2. REVIEW OF LITERATURE

The available literature concerning this study can be reviewed under the following headings:

2.1. Nature and number of testers.

2.2. Combining ability effects.

2.3. Genotypes x environmental interaction.

2.4. Heterosis.

2.1. Nature and number of testers.

The problem confronting breeders is the number of testers required for efficient evaluation of lines for GCA. Selecting suitable testers is the first and important step in evaluating inbred lines in maize breeding program. Review on the nature of testers is presented as follows:

Davis (1927) was the first to suggest the use of inbred, open pollinated varieties as a method for evaluating maize inbred lines.

Al-Naggar *et al.* (1997) studied effectiveness of different testers; narrow, medium and broad genetic base in evaluating combining ability of inbred lines of maize. They concluded that inbred tester sd.7 was the most powerful tester for the maximization of mean grain yield of the test crosses. The single cross tester S.C. 10 was the best based on the ability to reduce the magnitude of interaction variance of test cross x environment and provide of favorable SCA effects. They suggested that narrow or medium base testers are useful for evaluation of GCA of lines.

Abdel-Sattar (1998) top crossed twenty-four inbred lines were divided into two groups. First group (Consisted of 12 inbred lines) to each of Giza-2, T.W.C.310 and D.C 215 giving a total of 36 top crosses. Second group was top crossed to each of Giza-2, D.C. 204 and S.C. 10 giving a total 36 top crosses. They found that the testers D.C. 215 and T.W.C. 310 in the first set gave highest positive GCA effects for grain yield and number of kernels/ row. However the tester S.C.10 was the best general combiner for grain yield/ plant and its components in the second set.

Soliman and Sadek (1998) top crossed ten white maize inbred lines with three line testers and they found that the tester inbred line Gm.30 showed the highest significant GCA estimate for grain yield.

Sultan (1998) top crossed fourteen yellow maize inbred lines with two line testers, i.e. Gm-1002 and Gm-1004 and considered the two testers as best testers in classification inbred lines into high vrs low yielding ability.

Sadek *et al.* (2000) top crossed twenty white maize inbred lines to each of two line testers, i.e. Sd-7 and Sd-63 and they found that the tester line Sd-7 was the best combiner for grain yield while the tester inbred line Sd-63 showed desirable GCA effects for earliness and shortness.

Soliman *et al.* (2001) top crossed fourteen S_3 yellow maize inbred lines derived from the wide genetic base population Giza-45 (Ev-3) to each of three yellow maize inbred testers, i.e. Gz-638, Gm-1002 and Gm-1021. They found that inbred tester Gm-1021 manifested highest average performance of grain yield compared to test crosses of Gz-638 or Gm-1002.

Venkatesh *et al.* (2001) carried out line x tester analysis to determine the combining ability of modified single cross hybrids through their crosses and they inferred that among the sister line crosses used as female parents, (A_1 x A^-_1), (A_7 x A^-_7), (A_8 x A^-

$_8$), (A_{10} x $A^{'}_{10}$) and (A_{11} x $A^{'}_{11}$) are the best general combiners. Among the exotic testers that were used CML 290 had to be the best combiner. The indigenous tester CM111 widely used in the Indian maize program also showed its potential as a good tester.

Dodiya and Joshi (2002) mated twenty diverse advanced stage lines of maize with three inbred lines (testers) in Line x tester design and they found that T_1 had desired significant GCA effects for 100-grain weight and harvest index but best combiner for ear size and Stover yield. T_3 had desired significant GCA effects for grain yield and Stover yield.

Amer *et al.* (2003) crossed new seven yellow inbred lines of maize with four testers i.e. The inbred line L-121, two promising single crosses (Sk-21 and Sk-22) and one three way cross (T.W.C. 351) and they found that the inbred tester L-121 showed the best desirable GCA effect for grain yield and ear length. Moreover, the testers, S.C. Sk-21 and S.C. SK-22 were the best general combiners for ear height and ear diameter.

Abdel-Sattar (2004) crossed five inbred lines of maize in three levels of inbreeding (S_3, S_4 and S_5) to each of three different testers, i.e. S.C 122, T.W.C 310 and T.3057. He reported that the best parental tester for different traits were the broad genetic tester T.W.C.310.

Aly (2004) crossed thirty nine yellow and white inbred lines (S_8) of maize to each of the two testers, i.e. D.C. Dahab and synthetic variety Giza-2. He found that Dahab had desirable GCA effects for most of studied traits and this may be attributed to it had a narrower genetic base than Giza-2.

Amer (2004) top crossed eighteen new white inbred lines of maize to the three testers, i.e. Line Sk-7001/8, S.C. Sk-17 and Giza-2. He reported that the tester inbred line Sk-7001/8 had desirable significant GCA effects for short plant and ear position. While, the tester S.C. Sk-17 had desirable significant GCA effects for earliness, short plant, grain yield, ear length and ear diameter. Giza-2 as a tester had downer favorable genes for no. of rows/ ear and 100- kernel weight (g.).

Ibrahim and Motawei (2004) top crossed fourteen inbred lines of maize to the three testers, i.e. Sk-7001/8, S.C.Sk-17 and Gz-2. They found the inbred tester Sk-7001/8 showed the best desirable GCA effects for number of rows/ ear. Moreover, the tester S.C. SK-17 was the best combiner for grain yield and number of kernels/ row. While the tester Gz-2 was the best general combiner for earliness and short plants.

Mosa (2004) top crossed new white twenty seven inbred lines of maize to the two testers. i.e. homozygous inbred line GM-4 and heterozygous promising single cross sakha-1. the studied traits were silking date, plant and ear heights, grain yield, ear length, ear diameter, number of rows/ ear, number of kernels/ row and 100 kernel weight. He found that top crosses involving heterozygous S.C. Sk-1 as a common tester showed the heighest means for all traits and the widest range for all traits except plant height compared with top crosses involving homozygous inbred line Gm-4 as a common tester. Consequently, the heterozygous S.C. Sk-1 was the best tester for evaluating the inbred lines in top crosses. The heterozygous S.C. SK-1 as tester was the best general combiner for grain yield, ear length, number of rows/ ear, number of kernels/ row and 100- kernel weight. While the homozygous inbred line Gm-4 as tester was the best combiner for silking date, plant and ear heights and ear diameter.

Mosa *et al.* (2004) top crossed nine inbred lines of yellow maize to the three testers i.e. L-121, S.C. Sk-52 and composite - 21 and they found that the parental testers that exhibited better general combining ability were L-121 for grain yield/ plant. S.C. Sk-52 for number of rows/ ear and ear position and composite- 21 for number of kernels/ row.

Abd El-Moula (2005) Top crossed twenty yellow maize inbred lines (S_4) to each of three testers, i.e. Gz-45 (base population) and two elite inbred lines (Gm-1001 and Gm-1004). He found that the tester lines Gm-1001 was the best combiner for grain yield and no. of ears/ 100 plants. While, the tester Gm-1004 showed desirable GCA for shortness and tester pop-45 for earliness and shortness.

Ibrahim and Osman (2005) top crossed new fifteen white inbred line of maize with the two tester lines, i.e. Sids-63 and Sakha-9195. They indicated that the tester line Sk-9195 had desirable significant GCA effects for earliness, ear length, number of rows/ ear, 100-kernel weight and grain yield (ard/fed). While, the second tester (Sd-63) had favorable genes for ear diameter.

Motawei *et al.* (2005) crossed twenty-nine inbred lines of yellow maize derived from S_5 generation with two genetically diverse inbred testers. The top-crosses were divided into two different sets: set-I included 28 top-crosses and set-II included 30 top crosses. They found that the tester Gm-1001 was a good general combiner for ear position, no. of rows/ear and ear diameter in the two sets of top crosses and for grain yield in set II. While tester line sk-6241 had favorable alleles for days to 50% silking, no. of ears/100 plants and no. of kernels/ row.

2.2 Combining ability:

Combining ability of inbred lines in the ultimate factor determining future usefulness of the lines for hybrids. combining ability initially was general concept considered collectively for classifying an inbred line relative to its cross performance.

Al-Naggar *et al.* (1997) found that the inbred testers Sd-7, Sd-86 and S.C. 10 gave the highest GCA effects for grain yield. The range between low and high estimates of SCA effects for grain yield was widest for Sd-7 followed by S.C.10.

Abdel-sattar (1998) top crossed twenty-four inbred lines were divided into two groups. First group, (consisted of 12 inbred lines) to each of Giza-2, T.W.C. 310 and D.C. 215. Second group was top crossed to each of Giza-2, D.C. 204 and S.C. 10. The studied traits were grain yield/ plant, plant height, ear height, ear length, ear diameter, number of rows/ ear and number of kernels/ row. He found that the variance associated with SCA was more important than σ^2 GCA for all traits in two sets revealed that the non-additive component of gene action had the major role in the inheritance of all traits.

Sultan (1998) top crossed fourteen yellow maize inbred lines with two line testers, i.e. Gm-1002 and Gm-1004 to estimate GCA and SCA for days to 50 % silking, plant height, ear position (%), number of ears/ 100 plants, ear length and diameter, number of rows/ ear, number of kernels/ row, 100-kernel weight and grain yield were calculated. He found that variance magnitude due to GCA was higher than that due to SCA. This indicated that additive genetic variance was the major source of variation responsible for the inheritance of grain yield and other agronomic traits.

El-Zeir (1999) mated ten maize inbred lines to four testers and found that additive genetic effects among lines were the major source of genetic variance responsible for all studied traits except ear height and ear length.

El-Zeir *et al.* (2000) top crossed seventeen inbred lines of maize to two testers. They found that non-additive genetic variance play an important role in the inheritance for grain yield, ear length, number of kernels/ row and weight of 100-kernel. While the additive genetic variance played an important role in the inheritance for silking date, plant height, ear height and number of rows/ ear.

Gado (2000) crossed seventeen yellow maize inbred lines with two testers, i.e. Gm-2 and Gm-9. He estimated GCA and SCA for days to 50 % silking, plant height, ear height, ear length, ear diameter, number of rows/ ear, number of grains/ row, 100-grain weight and grain yield (ard./fed.). He indicated that the additive genetic variance was the major source of variation responsible for the inheritance of these traits.

Sadek *et al.* (2000) top crossed twenty white maize inbred lines to each of two line testers, i.e. Sd-7 and Sd-63. They estimated GCA and SCA for grain yield, days to 50% silking, no. of ears/ 100 plant and plant and ear heights. They found that variance magnitude due to SCA was higher than that due to GCA. This indicated that non-additive genetic variance was the major source of genetic variation responsible for the inheritance of grain yield and other traits.

Soliman (2000) top crossed sixteen yellow maize inbred lines to each of three different testers. i.e. Gz-45 and two elite inbred lines, Gm-1001 and Gm-1021. He estimated GCA and SCA for grain yield, number of days to mid silking, plant height, ear position and number of ears/ 100 plants. He found that the magnitude of σ^2 SCA among lines for grain yield was larger than that of σ^2 GCA. On the contrary σ^2 GCA was greetar than σ^2 SCA for the other traits.

Barakat(2001) top crossed sixteen white maize inbred lines to each of the two line testers, i.e. Sd-7 and Sd-63 to estimate GCA and SCA for days to 50% silking, plant height, ear height, number of ears/ 100 plants, grain yield / plant and per feddan, ear length and diameter, number of rows/ ear and 100-kernel weight were calculated. He found that variance magnitude due to GCA was higher than that due to SCA. This indicated that additive genetic variance was the major source of variation responsible for the inheritance of grain yield and other agronomic traits.

Dubey *et al.* (2001) crossed fifteen diverse early maturing white seeded inbred lines of maize with three testers. The data were recorded on grain yield and maturity traits. They reported that the ratio of σ^2 SCA/σ^2 GCA was greater than one for all characters. This indicated the preponderance of non-additive variance in the expression of traits under study.

Mahmoud ***et al.*** **(2001)** crossed nineteen white maize lines to each of two elite inbred tester lines Sd-7 and Sd-34 to estimate combining ability effects for grain yield/fed., days to mid silking, plant height and ear placement (%). They reported that non-additive was more important than additive gene action in the inheritance of grain yield, whereas additive gene action was comprised most of the genetic variance of other studied traits.

Soliman ***et al.*** **(2001)** top crossed fourteen S_3 yellow maize inbred lines to each of three yellow maize inbred testers. The studied traits were grain yield, silking date, plant height and ear position. They found that the magnitude of the ratio of general to specific combining ability variance (σ^2 GCA/σ^2 SCA) revealed that the additive Component of gene action had the major role in the inheritance of all traits.

Soliman ***et al.*** **(2001)** top crossed eighteen yellow maize inbred lines to each of three broad genetic base testers namely pop.-59E, pop. 21 and pop.-Fat-3 to estimate the combining ability effects and determine the type of gene action for grain yield. They indicated that the magnitude of dominance (σ^2D) gene effects was more important than additive (σ^2A) genetic effects in controlling that trait.

Amer ***et al.*** **(2002)** reported that non additive genetic variances played an important role in the inheritance for grain yield and number of kernels/row. While the additive genetic variance played an important role in the inheritance for silking date, plant and ear height, ear length, ear diameter, number of rows/ ear and weight of 100-kernel.

Dodiya and Joshi (2002) mated twenty diverse advanced stage inbred lines of maize with three inbred lines (testers) in line x tester design. The studied traits were grain yield/plant, (GCA) was predominating than non-additive genetic variance (SCA) in the inheritance of all traits.

Abd El-Moula (2005) top crossed twenty yellow maize inbred lines (S_4) to each of three testers, i.e. Gz-45 (base population) and two elite inbred lines, Gm-1001 and Gm-1004. The studied traits were grain yield, days to 50% silking, plant and ear heights and no. of ears/ 100 plants. He reported that variance magnitude due to SCA was higher than that due to GCA. This indicated that non-additive genetic variance was the major source of genetic variation for the inheritance of grain yield and other traits.

Ibrahim and Osman (2005) top crossed new fifteen white inbred lines of maize with two tester line. The data collected were days to 50% silking, plant height, ear height, ear length, ear diameter, number of rows/ ear, number of kernels/ row, 100-kernel weight and grain yield. They indicated that additive gene action was more important than non-additive one in the inheritance for all of the studied traits.

Motawei *et al.* (2005) reported that the additive genetic variance (σ^2 GCA) played an important role in the inheritance of ear position%, no. of rows/ ear and ear diameter in the two sets and days to 50% silking, no. of ears/ 100 plants and 100 kernel weight within set-I. Mean while, non-additive genetic variance was more important in the expression of grain yield, no. of kernels/ row and ear length in the two sets.

2.3. Genotype x environment interaction:

El-Hosary (1988) studied 20 new inbred lines by top cross method in maize. He found that the interaction between years and both types of combining ability were highly significant for all traits except plant height.

Sedhom (1992) studied thirty two inbred lines by top cross method. He found that the interaction between specific combining ability and environment was much higher than those of general combining ability for most studied traits.

Sedhom (1994) evaluated seven inbred lines using ten different testers and found that specific combining ability x years interaction was higher than that of general combining ability x years interaction for all traits except silking date, revealing that non additive gene effects seemed to be more affected by environment rather than additive ones.

Shehata *et al.* (1997) crossed five inbred maize lines with five narrow base elite inbred testers. They found that the interaction between entries (genotypes) by locations and its components, i.e. parent x location, crosses x location and parent vs. crosses x location were highly significant differences for all studied traits.

Sultan (1998) top crossed fourteen yellow maize inbred lines with two line testers. He found that both inbreds and testers significantly interacted with environments in case of grain yield and some other traits and indicated that the interaction of GCA by location was markedly higher and positive for grain yield and other traits.

El-Zeir (1999) mated ten maize inbred lines to four testers and found that the interaction between genotypes x locations for most attributes were significant.

El-Zeir *et al.* (2000) crossed seventeen inbred lines of maize with two testers. They found that additive type of gene action was found to be more affected by environment than non-additive type of gene action in most cases.

Gado (2000) evaluated seventeen yellow maize inbred lines using two testers and found that the interaction of inbreds with environment was significant in case of ear length and grain yield. Also significant interaction of testers with environment was also detected for number of days to 50% silking, plant height, ear height and ear diameter. The interaction of GCA by locations was higher and positive for grain yield and other traits except silking date, ear length and number of grain/ row.

Sadek *et al.* (2000) evaluated white maize inbred lines with two line tester. They found that both inbreds and testers significantly interacted with environments for most traits. Also, the interaction of SCA by location was higher than that of GCA ones for all studied traits.

Soliman (2000) crossed sixteen yellow maize inbred lines with three different testers. He found that the interaction of both lines and testers with locations were highly significant for grain yield, days to mid silking. Also, mean squares due to tester x location interaction was significant for plant height.

Barakat (2001) evaluated sixteen white maize inbred lines with two line testers. He found that both inbreds and testers significantly interacted with environments in all traits except plant height, ear height and number of ears / plant. However, the interaction of environments x lines x testers was significant for only grain yield/ plant and /feddan and ear length. Also, the interaction of GCA by locations was markedly higher and positive for grain yield and other traits.

Mahmoud *et al.* (2001) evaluated nineteen white maize lines with two elite inbred tester lines. They reported that non-additive gene action was affected more by environmental conditions than additive gene action for all studied traits.

Soliman *et al.* (2001) top crossed fourteen S_3 yellow maize inbred lines to each of three yellow maize inbred testers. They found that the magnitude of the interactions between σ^2 SCA x location was generally higher than σ^2 GCA x location for the studied traits except grain yield.

Amer *et al.* (2002) evaluated eight inbred lines of maize to four testers. They found that additive type of gene action was more affected by environment than non-additive type of gene action for all studied traits except ear length and ear diameter.

Dodiya and Joshi (2002) they found that environments played important role in the expression of GCA and SCA variance. The performance of the parents and their GCA effects varied in different environments which may be attributed to genotype x environment interaction.

Amer *et al.* (2003) evaluated seven new yellow inbred lines of maize to four testers. They found that additive more interacted by location than non-additive variance for grain yield, ear length, no. of rows/ear and no. of kernels/ row traits. While non-additive more influenced by location than additive variance for days to mid-silk, plant height, ear height and ear diameter traits.

EL-Shenawy *et al.* (2003) top crossed eight maize inbred lines to four testers. They found that the interactions were significant for most studied traits and the interaction between σ^2GCA x location was greater than σ^2SCA x location interaction for all studied traits except number of rows/ear.

Aly (2004) crossed thirty nine yellow and white inbred maize lines to two testers. They found that the variance interaction of σ^2GCA x location were larger than those of σ^2GCA$_T$ x location for studied traits indicated that the σ^2GCA for inbred lines was more affected by environments than for testers. Also, the combined data revealed that variance of σ^2GCA x location interaction was either negative or smaller than variance of σ^2SCA x Location interaction for all traits under study. these results indicated that non-additive type of gene action is more affected by environmental conditions than variance due to additive effects.

Ibrahim and Motawei (2004) top crossed fourteen inbred lines of maize to three testers. They reported that non- additive genetic variance was more affected interacted by locations than additive genetic variance for all studied traits except number of kernels/ row and ear diameter.

Mahmoud and Abdel-Azeem (2004) top crossed twenty three yellow inbred lines of maize to two testers. They found that the interaction of lines x location was highly significant for grain yield and significant for ear height. Tester x locations interaction was highly significant for ear height. Also, the interaction of lines x testers x locations was highly significant for grain yield.

Mosa (2004) crossed twenty seven inbred lines of maize to two testers. He found that a line x locations interaction was significant for all traits except number of rows/ear and 100-kernel weight. While testers x locations and line x testers x location interaction were not significant for most traits. The non-additive types of gene action were more sensitive to environmental differences than additive types of gene action for most traits.

Mosa *et al.* (2004) evaluated nine inbred lines of yellow maize to three testers. They reported that the non-additive genetic variance showed obvious interaction with locations for grain yield / plant, number of rows/ear and number of kernels/row.

Abd El-Moula (2005) top crossed twenty yellow maize inbred lines to each three testers. He found that the interaction of SCA with location was markedly higher than that of GCA ones for all studied traits.

Ibrahim and Osman (2005) evaluated new fifteen white inbred lines of maize to two tester lines. They reported that Genotypes x location interaction was significant for some traits i.e. grain yield, 100-kernel weight and ear height.

Motawei *et al.* (2005) crossed twenty-nine inbred lines of yellow maize with two genetically diverse inbred testers. They found that the magnitude of σ^2 SCA was more affected by location in most studied traits and σ^2 GCA was more sensitive to locations than σ^2SCA in the inheritance of days to 50% silking within two sets.

Seiam (2007) top crossed ten maize inbred lines to three inbred tester. He found that variation due to lines x locations interaction was highly significant for all studied traits. The variation due to tester x locations interaction was also significant for yield and plant height. The variation due to interaction of line x tester x location was highly significant for all studied traits.

2.4. Heterosis:

Shehata *et al.* (1997) crossed five maize inbred lines with five narrow base elite inbred testers. They found that one single cross (Gm-2 x Sd-35) gave the highest mean value and out yielded the recommended check single cross 10 by 4% while four hybrids (Gm-1 x Sd-7), (Gm-1 x Sd-35), (Gm-2 x Sd-34) and (Gm-5 x Sd-7) gave insignificant mean values grain yield/ plant or feddan relative to S.C. 10. The five single crosses surpassed and out yielded the two check hybrids S.C.9 and S.C. 103 by 15%. The highest value of heterotic effects relative to mid and better parent were obtained from the crosses, i.e. (Gm-1 x Sd-7), (Gm-1 x Sd-35), (Gm-2 x Sd-35), (Gm-3 x Sd-35), (Gm-3 x Sd-62), (Gm-3 x Sd-63), Gm-5 x Sd-7), (Gm-5 x Sd-35)and (Gm-5 x Sd-63) for grain yield and its components, significant negative heterotic effect for earliness were observed for the previous single crosses.

Soliman and Sadek (1998) top crossed ten white inbred maize lines with three inbred testers. They found that top cross (Gm-26 x Gm-30) out yielded the check hybrid Giza 10 by 7.9, 3.3 and 5.9 % at Sakha, Sids and their combined data , respectively.

El-Zeir (1999) mated ten maize inbred lines to four testers. He found that four single crosses (P4 x Sd-7), (P9 x Sd-62), (P10 x Sd-62) and (P7 x Sd-63) gave the highest mean values ard./fed)., Sk-5017/19 x Gm-4 (34.75 ard./ fed)., Sk-5015/4 x Gm-4 (32.98 ard./ fed) and Sk-5016/14 x Gm-4 (32.82 ard./ fed). Were superior for grain yield compared to S.C. 10 (32.68 ard./fed).

Mosa *et al.* (2004) top crossed nine inbred lines of yellow maize to three testers i.e. L-121, S.C. Sk-52 and composite-21. They found that the desirable heterotic effects for grain yield / plant relative to the check S.C. 155 were recorded for top cross Sk-7070 x L-121 (24.65%). Whereas, the highest heterosis values relative to the check T.W.C. 352 were detected for the top crosses Sk-7070 x L21 (28.82%) and Sk-7078/2 x L121 (17.73%).

Abd El-Moula (2005) top crossed twenty yellow maize inbred lines to each of three testers, i.e. Gz-45 and two elite inbred lines. He found that crosses L-2, L-10, L-11, L-13, L-15 and L-18 x Gm-1001 were the most superior and promising single crosses, since they outyielded the commercial check S.C. 155 by 40, 15.2, 26, 29.3, 30.8 and 20.7 %.

Ibrahim and Osman (2005) top crossed fifteen white inbred lines of maize with two tester line. They found that two single crosses i.e. Sk. 9195 x Sk-5027/6 (32.16 ard./ fed.) and Sk-9195 x 5037/15 (31.44 ard./ fed.) did not differ significantly than the commercial hybrid S.C. 10 (31.39 ard./ fed.) for grain yield and some agronomic traits.

Motawei *et al.* (2005) crossed twenty-nine inbred lines of yellow maize with two inbred testers. They found that one top cross (Sk-5001/11 x Sk6241) out yielded the best check S.C. 155. Meanwhile, in set-II one top cross (Sk-5001/26 x Gm-1001) was superior than the two checks and two crosses (Sk-5001/17 x Sk-6241) and (Sk-5001/18 x Gm-1001) were superior than the check Pioneer 3080 of grain yield.

Seiam (2007) top crossed ten white maize inbred lines to three inbred testers. He found that crosses of lines no. 1, 3, 6 and

8 across testers ranged from 27.98 to 31.35 ard./ fed. and significantly out yielded the highest yielding check S.C. 10 (26.77 ard./ fed.) by 5.7, 17.1, 6.35 and 4.5 % , respectively .