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ESTIMATES OF COMBINING ABILITY OF SOME YELLOW MAIZE INBRED LINES IN TOPCROSSES

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ABSTRACT

Seventeen yellow maize (*Zea mays,* L) inbred lines were top crossed into each of two line testers, *i.e* Gm 2 and Gm 9. All inbred lines and testers were developed at Gemmeiza Res. Station.The 34 topcrosses were evaluated at Gemmeiza and Nubaria Research Stations during 1999 summer season. General (GCA) and specific (SCA) combining ability as well as genetic parameters for days to 50 % silking, plant height, ear height, ear length, ear diameter, number of rows/ear, number of grains/row, 100-grain weight, grain yield (ard/fad) and grain yield/plant (g) were calculated.

Test of homogeneity of the experimental error for the two locations was found to be insignificant for all studied traits. Therefore the combined data were presented herein. Highly significant differences were found among the 34 top-crosses for all studied traits across the two locations. Differences among testers and inbreds due to partitioning crosses sums of squares were highly significant for all traits except lines and testers for number of grains/row and testers for 100-grain weight. The interaction of inbreds with environments was significant in case of ear length and grain yield per fad and per plant. Also, significant interaction of testers with environments was also detected for number of days to 50% silking, plant height, ear height and ear diameter.

For plant height, ear height, 100-grain weight and grain yield, the variance magnitude due to GCA (lines) was higher than that due to SCA. This indicates that additive genetic variance was the major source of variation responsible for the inheritance of theses traits. Also, the interaction of GCA by locations was markedly higher and positive for grain yield and other traits, except silking date, ear length and number of grains/row. General and specific combining ability effects for inbred lines, testers and their topcrosses were also estimated.

INTRODUCTION

Topcross (test-cross) selection with a broad and/or narrow base tester is among several procedures used to evaluate new improved inbreds for combining ability in maize hybrid breeding. This method was first suggested by Jenkins (1935) and Sprague (1939) under the early testing scheme for new inbreds. Rawlings and Thompson (1962) and Hallauer (1975) pointed out that a suitable tester should include simplicity in use and provide information that correctly classifies the relative merits of lines and maximizes genetic gain. However, procedures for developing and improving inbred lines of maize were reported by Geadlman and Peterson (1976), Kuhn and Stucker (1976), Bauman (1981) and Hallauer and Miranda (1981). They concluded that importing inbred lines increased grain yield, modified maturity and plant stature of the resultant hybrids. The most practical way of inbred lines improvement is to cross pairs of elite inbreds that complemented one another.

Several results concerning the genetic analysis of grain yield as well as other agronomic traits reported by Ahmed (1968), Singh *et al.* (1971); Rashed (1977); Ragheb (1985); Sultan (1998) and El-Zeir (1999) indicated that the relative importance of different components of genetic variance may vary with the type of genetic materials under study. Studies conducted with homozygous base populations indicated the importance of overdominance in grain yield performance (Robinson *et al*, 1949; Gardner *et al.*, 1953; Gardner and Lonnquist, 1959; Gamble, 1962; Findley, *et al.*, 1972; Stuber and Moll, 1977; Shehata *et al.*, 1982; Ragheb, 1985 and Vendeneev, 1988).

General (GCA) and specific (SCA) combining ability were firstly defined by Sprague and Tatum (1942). They and other investigators (Matzinger *et al.,* 1959; Rutger, 1971; Russell *et al.,* 1973; Stuber and Moll, 1977; Balko and Russell, 1980 and Ragheb 1985) reported that the variance component due to SCA for grain yield and other agronomic traits was relatively larger than that due to GCA. This indicated that the non-additive type of gene action appeared to be more important in materials or lines selected previously for grain yield performance. On the other hand, Rojas and Sprague (1952); Nelson and Scott (1973); Shehata and Dhawan (1975) and El-Zeir (1999) stated that when the lines were relatively unselected, GCA or the additive type of gene action became more important.

Comstock and Moll (1963) defined the genotype x environment interaction as the differential response of phenotype to the change in environment. However, Rojas and Sprague (1952); Darrah and Hallauer (1972); Shehata and Dhawan (1975); Stuber and Moll (1977) and Landi *et al.* (1983) found that the non-additive component of genetic variation significantly interacted with the environment more than the additive component. In contrast, Matzinger *et al.* (1959); Stuber and Moll (1977); El-Itriby *et al.* (1981) and Ragheb (1985) reported that general combining ability x environment interaction was significantly larger than the interaction of specific combining ability x environment even though the variance estimate for specific combining ability was more than that of general combining ability.

The main objectives of this investigation were to estimate combining ability variances and effects of several inbred lines and to determine the different types of gene action involved in the manifestation of grain yield and some other agronomic traits. Also, to estimate genotype x environment interaction as it reflects on the adequacy of testing procedures.

MATERIALS AND METHODS

The materials of this investigation consisted of seventeen inbred lines derived through selection from yellow maize population”composite-21”. This population has proved to be well adapted to climatic conditions of Egypt and characteristics with medium early maturity and medium plant height. It is also had highly resistant to diseases and drought with good yielding capacity and other agronomic traits. The two testers used in this investigation were L-Gm-2 and L-Gm-9. These two testers were isolated at Gemmieza Res.

Station. The above mentioned 17 inbred lines were top crossed to each of the two line testers, i.*e*. L-Gm-2 and L-Gm-9. The 34 top-crosses were constituted during the 1998 summer season at Gemmeiza Experimental Station. The thirty-four top crosses were evaluated in a replicated yield trials conducted in 1999 summer season at Gemmeiza and Nubaria Research Stations representing Delta region and Newly reclaimed land, respectively. A randomized complete block design with four replications was used. The experimental unit was one row, 6 meters long and 80 cm apart. Planting was done in hills, spaced 25 cm along. All statistical analyses were carried out for number of days from planting to 50% silking, plant and ear height (cm), ear length and diameter (cm), number of rows/ear, number of grains per row , 100-grain weight, and grain yield in ardab/faddan and per plant in gram adjusted to 15.5% moisture.

Analysis of variance was carried out separately for each location and combined according to Steel and Torrei (1969). The homogeneity of the experimental error of each character at the two locations found to be not significant. Therefore, the combined data across the two locations were used in the current analysis. Combining ability analysis was carried out for the combined data following Kempthorne's method, 1957 (Table 1). Also, the combined data over the two locations were used to estimate the interaction of general and specific combining ability variances with locations as shown in Table 1.

Table 1: Combined analysis of variance for the data obtained from two locations involving 34 top-crosses (17 inbred lines, females and 2 testers, males) in 4 replications.

S.O.V	DF	MS	EMS
Locations (L)	(l - 1)		
Rep's/L	L(r-1)		
Genotypes (G)	(g-1)		
Lines (F)	(f-1)	M1	$\sigma^2 + r\sigma^2 fml + rm\sigma^2 fl + rl\sigma^2 fm + rml\sigma^2 f$
Testers (M)	(m-1)	M2	$\sigma^2 + r\sigma^2 fml + rm\sigma^2 fl + rl\sigma^2 fm + rfl\sigma^2 m$
F x M	(f - 1)(m - 1)	M3	$\sigma^2 + r\sigma^2 fml + rl\sigma^2 fm$
G x L	(l - 1)(g - 1)		
F x L	(l - 1)(f - 1)	M4	$\sigma^2 + r\sigma^2 fml + rm\sigma^2 fl$
M x L	(l- 1)(m - 1)	M5	$\sigma^2 + r\sigma^2 fml + rf\sigma^2 ml$
F x M x L	(l-1)(f-1)(m-1)	M6	$\sigma^2 + r\sigma^2 fml$
Pooled error	L(r-1)(g-1)	M7	σ^2

Where:

1 - σ^2 f = variance due to inbreds 2 - σ^2 m = variance due to testers

3 - σ^2 fm = variance due to (inbreds x testers)

4- σ^2 fl = variance due to inbreds x locations

5- σ^2 ml = variance due to testers x locations

6- σ^2 fml = variance due to (inbreds x testers) x locations

The following estimates were calculated from the mean squares of the combined analysis (Table 2) :-

σ^2 f = [M1 - M3 - M4 + M6]/rml

σ^2 m = [M2 - M3 - M5 + M6]/rfl

σ^2 fm = [M3 - M6]/rl

σ^2 fl = [M4 - M6]/rm

σ^2 ml = [M5 - M6]/rf

σ^2 fml = [m6 - M7]/r

Cov HS = [mσ^2 f + fσ^2 m]/m+f

Cov FS = σ^2 fm + 2 Cov HS

σ^2 GCA. = Cov. H.S.

σ^2 SCA. = Cov.FS - 2Cov HS= σ^2 fm

σ^2 GCA. x L = [mσ^2 fl + fσ^2 ml]/m+f

σ^2 SCA. x L = σ^2 mfl

Estimates of general and specific combining ability effects for inbreds, testers and (inbred x tester) crosses were computed according to the following formula:-

1- GCA (lines) $= G_f = \frac{X_f}{mrl} - \frac{X...}{mfrl}$

2- GCA (testers) $= G_m = \frac{X_m}{frl} - \frac{X...}{mfrl}$

3- SCA $= S_{ij} = \frac{X_{ij}}{rl} - \frac{X_f}{mrl} - \frac{X_m}{frl} - \frac{X...}{mfrl}$

Standard errors for combining ability effects were calculated as follows:-

SE for GCA (inbred)	=	[Me/rml]
SE for GCA (tester)	=	[Me/rfl]
SE for SCA	=	[Me/rl]
SE for gi-gj (inbred)	=	[2Me/rml]
SE for gi-gj (tester)	=	[2Me/rfl]
SE for Sij-Skl	=	[2Me/rl]

RESULTS AND DISCUSSION

1. Analysis of variance:-

Data presented in Table (2) show significant differences among genotypes (34 crosses) for all studied traits, when the data were combined over the two locations.

When sum of squares due to genotypes (entries) was further partitioned into lines (females), testers (males) and (line x tester) interaction

as shown in Table (2), significant differences were obtained among lines with respect to all traits except number of grains/row. The two testers differed significantly in all traits except number of grains/row and 100-grain weight. Highly significant lines x testers interactions were obtained for all traits except number of grains/row.

2. Genotype x environment interaction:

Environments had highly significant effects on all studied traits except number of days to 50% silking and number of grains/row (Table 2). The genotypes x locations interactions were highly significant for number of days to 50% silking, ear height, number of grains/row, and grain yield in ard/fad and per plant (g). Partitioning of the variation due to genotypes x locations into inbreds x locations, testers x locations and inbred x tester x locations interactions showed that inbred lines x locations interaction was significant for 3 out of 10 studied traits, i.e. ear height, grain yield/fad and grain yield per plant. This may indicate that the studied inbred lines behaved different in the two environments. Testers x locations interaction was also significant across the two locations for days to 50 % silking, plant height, ear height and ear diameter, indicating that the studied two testers significantly differed from one location to another with respect to these four characters. The interaction of inbred x tester x locations was significant for only grain yield per faddan and per plant. This indicates that crosses performed similary in the two locations except for grain yield /fad.

3. Mean performance of topcrosses:

Results in Table (3) indicated that lines differed significantly in their top -crosses in most of the studied traits. For days to 50 % silking, the top crosses of all lines with the inbred tester (L-Gm-9) were earlier than topcrosses of these lines with the other inbred tester (L-Gm-2). For plant height, the inbred lines 21-49-99, 21-53-99, 21-59-99, 21.55-99, and 21-125-99 when topcrossed with either the inbred tester L-gm-2 or L-Gm-9 gave the shortest plants with low ear placement. However, two of them, i.e. (21-59-99 x L-Gm-9) and (21-44-99 x L- Gm-9) performed shorter in plant height and had low ear placement. With respect to ear length, the two inbred lines 21-44-99 and 21-42-99 produced the longest ears when topcrossed with the inbred tester L-Gm-2. Another three inbred lines, i.e. 21-45-99, 21.55-99 and 21-124-99 exhibited the longest ears when they topcrossed with the inbred tester L-Gm-9 (Table 3). Regarding ear diameter, all inbred lines produced the thickest ears when topcrossed with either one of the two testers (L-Gm-2 and L-Gm-9) with little exceptions.

Number of rows per ear differed significantly among topcrosses of all lines with the two testers. The highest number of rows/ear (16.8 rows/ear) was produced by the cross (21-56-99 x L-Gm-2) followed by the three crosses (21-11-99 x L-Gm-2), (21-34-99 x L-Gm-2) and (21-125-99 x L-Gm-2) which gave 16.5 rows/ear. The two topcrosses (21-44-99 x L-Gm-2 and 21-45-99 x L-Gm-9) exhibited the highest number of grains/row (40.4 and 38.4 grains/row, respectively.

The behavior of the studied inbred lines regarding 100-grain weight and grain yield differed remarkably in their topcrosses with the studied two testers (Table 3). The tester line L-Gm-2 when topcrossed with inbred lines 21-41-99, 21-45-99, 21-48-99 and 21-22-99 produced high yielding crosses as compared to other studied crosses. These crosses produced 29.69, 28.46, 27.18 and 27.08 ard/fad, respectively. On the other hand, the tester line L-Gm-9 gave the highest topcrosses when crossed with 21-11-99 and 21-45-99. These crosses were the highest ones as compared to other crosses and produced 29.03 and 26.57 ard/fad. These six crosses, i.e. (21-41-99 x L-Gm-2), (21-45-99 x L-Gm-2), (21-48-99 x L-Gm-2), (21-22-99 x L-Gm-2), (21-11-99 x L-Gm-9) and (21-45-99 x L-Gm-9) produced the highest grain yield and also possessed the heaviest grain weight (100-grain weight) and could be released as new single crosses or could be used as a good source for further hybrid breeding program. In this regard, Rawling and Thompson (1962) and Vedneev (1988) reported that a good tester should has ability to discriminate among genotypes under test, that is, the best tester would be the one that would give the most precise classification among entries for a given amount of testing.

4. General (GCA) combining abilty:

Data presented in Table (4) show the general combining ability effects (g_I) for lines and testers for all studied traits based on the combined data in 1999 growing season. Regarding number of days to 50 % silking, seven inbred lines exhibited negative and significant estimates of g_I (toward earliness), whereas other four inbred lines, i.e. 21.-11-99, 21-22-99, 21-44-99 and 21-55-99 possessed positive and also significant values of general combining ability effect (toward lateness).

It is worthy to note that non of the studied inbred lines exhibited significant values of GCA effects in case of plant and ear height, except the inbred line 21-45-99 which possessed significant and positive value for ear height (toward high ear placement). However, nine inbred lines had negative value of GCA effect (toward shortness) without reaching to the significant level. On the contrary, out of the 17 inbred lines, nine of them exhibited negative but not significant values of GCA effects for ear height. It was noted that the inbreds exhibited negative values of GCA effects toward shortness (short plants) had lower ear placement since it possessed negative values of GCA effects for ear height with few exceptions.

In case of the studied yield components, the general combining ability effects (g_I) were significant and negative or positive according to the amount and direction of these effects. For ear length, seven inbred lines had negative and highly significant g_I effect, while another six inbred lines possessed positive and significant g_i effect. In case of ear diameter all inbred lines had highly significant g_I effect with negative or positive values.

All the studied female lines possessed highly significant g_I effects in case of number of rows/ear, except inbred lines 21-48-99, 21-53-99 and 21-36-99 which had insignificant effect. For number of grains/row, 11 females possessed significant g_I effect, six of them had negative values. The same

trend was observed in case of 100-grain weight since eleven out of 17 females exhibited significant g_I values with varied amount and sign.

Regarding grain yield in ardab per faddan (Table 4), it is noticed that all inbred lines (females) had highly significant g_I effects, except the two lines 21-22-99 and 21-44-99, seven of them had negative values and the other eight exhibited positive g_I value. It is worthy to note that the female inbred line in the highest yielding topcrosses (21-41-99 x L-Gm-2), (21-11-99 x L-Gm-9) and (21-45-99 x L-Gm-2) (Table 3) exhibited positive and highly significant g_I effect. On the contrary, the inbred lines possessed negative values of g_I effect for grain yield produced low grain yield in its crosses with either of the two testers.

The estimates of GCA effects of the two testers for all studied traits are presented in Table (4). The results showed that g_I effect of the two inbred line testers (L-Gm-2 and L-Gm-9) was highly significant for all traits, except plant and ear height as well as 100-grain weight. The male inbred line (L-Gm-2) gave positive values of GCA effects for all traits, except 100-grain weight where this effect was negative (not significant). The opposite was true in case of the second tester line, L-Gm-9, which had negative and significant GCA effects for seven out of ten studied traits. In this respect, Hallauer and Miranda (1981), reported that inbred-line tester method was more effective in selecting lines that combine will with unrelated tester. They also pointed out that testers were more effective in detecting small differences in combining ability among the selected high yielding and low yielding groups than wide genetic base testers.

It could be concluded from the above mentioned results that the five top crosses, *viz* (21-41-99 x L-Gm-2), (21-45-99 x L-Gm-2), (21-11-99 x L-Gm-9), (21-48-99 x L-Gm-2) and (21-22-99 x L-Gm-2) are the best hybrids with regard to grain yield and other performance traits. Data in Tables (3 and 4) showed that inbred lines 21-41-99,21-45-99, 21-11-99 and 21-48-99 possessed good GCA effects as inbred line L-Gm-2. These promising inbreds may be utilized in hybrid maize breeding program to produce high yielding hybrids and improve the yielding ability.

5. Specific combining ability:

Specific combining ability effects S_{ij} of the 34 single (top) crosses for all studied traits are presented in Table (5). It was noted that the highest desirable and positive SCA effects respecting grain yield were obtained from three out of 34 studied single crosses. Russell *et al* (1973) reported that inbred testers are effective for improving general as well as specific combining ability.

For days to 50 % silking, 4 crosses, *viz* (21-36-99 x L-Gm-2), (21-41-99 x L-Gm-2), (21-55-99 x L-Gm-2), and (21-44-99 x L-Gm-9) exhibited negative (toward earliness) and significant SCA effects, whereas another five crosses showed positive (toward lateness) and significant SCA effect (Table 5). The topcross of 21-55-99 by either the two testers possessed highly significant SCA effects in an opposite direction.

Non of the studied topcrosses exhibited significant SCA regarding plant and ear height. For ear length, nine out of 34 topcrosses had significant and positive or negative SCA values. All studied topcrosses exhibited highly significant SCA effect for ear diameter except the cross (21-53-9 x L-Gm-2). The amount of this effect varied greatly in its amount and/or direction. The same results were obtained regarding number of rows/ear, since only seven crosses exhibited highly significant SCA effects with varied amount and direction.

Few crosses possessed significant SCA effect in case of number of grains/row, 100-grain weight and grain yield/fad. (Table 5).

Generally, the highest desirable SCA effects were obtained from the crosses (21-41-99 x L-Gm-2), (21-11-99 x L-Gm-9) and (21-55-99 x L-Gm-9). These results are in accordance with those obtained by Hallauer and Miranda (1981) and El-Zeir (1999). They reported that when the objective is the replacement of a line in a specific combination, specific combining ability is of prime importance and the most appropriate tester is the opposite inbred parent of a single cross on the opposite single cross parent of the double. The previous three crosses had superiority in all traits under study. Hence, it could be concluded that crosses offer a possibility for improving maize grain yield.

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تقدير قدرة التآلف لبعض سلالات الذرة الشامية الصفراء فى هجن قمية

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تم إجراء التهجين القمى لسبعة عشر سلالة نقية من الذرة الشامية عام 1998 مع سلالتين كشافتين هما L-Gm-2 , L-Gm-9 ، وقد تم إستنباط هذه السلالات بمحطة بحوث الجميزة ، وفى عام 1999 تم زراعة عدد 34 هجينا قميا فى تجارب حقلية بمحطات البحوث الزراعية بالجميزة (منطقة وسط الدلتا) والنوبارية (الأراضى الجديدة) حيث تم تقدير القدرة العامة والخاصة على التآلف ودراسة التفاعل البيئى لصفات التزهير وإرتفاع النبات والكوز وطول وقطر الكوز وعدد صفوف الكوز وعدد حبوب الصف ووزن المائة حبة ومحصول كل من النبات بالجرام والفدان بالأردب.

أوضحت النتائج تجانس الخطأ التجريبى بين الموقعين لجميع الصفات ، وجد أن الفروق بين جميع الهجن القمية موضع الدراسة كانت معنوية جدا لجميع الصفات موضع الدراسة ، كما كانت الفروق بين كل من السلالات والكشافين معنوية لجميع الصفات ماعدا عدد حبوب الصف للسلالات والكشافات ووزن المائة حبة للكشافات ، وأيضا كان التفاعل بين السلالات والبيئة معنويا لصفات طول الكوز ومحصول الحبوب ، كما كان التفاعل بين الكشافات والبيئة معنويا لصفات التزهير وإرتفاع كل من النبات والكوز وقطر الكوز

كان التباين الراجع للقدرة العامة على التآلف كبيرا ومعنويا عن ذلك الراجع للقدرة الخاصة على التآلف وذلك لصفات إرتفاع كل من النبات والكوز ووزن المائة حبة ومحصول الحبوب ويدل هذا على أن الفعل الجينى المضيف يلعب دورا هاما فى وراثة هذه الصفات ، كما كان التفاعل بين القدرة العامة على التآلف والبيئة معنويا لجميع الصفات موضع الدراسة فيما عدا تاريخ التزهير وإرتفاع النبات وعدد حبوب الصف.

Table 2: Analysis of variance for some agronomic traits, grain yield and some yield components of 34 top crosses (resulted from 17 lines and 2 testers) in 1999 season (data are combined over two locations).

S.O.V	DF	Days to 50% silking	Plant height	Ear height	Ear length	Ear diameter	No. of rows/ ear	No. of grains/ row	100-grain weight	Grain yield/fad	Grain yield (g) /plant
Locations (Loc)	1	2.12	93388.2**	21744.9**	176.6**	33.60**	20.13**	16.02	52.77**	309.1**	21823.7**
Rep (Loc)	6	1.18	455.4	460.9	3.6	0.11	1.11	51.33	24.66	73.4	1262.2
Genotypes (G)	33	18.28**	1396.2**	878.2**	14.1**	0.44**	3.26**	52.50**	44.10**	115.8	4924.2**
Lines (L)	16	8.16**	1777.8**	857.6**	7.1**	0.15**	2.80**	37.72	58.11**	156.3**	6409.3**
Testers (T)	1	357.88**	5689.5**	8673.9**	91.8**	0.45**	10.72**	503.31	1.88	543.8**	29162.2**
L x T	16	7.18**	746.4	411.6**	16.3**	0.11**	3.25**	39.11	32.73**	48.5**	1924.2**
Loc x G	33	3.41**	464.1	209.5**	1.5	0.03	1.56	14.08**	8.54	17.3**	748.3**
Loc x L	16	1.98	560.1	227.8**	1.1	0.02	1.79	10.02	7.80	20.0**	823.9**
Loc x T	1	38.25**	2134.7**	1136.5**	2.1	0.14**	0.13	0.02	1.06	0.1	32.2
Loc x L x t	16	2.66	263.6	133.3	1.8	0.02	1.41	19.03	9.76	15.7*	717.3**
Pooled error	198	1.88	500.5	105.8	1.5	0.04	1.23	9.18	6.20	8.1	236.2
C.v.		2.5	11.0	9.2	1.2	3.68	7.17	8.46	7.06	12.7	9.9

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

Table 3: Mean performance for some agronomic traits, grain yield and some yield components of 34 top crosses (resulted from 17 lines and 2 testers) in 1999 season (data are combined over two locations).

Topcrosses	Days to 50% silking	Plant height	Ear height	Ear length	Ear diameter	No. of rows/ ear	No. of grains/ row	100-grain weight	Grain yield/fad	Grain yield (g)/ plant
Means over the first tester (L-Gm-2)										
21- 11-99 x L.Gm-2	57.4	230.7	133.7	20.2	5.0	16.5	37.6	32.1	23.34	155.4
21- 22-99 x L.Gm-2	55.5	229.8	127.7	19.6	5.1	16.3	37.1	37.5	27.08	183.3
21- 44-99 x L.Gm-2	57.8	211.7	124.2	21.9	5.1	15.0	40.4	33.9	24.26	167.0
21- -99 x L.Gm-2	55.0	218.5	130.5	19.9	5.0	15.5	39.0	35.4	27.18	180.8
21- 49-99 x L.Gm-2	55.8	192.6	106.0	19.7	5.0	15.8	35.1	30.5	17.01	128.8
21- 51-99 x L.Gm-2	54.6	206.8	122.2	19.0	5.2	15.8	37.1	36.4	26.74	177.0
21- 53-99 x L.Gm-2	54.3	192.7	102.2	20.7	5.1	15.5	35.8	31.9	19.62	142.0
21- 56-99 x L.Gm-2	54.1	203.7	118.2	18.8	5.3	16.8	34.4	36.9	26.59	180.4
21- 59-99 x L.Gm-2	54.8	191.7	99.6	20.3	4.9	14.8	36.1	34.5	21.61	146.0
21- 34-99 x L.Gm-2	55.4	219.0	124.8	19.8	5.4	16.5	38.1	37.1	27.23	196.8
21- 36-99 x L.Gm-2	54.3	194.0	101.8	20.4	5.1	14.8	37.8	34.3	22.74	148.5
21- 41-99 x L.Gm-2	54.1	206.8	117.0	19.6	5.3	16.0	37.5	39.3	29.69	206.3
21- 42-99 x L.Gm-2	56.5	206.8	112.1	21.9	4.9	15.0	39.1	35.6	20.44	147.5
21- 45-99 x L.Gm-2	54.1	216.8	128.3	19.9	5.1	15.0	37.8	39.0	28.46	202.6
21- 55-99 x L.Gm-2	54.9	193.8	110.3	20.2	5.1	15.5	36.6	32.2	17.84	129.4
21-124-99 x L.Gm-2	55.3	212.2	125.7	19.6	5.4	16.5	36.8	37.8	26.86	168.9
21-125-99 x L.Gm-2	54.8	198.7	104.7	19.4	5.1	15.8	35.5	34.5	20.56	147.9

Table 3: C o n t I n u e d

Topcrosses	Days to 50% silking	Plant height	Ear height	Ear length	Ear diameter	No. of rows/ ear	No. of grains / row	100-grain weight	Grain yield/fad	Grain yield (g) / plant
Means over the second tester (L-Gm-9)										
21- 11-99 x L.Gm-9	54.1	202.1	108.3	19.5	5.3	16.0	36.6	38.4	29.03	196.8
21- 22-99 x L.Gm-9	53.1	207.0	106.3	19.2	5.1	15.3	37.1	34.4	20.60	138.0
21- 44-99 x L.Gm-9	52.0	180.3	97.7	17.3	5.0	15.0	32.6	32.4	19.49	127.9
21- 48-99 x L.Gm-9	52.8	199.1	103.3	18.7	5.1	15.3	33.6	36.1	22.28	157.8
21- 49-99 x L.Gm-9	52.4	187.3	103.2	17.6	5.1	16.3	32.4	34.4	18.32	124.1
21- 51-99 x L.Gm-9	52.6	193.7	102.7	19.1	5.0	14.8	35.1	35.6	22.00	149.9
21- 53-99 x L.Gm-9	52.4	191.0	99.0	18.1	5.0	15.8	31.9	34.3	18.65	127.9
21- 56-99 x L.Gm-9	51.1	202.1	108.0	18.7	5.0	15.0	35.5	35.7	20.86	162.6
21- 59-99 x L.Gm-9	52.3	176.5	101.0	17.1	5.0	15.8	31.3	34.1	17.28	126.4
21- 34-99 x L.Gm-9	53.1	207.0	113.7	19.8	5.2	15.3	38.1	33.2	24.58	165.3
21- 36-99 x L.Gm-9	53.8	187.5	100.2	18.5	5.1	16.0	34.9	31.6	18.52	127.0
21- 41-99 x L.Gm-9	53.8	202.2	110.0	20.6	5.0	14.3	35.5	38.2	21.64	149.4
21- 42-99 x L.Gm-9	53.1	190.5	108.6	16.5	4.8	15.0	28.4	36.7	17.10	117.5
21- 45-99 x L.Gm-9	53.5	222.1	120.0	22.2	5.0	14.5	38.4	39.4	26.57	168.9
21- 55-99 x L.Gm-9	54.3	202.7	109.7	20.0	4.9	15.0	35.3	37.3	20.43	137.8
21-124-99 x L.Gm-9	53.1	198.8	103.2	20.7	5.0	15.0	36.6	35.9	22.43	152.9
21-125-99 x L.Gm-9	52.0	221.2	102.2	17.7	5.0	16.0	32.3	33.9	19.40	126.5
LSD 0.05	0.9	15.5	7.1	0.8	0.1	0.8	2.1	1.7	2.0	10.1

Table 4: General (GCA) combining ability of 17 lines and two testers for grain yield and other agronomic and yield characters, in 1999 season (data are combined over two locations).

Lines/testers	Days to 50% silking	Plant height	Ear height	Ear length	Ear diameter	No. of rows/ ear	No. of grains/ row	100-grain weight	Grain yield/fad	Grain yield (g) /plant
21- 11-99	1.699**	13.53	9.67	0.408**	0.106**	0.757**	1.324*	-0.052	3.647**	21.221
21- 22-99	0.261*	15.53	5.67	-0.098	0.050**	0.257**	1.324*	0.617	1.301	5.796
21- 44-99	0.824**	-6.84	- 0.40	0.146	-0.038**	-0.493**	0.699	-2.140**	-0.668	- 7.385
21- 48-99	-0.176	5.91	5.54	-0.185**	-0.019**	-0.118	0.511	0.473	2.187**	14.409
21- 49-99	0.011	-12.90	- 6.77	-0.835**	-0.057**	0.507**	-2.051**	-2.871**	-4.877**	-28.404
21- 51-99	-0.426**	-2.59	1.10	-0.423**	0.031**	-0.243**	0.324	0.692	1.828**	8.596
21- 53-99	-0.739**	-11.03	-10.77	-0.073	-0.013**	0.132	-1.989**	-2.227**	-3.409**	-19.904
21- 56-99	-1.426**	0.03	1.73	-0.735**	0.075**	0.382**	-0.864	1.017**	1.179	16.659
21- 59-99	-0.551**	-18.78	-11.08	-0.760**	-0.113**	-0.243**	-2.114**	-1.021**	-3.100**	-18.654
21- 34-99	0.199	10.10	7.92	0.352	0.200**	0.382**	2.324**	-0.152	3.362**	26.159
21- 36-99	-0.051	-12.15	-10.33	-0.048	0.006**	-0.118	0.511	-2.371**	-1.909	-17.110
21- 41-99	-0.114	1.66	2.10	0.615**	0.037**	-0.368**	0.699	3.417**	3.127**	22.971
21- 42-99	0.761**	-4.22	- 1.02	-0.273	-0.232**	-0.493**	-2.051**	0.817*	-3.772**	-22.341
21- 45-99	-0.239*	16.60	12.79*	1.577**	-0.025**	-0.743**	2.261**	3.910**	4.975**	30.909*
21- 55-99	0.511**	-4.59	- 1.33	0.615**	-0.075**	-0.243**	0.136	-0.540	-3.410**	-21.279
21-124-99	0.136	2.66	3.10	0.665**	0.112**	0.257**	0.886	1.542**	2.102**	6.034
21-125-99	-0.676**	7.10	- 7.90	-0.948**	-0.044**	0.382**	-1.926**	-1.108**	-2.563**	-17.679
L.Gm-2	1.147**	4.57	5.65	0.581**	0.040**	0.199**	1.360**	-0.083	1.414**	10.354**
L. Gm-9	-1.147**	-4.57	- 5.65	-0.581**	-0.040**	-0.199**	-1.360**	0.083	-1.414**	-10.354**
S.E. for										
Lines Gi	0.12	31.28	6.61	0.09	0.0030	0.077	0.574	0.388	0.506	14.763
Gi-Gj	0.24	62.26	13.23	0.19	0.0050	0.154	1.148	0.775	1.013	29.525
Testers Gi	0.01	3.68	0.78	0.01	0.0003	0.009	0.068	0.046	0.060	1.73
Gi-Gj	0.03	7.36	1.56	0.02	0.0006	0.018	0.135	0.091	0.119	3.474

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

Table 5: Specific (SCA) combining ability of 34 topcrosses resulted from 17 lines and two testers for grain yield and other agronomic and yield characters, in 1997 season (data are combined over two locations).

Topcrosses	Days to 50% silking	Plant height	Ear height	Ear length	Ear diameter	No. of rows/ ear	No. of grains/ row	100-grain weight	Grain yield/fad	Grain yield (g) /plant
21- 11-99 x L.Gm-2	0.478*	9.739	7.040	-0.237	-0.178**	0.051	-0.860	-3.104**	-4.25**9	-31.042
21- 22-99 x L.Gm-2	0.040	6.864	5.040	-0.368*	-0.059**	0.301	-1.360	1.639	1.827	12.258
21- 44-99 x L.Gm-2	1.728**	11.114	7.603	1.725**	-0.022**	-0.199	2.515*	0.846	0.971	9.189
21- 48-99 x L.Gm-2	-0.022	5.114	7.915	-0.006	-0.078**	-0.074	1.327	-0.279	1.039	1.146
21- 49-99 x L.Gm-2	0.540*	- 1.949	-4.272	0.444*	0.090**	-0.449**	0.015	-1.861*	-2.072	- 7.967
21- 51-99 x L.Gm-2	-0.147	1.989	4.103	-0.618**	0.060**	0.301	-0.360	0.502	0.956	3.208
21- 53-99 x L.Gm-2	-0.210	- 3.699	-4.022	0.757**	0.003	-0.324	0.577	-1.129	-0.928	- 3.292
21- 56-99 x L.Gm-2	0.353	3.761	-0.522	-0.531	0.066**	0.676**	-1.923	0.664	1.450	- 1.479
21- 59-99 x L.Gm-2	0.103	3.051	-6.335	0.994	-0.097**	-0.699**	1.077	0.277	0.750	- 0.542
21- 34-99 x L.Gm-2	-0.022	1.426	-0.085	-0.568	0.041**	0.426	-1.360	2.071**	-0.087	5.396
21- 36-99 x L.Gm-2	-0.897**	1.324	-4.835	0.382	-0.040**	-0.824**	0.077	1.402	0.696	0.414
21- 41-99 x L.Gm-2	-0.960**	2.261	-2.147	-1.081**	0.103**	0.676**	-0.360	0.639	2.610**	18.083
21- 42-99 x L.Gm-2	0.540*	3.614	-3.897	2.157**	0.022**	-0.199	4.015**	-0.461	0.254	4.646
21- 45-99 x L.Gm-2	-0.835	7.199	-1.460	-1.693**	0.041**	0.051	-1.673	-0.104	-0.467	6.521
21- 55-99 x L.Gm-2	-0.835**	9.011	-5.335	-0.481	0.053**	0.051	-0.673	-2.467**	-2.708**	-14.542
21-124-99 x L.Gm-2	-0.085	2.114	5.603	-1.131**	0.153**	0.551**	-1.298	1.002	0.798	- 2.354
21-125-99 x L.Gm-2	0.228	15.824	-4.397	0.257	0.022**	-0.324*	0.265	0.364	-0.830	0.358

Table (5): C o n ti n u e d

Topcrosses	Days to 50% silking	Plant height	Ear height	Ear length	Ear diameter	No. of rows/ ear	No. of grains/ row	100-grain weight	Grain yield/fad	Grain yield (g)/ plant
21- 11-99 x L.Gm-9	-0.478	- 9.739	-7.040	0.237	0.178**	-0.051	0.860	3.104**	4.259**	31.042
21- 22-99 x L.Gm-9	-0.040	- 6.864	-5.040	0.368*	0.059**	-0.301	1.360	-1.639	-1.827	-12.258
21- 44-99 x L.Gm-9	-1.728**	- 11.114	-7.603	-1.725**	0.022*	0.199	-2.515*	-0.846	-0.971	- 9.189
21- 48-99 x L.Gm-9	0.022	- 5.114	-7.915	0.006	0.078**	0.074	-1.327	0.279	-1.039	- 1.146
21- 49-99 x L.Gm-9	-0.540*	1.949	4.272	-0.444	0.090**	0.449**	-0.015	1.861	2.072	7.967
21- 51-99 x L.Gm-9	0.147	- 1.989	-4.103	0.618*	-0.060**	-0.301	0.360	-0.502	-0.956	- 3.208
21- 53-99 x L.Gm-9	0.210	3.699	4.022	-0.757**	-0.003	0.324	-0.577	1.129	0.928	3.292
21- 56-99 x L.Gm-9	-0.353	3.761	0.522	0.531	-0.066**	-0.676**	1.923	-0.664	-1.450	1.479
21- 59-99 x L.Gm-9	-0.103	- 3.051	6.335	-0.994**	0.097**	0.699**	-1.077	-0.277	-0.750	0.542
21- 34-99 x L.Gm-9	0.022	- 1.426	0.085	0.568	-0.041**	-0.426	1.360	-2.071	0.087	- 5.396
21- 36-99 x L.Gm-9	0.897**	1.324	4.835	-0.382	0.040**	0.824**	-0.077	-1.402	-0.696	- 0.414
21- 41-99 x L.Gm-9	0.960**	2.261	2.147	1.081**	-0.103**	-0.676**	0.360	-0.639	-2.610**	-18.083
21- 42-99 x L.Gm-9	-0.540*	- 3.614	3.897	-2.157**	-0.022**	0.199	-4.015**	0.461	-0.254	- 4.646
21- 45-99 x L.Gm-9	0.835	7.199	1.460	1.693**	-0.041**	-0.051	1.673	0.104	0.467	- 6.521
21- 55-99 x L.Gm-9	0.835**	9.011	5.335	0.481	-0.053**	-0.051	0.673	2.467	2.708**	14.542
21-124-99 x L.Gm-9	0.085	- 2.114	-5.603	1.131**	-0.153**	-0.551**	1.298	-1.002	-0.798	2.354
21-125-99 x L.Gm-9	-0.228	15.824	4.397	-0.257	-0.022**	0.324*	-0.265	-0.364	0.830	- 0.358
S.E. for										
S_{ij}	0.235	66.56	13.23	0.188	0.005	0.154	1.148	0.775	1.013	29.525
$S_{ij} - S_{kl}$	0.470	125.13	26.45	0.375	0.10	0305	2.295	1.550	2.025	59.050

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