could be considered as good general combiners for improving maize genotypes for earliness and high yielding ability. The 9 crosses; $P_1 \times P_2$, $P_1 \times P_4$, $P_1 \times P_5$, $P_2 \times P_6$, $P_3 \times P_4$, $P_3 \times P_7$, $P_5 \times P_6$, $P_5 \times P_7$ and $P_6 \times P_7$ possessed significant positive desirable SCA effects for high yielding ability, as well as significant negative desirable SCA effects for earliness. The dominance was in over dominance range for all the studied traits, where the average degree of dominance was more than one.


*Keywords:* Maize, combining ability, gene action, standard heterosis, yield and earliness

## INTRODUCTION

Maize (*Zea mays* L.) used in human food, animal feeding and industry (Keskin *et al.*, 2005). It ranks as the third position among cereal crops for production and consumption after wheat and rice over all the world. Maize improvement productivity is the main target of maize breeders to face the gap between production and consumption. To achieve this target more genetic information is needed for the successful breeding programs. Several types of hybrids are possible in maize, however the most common ones used for commercial production are derived from inbred lines. Studying heterosis in hybridization programs is a prime importance to develop new superior hybrids. The diallel analysis is an important method to know gene action and its frequently used by crop breeders to choose the parents with high general combining ability (GCA) and hybrids with high specific combining ability (SCA) effects (Yingzhong, 1999). The two main genetic parameters of diallel analysis are GCA and SCA, which are essential in developing breeding strategies. Variance for GCA contains additive part, while for SCA includes non-additive part emerging mostly from dominance and epistatic deviations (Izhar and Chakraborty, 2013). Most of the literature about maize, suggest that additive effects of genes with partial to complete dominance are more important than dominance effects in determining grain yield (Lamkey and Lee 1993). Breeders still contend, however that dominance effects caused by genes with over dominant gene action are also important (Horner *et al.*, 1989). Heritability estimates are useful for breeding quantitative traits because it permits to determine the most effective selection strategy, breeding method to use in a breeding program and to predict gain from selection (Bilgin *et al.*, 2010). The objectives of the present investigation were to identify the best parents regarding the general combining ability and the best crosses regarding the specific combining ability, as well as determine the type of gene action that controls the inheritance of the studied traits.

## MATERIALS AND METHODS

Seven $S_6$ white maize inbred lines were derived from selfing of $S_4$ inbred lines of two populations; Three Way Cross-324 (TWC-324) with five $S_6$ inbred lines; $P_1$ - $P_5$ and Giza-2 with two $S_6$ inbred lines; $P_6$ and $P_7$ were used as parents of a 7 x 7 half-diallel crossing.

**Procedures and field experiments:**

The present study was conducted at Experimental Farm, Faculty of Agriculture, Al-Azhar University, Assiut Branch during three successive seasons from 2019 to 2021. In 2019 spring and summer seasons, the self-pollination was performed on the $S_4$ inbred lines of each population to obtain $S_5$ and $S_6$, respectively. In 2020 summer season, the 7 $S_6$ inbred lines were crossed in a 7 x 7 half-diallel mating design and were obtained on the 21 $F_1$ crosses. In 2021 summer season, the 7 $S_6$ inbred lines and their 21 $F_1$ crosses along with the 2 check hybrids, i.e., SC-128 and SC-129 were evaluated. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Planting was carried out on 25th of May. Experimental plot size was one ridge, 4 m in long with 70 cm between ridges. Planting was done in hills spaced 25 cm apart on one side of the ridge. The recommended

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agricultural practices of maize production were applied at the proper time. Data were recorded for days to 50% tasseling (day), days to 50% silking (day), plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), number of rows/ear, 100-kernel weight (g) and grain yield/plant (g), which was adjusted on the basis of 15.5% grain moisture content.

**Statistical Analysis Procedure:**

An ordinary analysis of variance of RCBD for the obtained data was performed according to Snedecor and Cochran (1967) to test the significance of differences among the genotypes and treatments means were compared statistically using the test of the Revised Lest Significant Differences (Rev. LSD). Standard heterosis (relative superior over the check) was determined for each cross as the percentage deviation of $F_1$ mean from each of the commercial check hybrid mean and expressed as percentage according to Fehr (1991) as follows:

$$\textbf{Standard heterosis\%} = \frac{\textbf{F1} - \textbf{check}}{\textbf{check}} \; \textbf{x 100}$$

Significance of standard heterotic effects were computed at appropriate Rev. LSD values.

Estimation of genetic variance components were based on Griffing′s (1956), diallel cross analysis, method II, model I (fixed model).

## RESULTS AND DISCUSSION

**Analysis of variance:**

Observed mean squares from ordinary analysis and combining ability for all the studied traits of the 7 $S_6$ white maize inbred lines and their 21 $F_1$ crosses in 2021 season is presented in Table 1. The obtained results cleared that highly significant differences were detected among genotypes for all the studied traits, indicating a wide range of diversity among the studied materials and combining ability analysis according to Griffing′s (1956), method II, model I could be done. As well as, highly significant differences were detected among parents and crosses for all the studied traits, indicating great diversity among them. Also, highly significant differences between parents vs. crosses were detected for all the studied traits, indicating presence of highly heterosis response in the materials study. Both GCA and SCA mean squares were highly significant for all the studied traits, indicating both additive and non-additive gene actions are involved in the inheritance of all the studied traits. These results were in confirmation with Ahmed *et al.* (2008), Abdel-Moneam *et al.* (2009), Osman *et al.* (2012), Attia *et al.* (2013), Abo El-Haress (2015), Bisen *et al.* (2017), Hammadi and Abed (2018), Anees *et al.* (2019), Hussain *et al.* (2019), Hemada *et al*. (2020) and El-Shahed *et al*. (2021).

**Table 1. Observed mean squares from ordinary analysis and combining ability for all the studied traits of the 7 $S_6$ white maize inbred lines and their 21 $F_1$ crosses in 2021 season.**

| S.O.V | D.F | Days to 50% tasseling | Days to 50% silking | Plant height | Ear height | Ear length | Ear diameter | Number of rows/ear | 100-kernel weight | Grain yield/plant |
|---|---|---|---|---|---|---|---|---|---|---|
| Replication | 2 | 10.44 | 17.58 | 145.32 | 93.65 | 7.30 | 0.29 | 0.33 | 25.37 | 263.44** |
| Genotypes | 27 | 22.77** | 23.52** | 7332.00** | 1869.75** | 22.32** | 0.75** | 9.85** | 269.17** | 7941.03** |
| Parents (P) | 6 | 14.49** | 16.38** | 545.87** | 896.10** | 15.33** | 0.51** | 6.86** | 9.16** | 324.41** |
| Crosses (C) | 20 | 21.98** | 21.24** | 1317.94** | 613.05** | 13.82** | 0.45** | 10.62** | 100.05** | 1556.08** |
| P vs. C | 1 | 88.10** | 112.00** | 168330.04** | 32845.75** | 234.32** | 8.08** | 12.44** | 5211.57** | 181339.68** |
| Error | 54 | 1.32 | 1.36 | 22.69 | 4.78 | 0.66 | 0.02 | 0.98 | 1.44 | 6.69 |
| GCA | 6 | 14.20** | 15.64** | 1133.36** | 707.23** | 16.32** | 0.24** | 4.86** | 33.41** | 1152.27** |
| SCA | 21 | 5.70** | 5.61** | 2818.47** | 599.26** | 4.90** | 0.25** | 2.83** | 105.81** | 3074.08** |
| Error | 54 | 0.44 | 0.45 | 7.56 | 1.59 | 0.22 | 0.01 | 0.33 | 0.48 | 2.23 |
| $\sigma^2$ GCA | | 1.53 | 1.69 | 125.09 | 78.40 | 1.79 | 0.03 | 0.50 | 3.66 | 127.78 |
| $\sigma^2$ SCA | | 5.26 | 5.16 | 2810.90 | 597.67 | 4.69 | 0.24 | 2.51 | 105.33 | 3071.85 |
| $\sigma^2$GCA/$\sigma^2$SCA | | 0.29 | 0.33 | 0.04 | 0.13 | 0.38 | 0.11 | 0.20 | 0.03 | 0.04 |

**** indicates to significant at 0.01 level of probability.**

The ratio of $\sigma^2$GCA/$\sigma^2$SCA after subtraction the environmental effect of both GCA and SCA variances as estimated according to Singh and Chaudhary (1979) was less than one for all the studied traits, indicating the non-additive gene action played the major role in the inheritance of all the studied traits, therefore selection procedure in the late or advanced generations will be very important to improve these traits. These obtained results are in the same line with those obtained by Haddadi *et al.* (2012), Amin *et al.* (2014), Azad *et al.* (2015), Hassan *et al.* (2019), El Hosary (2020), Hemada *et al*. (2020) and El-Shahed *et al.* (2021).

**Mean performance:**

Mean performance values for all the studied traits of the 7 $S_6$ white maize inbred lines and their 21 crosses along with the two check hybrids, i.e., SC-128 and SC-129 are presented in Table 2. The obtained results showed that the parent $P_7$ was significantly the best one, where it had significantly the lowest mean performance values for tasseling (54.67 day) and silking (56.33 day) earliness, as well as the highest values for increasing plant height (193.00 cm), ear height (126.00 cm), ear length (20.00 cm), ear diameter (4.15 cm), number of rows/ear (16.00 row) and grain yield/plant (104.33 g).

The 4 crosses; $P_3$ x $P_7$, $P_5$ x $P_6$, $P_5$ x $P_7$ and $P_6$ x $P_7$ had significantly the lower mean performance values for both tasseling date with values 52.67, 52.00, 52.67 and 51.33 day, respectively and silking date with values 54.33, 53.67, 54.00 and 53.00 day, respectively, as well as were significantly earlier tasseling and silking dates than both the check hybrids, i.e., SC-128 and SC-129. The 2 crosses; $P_1$ x $P_7$ and $P_2$ x $P_7$ had significantly the highest mean performance values for both plant height with 301.33 and 300.33 cm, respectively and ear height with 160.33 and 161.00 cm, respectively, as well as were significantly taller plant and higher ear placement than both the check hybrids, while none of the crosses had significantly mean performance value for both plant shortness and low ear placement. The 2 crosses; $P_2$ x $P_7$ and $P_6$ x $P_7$ had significantly the longest ear with 23.33 and 24.00 cm, respectively, as well as were significantly longer ear than both the check hybrids. The 3 crosses; $P_3$ x $P_5$, $P_3$ x $P_6$ and $P_3$ x $P_7$ had significantly the highest mean performance values for both ear diameter with values 5.10, 5.27 and 5.20 cm, respectively and number of rows/ear with 17.33 rows /ear, as well as were significantly wider ear and higher rows/ear than both the check hybrids. The 4 crosses; $P_1$ x $P_7$, $P_4$ x $P_7$, $P_5$ x $P_6$ and $P_5$ x $P_7$ were significantly the heaviest kernel weight with values 46.33, 46.00, 45.00 and 45.67 g, as well as were significantly heavier kernel than both the check hybrids. The 7 crosses; $P_1$ x $P_7$, $P_2$ x $P_7$, $P_3$ x $P_7$, $P_4$ x $P_7$, $P_5$ x $P_6$, $P_5$ x $P_7$ and $P_6$ x $P_7$ had significantly the highest grain yield/plant mean performance values with 218.67, 218.00, 212.67, 224.67, 220.67, 228.67 and 233.33 g, respectively and among them the 4 crosses; $P_3$ x $P_7$, $P_5$ x $P_6$, $P_5$ x $P_7$ and $P_6$ x $P_7$, also were significantly the earliest tasseling and silking dates, therefore these parents in these crosses accumulated favorable alleles for yielding ability and earliness and could be used in the future breeding programs. Among the previous crosses only the cross $P_6$ x $P_7$ out-yielded significantly both the check hybrids.

**Table 2. Mean performance values of the 7 $S_6$ inbred lines and their 21 $F_1$ crosses along with the 2 check hybrids, i.e., SC-128 and SC-129 for all the studied traits in 2021 season.**

| Parents | | Number of days to 50% tasseling (day) | Number of days to 50% silking (day) | Plant height (cm) | Ear height (cm) | Ear length (cm) | Ear diameter (cm) | Number of rows /ear | 100-kernel weight (g) | Grain yield/plant (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| $P_1$ | | 60.00 | 62.67 | 154.67 | 75.67 | 13.33 | 3.03 | 11.33 | 20.33 | 73.00 |
| $P_2$ | | 60.00 | 61.67 | 162.00 | 75.67 | 14.67 | 3.57 | 13.33 | 23.00 | 80.67 |
| $P_3$ | | 58.00 | 60.67 | 166.33 | 89.33 | 15.00 | 3.93 | 14.00 | 21.67 | 91.00 |
| $P_4$ | | 60.00 | 61.67 | 172.33 | 98.00 | 16.00 | 4.07 | 14.00 | 21.33 | 96.67 |
| $P_5$ | | 61.00 | 62.67 | 184.33 | 95.00 | 17.67 | 4.13 | 14.67 | 22.67 | 87.33 |
| $P_6$ | | 57.33 | 58.67 | 163.33 | 101.67 | 17.67 | 4.07 | 15.33 | 25.67 | 94.00 |
| $P_7$ | | 54.67 | 56.33 | 193.00 | 126.00 | 20.00 | 4.15 | 16.00 | 23.67 | 104.33 |
| Mean | | 58.71 | 60.62 | 170.86 | 94.48 | 16.33 | 3.85 | 14.09 | 22.62 | 89.57 |
| Crosses | | | | | | | | | | |
| $P_1$ x $P_2$ | | 57.00 | 59.00 | 243.00 | 115.00 | 16.33 | 4.20 | 11.33 | 22.67 | 162.33 |
| $P_1$ x $P_3$ | | 59.00 | 60.33 | 264.67 | 121.00 | 18.33 | 4.53 | 15.33 | 41.33 | 175.67 |
| $P_1$ x $P_4$ | | 57.00 | 58.67 | 276.00 | 127.00 | 19.33 | 4.77 | 14.67 | 43.67 | 193.33 |
| $P_1$ x $P_5$ | | 55.00 | 57.00 | 284.00 | 130.00 | 18.33 | 4.60 | 16.00 | 44.00 | 179.00 |
| $P_1$ x $P_6$ | | 59.00 | 60.00 | 246.67 | 134.67 | 20.00 | 4.30 | 14.67 | 41.00 | 193.67 |
| $P_1$ x $P_7$ | | 55.67 | 57.00 | 301.33 | 160.33 | 22.00 | 4.90 | 16.67 | 46.33 | 218.67 |
| $P_2$ x $P_3$ | | 60.00 | 61.33 | 263.67 | 129.67 | 19.00 | 3.93 | 12.67 | 37.33 | 186.33 |
| $P_2$ x $P_4$ | | 59.33 | 61.00 | 275.00 | 132.33 | 19.33 | 4.50 | 16.00 | 39.00 | 169.00 |
| $P_2$ x $P_5$ | | 58.00 | 60.00 | 293.00 | 158.33 | 20.33 | 4.27 | 14.00 | 42.00 | 174.33 |
| $P_2$ x $P_6$ | | 55.67 | 57.33 | 238.33 | 138.33 | 22.00 | 4.77 | 15.33 | 42.33 | 208.00 |
| $P_2$ x $P_7$ | | 58.33 | 59.67 | 300.33 | 161.00 | 23.33 | 4.03 | 13.33 | 44.00 | 218.00 |
| $P_3$ x $P_4$ | | 54.67 | 56.33 | 276.00 | 142.00 | 17.00 | 4.83 | 16.67 | 35.67 | 178.00 |
| $P_3$ x $P_5$ | | 54.67 | 56.67 | 293.00 | 147.00 | 16.67 | 5.10 | 17.33 | 29.00 | 157.00 |
| $P_3$ x $P_6$ | | 56.00 | 57.33 | 254.00 | 129.00 | 19.67 | 5.27 | 17.33 | 40.67 | 197.67 |
| $P_3$ x $P_7$ | | 52.67 | 54.33 | 296.33 | 150.67 | 21.67 | 5.20 | 17.33 | 43.00 | 212.67 |
| $P_4$ x $P_5$ | | 59.00 | 60.67 | 280.67 | 140.67 | 19.67 | 3.97 | 12.67 | 40.33 | 198.00 |
| $P_4$ x $P_6$ | | 60.33 | 62.00 | 235.67 | 118.67 | 21.00 | 4.35 | 13.33 | 44.00 | 205.33 |
| $P_4$ x $P_7$ | | 56.00 | 57.67 | 298.33 | 155.00 | 22.67 | 4.60 | 14.67 | 46.00 | 224.67 |
| $P_5$ x $P_6$ | | 52.00 | 53.67 | 273.33 | 143.00 | 21.67 | 4.83 | 12.00 | 45.00 | 220.67 |
| $P_5$ x $P_7$ | | 52.67 | 54.00 | 292.33 | 159.00 | 21.67 | 4.27 | 16.00 | 45.67 | 228.67 |
| $P_6$ x $P_7$ | | 51.33 | 53.00 | 273.33 | 150.33 | 24.00 | 4.67 | 17.33 | 44.00 | 233.33 |
| Mean | | 56.35 | 57.95 | 274.24 | 140.14 | 20.19 | 4.57 | 14.98 | 40.81 | 196.87 |
| Checks | SC-128 | 57.67 | 60.67 | 271.67 | 146.67 | 22.33 | 5.21 | 14.67 | 42.33 | 202.67 |
| | SC-129 | 55.67 | 59.33 | 284.33 | 151.00 | 20.33 | 4.83 | 15.33 | 43.67 | 212.67 |
| Rev. | 0.05 | 1.75 | 1.78 | 6.85 | 3.14 | 1.19 | 0.21 | 1.51 | 1.72 | 3.72 |
| L.S.D | 0.01 | 2.31 | 2.34 | 9.02 | 4.14 | 1.57 | 0.27 | 1.99 | 2.27 | 4.90 |

**Standard heterosis:**

Standard heterosis values of the 21 $F_1$ crosses relative to the two check hybrids, i.e., SC-128 and SC-129 for all the studied traits are presented in Table 3. The obtained results manifested that the 6 crosses; $P_3$ x $P_4$, $P_3$ x $P_5$, $P_3$ x $P_7$, $P_5$ x $P_6$, $P_5$ x $P_7$ and $P_6$ x $P_7$ possessed significant negative desirable standard heterotic effects for tasseling and silking earliness relative to both the check hybrids, i.e., SC-128 and SC-129. The 4 crosses; $P_1$ x $P_2$, $P_1$ x $P_6$, $P_2$ x $P_6$ and $P_4$ x $P_6$ possessed desirable significant negative heterotic effects for decreasing both plant height and ear height relative to both the check hybrids, while none of the crosses possessed desirable significant positive heterotic effects for increasing both plant height and ear height relative to both the check hybrids. The 3 crosses; $P_2$ x $P_7$, $P_4$ x $P_7$ and $P_6$ x $P_7$ possessed desirable significant positive heterotic effects for increasing ear length relative to both the check hybrids. Only the cross $P_3$ x $P_6$ possessed desirable significant positive heterotic effect for increasing both ear diameter and number of rows/ear relative to both the check hybrids. The 4 crosses; $P_1$ x $P_7$, $P_4$ x $P_7$, $P_5$ x $P_6$ and $P_5$ x $P_7$ possessed desirable significant positive heterotic effects for increasing kernel weight relative to both the check hybrids. The 4 crosses; $P_4$ x $P_7$, $P_5$ x $P_6$, $P_5$ x $P_7$ and $P_6$ x $P_7$ possessed desirable significant positive heterotic effects for increasing grain yield/plant relative to the check hybrid SC-128 with values 10.85, 8.88, 12.83 and 15.13 %, respectively and the check hybrid SC-129 with values 5.64, 3.76, 7.52 and 9.72 %, respectively and among them the 3 crosses; $P_5$ x $P_6$, $P_5$ x $P_7$ and $P_6$ x $P_7$, also possessed significant negative desirable standard heterotic effects for tasseling and silking earliness relative to both the check hybrids, therefore these crosses possessed the highest frequency of favorable alleles for high yielding ability with earliness.

**Table 3. Standard heterosis values of the 21 $F_1$ white maize crosses relative to the 2 check hybrids, i.e., SC-128 and SC-129 for all the studied traits in 2021 season.**

| Crosses | | Days to 50% tasseling | | Days to 50% silking | | Plant height | | Ear height | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-128 | SC-129 | SC-128 | SC-129 | SC-128 | SC-129 | SC-128 | SC-129 |
| $P_1$ x $P_2$ | | -1.16 | 2.40** | -2.75** | -0.56 | -10.55** | -14.54** | -21.59** | -23.84** |
| $P_1$ x $P_3$ | | 2.31** | 5.99** | -0.55 | 1.69* | -2.58 | -6.92 | -17.50** | -19.87** |
| $P_1$ x $P_4$ | | -1.16 | 2.40** | -3.30** | -1.12 | 1.59 | -2.93 | -13.41** | -15.89** |
| $P_1$ x $P_5$ | | -4.62** | -1.20 | -6.05** | -3.93** | 4.54 | -0.12 | -11.37** | -13.91** |
| $P_1$ x $P_6$ | | 2.31** | 5.99** | -1.10 | 1.13 | -9.20* | -13.25** | -8.18** | -10.82** |
| $P_1$ x $P_7$ | | -3.47** | 0.00 | -6.05** | -3.93** | 10.92** | 5.98 | 9.32** | 6.18** |
| $P_2$ x $P_3$ | | 4.05** | 7.78** | 1.09 | 3.38** | -2.95 | -7.27* | -11.59** | -14.13** |
| $P_2$ x $P_4$ | | 2.89** | 6.59** | 0.54 | 2.81** | 1.23 | -3.28 | -9.77** | -12.36** |
| $P_2$ x $P_5$ | | 0.58 | 4.19** | -1.10 | 1.13 | 7.85* | 3.05 | 7.95** | 4.86** |
| $P_2$ x $P_6$ | | -3.47** | 0.00 | -5.50** | -3.37** | -12.27** | -16.18** | -5.68** | -8.39** |
| $P_2$ x $P_7$ | | 1.16 | 4.79** | -1.65* | 0.57 | 10.55** | 5.63 | 9.77** | 6.62** |
| $P_3$ x $P_4$ | | -5.20** | -1.80* | -7.15** | -5.05** | 1.59 | -2.93 | -3.18* | -5.96** |
| $P_3$ x $P_5$ | | -5.20** | -1.80* | -6.60** | -4.49** | 7.85* | 3.05 | 0.22 | -2.65 |
| $P_3$ x $P_6$ | | -2.89** | 0.60 | -5.50** | -3.37** | -6.50 | -10.67** | -12.05** | -14.57** |
| $P_3$ x $P_7$ | | -8.67** | -5.39** | -10.44** | -8.42** | 9.08** | 4.22 | 2.72 | -0.22 |
| $P_4$ x $P_5$ | | 2.31** | 5.99** | -0.01 | 2.25* | 3.31 | -1.29 | -4.09* | -6.84** |
| $P_4$ x $P_6$ | | 4.62** | 8.38** | 2.19* | 4.50** | -13.25** | -17.12** | -19.09** | -21.41** |
| $P_4$ x $P_7$ | | -2.89** | 0.60 | -4.95** | -2.80** | 9.81** | 4.93 | 5.68** | 2.65 |
| $P_5$ x $P_6$ | | -9.83** | -6.59** | -11.54** | -9.55** | 0.61 | -3.87 | -2.50 | -5.30** |
| $P_5$ x $P_7$ | | -8.67** | -5.39** | -10.99** | -8.98** | 7.61* | 2.81 | 8.41** | 5.30** |
| $P_6$ x $P_7$ | | -10.98** | -7.78** | -12.64** | -10.67** | 0.61 | -3.87 | 2.50 | -0.44 |
| Rev. L.S.D | 0.05 | 1.57 | | 1.59 | | 7.00 | | 3.14 | |
| | 0.01 | 2.31 | | 2.34 | | 9.22 | | 4.14 | |

*** and ** indicate to significant at 0.05 and 0.01 levels of probability, respectively.**

**Table 3. Cont.**

| Crosses | | Ear length | | Ear diameter | | Number of rows/ear | | 100-kernel weight | | Grain yield/plant | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SC-128 | SC-129 | SC-128 | SC-129 | SC-128 | SC-129 | SC-128 | SC-129 | SC-128 | SC-129 |
| $P_1$ x $P_2$ | | -26.85** | -19.66** | -19.45** | -13.11** | -22.74** | -26.07** | -46.45** | -48.10** | -19.90** | -23.67** |
| $P_1$ x $P_3$ | | -17.90** | -9.82** | -12.99** | -6.14** | 4.52** | 0.02 | -2.35** | -5.35** | -13.32** | -17.40** |
| $P_1$ x $P_4$ | | -13.42** | -4.90** | -8.51** | -1.31** | -0.02 | -4.33** | 3.16** | -0.01 | -4.61* | -9.09** |
| $P_1$ x $P_5$ | | -17.90** | -9.82** | -11.71** | -4.76** | 9.07** | 4.37** | 3.95** | 0.76 | -11.68** | -15.83** |
| $P_1$ x $P_6$ | | -10.43** | -1.62* | -17.47** | -10.97** | -0.02 | -4.33** | -3.14** | -6.11** | -4.44* | -8.94** |
| $P_1$ x $P_7$ | | -1.48* | 8.21** | -5.95** | 1.45** | 13.61** | 8.72** | 9.46** | 6.10** | 7.89** | 2.82 |
| $P_2$ x $P_3$ | | -14.91** | -6.54** | -24.50** | -18.56** | -13.66** | -17.37** | -11.80** | -14.51** | -8.06** | -12.38** |
| $P_2$ x $P_4$ | | -13.42** | -4.90** | -13.63** | -6.83** | 9.07** | 4.37** | -7.87** | -10.69** | -16.61** | -20.53** |
| $P_2$ x $P_5$ | | -8.94** | 0.02 | -18.11** | -11.66** | -4.57** | -8.68** | -0.78 | -3.82** | -13.98** | -18.03** |
| $P_2$ x $P_6$ | | -1.48* | 8.21** | -8.51** | -1.31** | 4.52** | 0.02 | 0.01 | -3.06** | 2.63 | -2.20 |
| $P_2$ x $P_7$ | | 4.49** | 14.77** | -22.58** | -16.49** | -9.11** | -13.02** | 3.95** | 0.76 | 7.56** | 2.51 |
| $P_3$ x $P_4$ | | -23.87** | -16.38** | -7.23** | 0.07 | 13.61** | 8.72** | -15.74** | -18.33** | -12.17** | -16.30** |
| $P_3$ x $P_5$ | | -25.36** | -18.02** | -2.11** | 5.59** | 18.15** | 13.07** | -31.49** | -33.59** | -22.53** | -26.18** |
| $P_3$ x $P_6$ | | -11.93** | -3.26** | 1.09** | 9.04** | 18.15** | 13.07** | -3.93** | -6.88** | -2.47 | -7.05** |
| $P_3$ x $P_7$ | | -2.97** | 6.57** | -0.19** | 7.66** | 18.15** | 13.07** | 1.58 | -1.53 | 4.93** | 0.00 |
| $P_4$ x $P_5$ | | -11.93** | -3.26** | -23.86** | -17.87** | -13.66** | -17.37** | -4.72** | -7.64** | -2.30 | -6.90** |
| $P_4$ x $P_6$ | | -5.96** | 3.30** | -16.51** | -9.94** | -9.11** | -13.02** | 3.95** | 0.76 | 1.31 | -3.45 |
| $P_4$ x $P_7$ | | 1.51* | 11.49** | -11.71** | -4.76** | -0.02 | -4.33** | 8.67** | 5.34** | 10.85** | 5.64** |
| $P_5$ x $P_6$ | | -2.97** | 6.57** | -7.23** | 0.07 | -18.20** | -21.72** | 6.31** | 3.05** | 8.88** | 3.76* |
| $P_5$ x $P_7$ | | -2.97** | 6.57** | -18.11** | -11.66** | 9.07** | 4.37** | 7.88** | 4.57** | 12.83** | 7.52** |
| $P_6$ x $P_7$ | | 7.48** | 18.05** | -10.43** | -3.38** | 18.15** | 13.07** | 3.95** | 0.76 | 15.13** | 9.72** |
| Rev. L.S.D | 0.05 | 1.11 | | 0.19 | | 1.35 | | 1.76 | | 3.72 | |
| | 0.01 | 1.63 | | 0.28 | | 1.99 | | 2.32 | | 4.90 | |

*** and ** indicate to significant at 0.05 and 0.01 levels of probability, respectively.**

**General combining ability:**

Estimates of the general combining ability (GCA) effects for all the studied traits of the 7 $S_6$ parental inbred lines are presented in Table 4. The obtained data exhibited that the 2 parents; $P_1$ and $P_2$ possessed significant negative desirable GCA effects in direction to plant shortness and low ear placement. The $P_3$ possessed significant negative desirable GCA effects for low ear placement and significant positive desirable GCA effects for increasing ear diameter and number of rows/ear. The $P_4$ possessed significant negative desirable GCA effects for low ear placement. The $P_5$ possessed significant positive desirable GCA effects in direction to plant heightens and ear heightens. The $P_6$ possessed significant negative desirable GCA effects for tasseling and silking earliness, plant shortness and low ear placement, as well as significant positive desirable GCA effects for increasing ear length, ear diameter, 100-kernel weight and grain yield/plant. The $P_7$ possessed significant negative desirable GCA effects for tasseling and silking earliness, as well as significant positive desirable GCA effects for increasing plant height, ear height, ear length, ear diameter, number of rows/ear, 100-kernel weight and grain yield/plant. Therefore, the two parents; $P_6$ and $P_7$, which derived from Giza-2 population could be considered as good general combiners and could be used in the future breeding programs for improvement white maize genotypes for earliness and high yielding ability.

**Table 4. General combining ability effects of the 7 $S_6$ parental inbred lines for all the studied traits in 2021 season.**

| Parents | | Days to 50% tasseling | Days to 50% silking | Plant height | Ear height | Ear length | Ear diameter | Number of rows/ear | 100-kernel weight | Grain yield/plant |
|---|---|---|---|---|---|---|---|---|---|---|
| $P_1$ | | 0.79** | 0.93** | -6.90** | -10.05** | -1.42** | -0.19** | -0.76** | -1.17** | -10.19** |
| $P_2$ | | 1.42** | 1.41** | -5.53** | -4.87** | -0.46* | -0.26** | -0.98** | -1.86** | -9.01** |
| $P_3$ | | -0.28 | -0.14 | -0.76 | -3.53** | -1.28** | 0.18** | 0.73** | -2.20** | -7.89** |
| $P_4$ | | 1.20** | 1.19** | -0.09 | -2.02** | -0.31 | 0.01 | -0.23 | 0.14 | 0.14 |
| $P_5$ | | -0.24 | -0.18 | 10.87** | 4.24** | -0.02 | 0.02 | -0.08 | 0.14 | -3.12** |
| $P_6$ | | -0.72** | -0.92** | -15.46** | -1.39** | 1.10** | 0.14** | 0.29 | 2.03** | 9.59** |
| $P_7$ | | -2.17** | -2.29** | 17.87** | 17.62** | 2.39** | 0.10** | 1.03** | 2.92** | 20.48** |
| L.S.E (gi) | 0.05 | 0.48 | 0.49 | 1.99 | 0.91 | 0.34 | 0.05 | 0.42 | 0.50 | 1.08 |
| | 0.01 | 0.67 | 0.68 | 2.79 | 1.28 | 0.47 | 0.07 | 0.59 | 0.70 | 1.52 |

*** and ** indicate to significant at 0.05 and 0.01 levels of probability, respectively.**
**L.S.E is least significant effect.**

**Specific combining ability effects:**

Estimates of the specific combining ability (SCA) effects of the 21 $F_1$ white maize crosses for all the studied traits are presented in Table 5. The obtained results manifested that the 9 crosses; $P_1 \times P_2$, $P_1 \times P_4$, $P_1 \times P_5$, $P_2 \times P_6$, $P_3 \times P_4$, $P_3 \times P_7$, $P_5 \times P_6$, $P_5 \times P_7$ and $P_6 \times P_7$ possessed significant negative desirable SCA effects for both tasseling and silking earliness, as well as possessed significant positive desirable SCA effects for high yielding ability, therefore these 9 crosses could be considered as good combinations for high yielding ability with earliness. All the 21 crosses, except the 2 crosses; $P_1 \times P_2$ and $P_4 \times P_6$ possessed significant positive desirable SCA effects for both plant heightens, and ear heightens, while none of the crosses possessed significant negative desirable SCA effects for both plant shortness and low ear placement. Fifteen crosses out of the 21 possessed significant positive desirable SCA effects for increasing ear length. The 8 crosses; $P_1 \times P_4$, $P_1 \times P_5$, $P_1 \times P_7$, $P_2 \times P_4$, $P_2 \times P_6$, $P_3 \times P_4$, $P_3 \times P_5$ and $P_3 \times P_6$ possessed significant positive desirable SCA effects for increasing both ear diameter and number of rows/ear. All the crosses possessed significant positive desirable SCA effects for kernel heaviness and high yielding ability, except the cross $P_1 \times P_2$ for kernel heaviness and the cross $P_3$ x $P_5$ for both traits.

**Table 5. Specific combining ability effects of the 21 $F_1$ white maize crosses for all the studied traits in 2021 season.**

| Crosses | | Days to 50% tasseling | Days to 50% silking | Plant height | Ear height | Ear length | Ear diameter | Number of rows/ear | 100-kernel weight | Grain yield/plant |
|---|---|---|---|---|---|---|---|---|---|---|
| $P_1$ x $P_2$ | | -2.16** | -1.96* | 7.05** | 1.19 | -1.01** | 0.25** | -1.70** | -10.57** | 11.48** |
| $P_1$ x $P_3$ | | 1.55** | 0.93 | 23.94** | 5.86** | 1.81** | 0.16** | 0.59 | 8.43** | 23.70** |
| $P_1$ x $P_4$ | | -1.94** | -2.07* | 34.60** | 10.34** | 1.84** | 0.57** | 0.89* | 8.43** | 33.33** |
| $P_1$ x $P_5$ | | -2.49** | -2.37** | 31.64** | 7.08** | 0.55 | 0.38** | 2.07** | 8.76** | 22.26** |
| $P_1$ x $P_6$ | | 1.99** | 1.37 | 20.64** | 17.38** | 1.10** | -0.03 | 0.37 | 3.87** | 24.22** |
| $P_1$ x $P_7$ | | 0.10 | -0.26 | 41.97** | 24.05** | 1.81** | 0.61** | 1.63** | 8.31** | 38.33** |
| $P_2$ x $P_3$ | | 1.92** | 1.44 | 21.56** | 9.34** | 1.51** | -0.38** | -1.85** | 5.13** | 33.19** |
| $P_2$ x $P_4$ | | -0.23 | -0.22 | 32.23** | 10.49** | 0.88* | 0.36** | 2.44** | 4.46** | 7.81** |
| $P_2$ x $P_5$ | | -0.12 | 0.15 | 39.27** | 30.23** | 1.58** | 0.11* | 0.30 | 7.46** | 16.41** |
| $P_2$ x $P_6$ | | -1.97** | -1.78* | 10.94** | 15.86** | 2.14** | 0.50** | 1.26** | 5.91** | 37.37** |
| $P_2$ x $P_7$ | | 2.14** | 1.93* | 39.60** | 19.53** | 2.18** | -0.20** | -1.48** | 6.69** | 36.48** |
| $P_3$ x $P_4$ | | -3.19** | -3.33** | 28.45** | 18.82** | -0.64 | 0.26** | 1.41** | 1.46** | 15.70** |
| $P_3$ x $P_5$ | | -1.75** | -1.63 | 34.49** | 17.56** | -1.27** | 0.51** | 1.93** | -5.20** | -2.04 |
| $P_3$ x $P_6$ | | 0.06 | -0.22 | 21.82** | 5.19** | 0.62 | 0.56** | 1.56** | 4.57** | 25.93** |
| $P_3$ x $P_7$ | | -1.82** | -1.85* | 30.82** | 7.86** | 1.32** | 0.53** | 0.81 | 6.02** | 30.04** |
| $P_4$ x $P_5$ | | 1.10* | 1.04 | 21.49** | 9.71** | 0.77* | -0.45** | -1.78** | 3.80** | 30.93** |
| $P_4$ x $P_6$ | | 2.92** | 3.11** | 2.82 | -6.66** | 0.99** | -0.18** | -1.48** | 5.57** | 25.56** |
| $P_4$ x $P_7$ | | 0.03 | 0.15 | 32.16** | 10.68** | 1.36** | 0.11* | -0.89* | 6.69** | 34.00** |
| $P_5$ x $P_6$ | | -3.97** | -3.85** | 29.53** | 11.42** | 1.36** | 0.29** | -2.96** | 6.57** | 44.15** |
| $P_5$ x $P_7$ | | -1.86** | -2.15* | 15.19** | 8.42** | 0.06 | -0.24** | 0.30 | 6.35** | 41.26** |
| $P_6$ x $P_7$ | | -2.71** | -2.41** | 22.53** | 5.38** | 1.29** | 0.05 | 1.26** | 2.80** | 33.22** |
| L.S.E (Sij) | 0.05 | 0.98 | 1.74 | 4.08 | 1.87 | 0.69 | 0.11 | 0.86 | 1.03 | 2.21 |
| | 0.01 | 1.30 | 2.31 | 5.40 | 2.48 | 0.92 | 0.14 | 1.14 | 1.36 | 2.93 |

*** and ** indicate to significant at 0.05 and 0.01 levels of probability, respectively.**
**L.S.E is least significant effect.**

**Genetic variance components:**

Estimation of genetic variances of additive ($\sigma^2$A), dominance ($\sigma^2$D), environmental ($\sigma^2$E) and phenotypic ($\sigma^2$P), as well as average degree of dominance (ā) and heritability in narrow sense ($h^2$ns) for all the studied traits are presented in Table 6. The obtained results manifested that low narrow sense heritability (< 20 %) estimates with high degree of dominance and less than the unity of the ratio $\sigma^2$GCA/$\sigma^2$SCA were detected for plant height, ear diameter, 100-kernel weight and grain yield/plant, indicating the non-additive genetic effect played the major role in the inheritance of these traits.

Medium narrow sense heritability (20 to 50%) estimates with high degree of dominance and less than the unity of the ratio $\sigma^2$GCA/$\sigma^2$SCA were detected for number of days to 50% tasseling, number of days to 50% silking, ear height, ear length and number of rows/ear, indicating both additive and non-additive genetic effects were important in the inheritance of these traits with preponderance of the non-additive.

The average degree of dominance was more than onefor all the studied traits, indicating the dominance was in over dominance range for controlling the inheritance of these traits.

These results agreed with the findings of Mohamad *et al.* (2007), Dawod *et al.* (2012), Wannows *et al.* (2012), Dar *et al.* (2017), Al-Rawi *et al.* (2018), Ali (2020) and Hemada *et al*. (2020).

**Table 6. Estimation of genetic variances of additive ($\sigma^2$A), dominance ($\sigma^2$D), environmental ($\sigma^2$E) and phenotypic ($\sigma^2$P), as well as average degree of dominance (ā) and heritability in narrow sense ($h^2$ns).**

| S.O.V | Days to 50% tasseling | Days to 50% silking | Plant height | Ear height | Ear length | Ear diameter | Number of rows/ear | 100-kernel weight | Grain yield/plant |
|---|---|---|---|---|---|---|---|---|---|
| GCA/ SCA | 0.29 | 0.33 | 0.04 | 0.13 | 0.38 | 0.11 | 0.20 | 0.03 | 0.04 |
| $\sigma^2$A | 3.06 | 3.38 | 250.18 | 156.80 | 3.58 | 0.06 | 1 | 7.32 | 255.56 |
| $\sigma^2$D | 5.26 | 5.16 | 2810.90 | 597.67 | 4.69 | 0.24 | 2.51 | 105.33 | 3071.85 |
| $\sigma^2$E | 0.44 | 0.45 | 7.56 | 1.59 | 0.22 | 0.01 | 0.33 | 0.48 | 2.23 |
| $\sigma^2$P | 8.76 | 8.99 | 3068.64 | 756.06 | 8.49 | 0.31 | 3.84 | 113.13 | 3329.64 |
| ā | 1.85 | 1.75 | 4.74 | 2.76 | 1.62 | 2.83 | 2.24 | 5.36 | 4.90 |
| $h^2$ns | 34.93 | 37.60 | 8.15 | 20.74 | 42.17 | 19.35 | 26.04 | 6.47 | 7.68 |

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## تقدير القدرة على التآلف ونوع الفعل الجيني باستخدام التهجين النصف تبادلي بين سبع سلالات من سلالات الجيل الذاتي السادس من الذرة الشامية البيضاء

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أجريت هذه الدراسة خلال الفترة من 2019- 2021 بمزرعة كلية الزراعة جامعة الأزهر فرع أسيوط لتقدير قوة الهجين القياسية والقدرة العامة والخاصة على التآلف ومكونات التباين الوراثي ومتوسط درجة السيادة ودرجة التوريث بالمعنى الضيق لـ 21 هجين فردي و7 من سلالات الجيل الذاتي السادس $S_6$ من الذرة الشامية البيضاء الحبوب المستنبطة من عشيرتين هما عشيرة الهجين الثلاثي 324 بعدد 5 سلالات ($P_5$-$P_1$) والعشيرة جيزة -2 بعدد سلالتين ($P_7$-$P_6$). في الزراعة المبكرة والمتأخرة في فصلي الربيع والصيف لموسم 2019، تم إجراء التلقيح الذاتي لسلالات الجيل الذاتي الرابع $S_4$ والخامس $S_5$ على التوالي للحصول على سلالات الجيل الذاتي السادس $S_6$. في موسم 2020 تم إجراء التهجين بين الـ 7 سلالات $S_6$ بكل الطرق الممكنة بدون إجراء الهجن العكسية لإنتاج حبوب الـ 21 هجين فردى. وفي موسم 2021 تم تقييم الـ 21 هجين فردي مع اثنين من هجن المقارنة هما الهجين الفردي 128 والهجين الفردي 129 باستخدام تصميم القطاعات الكاملة العشوائية في ثلاث مكررات. تم تحليل البيانات وراثيا تبعا للطريقة الثانية، الموديل الأول للعالم جريفنج 1956. تم تسجيل البيانات لصفات، عدد الأيام حتى ظهور 50٪ من النورة المذكرة، عدد الأيام حتى ظهور 50٪ من النورة المؤنثة، ارتفاع النبات، ارتفاع الكوز، طول الكوز، قطر الكوز، عدد صفوف الكوز، وزن الـ 100 حبة ومحصول حبوب النبات. أظهر تحليل التباين وجود اختلافات عالية المعنوية بين التراكيب الوراثية والآباء والهجن والآباء مقابل الهجن (تأثير قوة الهجين) والقدرة العامة والخاصة على التآلف لجميع الصفات المدروسة. كانت التأثيرات الجينية المضيفة والغير مضيفة (السيادية) مهمة في وراثة جميع الصفات المدروسة مع تفوق تأثيرات الجينات غير المضيفة (السيادية). كان التأثير الجيني السيادي راجع إلى السيادة الفائقة لجميع الصفات المدروسة حيث كان متوسط درجة السيادة أكبر من واحد. تفوقت الهجن الأربعة، $P_4 \times P_7$ ، $P_5 \times P_6$ ، $P_5 \times P_7$ ، $P_6 \times P_7$ معنويا في محصول حبوب النبات بالنسبة إلى كلا من هجيني المقارنة بزيادة قدرها 10،85 ، 8،88 ، 12،83 ،15،13 % عن الهجين الفردي 128على التوالي و 5،64 ، 3،76 ، 7،52 ، 9،72 % عن الهجين الفردي 129 على التوالي. امتلك الأبوان $P_6$ , $P_7$ تأثير قدرة عامة على التآلف معنوي ومرغوب لكل الصفات المدروسة باستثناء عدد صفوف الكوز للأب $P_6$. سجلت الـ 9 هجن، $P_1 \times P_2$, $P_1 \times P_4$, $P_1 \times P_5$, $P_2 \times P_6$, $P_3 \times P_4$, $P_3 \times P_7$, $P_5 \times P_6$, $P_5 \times P_7$, $P_6 \times P_7$ تأثيرا للقدرة الخاصة على التآلف معنوي لزيادة محصول حبوب النبات ولتبكير النورة المذكرة والمؤنثة.