ABSTRACT

A diallel cross among inbred lines of maize (Zea mays L.) with medium maturity and an evaluation to estimate the genetic parameters for days to 50% tasseling, days to 50% silking, plant and ear heights, resistance to late wilt disease, ear position were carried out. Mean squares were significant for all of the studied traits. Hybrids mean squares were highly significant for the all studied traits under both planting dates and combined analysis, except days to 50% silking. Indicating that the hybrids performance differed from planting date to another. The highest negative heterosis effect was exhibited by cross P5×P2, P6×P2, P2×P6, P3×P5 and P3×P6 over better parent, crosses P5×P2, P6×P2 and P2×P6 over mid-parents and crosses P5×P1, P3×P2, P4×P2, P5×P2, P6×P2, P2×P6, P3×P5 and P3×P6 over check varieties for tasseling date. For days to 50% silking showed that highest significant and negative heterotic effect was exhibited by crosses P6×P1, P6×P2, P2×P6, P4×P3 and P3×P6 over mid-parents and all crosses had highly significant and negative heterosis over check varieties, the highest significant and negative heterotic effects were reported by P6×P1, P6×P2, P2×P6, P4×P3 and P3×P6 over mid-parents and, P3×P2, P4×P2 reciprocal, P5×P2, P6×P2 and P3×P6 over ear height values. The highest significant and positive heterotic effect was exhibited by P3×P5 and P4×P3 (40.35 and 37.46%) over better-parent and mid-parents respectively, P4×P2 (13.93%) highest negative significant heterotic effect over check varieties for plant height. For ear height cross P4×P3 showed maximum negative heterosis over check varieties. For resistance to late wilt disease results regarding significant for crosses P1×P3, P4×P1, P1×P5 and P5 × P1 (1.522%) over mid-parents, indicating that these crosses are the best combinations for resistance to late wilt disease. For ear position, 25 crosses show highly significant and negative heterosis over better-parent value for ear position, P4×P3 showed maximum negative heterosis over better-parent and over mid-parents. Seven crosses show highly significant and negative heterosis over check varieties value for ear position, P6×P4 (-8.92%) showed maximum negative heterosis over check varieties. Heritability estimates in broad sense were generally higher at combined data. In the combined data percentage of heritability in the narrow sense for studied traits ranged from 20% for plant height to 46% for days to 50% tasseling or silking. Heritability estimates were low for plant and ear heights in narrow sense (20% and 28%) and the same in broad sense (29% and 38%), respectively. Heritability estimates in broad sense were medium (29% -64%) of all studied traits. Hence it could be concluded that these crosses may be useful for improving maize grain yield program.

Key words: Heterosis, Heritability, diallel analysis, maize inbred line.
INTRODUCTION

The use of heterosis started in 1933 when in the USA approximately 1 % of the total farming acreage was planted with heterosis maize hybrids, while in 1953 the heterosis of the maize hybrids were expanded up to 96% (Sprague, 1962). The choice of the most efficient breeding program depends on the said information (Liao 1989, Hallauer, 1990). The effects of general Combining Abilities (GCA) and Specific Combining Abilities (SCA) are important indicators of potential value for inbred lines in hybrid combinations. Differences in GCA effects have been attributed to additive, the interaction of additive x additive, and the higher-order interactions of additive genetic effects in the base population, while differences in SCA effects have been attributed to non-additive genetic variance (Falconer, 1981). The concept of GCA and SCA has become increasingly important to plant breeders because of the widespread use of hybrid cultivars in many crops. The evaluation of crosses among inbred lines is an important step towards the development of hybrid varieties in maize (Hallauer, 1990). This process ideally should be through the evaluation of all possible crosses (diallel crosses), where the merits of each inbred line can be determined. A Diallel analysis provides good information on the genetic identity of genotypes especially on dominance-recessive relations and some other genetic interactions. Diallel crosses have been used in genetic research to determine the inheritance of a trait among a set of genotypes and to identify superior parents for hybrid or cultivar development (Yan and Kang, 2003). The main objective of our study was to estimate the heterosis and genetic parameters among these maize inbred lines and, consequently, to identify superior single-cross hybrids (SCH) developed from the studied new maize inbred lines.

MATERIALS AND METHODS

The following six new yellow parental inbred lines were studied: 10RF, 11RF, 39RF, 45RF, 48RF and 50RF. These lines were differed considerably in expression of various agronomic traits. Six inbred lines were crossed at Gemmeiza in a full diallel to give 30 crosses including reciprocal crosses in the summer of 2010 at Agricultural Research Center in Egypt (A. R. C.) . The parents and their 30 F1 hybrids as well as two check hybrids (single cross 155 and single cross 162) were evaluated at Gemmeiza location on randomized complete block design (RCBD) with four replications in two different planting dates in 15 April and 15 May 2011. Kernels were hand- sown at 3 to 4 grains per hill then thinned at two plants per hill after emergence. Each replication contained 38 plots and each plot consisted of one ridge with 6 m long and spacing of 35 cm between plants within ridge and 80 cm between ridges. In Experiments data were recorded on the following characters on plot basis: days to 50 % tasseling, days to 50% silking, plant and ear heights, resistance to late wilt disease and ear position.

Statistical analysis procedure:

Analysis of variance for mean of performance according to the method outlined by Snedecor and Cochran (1977) was used for each experiment and then combined over the two planting dates. The L.S.D. test at 5% and 1% according to (Steel and Torrie, 1980) was used for comparison the mean performance of the different genotypes.

General combining ability (GCA) and specific combining ability (SCA) effects were estimated according to Griffings (1956) Method 1 Model 1. In addition the mathematical model for a single inbred cross were tested for normality by statistical software. Then, data were analyzed using AGR 21 Statically Software (2001). The evaluating main genotype effects obtain GCA, SCA, reciprocal, maternal and non-maternal effects and their interaction with environment.

Broad sense heritability $h^2_A$ and narrow sense heritability $h^2_n$ for mean values over environments were calculated following the components of variance (Teklewold and Becker, 2005)

\[
\begin{align*}
\hat{h}^2_A & = \frac{2\sigma^2_{gca} + \sigma^2_{sca}}{2\sigma^2_{gca} + \sigma^2_{sca} + 2\sigma^2_{\text{error}} / \text{mean squares}} \\times \left( \frac{\sigma^2_{\text{error}} / \text{mean squares}}{\sigma^2_{\text{error}}} \right) + \frac{\sigma^2}{\text{R.E.}^2} \\
\hat{h}^2_n & = \frac{2\sigma^2_{gca}}{2\sigma^2_{gca} + \sigma^2_{sca} + 2\sigma^2_{\text{error}} / \text{mean squares}} \\times \left( \frac{\sigma^2_{\text{error}} / \text{mean squares}}{\sigma^2_{\text{error}}} \right) + \frac{\sigma^2}{\text{R.E.}^2} 
\end{align*}
\]

Baker (1978) suggested genetic ratio that the progeny performances could be predicted by the use of the ratio of combining ability variance components:

Genetic ratio = $2 MS_{gca} / (2MS_{gca} + MS_{sca})$

Heterosis for all traits was estimated based on the behavior of the most outstanding parent, given that such estimation is useful to justify the use of hybrid seed (Fehr, 1991).

Heterosis (BP) (Heterobeltosis)(%) = [( F1 – BP )/ BP] x 100
Heterosis (MP) (%) = [(F₁ – MP)/MP] × 100

Heterosis (CV)(%) = [(F₁ – CV)/CV] × 100

Where, F₁=performance of F₁ hybrid; HP= performance of the best parent, MP = mid-parents and CV= check variety.

The difference of F₁ means from the respective better parent value and check variety were evaluated as follows:

\[ \text{LSD} = t \left( \frac{2MS_e}{r} \right)^{1/2} \]

Where, MSₐ= the error mean squares; r = the number of replication and t = the table value of t at 5 or 1% level of significance. Combined analyses of variance based on RCBD, genetic parameters and comparison of quantitative traits means based on Griffing’s (1956) Method 1 (Model 1) diallel analysis.

RESULTS AND DISCUSSION

The analysis of variance for ordinary analysis and combining ability in two planting dates and combined data over two planting dates for days to 50 % tasseling, days to 50% silking, plant and ear heights, resistance to late wilt disease and ear position is presented in Table 1.

Results in Table 1 show that both general (GCA) and specific (SCA) combining ability mean squares were significant or highly significant for all studied traits, except for days to 50% silking for (GCA) and resistance to late wilt for GCA and SCA. These results indicated that both additive and non additive types of gene effects were involved in the inheritance of these traits. The ratio of GCA/SCA was less than unity for all studied traits, indicating that the non-additive genetic effects were more important and played the major role in the inheritance of all studied traits indicating the non-additive gene under both planting dates and combined analysis.

On the other hand, reciprocals mean squares were significant or highly significant for all studied traits under both planting dates and combined analysis, except days to 50% silking, days to 50% tasseling and resistance to late wilt disease in the combined analysis. These results indicate that the maternal effect played an important role in the expression. These results are in agreement with those obtained by Hee Chung et al. (2006) and Rakesh Kumar et al. (2006).

The interactions between GCA, SCA and reciprocals with planting dates (Table 1) were significant for all studied traits , except days to 50% silking for reciprocal x dates. The magnitude of the interaction was lowest for GCA x planting dates than the SCA x planting dates for all studied traits. This indicates that non-additive genetic variance was influenced by environment. The non-additive effect component interacted more with the environment than the additive. This conclusion supports the findings by Daniel et al. (2006) and Singh and Roy (2007).

The closer of GCA/SCA genetic ratio (Baker,1978) to unity shows the predictability based on GCA alone. Also the GCA/SCA ratio reveals that different traits show an additive or non-additive genetic effect. A GCA/SCA ratio with a value greater than one indicates additive genetic effect, whereas a GCA/SCA ratio with a value lower than one indicates dominant genetic effect. However, in contrast to our results, other researchers indicated predominance of additive genetic effects for plant height Daniel et al. (2006) , Akanda et al. (2007) and Sultan et al.(2011).
Table 1: Analysis of variance for ordinary analysis and combining ability based combined data over two planting dates for studied traits during 2011 season.

| S.O.V. | D.F. | Days to 50% Silking | Days to 50% Tasseling | Plant height (cm) | Ear height (cm.) | Resistance to late wilt (%) | Ear position (%) |
|--------|------|---------------------|----------------------|-------------------|------------------|----------------------------|------------------|
| Rep    | 3    | 12.94**             | 203.34**             | 2602.8**          | 1195.5**         | 0.706                      | 57.20**          |
| Date   | 1    | 43.55**             | 30.07**              | 17205.1**         | 7822.9**         | 0.014                      | 17.02**          |
| Rep × Date | 6   | 7.84**              | 1.20                 | 169.16**          | 90.9**           | 0.822                      | 10.25            |
| Genotype | 35  | 10.36**             | 9.31**               | 3216.2**          | 549.1**          | 3.634**                    | 71.28**          |
| Geno. × Loc. | -   | 14.02**             | 5.14**               | 376.62**          | 203.8**          | 0.492                      | 23.35**          |
| Error  |      | 105                 | 210                 | 10.44             | 2.50            | 46.41                      | 27.1             |
| GCA    | 5    | 1.78                | 0.97*                | 125.3**           | 8.89**           | 0.330                      | 5.87**           |
| SCA    | 15   | 2.15*               | 2.13**               | 860.6**           | 131.9**          | 0.588                      | 15.21**          |
| Reciprocal | 15  | 0.27                | 0.25                 | 35.61**           | 25.2**           | 0.362                      | 3.61**           |
| GCA × Date | 5   | 5.77**              | 3.12**               | 164.5**           | 34.12**          | 0.574                      | 8.39**           |
| SCA × Date | -   | 8.36**              | 3.74**               | 957.6**           | 175.45**         | 0.657                      | 20.56**          |
| Recip. × date | -   | 1.52                | 0.92**               | 145.2**           | 92.11**          | 0.498                      | 11.07**          |
| Error (me) | 105 | 2.61                | 0.34                 | 11.69             | 6.53            | 0.134                      | 1.09             |
| GCA / SCA | 0.82 | 0.45               | 0.14                 | 0.067             | 0.561           | 0.38                        |                  |

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

Mean performance

The combined data of mean performance across the two planting dates for studied traits of the six parental inbred lines, 30 F1 crosses and two check hybrids were presented in Table 2. Results indicated that the P1 was earliest, P5 was shorter than other five parental. The parental inbred line P4 and P6 were lower ear placement than other parental inbred lines and six parental inbreds were resistant to late wilt disease. All crosses were earlier than both check single crosses 155 and 162. Out of 30 crosses; 23 crosses were significantly earlier than the best check SC 155. Twenty eight crosses out of the evaluated new yellow 30 single crosses were significantly shorter than the best check single cross 155. However twenty two crosses out of the same evaluated 30 crosses were significantly lower ear placement than the best check SC155. However the shorter plant height was the single cross (P4×P2) among the 30 crosses with 210 cm and the cross (P4×P3) was also the lowest ear placement out of the 30 crosses with 117 cm. For resistance to late wilt disease most of the crosses were resistant compared with the checks.
Table 2: Mean Performance of maize genotypes at their combined for the traits studied during 2011 season.

| Genotypes       | 50% Tasseling date | 50% Silking date | Plant height (cm) | Ear height (cm.) | Resistance to late wilt (%) | Ear position (%) |
|-----------------|--------------------|------------------|-------------------|------------------|-----------------------------|-----------------|
| P₁ (10RF)       | 58                 | 59               | 183               | 109              | 97                          | 60              |
| P₂ (11RF)       | 59                 | 60               | 179               | 110              | 99                          | 62              |
| P₃ (39RF)       | 61                 | 60               | 179               | 109              | 100                         | 61              |
| P₄ (45RF)       | 60                 | 61               | 176               | 108              | 100                         | 62              |
| P₅ (48RF)       | 61                 | 62               | 171               | 109              | 100                         | 64              |
| P₆ (50RF)       | 61                 | 63               | 176               | 108              | 100                         | 62              |
| P₁×P₂           | 58                 | 59               | 225               | 133              | 100                         | 59              |
| P₁×P₃           | 58                 | 60               | 215               | 128              | 100                         | 59              |
| P₁×P₄           | 59                 | 60               | 242               | 125              | 100                         | 52              |
| P₁×P₅           | 59                 | 60               | 225               | 128              | 100                         | 57              |
| P₁×P₆           | 58                 | 59               | 232               | 128              | 100                         | 55              |
| P₁×P₁           | 58                 | 59               | 236               | 137              | 100                         | 58              |
| P₂×P₄           | 59                 | 60               | 228               | 124              | 99                          | 54              |
| P₂×P₅           | 58                 | 59               | 229               | 124              | 99                          | 54              |
| P₂×P₄           | 58                 | 59               | 224               | 131              | 100                         | 58              |
| P₂×P₅           | 57                 | 58               | 219               | 122              | 100                         | 56              |
| P₂×P₆           | 58                 | 59               | 220               | 126              | 100                         | 57              |
| P₂×P₁           | 57                 | 58               | 210               | 119              | 99                          | 57              |
| P₂×P₂           | 58                 | 59               | 218               | 130              | 100                         | 60              |
| P₂×P₃           | 57                 | 58               | 229               | 128              | 100                         | 56              |
| P₂×P₄           | 57                 | 58               | 215               | 124              | 100                         | 57              |
| P₂×P₅           | 57                 | 58               | 226               | 127              | 100                         | 56              |
| P₂×P₆           | 58                 | 59               | 231               | 128              | 97                          | 55              |
| P₂×P₁           | 59                 | 60               | 224               | 117              | 100                         | 52              |
| P₂×P₂           | 57                 | 58               | 219               | 122              | 100                         | 56              |
| P₂×P₃           | 57                 | 59               | 240               | 133              | 100                         | 55              |
| P₂×P₄           | 58                 | 59               | 235               | 127              | 100                         | 54              |
| P₂×P₅           | 57                 | 58               | 237               | 136              | 100                         | 57              |
| P₂×P₆           | 58                 | 60               | 228               | 127              | 100                         | 56              |
| P₂×P₁           | 58                 | 59               | 216               | 120              | 100                         | 55              |
| P₂×P₂           | 58                 | 59               | 223               | 120              | 98                          | 54              |
| P₂×P₃           | 58                 | 59               | 225               | 124              | 100                         | 55              |
| P₂×P₄           | 58                 | 59               | 232               | 140              | 100                         | 61              |
| P₂×P₅           | 58                 | 59               | 222               | 120              | 100                         | 54              |
| P₂×P₆           | 59                 | 60               | 229               | 121              | 100                         | 53              |
| Checks          | SC155              | 63               | 63                | 244              | 135                         | 56              |
|                 | SC162              | 68               | 68                | 282              | 169                         | 60              |
| C.V.            | 2.91               | 5.59             | 4.42              | 5.84             | 1.03                        | 5.21            |
| L.S.D.at        | 0.05               | 1.55             | 3.16              | 6.67             | 5.09                        | 1.01            | 2.90 |
|                 | 0.01               | 2.03             | 4.15              | 8.75             | 6.68                        | 1.32            | 3.80 |
HETEROSIS STUDIES:

Heterosis is a major reason for the commercial maize industry as well as for the success of breeding efforts in many other crops. Although some progress has been made in understanding the genetic basis of heterosis, there is relatively little information regarding the biochemical, physiological, and molecular basis of this event. In this review, we try to explain heterosis. Beginning in the early 1900s, scientists began designing experiments to determine the mechanism of heterosis. Over the years, the majority of the scientific community has attributed heterosis to dominance or over dominance, and recently scientists have reported that epistasis and linkage are major contributors. One common theme throughout the last century has been that no one hypothesis of heterosis holds true for every experiment or every organism. Leyla Cesurer et al. (2002).

Results given in Table 3 revealed that 17 cross combinations manifested negative and highly significant heterosis over better parents, 20 cross combinations manifested negative and highly significant heterosis over mid-parents and all crosses had negative and highly significant heterosis over check varieties for tasseling dates. The highest negative heterosis effect was exhibited by crosses P5×P2, P6×P6, P5×P5 and P3×P6 over better parent, crosses P5×P2, P6×P2 and P2×P5 over mid-parents and crosses P5×P1, P3×P2, P4×P2, P5×P2, P6×P2, P5×P6, P3×P5 and P3×P6 over check varieties for tasseling date. These results are in harmony with those obtained by Abd El-Aty and Katta (2002) and Shalim Uddin et al. (2006).

For days to 50% silking, Table 3 showed that highest significant and negative heterotic effect was exhibited by cross P3×P2, P3×P5, P4×P3 and P3×P6 over better-parent and all crosses had highly significant and negative heterosis over check varieties, the highest significant and negative heterotic effects were reported by P3×P1, P6×P2, P2×P6, P4×P3 and P3×P6 over mid-parent and, P3×P5, P4×P3 reciprocal, P3×P2, P6×P2 and P3×P6 over check varieties, respectively. These results are in harmony with those obtained by Muraya et al. (2006) and Shalim Uddin et al. (2006). Plant height of maize plants are preferred as shortness because plants with greater height are likely to lodge during wind storm. Therefore, the plant height heterosis in the negative direction is desirable. The results of heterosis in Table 3 revealed that none of the crosses showed negative heterosis for plant height. The highest significant and positive heterotic effect was exhibited by all crosses in case over mid-parents and better-parent. The highest significant and negative heterotic effect was exhibited by 24 crosses over check varieties. The highest significant and positive heterotic effect was exhibited by P3×P2 and P3×P6 (40.35 and 37.46%) over better-parent and mid-parents respectively, P3×P2 (-13.93%) highest negative significant heterotic effect over check varieties for plant height. Appunu et al. (2007) came to similar results. Ear height on maize plant is preferred low ear placement because plants with greater ear height are likely to lodge during wind storm especially during irrigation practice. Therefore, the ear height heterosis in the negative direction is desirable. Table 3 revealed that all the crosses manifested highly significant and positive heterosis over mid-parents and better-parent. Cross P3×P5 (29.62%) showed maximum positive heterosis over better-parent. The highest significant and negative heterotic effect was exhibited by 25 crosses over check varieties, cross P4×P5 (-13.33%) showed maximum negative heterosis over check variety. Murray et al., (2003) came to similar results. For resistance to late wilt disease in Table 3, results showed significant for crosses P1×P5, P2×P1, P1×P4, P4×P1, P4×P5 and P4×P1 (1.52%) over mid-parents, indicating that these crosses are the best combinations for resistance to late wilt disease. Ear position on maize plant is preferred low ear placement because plants with greater ear height are likely to lodge during wind storm especially during irrigation practice. Therefore, the ear height heterosis in the negative direction is desirable. Data in Table 3 revealed that most of the crosses manifested highly significant and negative heterosis over mid-parent and better-parents value for ear position. 25 Cross showed highly significant or significant and negative heterosis over mid-parents value for ear position, P3×P3 (-15.44%) showed maximum negative heterosis over better-parent and (-14.75) over mid-parents. Seven crosses showed highly significant or significant and negative heterosis over check variety value for ear position, P6×P4 (-8.92%) showed maximum negative heterosis over check varieties. These results are in agreement with those obtained by Abdel-Moneam et al. (2009), Patel et al. (2009) and Amiruzzaman et al. (2010).
Table 3: Estimates of heterotic effects of 30 yellow single crosses maize genotypes at Gemmeiza in their combined for the traits studied in growing season 2011.

| Genotypes  | 50% tasseling date | 50% silking date | Plant height (cm) |
|------------|---------------------|------------------|------------------|
|            | BP      | CV   | MP  | BP   | CV   | MP  | BP   | CV   | MP  |
| P1 x P2    | 0.00    | -7.93**| -0.85 | 0.00 | -7.93**| -0.85 | 25.69* | -7.78**| 24.30**|
| P2 x P1    | 0.00    | -7.93**| -0.85 | 0.00 | -7.93**| -0.85 | 20.11** | -11.88**| 18.78**|
| P1 x P5    | 1.72    | -6.34**| -0.84 | 1.72 | -6.34**| -0.84 | 35.19** | -0.81 | 33.70**|
| P1 x P1    | 1.72    | -6.34**| -0.84 | 1.72 | -6.34**| -0.84 | 25.69** | -7.78**| 24.30**|
| P1 x P4    | 0.00    | -7.93**| -1.69 | 0.00 | -7.93**| -1.69 | 31.81** | -4.91**| 29.24**|
| P2 x P1    | 0.00    | -7.93**| -1.69 | 0.00 | -7.93**| -1.69 | 31.81** | -3.27 | 29.24**|
| P1 x P3    | 0.00    | -7.93**| -2.52 | 0.00 | -7.93**| -2.52 | 34.50** | -5.73**| 29.94**|
| P1 x P1    | -1.72   | -9.52**| -4.20* | -1.72 | -9.52**| -4.20* | 37.42** | -3.68**| 32.76**|
| P2 x P1    | -1.72   | -6.34**| -0.84 | -1.72 | -6.34**| -0.84 | 29.54** | -6.55**| 27.09**|
| P1 x P1    | 0.00    | -7.93**| -2.52 | 0.00 | -7.93**| -2.52 | 31.01** | -6.14**| 27.57**|
| P2 x P1    | -1.69   | -7.93**| -3.33**| -1.69 | -7.93**| -3.33**| 25.13** | -8.19**| 25.13**|
| P1 x P3    | -3.38*  | -9.52**| -5.53* | -3.38* | -9.52**| -5.53* | 22.34** | -10.24**| 22.34**|
| P3 x P1    | -1.96   | -7.93**| 2.52  | -1.96 | -7.93**| 2.52  | 25**    | -9.83**| 23.94**|
| P1 x P3    | -3.38*  | -9.52**| -4.20**| -3.38* | -9.52**| -4.20**| 19.31** | -13.93**| 18.30**|
| P3 x P1    | -4.91** | -7.93**| -5.69**| -4.91** | -7.93**| -5.69**| 27.48** | -10.65**| 24.57**|
| P1 x P5    | -6.55** | -9.52**| -7.31**| -6.55** | -9.52**| -7.31**| 33.91** | -6.14**| 30.85**|
| P3 x P1    | -6.55** | -9.52**| -7.31**| -6.55** | -9.52**| -7.31**| 22.15** | -11.88**| 21.12**|
| P1 x P2    | -6.55** | -9.52**| -7.31**| -6.55** | -9.52**| -7.31**| 28.40** | -7.37**| 27.32**|
| P3 x P1    | -3.33** | -7.93**| -4.13**| -3.33** | -7.93**| -4.13**| 31.25** | -5.32**| 30.14**|
| P3 x P1    | -1.66   | -6.34**| -4.06**| -1.66 | -6.34**| -4.06**| 38.63** | 0.00  | 37.46**|
| P3 x P2    | -6.55** | -9.52**| -6.55**| -6.55** | -9.52**| -6.55**| 40.35** | -1.63 | 37.14**|
| P3 x P1    | -4.91** | -7.93**| -4.91**| -4.91** | -7.93**| -4.91**| 37.42** | -3.68 | 34.28**|
| P3 x P1    | -6.55** | -9.52**| -6.55**| -6.55** | -9.52**| -6.55**| 34.65** | -2.86 | 33.52**|
| P3 x P1    | -4.91** | -7.93**| -4.91**| -4.91** | -7.93**| -4.91**| 29.54** | -6.55**| 29.82**|
| P3 x P1    | -3.33** | -7.93**| -4.13**| -3.33** | -7.93**| -4.13**| 26.31** | -11.47**| 27.49**|
| P3 x P1    | -3.33** | -7.93**| -4.13**| -3.33** | -7.93**| -4.13**| 30.40** | -8.60**| 28.53**|
| P3 x P1    | -3.33** | -7.93**| -5.69**| -3.33** | -7.93**| -5.69**| 27.84** | -7.78 | 27.84**|
| P3 x P1    | -3.33** | -7.93**| -5.69**| -3.33** | -7.93**| -5.69**| 31.81** | -4.91**| 31.81**|
| P3 x P1    | -4.91** | -7.93**| -4.91**| -4.91** | -7.93**| -4.91**| 29.82** | -9.01**| 27.95**|
| P3 x P1    | -3.27   | -6.34**| -3.27 | -3.27 | -6.34**| -3.27 | 33.91** | -6.14**| 31.98**|
| LSD        | 0.05   | 1.55  | 1.55 | 3.16 | 3.16  | 3.45 | 6.67  | 6.67  | 7.92 |
|            | 0.01   | 2.03  | 2.03 | 2.49 | 4.15  | 4.15 | 5.08  | 8.75  | 8.75 |

*, ** significant at 0.05 and 0.01 level of probability, respectively.
### Table 3: Continue...

| Genotypes  | Ear height (cm) | Resistance to late wilt(%) | Ear position (%) |
|------------|-----------------|----------------------------|------------------|
|            | BP  | CV  | MP  | BP  | CV  | MP  | BP  | CV  | MP  |
| P1 x P2    | 22.01** | -1.48 | 21.46** | 1.01 | 0.00 | 2.04 | -1.66 | -5.35* | -3.27 |
| P1 x P1    | 17.43** | -5.18 | 16.89** | 1.01 | 0.00 | 2.04 | -1.66 | -5.35** | -3.27 |
| P1 x P3    | 14.67** | -7.40 | 14.67** | 0.00 | 0.00 | 1.52 | -13.33** | -7.14** | 14.04** |
| P3 x P1    | 17.43** | -5.18 | 14.43** | 0.00 | 0.00 | 1.52 | -5.00* | 1.78 | -5.78** |
| P1 x P4    | 18.51** | -5.18 | 17.97** | 0.00 | 0.00 | 1.52 | -8.33** | -1.78 | -9.83** |
| P3 x P1    | 26.85** | 1.48 | 26.26** | 0.00 | 0.00 | 1.52 | -3.33 | 3.57 | -4.91 |
| P1 x P3    | 18.34** | -4.44 | 18.34** | 0.00 | 0.00 | 1.52 | -6.66** | 0.00 | -9.67** |
| P1 x P1    | 15.59** | -6.66 | 15.59** | 0.00 | 0.00 | 1.52 | -10.00** | -3.57 | -12.90** |
| P3 x P3    | 14.81** | -8.14 | 14.28** | 0.00 | -1.00 | 1.02 | -10.00** | -3.57 | -11.47** |
| P3 x P4    | 14.81** | -8.14 | 14.28** | 0.00 | -1.00 | 1.02 | -10.00** | -3.57 | -11.47** |
| P2 x P3    | 20.18** | -2.96 | 19.63** | 0.00 | 0.00 | 0.50 | -4.91** | 3.57 | -5.69** |
| P1 x P2    | 11.92** | -9.62 | 11.41** | 0.00 | 0.00 | 0.50 | -8.19** | 0.00 | -8.94** |
| P2 x P1    | 16.66** | -6.66 | 15.59** | 0.00 | 0.00 | 0.50 | -8.06** | 1.78 | -8.06** |
| P2 x P3    | 10.18** | -11.85 | 9.17** | -1.00 | -1.00 | 0.50 | -8.06** | 1.78 | -8.06** |
| P2 x P3    | 19.26** | -3.70 | 18.72** | 0.00 | 0.00 | 0.50 | -3.22 | -7.14** | -4.76 |
| P2 x P2    | 17.43** | -5.18 | 16.89** | 0.00 | 0.00 | 0.50 | -9.67** | 0.00 | -11.11** |
| P2 x P2    | 14.18** | -8.14 | 13.76** | 0.00 | 0.00 | 0.50 | -9.67** | 1.78 | -9.67** |
| P2 x P2    | 17.59** | -5.92 | 16.51** | 0.00 | 0.00 | 0.50 | -8.06** | 0.00 | -8.06** |
| P3 x P3    | 18.51** | -5.18 | 17.97** | -3.00 | -3.00 | -3.00** | -9.83** | -1.78 | -10.56** |
| P3 x P2    | 8.33** | -13.33 | -7.80** | 0.00 | 0.00 | 0.00 | -14.75** | -7.14** | -15.44** |
| P3 x P2    | 22.01** | 0.00 | 22.01** | 0.00 | 0.00 | 0.00 | -9.83** | -1.78 | -12** |
| P3 x P3    | 16.51** | -5.92 | 16.51** | 0.00 | 0.00 | 0.00 | -11.47** | -3.57 | -13.6** |
| P3 x P3    | 25.92** | 0.74 | 25.34** | 0.00 | 0.00 | 0.00 | -6.55** | 1.78 | -7.31** |
| P3 x P2    | 17.59** | -5.92 | 17.05** | 0.00 | 0.00 | 0.00 | -8.19** | 0.00 | -8.94** |
| P3 x P1    | 11.11** | -11.11 | 10.59** | 0.00 | 0.00 | 0.00 | -11.29** | -1.78 | -12.69** |
| P3 x P4    | 11.11** | -11.11 | 10.59** | -2.00 | -2.00 | -2.00 | -12.90** | -3.57 | -14.28** |
| P3 x P4    | 14.81** | -8.14 | 14.81** | 0.00 | 0.00 | 0.00 | -11.29** | -1.78 | -11.29** |
| P4 x P4    | 29.62** | 3.57 | -29.6** | 0.00 | 0.00 | 0.00 | -1.61 | -8.92** | -1.61 |
| P4 x P4    | 11.11** | -11.11 | 10.59** | 0.00 | 0.00 | 0.00 | -12.90** | -3.57 | 14.28** |
| P4 x P2    | 12.03** | -10.37 | 11.52** | 0.00 | 0.00 | 0.00 | 14.51** | -5.35** | -15.87** |

LSD

| LSD | 0.05 | 5.09 | 5.09 | 6.05 | 1.01 | 1.01 | 1.20 | 2.90 | 2.90 | 3.44 |
|------|------|------|------|------|------|------|------|------|------|------|
| 0.01 | 6.68 | 6.68 | 8.18 | 1.32 | 1.32 | 1.62 | 3.80 | 3.80 | 4.66 |

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

Heritability and genetic parameters:

Estimates of variance for general ($\delta^2_{gca}$) and specific ($\delta^2_{sca}$) combining ability and their interaction with dates showed that in Table 4 ($\delta^2_{gca}$) was higher than ($\delta^2_{sca}$) for all studied traits, except ear position, this indicated that the additive gene action was more important in inheritance of all studied traits. On the other side, the $\delta^2_{gca_{env}}$ was higher than $\delta^2_{sca_{env}}$ for all traits studied except ear position (Osman and Ibrahim, 2007). For $\delta^2_{gca}$/$\delta^2_{sca}$ and genetic ratio. Estimation of genetic parameters is given in Table 4 the closer genetic ratio (Baker, 1978) to unity shows the predictability based on GCA alone. Also, the GCA/SCA ratio reveals that different traits show an additive or non-additive genetic effect indicates additive genetic effect, whereas a genetic ratio with a value lower than one indicates dominant genetic effect, percentage of heritability in the narrow sense for studied traits ranged from 20% for plant height to 46% for tasseling and silking dates, in broad sense ranged from 29% for plant height to 64% for ear position. Wannows et al. (2010) came to similar results.
Table 4: Estimation of genetic parameters of maize in a 6×6 diallel crosses for the traits studied in growing season 2011.

|                  | Days to 50% Tasseling | Days to 50% silkling | Plant height (cm) | Ear height (cm) | Ear position (%) | Resistance to late wilt (%) | Grain yield (arbd/feaf) |
|------------------|------------------------|----------------------|-------------------|-----------------|------------------|---------------------------|------------------------|
| \( \sigma^2 \text{gca} \) | 0.89                   | 1.27                 | 1.05              | 1.11            | 0.84             | 1.11                      | 1.01                   |
| \( \sigma^2 \text{sca} \) | 0.57                   | 0.25                 | 0.89              | 0.75            | 0.89             | 0.74                      | 0.97                   |
| \( \sigma^2 \text{gca}_{\text{Env}} \) | 1.49                   | 0.80                 | 20.63             | 6.48            | 0.61             | 2.33                      | 43.56                  |
| \( \sigma^2 \text{sca}_{\text{Env}} \) | 0.83                   | 0.69                 | 0.17              | 0.19            | 0.87             | 0.40                      | 0.01                   |
| \( \sigma^2 e \) | 2.50                   | 10.44                | 46.41             | 27.05           | 1.06             | 8.79                      | 3.55                   |
| \( \sigma^2 \text{gca}/ \sigma^2 \text{sca} \) | 1.57                   | 4.97                 | 1.16              | 1.47            | 0.95             | 1.51                      | 1.03                   |
| \( h^2_p \) | 0.46                   | 0.46                 | 0.20              | 0.28            | 0.42             | 0.40                      | 0.40                   |
| \( h^2_n \) | 0.61                   | 0.50                 | 0.29              | 0.38            | 0.64             | 0.53                      | 0.60                   |
| Genetic ratio  | 0.47                   | 0.62                 | 0.23              | 0.12            | 0.52             | 0.42                      | 0.01                   |

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