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TOPCROSSES ANALYSIS AND MAIZE INBRED LINES SELECTION IN THE EARLY SELF GENERATION

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ABSTRACT: *Ten selected S_4 white maize lines developed from different heterotic groups were topcrossed to each of three commercial white testers, i.e. Gm 12, SC 21 and Gm.W.Pop. in 2009 summer season. The resultant 30 topcrosses along with its parents (10 inbred lines and three testers) and three check hybrids, i.e SC 10, TWC 321 and GWP (46 genotypes) were evaluated in 2010 growing season at tow locations. Stns. for days to 50% silking, plant and ear height, number of ears/100 plants, grain yield, ear length, ear diameter, rows/ear, grains/row and 100-gran weight. Testers contributed much more than the lines to the total genetic variation in all studied traits, except silking date, ears/100 plants and grains/row. This indicates that the inbred testers ranked the 10 inbreds differently. The tested lines Gm-11 and Gm-21 were found to be the best general combiners for high yielding ability, whereas Gm-11, Gm-21, Gm-36, Gm-101, Gm-137, and Gm-141 were the best general combiner for prolificacy. Parental females Gm-21, Gm-36, Gm-83, and Gm-101 were good donors for ear length, whereas Gm-11, Gm-21, Gm-56 and Gm-83 were the best combiner for ear diameter. In addition, Gm-7 and Gm-101 inbred lines were the best combiner in case of days to 50% silking, plant and ear height. The inbred tester Gm 2 manifested better GCA effects and average performance of grain yield and all studied traits, except ear diameter and number of grains/row as compared to testcrosses of the other inbred testers, SC 21 and Gm. W.Pop. Results showed that the inbred tester Gm 2 crossed to the tested lines Gm-11, Gm-36, Gm-56 and Gm-83 would produce the best four single crosses which significantly outyielded the checks single cross hybrid SC 10 by 7.1, 8.3, 5.2 and 4.5 ard/fad, respectively. The magnitude of the ratio of general to specific combining ability variances (σ^2gca/σ^2sca) revealed that the additive gene action plays an important role in the inheritance of all studied traits. The non-additive gene action, however, interacted more with the environmental conditions (σ^2sca x loc) than the additive component (σ^2gcs x loc) for all studied traits, except number of ears/100 plants and ear height. Parents vs. crosses was highly significant for all studied traits indicating the present of valuable amount heterosis in the materials used in this study. For all studied traits, better parent heterosis was significant in most studied crosses, especially that involved the two testers, Gm-2 and Gm.W.Pop. Ear length, ear diameter and number of ears/100 plants exhibited the highest direct effect on grain yield. They also have string indirect effect on grain yield via number of rows/ear and 100-grain weight.*

Key words: *Maize, Topcross, Tester, Inbred, Combining ability, variance.*

INTRODUCTION

The increased demand for maize grains to cover the requirements of growing poultry industry and animal feed has emphasized the need for developing superior white grain maize hybrids. To overcome the increasing demands of white maize consumption, Maize Res. Dept. breed and release new white maize inbred lines for use in developing high yielding hybrids, resistant to late wilt disease and has desirable agronomic characters. Procedures for developing and improving inbred lines of maize were reported by Geadlman and Peterson (1976), Kuhn and Stucker (1976) and Hallauer and Miranda (1981) they stated that, improving inbred lines had resulted increase in grain yield, modified maturity and plant stature of their hybrids. Moreover, Bauman (1981) indicated that, the most logical sequel is to cross pairs of lines that complement each other to produce the F_2 generation (F_2 population) of specific single crosses which is used most frequently as a source of new inbred lines development. If one parent of such single cross is decidedly better than the other one, the chance of obtaining a derivative line superior to the better parent is remoted (Baily and Comstock, 1976).

Successful development of improved maize hybrids is dependent upon accurate evaluation of inbred lines performance in crosses. The standard topcrosses procedure as suggested by Davis (1927) has been widely used to evaluate the general combining ability of inbred lines in hybrid maize breeding programs. Inbreds of high general combining ability are crossed to detect particular combinations that result in superior single cross, i.e.; two line combinations for commercial use. The concepts of general (GCA) and specific (SCA) combining ability are useful for characterizing inbred lines in crosses. If additive gene effects are important, recurrent selection methods that emphasize GCA should be used. However, if overdominance is of primary importance, recurrent selection methods that emphasize SCA would be appropriate (Hallauer and Miranda, 1981). The choice of suitable testers for testing the developed inbred lines is an important decision. Darrah *et al.* (1972) and Horner *et al.* (1973) reported that inbred testers have the advantage with no sampling errors to follow genetic variability within the testers and greater genetic variation among testcrosses. Furthermore, Russell *et al.* (1973) and Zambezi *et al* (1986) suggested that inbred testers could be used successfully for improving general (GCA) and specific (SCA) combining abilities in maize.

Shehata and Dahawan (1975), Balko and Russell (1980), El-Itriby *et al.,* (1990) and Aydm *et al* (2007) reported that the variance component due to SCA for grain yield and other agronomic traits was relatively larger than that due to GCA indicating the presence of reasonable amount of useful heterosis and that the non-additive type of gene action appeared to be more important in lines selected previously for grain yield performance. On the other hand, Rojas and Sprague (1952), El-Zeir *et al.* (2000), Soliman *et al.* (2001) and Abd El-Azeem *et al.* (2004) stated that when the lines were relatively unselected, GCA or additive type of gene action becomes more important. Comstock and Robinson (1963) defined the genotype x environment interaction as the differential response of phenotype to the change in environments. However, Rojas and Sprague (1952) Darrah and Hallauer (1972) and Landi and Conti (1983) stated that the non-additive component of genetic variation significantly interacted with the environments more than the additive component. In contrast, El-Itriby *et al.* (1981), El-Zeir *et al.* (1993) and Abd El-Azeem *et al* (2004) reported that GCA x environment interaction was significantly larger than the interaction of SCA x environment even though the variance estimate for SCA was more than that of GCA.

The objectives of this study were to evaluate general (GCA) and specific (SCA) combining ability effects and variances involved in the manifestation of grain yield and some other attributes of ten newly developed white inbred lines and three inbred testers and to identify the most superior line(s) and single crosses for further use in the breeding program.

MATERIALS AND METHODS

Ten selected white maize lines in S_4 generation (Gm. 11 ,21 , 36, 56, 83, 101, 137, 141, 149 and 258) derived from different heterotic groups [Synthetic AA-USA (L-1), Tuxpenõ x Corn Belt (L-2 – L-11), J.M.L. 230-Mex (L-12 – L-16), V.BC.III (Late)-USA (L-17 & L-18), and NST 89101 (TF 940 D)-Thailand (L-19)] through selection from segregating generations in the disease nursery field at Gemmeiza Agricultural Research Station, were used in this study. In 2009 summer season, these 10 lines were topcrossed to each of three narrow base inbred testers, *i.e.*; Gemmeiza 2, Single cross (SC) 21 and Gemmeiza White Populations (Gm.W.Pop.). at Gemmeiza Experimental Station. The first two testers has being used in commercial single and three-way cross hybrids seed production. In 2010 growing season, the 30 resultant topcrosses along with their parents (10 lines and three testers) as well as three commercial check hybrids, i.e. SC 10, three-way cross 321 , and Gm.W.Pop. were evaluated in a field trial conducted at Gemmeiza and Sids Agric. Res. Stations. The experimental design was a randomized complete block with four replications. Plot size was one row, 6 m long and 80 cm apart and hills were spaced 25 cm with in row. Two kernels were sown per hill then thinned to one plant per hill to provide a population of approximately 21000 plants/faddan (Faddan = 4200 m^2). All cultural practices for maize production were applied as recommended. Data were recorded for number of days to 50% silking, plant height (cm), ear height (cm), number of ears/100 plants, grain yield adjusted to 15.5% grain moisture content and converted to ardab/faddan (ardab=140 kg), ear length, ear diameter, rows/ear, grains/row and 100-grain weight. Analysis of variance was performed for the combined data over locations according to Steel and Torrie (1980), and Kempthorne procedure (1957) as outlined by Singh and Chaudhary (1979) was followed to obtain information about the combining ability of lines and testers as well as estimating types of gene effects controlling the studied traits. Also, better parent heterosis for was also determined. Simple genotypic correlations between all the studied traits were calculated using the combined data. Path analysis was done to estimate the direct and indirect effect of different agronomic traits as well as yield components on grain yield.

RESULTS AND DISCUSSION

The combined analysis of variance for the ten studied traits is presented in Table 1. Highly significant differences were detected among locations for all studied traits, except for ear diameter, indicating that the two locations differed in their environmental conditions. All studied entries (parents “females and males”, crosses and checks) significantly differed respecting all studied traits. The entry x locations interaction was also significant for all traits except ear diameter and rows/ear. Female and male parents and their interaction for with locations were significantly differed in all traits, except rows/ear for location x parents interaction. The studied crosses significantly differed in all traits, however the interaction of locations their crosses was significant only in case plant height, ear height, ears/100 plants, grain yield, and 100-grain weight. It’s worthy to note that the differences among checks were not significant for all studied traits, except for, days to 50% silking. The same result was obtained for the interaction of location x checks which was insignificant in all traits, except, silking date, grain yield and ear length. Parents *vs* crosses was highly significant for all studied traits indicating the presence of useful heterosis in the studied topcrosses. However, the interaction of Parents vs crosses with locations was not significant for all traits, except for days to 50% silking, plant height and grain yield.

Partitioning the sum of squares due to crosses into its components (lines, testers and lines x testers) and its interaction with locations (Table 1) showed that mean squares due to lines and testers were highly significant for all traits, except that of testers for grains/row, revealing that greater diversity existed among both lines and testers. The magnitude of the variances due to testers was higher than that for lines for all studied traits, except silking date, ears/100 plants and grains/row. Mean squares of the lines x testers interaction were highly significant for all studied traits, except that of silking date, ear length, ear diameter, rows/ear and grains/row, indicating that the lines (females) differed in order of performance in crosses with each of the testers (males). A line x locations interaction was highly significant for plant height, ear height, ears/100 plants, grain yield and 100-grain weight. Whereas, mean square due to the interaction of the testers with locations was highly significant for only plant height and grain yield. These interactions with locations were indicative of different ranking of lines and testers from one location to another. The magnitude of tester x locations was higher than that of lines x locations for all studied traits, except that for plant height, ear height as well as ear length and diameter and 100-grain weight. However, highly significant lines x testers x locations mean squares were

Table 1

detected for days to 50% silking, plant height, ear height and grain yield, revealing that the crosses between lines and testers behaved somewhat differently from location to location. These results are in accordance with those obtained by El-Itriby *et al.* (1990), Gado *et al.* (2000), Soliman *et al.* (2001), Narro et al (2003) and Aydm *et al* (2007).

Mean performance:

Data in Table 2 indicate that both lines, testers and their topcrosses differed greatly in their performance. Bothe lines and testers were earlier and had taller plants and higher ear placement compared to lines and testers *per ce*. Topcrosses with the tester Gm.W.Pop had short plants with low ear placement followed by those with SC 21 and Gm 2, respectively. For number of ears/100 plant both lines, testers and their topcrosses were more prolific than lines and testers *per ce*. Respecting grain yield, topcrosses with the tester Gm 2 produced more grain yield followed by those with Gm. W. Pop. and SC 21, respectively. For different yield components, no clear differences in performance due to using the three testers in topcrosses.

For topcrosses, the range of different traits differed from cross to cross indicating the presence of great amount of variability among studied topcrosses. For example, the lowest grain yield (17.3, 22.6 and 22.4 ard/fad) was obtained from the three topcrosses Gm-21 x Gm 2, Gm-137 x SC 21 and Gm-36 x Gm.W.Pop. respectively. However, the highest grain yield (34.8, 33.7 and 31.7 ard/fad) was obtained from the three topcrosses Gm-36 x Gm 2, Gm-11 x Gm 2 and Gm-56 x Gm 2. It is worth noting that, all topcrosses with the inbred tester Gm 1021 had high grain yield with good performance for most of the studied traits. Some topcrosses from Gm.W.Pop. tester possessed somewhat good yield performance similar to Gm. 56 x Gm.W.Pop.(29.6 ard/fad) and Gm. 258 x Gm 2 (28.9 ard/fad). These crosses produced the same grain yield as the check cross "TWC 321" without with insignificant differences. Similar findings were also obtained by Salama *et al* (1995) and Sadek *et al* (2001)

Better-parent heterosis:

Estimates of better-parent heterosis for of the grain yield 30 topcrosses for and other studied traits is presented in Table 3. The amount of heterosis relative to better or high parent differed greatly from trait to trait. For days to 50% silking, all topcrosses, except Gm-21 x SC 21 and Gm-137 x SC 21 possessed negative desirable heterosis toward earliness, out of them, 19 topcrosses exhibited useful and significant heterosis toward earliness. All topcrosses exhibited positive and highly significant heterosis respecting plant and ear height with few exceptions. For grain yield, topcrosses with the inbred tester Gm 2 and Gm.W.Pop. exhibited significant and high values of heterosis. On the other hand, the three topcrosses of inbred lines Gm-56, 101 and 137 with the tester SC 21 exhibited highly significant and negative heterosis. The same trend was obtained for other studied traits. It is worthy to note that, all crosses with SC 21 and/or Gm.W.Pop. possessed valuable amount of heterosis as compared to that crosses with the inbred tester Gm. 2 indicating the presence of dominance and/or overdominance in the inheritance of such crosses.

General (GCA) and specific (SCA) combining ability effects:

For days to 50% silking, seven inbred lines possessed significant general combining ability effects, three of them (Gm. 11, Gm. 83 and Gm. 258) had negative values toward earliness (-1.204**, -1.308** and -1.329**, respectively). Meanwhile, the inbred tester Gm-2 exhibited highly significant and negative GCA value toward earliness (-0.408**). Its worth to note that, all topcrosses of the studied inbred lines with this tester were earlier in flowering date and possessed valuable amount of better parent heterosis Table 3). Non of the studied 30 topcrosses exhibited valuable and significant SCA effects, except the cross (Gm-37 x Gm.W.Pop.) which possessed significant

Table 2

Table 2

Table 3

and positive SCA values (1.046*). Also, correlation coefficient between the mean values of days to 50% silking and SCA effects was positive but insignificant (0.3639), indicating that additive effects played a role in the inheritance of these traits. Hallauer and Lopez-Perez (1979), Hallauer and Miranda (1981), Aboul Saad *et al* (1989), and Narro *et al* (2003) obtained similar findings.

With respect to plant height, data presented in Table 2 revealed significant differences between the three testers. The inbred tester Gm 2 induced taller plants over all parental lines. This result was reflected in the combining ability effects (Table 4), where Gm.W.Pop., Gm. 2 had highly significant and positive GCA effect. This indicates that Gm. 2 had favorable dominant genes for plant height. On the contrary, the two single cross testers, SC 21 and Gm.W.Pop., had negative and highly significant (desirable) GCA effect. In this regard, Soliman *et al.* (2001) and Abd El-Azeem *et al.* (2004), reached similar findings. As for the tested lines, the best general combiners were Gm. 83, Gm. 101, and Gm. 258, since, they had highly significant and negative (desirable) GCA effects (-11.892**, -6.225** and -10.725**) and the shortest plants (Tables 2 and 4). However,

Plant height of the 30 topcrosses (Table 2) ranged from 249.0 to 306 cm for crosses Gm-83 x Gm.W.Pop.and Gm-141 x Gm 2, respectively. In general, all topcrosses involving the inbred tester Gm 2 showed taller plants than those involving the other two testers SC 21 and Gm.W.Pop. Furthermore, all the topcrosses of the Gm.W.Pop., in addition to the crosses of Gm. 21, Gm. 83, Gm. 137 and Gm. 258 with Gm 2 and Gm-11, Gm-36, Gm-83, Gm-101, Gm-137, Gm-149 and Gm-258 with SC 21 were significantly shorter than SC 10 (283 cm). On the other hand, nine topcrosses showed significantly SCA effect for plant height (Table 5). Five of them (Gm-21 x Gm-2, Gm-137 x Gm-2, Gm-101 x SC 21, Gm-141 x SC 21 and Gm-258 x SC 21) manifested negative (desirable) SCA effects (-9.392**, -7.142**, -5.988**, -7.113** and -6.488**, respectively). It's worth noting that all topcrosses that have

Considering ear height, results in Tables (1 and 2) revealed that the SC 21 tester had more favorable effect on ear placement than the other two testers Gm 2 and Gm.W.Pop., since it showed significantly lower average ear height and highly significant negative GCA effect (-4.783**) towards lower ear placement. These results support the findings of Soliman *et al.* (2001), Soliman *et al* (2005) and Abd El-Azeem *et al.* (2004). As for the tested lines across the three testers, Gm-83, Gm-258, and Gm-11 ranked the best with an average of 141, 143, and 144 cm, respectively, which corresponded with their highly significant negative GCA effects (-5.842**, -3.467** and -3.383**), respectively. On the other hand, the three parental lines Gm-56, Gm-137 and Gm-141 exhibited the highest average for ear height (154, 150 and 150 cm), respectively, with highly significant positive GCA effects (7.033**, 3.200** and 3.283**), respectively. The correlation coefficient between means of ear height and GCA effect was negative and highly significant (-0.528), indicating that, the additive gene effects toward low ear placement was responsible for the inheritance of this trait. On the other hand, correlation coefficient between mean ear height of the testers and its GCA effect was found negative and highly significant indicating that, the testers used in this study can discriminate the inbred lines perfectly.

Ear height of the 30 topcrosses (Table 2) ranged from 130 to 162 cm for crosses Gm-83 x Gm.W.Pop., and Gm-56 x Gm 2 as well as Gm-101 x Gm-2, respectively. Generally, all topcrosses involving the inbred tester SC 21 or Gm.W.Pop. showed lower ear height than those involving the inbred tester Gm 2. Moreover, all studied topcrosses were significantly lower in ear placement than the commercial check SC 10 (155 cm), as well as the other two checks, (TWC 321 and significant SCA effects exhibited also significant and high values of better parent heterosis (Table 3) and significantly correlated with mean plant height (0.4224**) indicating that dominance and non-additive

Table 4

gene effects plays an important role in the inheritance of plant height in these crosses. Similar findings were also obtained by Salama *et al* (1995) and Sadek *et al* (2001). G.W.P.) , except two crosses, in (Gm. 56 x Gm. 2 and Gm. 101 x Gm. 2) which had significantly higher ear placement. Out of the studied 30 topcrosses, 13 topcrosses possessed significant SCA effects, 7 of them had negative GCA values (desirable), whereas the other six crosses had positive SCA effects toward high ear placement (not desirable (Table 5). Simple correlation coefficient between average ear height of all studied topcrosses and SCA effects was negative and highly significant, indicating that, the inbred lines used in this study had high breeding value.

With respect to number of ears/100 plants, data in Tables 2 and 4 illustrated that, the inbred tester Gm 2 showed more favorable effect on number of ears/100 plants than the other two testers (SC. 21 and Gm.W.Pop.), since, it showed significantly higher average number of ears per plant (126 ears/100 plants) and highly significant positive GCA effect (4.887**). These results are supported by the findings of Sadek *et al.* (2000) and Soliman and Osman (2006). As for the tested lines, the best general combiners over testers were Gm-11, Gm-141, and Gm-36 (Tables 2 and 4), since, they exhibited more ears per plant (138, 133, and 130 ears/100 plants, respectively), and had highly significant positive GCA effects (16.945**, 11.724** and 8.582**, respectively),. On the other hand, the tested lines Gm-137, Gm-101, and Gm-21 produced the lowest numbers of ears/100 plants (108, 110 and 111 ears/100 plants) and possessed negative and significant GCA effects in the direction of fewer ears per plant (-12.768**, -11.085** and -9.676**, respectively). Simple correlation coefficients between the average number of ears/100 plants and GCA effects of both lines and testers was positive and highly significant indicating the high breeding values of these materials in breeding for prolificacy in maize.

Regarding the topcrosses, data in Table 2 showed that average ears number ranged from 104 to 156 ears/100 plants for crosses Gm-21 x Gm 2 and Gm-11 x Gm 2, respectively. Generally, all topcrosses involving the inbred tester Gm 2 showed more ears per plant than those involving the two single cross testers, SC 21 and Gm.W.Pop.. The difference between the three checks; SC 10 (117 ears/100 plants), TWC 321 (110 ears/100 plants) and G.W.P. (113 ears/100 plants) was insignificant. However, four topcrosses of Gm 2 with the tested lines (female lines) Gm11, Gm-36, Gm-83 and Gm-141, in addition to topcrosses of Gm SC 21 with Gm-11 and Gm-141 as well as topcrosses of Gm.W.Pop.with Gm-11 and Gm-141 exhibited significantly more ears per plant than SC 10 and TWC 321 (Table 2). However, data of Table 4 showed that the best specific combination (positively significant SCA effects) resulted from Gm-11 x Gm 2 (12.975**), Gm-36 x Gm-2 (11.200*) and Gm-21 x SC 21 (12.250*).

Grain yield of the 10 tested lines across the three testers (Table 2) ranged from 23.3 ard/fad (Gm-21) to 28.8 ard/fad (Gm-11). The most preferable lines were Gm-11, Gm-36, Gm-56, Gm-83, and Gm-141. These lines produced the highest average grain yield (28.8, 27.6, 28.2, 28.2, and 27.7 ard/fad, respectively), and exhibited positive GCA effects (Table 3). However, three of them (Gm-11, Gm-56 and Gm83) exhibited significant GCA effect (2.178**, 1.589*, 1.656**, respectively). In other words, these lines in addition to the inbred tester Gm. 2 had accumulated favorable alleles for grain yield and contributed to high grain yield of all crosses involving these lines. On the other hand, the inbred line Gm. 21 produced the lowest grain yield (23.3 ard/fad) and had a high negative GCA effects (-3.358**) (Tables 2 and 3). The results reported herein are in accordance with those previously reached by Rawling and Thompson (1962), Liakat and Teparo (1986), El-Hosary (1988), Mahgoub *et al.* (1996), Al-Naggar *et al.* (1997), and Soliman *et al.* (2001), who reported that the inbred tester method was more effective to select lines which combine well with unrelated tester. They emphasized that inbred testers were more effective in detecting small differences in combining

Table 5

ability than the wide genetic base testers. Considering the testers used in this study, tester line Gm 2 produced higher grain yield (28.9 ard/fad) over all the tested lines compared to the other two testers SC 21 and Gm.W.Pop. (25.3 and 25.7 ard/fad), respectively. This result was reflected in the combining ability effects (Table 3), where Gm 2 was better inbred tester in GCA effect (2.268**), which had a good yield in its crosses with all the tested lines (female lines). These results indicate that the inbred tester Gm 2 possesses a high frequency of favorable dominant alleles, which contributed to the grain yield of testcrosses. On the contrary, the other two testers SC 21 and Gm.W.Pop. had a high negative and significant GCA effect (-1.348** and -0.921*), respectively. Similar results were obtained by Soliman (2000), Soliman *et al.* (2001) and Abd El-Azeem *et al.* (2004) for Gm 1021.

Grain yield of the 30 topcrosses (Table 2) ranged from 17.3 to 34.8 ard/fad for Gm-21 x Gm 2 and Gm-36 x Gm 2, respectively. Five out of the 30 tested topcrosses were superior. These crosses outyielded the commercial white check hybrid SC 10 (26.5 ard/fad) with minimum of 3.6 ard/fad and maximum of 8.3 ard/fad. Furthermore, these crosses which were the top most outyielding crosses, *i.e.* Gm-36 x Gm 2, Gm-11 x Gm 2, Gm-56 x Gm 2 , Gm-83 x Gm-2 and Gm-141 x Gm 2 gave the highest grain yield (34.8, 33.7, 31.7, 31.0 and 30.1 ard/fad), respectively, and significantly outyielded the check hybrid SC 10 by 8.3, 7.2, 5.2, 6 , and 2.5 ard/fad, respectively.

Data presented in Table 5 showed that the best specific combinations (positively significant SCA effects) resulted from Gm-11 x Gm 2, Gm-36 x Gm-2, Gm-21 x SC 21, and Gm-149 x SC 21 (2.684*, 4.952**, 6.665** and 2.942*), respectively, confirming their outstanding. However, Gm-21 x Gm 2, Gm-149 x Gm 2 and Gm-36 x Gm.W.Pop. showed negatively significant SCA effects (-8.228**, -3.692** and -4.304**) with low yield performance. Testcross which rank the highest for SCA effect in a certain trait and in the same time ranks the best in its performance are considered to be good breeding materials to improve this trait. Thus, the crosses Gm-36 x Gm 2 and Gm-11 x Gm 2 appeared to be a promising single crosses, since they had positively significant SCA effects (Table 4) and outyielded the best white commercial hybrids SC 10 (Table 2). It is worth noting that a cross exhibiting high SCA effect may come from two parents possessing good GCA (Gm-11 x Gm 2) or from one parent with good GCA effect and another with poor GCA effect (Gm-36 x Gm-2). For example, the best S_{ij} for grain yield was exhibited between parents with poor and good GCA; Gm-36 x Gm 2 and Gm-21 x SC 21. Similar findings were obtained by Nawar *et al.* (1979), Nawar and El-Hosary (1985), Soliman *et al.* (2001), and Soliman and Osman (2006).

With respect to ear length (Table 2), performance of the 10 lines across the three testers ranged from 18.2 cm to 20.0 cm for lines Gm-83 and Gm-21, respectively. Five inbred lines, i.e. Gm-21, Gm-101, Gm-141, Gm-258 and Gm-149 exhibited the highest values of ear length across the three testers (20.0, 19.7, 19.6, 19.5, and 19.4 cm), respectively. Meanwhile, four lines crossed with Gm 2 (Gm-21, Gm-101, Gm-137, and Gm-141) differ significantly from the commercial white check hybrid, SC 10 (19.0 cm). For ear length, the two inbred lines Gm-21 and Gm-101 had the best significant and positive general combining ability effects, 0.752** and 0.527*, respectively (Table 3) suggesting that these parents are good donors for the tallest ears. Considering SCA effects (Table 4), none of the 30 tested topcrosses had significant SCA effects, except that for Gm-137 x Gm.W.Pop. (1.046*). However, 14 out of 30 studied topcrosses possessed positive, valuable but not significant SCA effects. These crosses exhibited also high mean value of this trait. These results are in the same line with those previously reached by Abd El-Azeem *et al.* (2004).

Data obtained in Table 2 showed that values of ear diameter ranged from 4.5 cm to 4.9 cm for the two inbred lines Gm-83 and Gm-21, respectively. The most preferable lines were Gm-21, Gm-56, Gm-137, Gm-

149, and Gm-36. These lines produced the highest average ear diameter (4.9, 4.9, 4.8, 4.8, and 4.7 cm), respectively. Two of them, Gm-21 and Gm-56 exhibited positive GCA effects, 0.173** and 0.1**, respectively (Table 3), however, the other three lines exhibited small and insignificant GCA effect. These results are in agreement with those of Rawlings and Thompson (1962). Hallauer and Lopez-Perez (1979), El-Itriby *et al.* (1990) and Soliman *et al.* (2001) who concluded that narrow genetic base testers can be effectively used to identify lines having good GCA, and the most efficient tester is the one having a low frequency of favorable alleles. However, None of the 30 tested topcrosses had significant SCA effects. However, the two topcrosses Gm-137 x Gm-2 and Gm-36 x Gm.W.Pop.possessed positive, valuable but not significant SCA effects. These crosses exhibited also high mean value of this trait 5.0 and 4.7 cm), respectively.

For number of rows/ear, data obtained in Table 2 showed that it ranged from 15.6 to 14.6 rows/ear for the two inbred lines Gm-149 and Gm-141, respectively. The most preferable lines were Gm-149, Gm-21, Gm-137, Gm-36, and Gm-11. These lines produced the highest average number of rows/ear (15.6, 15.4, 15.4, 15.3, and 15.1 rows/ear), respectively. Non of the tested inbred lines had significant GCA effects. Both testers Gm-2 and SC 21 had highly significant GCA effect but in opposite direction (-0.588** and 0.588), respectively. Data in Table 5 revealed that none of the 30 tested topcrosses had significant SCA effects, except Gm-36 x Gm-2 which had significant negative SCA effect (-0.728*). However, the topcross Gm-149 x SC 21 possessed significant positive SCA effect (0.835*). This cross exhibited also high mean value of this trait (17.0 rows/ear) and significantly surpassed the chick hybrid SC. 10 (15.4 rows/ear).

Values of number of grains/row for the studied 10 inbred lines across and the three testers (Table 2) and ranged from 39.5 to 42.7 grains /row for Gm-141 and Gm-101, respectively. The best five inbreds concerning this traits were Gm-101, Gm-137, Gm-149, Gm-258 and Gm-21 (42.7, 41.4, 41.1, 40.8 and 40.6 grains/row), respectively. The inbred line Gm-101 had positive significant GCA effect (2.142**) toward the largest number of grains/row. However, the inbred lines Gm-21, Gm-137, Gm-149 and Gm-258 had positive but not significant GCA values toward producing high number of grains/row (Table 2 and 4). None of the studied testers exhibited significant GCA effects. Also, none of the 30 topcrosses possessed significant SCA effects, except that for Gm-137 x Gm-2 (2.490*). This cross had high mean value of number of grains/row (43.6 grains/row, Table 2).

Simple correlations and path analysis:

Simple correlation coefficients were determined between grain yield and all other studied traits. Data in Table 6 indicated that simple correlation values between days to 50% silking and ears/100 plants, grain yield and number of rows/ear were significant. Meanwhile, significant correlation was obtained between plant height and each of ear height, grain yield, ear length, rows/ear as well as 100-grain weight. The same results were obtained concerning the correlation between ear height and both rows/ear and 100-grains weight. Number of ears/100 plant was significantly correlated with grain yield, rows/ear, number of grains/row and 100-grain weight which significantly correlated with ear length and diameter as well as number of rows/ear.

Data in (Table 7 a and b) revealed that number of ears/100 plants, number of rows/ear, 100-grain weight had a high direct effect on grain yield. This was true since these traits were significantly correlated with grain yield per unit area (faddan). The amount of indirect effect of all studied traits on grain yield varied greatly in there amounts and directions.

Table 6

Table 7a. Direct (diagonal) and indirect (above and below diagonal) effects of some yield components on grain yield

Characters	Ear length	Ear diameter	Ears/ row	Grains/ row	100-grain wt	Genotypic correlation with yield
Ear length	0.1571	0.0548	0.1195	-0.0792	-0.2178	0.0343
Ear diameter	0.0536	0.1606	-0.2077	-0.0563	-0.1876	-0.2375
Ears/ row	-0.0279	0.0497	-0.6720	-0.0452	0.1829	-0.5125
Grains/ row	0.0638	0.0464	-0.1555	-0.1951	-0.0606	-0.3010
100-grain wt	0.0896	0.0789	0.3219	-0.0309	-0.3819	0.0776

Table 7b. Direct (diagonal) and indirect (above and below diagonal) effects of some yield components on grain yield

Traits	Direct and indirect effects				Genotypic correlation with yield
	Days to 50% silking	Plant height	Ear height	Ears/100 plants	
Days to 50% silking	-0.0222	0.0005	-0.0035	-0.3415	-0.3667
Plant height	-0.0001	0.0816	0.0495	0.2834	0.4143
Ear height	0.0010	0.0517	0.0780	0.1098	0.2405
Ears/100 plants	0.0115	0.0351	0.0130	0.6578	0.7175

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تحليل الهجن القمية وإنتخاب سلالات من الذرة الشامية فى الأجيال الذاتية المبكرة

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الملخص العربي

تم فى موسم ٢٠٠٩ إجراء التهجين القمى لـ ١٠ سلالة بيضاء الحبوب من الذرة الشامية مستنبطة فى الجيل الإنعزالى الرابع من مجاميع أئتلافية مختلفة مع ثلاث كشافات بيضاء الحبوب (سلالة تجارية "جميزة ٢" ، هجين فردي ٢١ ، مجتمع الجميزة الأبيض. تم تقييم الهجن القمية الـ ٣٠ الناتجة فى تجارب مكررة تم تنفيذها فى محطات البحوث الزراعية بالجميزة وسدس فى موسم ٢٠١٠ وذلك لكل من صفات التزهير وارتفاع كل من النبات والكوز ،

عدد الكيزان/١٠٠ نبات ، محصول الحبوب (أردب/فدان) ، وطول وقطر الكوز وعدد صفوف الكوز وعدد الحبوب بالصف ووزن المائة حبة. أظهرت النتائج أن التباين بين السلالات الكشافة كان أكبر من التباين بين السلالات المختبرة. وقد رتبت السلالات الكشافة السلالات المختبرة بصورة مختلفة تتوقف على الصفة موضع الدراسة. بصفة عامة فقد أظهرت السلالات المختبرة أرقام ١١ ، ٥٦ ، ٨٣ أفضل التقديرات المعنوية الموجبة للقدرة العامة على التآلف لمعظم الصفات موضع الدراسة. فالنسبة لصفة التزهير فإن السلالات الأبوية أرقام ١١ ، ١٣ ، ٢٥٨ أظهرت تأثيرات سالبة ومعنوية أى مرغوبة (تجاه التبكير) للقدرة العامة على التآلف ، لذلك توصى الدراسة بإستخدامها فى برنامج التربية للهجن عالية المحصول مع التبكير وكذلك استعمالها فى تكوين مجتمع وراثى جديد يخدم برنامج عزل السلالات . هذا وقد أعطت السلالة الكشافة جميزة ٢ أعلى محصول بالنسبة لهجنها الإختبارية إذا ما قورنت بالهجين الفردي ٢١ ، مجتمع الجميزة الأبيض. أعطت هجن السلالة الكشافة جميزة ٢ مع السلالات المختبرة أرقام ١١ ، ٣٦ ، ٥٦ ، ٨٣ ، ١٤١ قوة هجين عالية ومحصول حبوب يتفوق معنويا على أصناف المقارنة هـ.ف. ١٠ ، هـ.ث. ٣٢١ ، مجتمع الجميزة الأبيض. وقد أظهرت البيانات ان معامل الإرتباط البسيط بين جميع الصفات موضع الدراسة كان معنويا في معظم الحالات ، هذا وقد كان لكل من عدد الكيزان لكل ١٠٠ نبات ، وطول وقطر الكوز تأثيرا مباشرا وموجبا وواضحا على محصول الحبوب ، بينما إختلفت التأثيرات الغير مباشرة لمعظم الصفات موضع الدراسة على محصول الحبوب.

Table 1. Analysis of variance for grain yield and other agronomic traits of 10 inbred lines topcrossed with three testers combined over two locations, 2010 growing season.

S.O.V.	DF	Days to 50% silking	Plant height	Ear height	Ears/100 plants	Grain yield	Ear length	Ear diameter	Rows/ ear	Grains/ row	100-grain weight
LOC	1	3531.52**	101246.8**	11364.2**	5700.7**	261.8**	128.2**	0.126	31.05**	1055.0**	395.7**
Rep. /Loc.	6	3.68	63.3	48.1	230.4	32.6	7.1	0.249	2.61	32.6	12.8
ENTRY	45	68.58**	11129.8**	3301.4**	1172.6**	523.7**	37.9**	1.417**	6.52**	218.8**	129.7**
Parents	12	56.94**	9690.1**	3583.7**	590.8**	341.4**	34.2**	1.148**	10.32**	182.2**	122.9**
Checks	2	6.50*	16.8	16.1	91.2	11.0	0.1	0.082	1.04	0.2	7.9
Par vs Cr	1	2077.04**	330222.7**	82971.9**	8384.5**	15825.5**	1137.0**	41.286**	29.73**	7110.0**	2447.6**
Cr vs Ch	1	57.91**	2341.0**	955.2**	1216.8*	2.3	0.3	0.209	11.72**	26.0**	30.1**
Crosses	29	10.79**	1140.9**	558.3**	1265.9**	107.1**	4.6**	0.213**	4.08**	16.2*	65.3**
Lines	9	27.37**	1661.3**	357.4**	2558.7**	74.6**	7.6**	0.411**	3.95**	23.1*	81.3**
Testers	2	11.25**	6118.5**	3926.6**	1525.1**	312.4**	10.7**	0.743**	24.68**	14.3	390.9**
Lines x testers	18	2.44	327.6**	284.5**	590.7**	100.6**	2.3	0.054	1.86	12.9	21.1**
Loc x Entry	45	18.06**	895.4**	514.2**	463.6**	71.6**	4.2**	0.129	1.34	21.2**	30.7**
Loc x Parents	12	54.56**	1500.4**	1472.1**	618.2**	59.3**	9.5**	0.374**	2.04	56.3**	49.9**
Loc x Checks	2	5.17**	108.9	43.3	20.5	71.8**	6.8*	0.135	0.24	6.9	7.3
Loc x Par vs Cr	1	40.99**	13407.7**	2.3	215.7	129.9**	1.2	0.022	1.86	20.4	12.0
Loc x Cr vs Ch	1	5.01*	134.6	115.4	216.3	512.8**	2.8	0.011	0.09	4.3	58.7**
Loc x Crosses	29	3.63	265.1**	181.7**	447.3**	59.4**	2.0	0.036	1.15	8.3	24.0**
Loc x Lines	9	2.79	381.9**	262.6**	259.3	58.8**	3.1	0.065	0.39	6.5	29.2**
Loc x Testers	2	3.00	177.8**	29.3	565.4	172.5**	0.8	0.023	1.45	19.1	0.8
Loc x Lines x testers	18	4.12*	216.5**	158.2**	528.1	47.1**	1.6	0.023	1.49	8.0	24.0**
Error	270	1.72	40.3	37.7	189.6	13.0	1.6	0.091	1.14	7.9	6.5
C.V.		2.18	2.51	4.46	11.73	16.08	7.04	6.70	7.18	7.49	7.89

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

Table 2. Mean performance of 30 topcrosses between 10 inbred line and three testers, as well as three checks for grain yield and other agronomic traits, combined over two locations, 2010 growing season.

Genotypes	Days to 50% silking				Plant height (cm)				Ear height (cm)				Ears/100 plants				Grain yield (ard/fad)			
	Gm 2	SC 21	G.W.P	Mean	Gm 2	SC 21	G.W.P	Mean	Gm 2	SC 21	G.W.P	Mean	Gm 2	SC 21	G.W.P	Mean	Gm 2	SC 21	G.W.P	Mean
Gm- 11	57	59	57	57	288	271	266	275	150	140	140	144	156	134	124	138	33.7	25.2	27.4	28.8
Gm- 21	60	60	60	60	277	287	265	276	154	140	141	145	104	120	110	111	17.3	28.6	23.9	23.3
Gm- 36	59	60	60	59	280	266	268	271	157	133	155	148	146	120	123	130	34.8	25.6	22.4	27.6
Gm- 56	58	58	58	58	289	278	268	278	162	154	146	154	126	114	123	121	31.7	23.3	29.6	28.2
Gm- 83	57	58	58	58	272	258	249	260	155	138	130	141	141	115	124	127	31.0	27.5	26.2	28.2
Gm- 101	60	59	60	59	279	257	260	265	162	141	139	147	112	106	113	110	28.6	22.9	24.0	25.2
Gm- 137	59	60	62	60	272	272	264	270	156	150	145	150	109	110	105	108	28.4	22.6	25.6	25.5
Gm- 141	59	58	58	58	306	278	277	287	160	147	144	150	137	128	133	133	30.1	24.8	28.2	27.7
Gm- 149	58	59	58	58	280	273	265	273	152	136	151	146	107	118	118	115	24.1	27.2	25.4	25.6
Gm-258	57	58	57	57	270	252	260	261	144	141	145	143	121	111	122	118	28.9	24.9	24.2	26.0
Mean	58	59	59		281	269	264		155	142	144		126	117	120		28.9	25.3	25.7	
Checks																				
SC 10			60				283				155				117				26.5	
TWC 321			60				283				153				110				28.3	
G.w.P.			61				280				153				113				26.1	
Parents *per ce*																				
Gm- 11			63				178				122				108				17.2	
Gm- 21			64				215				110				102				10.8	
Gm- 36			66				176				94				117				8.6	
Gm- 56			63				186				99				109				10.4	
Gm- 83			63				183				101				115				11.3	
Gm- 101			64				199				112				105				7.9	
Gm- 137			69				146				74				99				5.6	
Gm- 141			66				198				105				113				6.1	
Gm- 149			68				195				106				111				8.9	
Gm-258			63				222				127				102				5.5	
Gm 2			61				218				124				133				12.5	
SC 21			60				270				147				106				27.1	
G.w.P.			62				266				151				115				21.9	
LSD																				
0.05			1.3				6.2				6.0				13.5				3.5	
0.01			1.7				8.1				7.9				17.7				4.6	

Table 2. Con.

Genotypes	Ear length (cm)				Ear diameter (cm)				Rows/ear				Grains/row				100-grain weight (g)			
	Gm 2	SC 21	G.W.P	Mean	Gm 2	SC 21	G.W.P	Mean	Gm 2	SC 21	G.W.P	Mean	Gm 2	SC 21	G.W.P	Mean	Gm 2	SC 21	G.W.P	Mean
Gm- 11	19.4	18.9	19.4	19.2	4.5	4.7	4.5	4.6	14.8	15.5	15.1	15.1	39.3	39.8	39.9	39.7	31.7	30.9	30.9	31.2
Gm- 21	20.5	19.9	19.5	20.0	5.0	5.0	4.7	4.9	15.1	15.5	15.5	15.4	40.5	41.7	39.6	40.6	38.4	33.2	32.1	34.6
Gm- 36	18.5	18.9	17.9	18.4	4.7	4.8	4.7	4.7	14.0	16.0	16.0	15.3	39.0	40.3	40.3	39.9	32.9	33.2	31.1	32.4
Gm- 56	19.6	18.8	19.2	19.2	5.0	5.0	4.7	4.9	14.0	15.4	15.0	14.8	41.1	40.6	39.6	40.4	39.9	35.2	35.6	36.9
Gm- 83	18.0	18.6	18.1	18.2	4.5	4.5	4.5	4.5	14.2	14.7	15.0	14.6	37.7	40.9	40.8	39.8	35.4	29.3	29.7	31.5
Gm- 101	20.7	19.0	19.5	19.7	4.6	4.7	4.5	4.6	13.7	15.1	15.3	14.7	42.8	43.0	42.3	42.7	36.9	34.9	32.1	34.6
Gm- 137	20.4	18.1	18.3	18.9	5.0	4.9	4.6	4.8	15.2	15.7	15.2	15.4	43.6	40.9	39.6	41.4	38.9	32.8	30.3	34.0
Gm- 141	20.1	19.5	19.3	19.6	4.7	4.9	4.6	4.7	13.7	15.3	14.1	14.4	40.2	40.8	37.5	39.5	38.3	33.2	35.1	35.5
Gm- 149	19.3	19.9	19.0	19.4	4.8	4.9	4.7	4.8	14.9	17.0	15.0	15.6	40.2	41.7	41.4	41.1	36.7	31.3	35.0	34.3
Gm-258	19.8	18.8	19.8	19.5	4.8	4.7	4.6	4.7	14.7	15.4	14.7	14.9	39.1	41.0	42.2	40.8	36.9	34.2	35.2	35.4
Mean	19.6	19.0	19.0		4.8	4.8	4.6		14.4	15.6	15.1		40.4	41.1	40.3		36.6	32.8	32.7	
Checks																				
SC 10			19.0				4.7				15.4				39.6				33.0	
TWC 321			19.1				4.9				16.1				39.5				31.8	
G.w.P.			19.1				4.9				15.9				39.4				33.8	
Parents *per ce*																				
Gm- 11			12.7				3.7				15.1				22.6				24.6	
Gm- 21			16.1				4.1				15.9				34.3				26.7	
Gm- 36			12.4				3.6				13.6				27.2				26.9	
Gm- 56			14.3				3.8				13.0				31.4				27.4	
Gm- 83			15.7				3.8				12.7				29.5				25.6	
Gm- 101			14.3				3.8				13.9				29.9				26.3	
Gm- 137			13.9				3.7				14.8				28.7				23.6	
Gm- 141			15.0				3.7				14.3				29.5				28.6	
Gm- 149			18.8				4.0				14.8				35.2				32.6	
Gm-258			15.1				4.1				13.8				28.6				23.5	
Gm 2			13.7				3.9				13.2				25.1				33.5	
SC 21			18.0				4.9				16.0				37.9				33.1	
G.w.P.			18.4				4.6				15.9				39.0				34.7	
LSD																				
0.05			1.2				0.3				1.0				2.8				2.5	
0.01			1.6				0.4				1.4				3.6				3.3	

Table 3. Better parent heterosis for grain yield and other agronomic traits of 30 top crosses, data are combined over two locations, 2010 season

Genotypes	Days to 50% silking			Plant height (cm)			Ear height (cm)			Ears/100 plants			Grain yield (ard/fad)		
	Gm 2	SC 21	G.W.P	Gm 2	SC 21	G.W.P	Gm 2	SC 21	G.W.P	Gm 2	SC 21	G.W.P	Gm 2	SC 21	G.W.P
Gm- 11	-6.39**	-2.70	-8.62**	61.4**	52.1**	49.1**	23.6**	15.4*	15.3*	17.5	23.9	8.5	96.7**	-6.9	25.0**
Gm- 21	-1.86	0.42	-4.21**	28.5**	33.6**	23.1**	39.1**	27.2**	27.9**	-21.3	13.0	-4.4	38.5**	5.4	9.1*
Gm- 36	-3.30*	-1.04	-4.41**	58.7**	51.2**	52.0**	67.1**	42.3**	64.8**	9.9	3.1	5.5	178.9**	-5.6	2.1
Gm- 56	-4.33**	-3.12*	-6.61**	55.9**	49.9**	44.2**	63.7**	55.9**	48.0**	- 5.2	4.8	7.6	153.8**	-14.0**	35.1**
Gm- 83	-5.77**	-4.37**	-6.81**	48.3**	40.5**	36.0**	53.8**	37.3**	29.4**	6.4	0.2	8.0	148.7**	1.6	19.7**
Gm- 101	-1.86	-1.46	-4.61**	39.9**	29.0**	30.4**	44.5**	25.9**	24.3**	-15.9	- 0.6	-1.8	129.4**	-15.4**	9.7*
Gm- 137	-2.27	0.42	-1.40	85.8**	86.1**	80.4**	111.5**	103.7**	96.3**	-17.6	3.5	-8.0	127.5**	-16.6**	16.9**
Gm- 141	-3.51*	-3.12	-6.41**	54.8**	40.4**	40.2**	52.4**	40.3**	37.9**	3.3	13.4	16.3	141.2**	-8.6	28.6**
Gm- 149	-4.54**	-1.25	-6.81**	43.4**	40.1**	35.8**	43.2**	28.2**	42.7**	-19.0	6.8	3.0	93.5**	0.2	16.0**
Gm- 258	-5.98**	-3.33*	-9.02**	24.0**	13.5	17.18	13.4	11.4	14.3	- 8.7	4.1	6.8	131.4**	-8.3	10.5*
sig.(-) values		19			0			0			0			3	
Sig (+) values		0			28			27			0			18	
LSD 0.05		3.15			15.2			14.7			33.1			8.7	
0.01		4.11			19.9			19.3			43.2			11.3	
Genotypes	Ear length (cm)			Ear diameter (cm)			Rows/ear			Grains/row			100-grain weight (g)		
Gm- 11	41.2**	5.14**	5.6**	16.9**	-4.6**	-1.1**	-2.2	-3.1*	-5.0**	56.2**	5.2	2.3	-5.2	-6.7	-11.0**
Gm- 21	27.7**	10.4**	6.1**	20.6**	2.0**	3.3**	-5.2**	-3.4**	-2.7	18.2**	10.2**	1.6	14.8**	0.4	-7.6
Gm- 36	35.0**	4.7**	-2.3	21.4**	-2.0**	4.1**	3.3**	0.0	0.5	43.4**	6.5	3.5	-1.5	0.5	-10.5**
Gm- 56	37.7**	4.2**	4.4**	29.2**	1.0**	3.3**	7.7**	-3.9**	-6.1**	31.0**	7.3	1.6	19.1**	6.3	2.7
Gm- 83	14.1**	3.1*	-1.6	17.5**	-8.2**	-0.5	12.1**	-8.4**	-5.8**	27.8**	7.9	4.8	5.7	-11.5**	-14.3**
Gm- 101	45.4**	5.6**	6.1**	19.5**	-5.1**	-0.5	-1.8	-5.9**	-3.8**	43.1**	13.7**	8.6*	10.4**	5.6	-7.5
Gm- 137	46.1**	0.3	-0.5	28.6**	-0.5	1.1**	3.0*	-2.2	-4.4**	51.8**	7.9	1.7	16.3**	-1.0	-12.6**
Gm- 141	34.0**	8.2**	5.2**	21.4**	-0.5	0.0	-4.0**	-4.7**	-11.6**	36.3**	7.7	-3.7	14.3**	0.3	1.2
Gm- 149	3.1*	5.9**	1.2	19.9**	0.5	2.7**	0.8	6.1**	- 5.8**	14.2**	10.2**	6.2	9.6**	-5.4	0.8
Gm- 258	31.0**	4.6**	7.9**	17.9**	-3.6**	1.1**	6.4**	-3.6**	-7.7**	36.8**	8.2	8.4*	10.2**	3.3	1.4
sig.(-) values		0			6			17			0			5	
Sig (+) values		25			17			6			15			7	
LSD 0.05		3.0			0.7			2.6			6.7			6.1	
0.01		4.0			0.9			3.3			8.8			8.0	

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

Table 4. General combining ability effects ($\hat{g}_i$) of 10 inbred lines and 3 testers for grain yield and other agronomic traits combined over two locations, 2010 growing season.

Lines/ Testers	Days to 50% silking	Plant height	Ear height	Ears/100 plants	Grain yield	Ear length	Ear diameter	No rows/ ears	No. grains/ row	100- grain weight
Lines										
Gm- 11	-1.204**	3.275**	-3.383**	16.945**	2.178**	0.018	-0.160**	0.116	-0.929**	-2.878**
Gm- 21	1.254**	4.692**	-1.883	- 9.676**	-3.358**	0.752**	0.173**	0.316	0.033	0.526
Gm- 36	0.629*	- 0.392	1.283	8.582**	0.978	-0.773**	0.019	0.325	-0.700	-1.624
Gm- 56	-0.454	6.692**	7.033**	0.136	1.589	-0.032	0.156**	-0.242	-0.142	2.847**
Gm- 83	-1.038**	-11.892**	-5.842**	5.578	1.656	-1.023**	-0.202**	-0.388	-0.783	-2.582**
Gm- 101	0.796**	- 6.225**	0.492	-11.085**	-1.402	0.527*	-0.127*	-0.342	2.142**	0.618
Gm- 137	1.754**	- 2.058	3.200**	-12.768**	-1.071	-0.323	0.090	0.341	0.779	-0.032
Gm- 141	-0.246	15.650**	3.283**	11.724**	1.081	0.418	-0.019	-0.667	-1.092	1.472**
Gm- 149	-0.163	0.983	-0.717	- 6.468	-1.030	0.177	0.090	0.608	0.525	0.276
Gm- 258	-1.329**	-10.725**	-3.467**	- 2.968	-0.622	0.260	-0.019	-0.067	0.167	1.376*8
LSD 0.05										
g_{ii}	0.268	1.296	1.253	2.811	0.736	0.258	0.061	0.218	0.574	0.520
$g_{ii} - g_{jj}$	0.379	1.833	1.772	3.975	1.041	0.365	0.087	0.308	0.811	0.736
Testers										
Gm 2	-0.408**	9.642**	8.042**	4.887**	2.268**	0.421**	0.029	-0.588**	-0.231	2.552**
SC 21	0.329*	-2.221**	-4.783**	- 3.517*	-1.348**	-0.192	0.079	0.515**	0.488	-1.227**
G.W. Pop.	0.079	-7.421**	-3.258**	- 1.370	-0.921*	-0.229	-0.108*	0.073	-0.256	-1.325**
LSD 0.05										
g_{ii}	0.147	0.710	0.686	1.539	0.403	0.141	0.033	0.119	0.314	0.285
$g_{ii} - g_{jj}$	0.207	1.003	0.971	2.177	0.570	0.200	0.048	0.169	0.444	0.403

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

Table 5. Specific combining ability ($\hat{s}_{ij}$) effects of 36 topcrosses (10 inbred line and 3 testers) for grain yield and other agronomic traits combined over two locations, 2010 growing seasons.

Genotypes	Days to 50% silking			Plant height			Ear height			Ears/100 plants			Grain yield		
	Gm 2	SC 21	G.W.P	Gm 2	SC 21	G.W.P	Gm 2	SC 21	G.W.P	Gm 2	SC 21	G.W.P	Gm 2	SC 21	G.W.P
Gm- 11	-0.258	0.754	-0.496	3.150	-1.488	-1.663	-1.417	1.533	-0.117	12.975**	- 0.846	- 12.130*	2.684*	-2.206	-0.477
Gm- 21	0.033	0.171	-0.204	-9.392**	13.346**	-3.954	0.458	0.158	-0.617	-11.891*	12.250*	- 0.359	-8.228**	6.665**	1.563
Gm- 36	-0.217	-0.079	0.296	-1.308	-2.571	3.879	0.417	-10.008**	9.592**	11.200*	- 5.971	- 5.230	4.952**	-0.647	-4.304**
Gm- 56	0.242	-0.246	0.004	1.233	2.096	-3.329	-0.333	4.867*	-4.533*	- 0.266	- 3.325	3.591	1.216	-3.539*	2.323
Gm- 83	-0.050	-0.413	0.463	2.692	0.179	-2.871	5.667*	1.867	-7.533**	9.580*	- 8.279	- 1.300	0.517	0.614	-1.131
Gm- 101	0.492	-0.496	0.004	3.900	-5.988*	2.088	6.458**	- 1.592	-4.867*	- 3.308	- 0.767	4.075	1.167	-0.913	-0.254
Gm- 137	-0.717	-0.329	1.046*	-7.142**	5.096*	2.046	-2.375	4.700*	-2.325	- 3.837	5.229	- 1.392	0.598	-1.589	0.991
Gm- 141	0.533	-0.454	-0.079	9.525**	-7.113**	-2.413	1.292	1.367	-2.658	- 0.679	- 1.325	2.004	0.152	-1.555	1.403
Gm- 149	-0.175	0.588	-0.413	-2.558	2.929	-0.371	-2.583	- 5.633*	8.217**	-11.950*	6.979	4.970	-3.692**	2.942*	0.751
Gm- 258	0.117	0.504	-0.621	-0.100	-6.488**	6.588**	-7.583**	2.742	4.842*	- 1.825	- 3.946	5.770	0.636	0.228	-0.864
LSD 0.05															
S_{ij}		0.463			2.244			2.171			4.869			1.275	
$S_{ij} - S_{kl}$		0.656			3.174			3.070			6.885			1.802	

Genotypes	Ear length			Ear diameter			No rows/ ears			No. grains/ row			100-grain weight		
Gm- 11	-0.271	-0.108	0.379	-0.087	0.038	0.049	0.230	-0.149	-0.081	-0.165	-0.308	0.473	-2.006*	0.935	1.070
Gm- 21	0.146	0.108	-0.254	0.055	0.030	-0.084	0.305	-0.399	0.094	0.148	0.629	-0.777	1.278	-0.119	-1.159
Gm- 36	-0.329	0.608	-0.279	-0.091	-0.016	0.108	-0.728*	0.143	0.585	-0.669	-0.038	0.706	-2.023*	2.056*	-0.034
Gm- 56	0.029	-0.233	0.204	0.071	-0.004	-0.068	-0.187	0.085	0.102	0.923	-0.321	-0.602	0.419	-0.490	0.070
Gm- 83	-0.654	0.558	0.096	-0.020	-0.095	0.116	0.197	-0.495	0.298	-1.860	0.571	1.290	1.361	-0.960	-0.400
Gm- 101	0.571	-0.542	-0.029	-0.020	-0.020	0.041	-0.437	-0.140	0.577	0.340	-0.179	-0.160	-0.289	1.515	-1.225
Gm- 137	1.046*	-0.642	-0.404	0.113	-0.012	-0.101	0.430	-0.224	-0.206	2.490*	-0.992	-1.498	2.361*	-0.023	-2.338
Gm- 141	0.054	0.042	-0.096	-0.054	0.096	-0.043	-0.037	0.385	-0.348	0.923	0.779	-1.702	0.194	-1.115	0.920
Gm- 149	-0.479	0.658	-0.179	-0.012	0.038	-0.026	-0.137	0.835*	-0.698	-0.669	0.138	0.531	-0.210	-1.794*	2.004*
Gm- 258	-0.113	-0.450	0.563	0.046	-0.054	0.008	0.363	-0.040	-0.323	-1.460	-0.279	1.740	-1.085	-0.006	1.091
LSD 0.05															
S_{ij}		0.447			0.107			0.377			0.994			0.901	
$S_{ij} - S_{kl}$		0.632			0.151			0.534			1.405			1.275	

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

Table 6: Genotypic correlations between grain yield and other agronomic traits for 30 topcrosses, data are combined over two locations.

Characters	Plant height (cm)	Ear height (cm)	Ears/ 100 plants	Grain yield (ard/fad)	Ear Length (cm)	Ear Diameter (cm)	Rows/ ear	Grains/ row	100-grain weight
Days to 50% silking	0.006	-0.045	-0.519**	-0.367*	-0.011	0.342	0.392*	0.277	-0.134
Plant height (cm)		0.634**	0.431*	0.414*	0.423*	0.395*	-0.371*	-0.186	0.481**
Ear height (cm)			0.167	0.241	0.227	0.273	-0.561**	-0.009	0.668**
Ears/100 plants				0.717**	-0.154	-0.326	-0.370*	-0.553**	-0.107
Grain yield (ard/fad)					0.034	-0.237	-0.513**	-0.301	0.078
Ear Length (cm)						0.341	-0.178	0.406*	0.570**
Ear Diameter (cm)							0.309	0.289	0.491**
Rows/ear								0.231	-0.479**
Grains/row									0.159

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