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HETEROTIC PATTERNS OF NINETY-TWO WHITE TROPICAL CIMMYT MAIZE LINES

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ABSTRACT - Development of inbred-based populations which are heterotic to each other was considered one of the primary goals when CIMMYT started its hybrid maize program in 1985. The objectives of this study were to determine the combining ability and heterotic patterns of tropical maize (*Zea mays* L.) inbred lines developed at CIMMYT and to identify and form heterotic groups for the tropics. Ninety-two tropical late white inbred lines at S3-S6 levels of inbreeding derived from nine CIMMYT populations and pools were crossed to four tester lines (two dent and two flint). The 368 line x tester combinations were divided into four sets, each set comprising of crosses of 23 lines to the four testers and tested in multilocation trials during 1988 to 1990. Mean grain yield for the four sets ranged from 5.6 to 6.5 t/ha. General combining ability (GCA) and specific combining ability (SCA) estimates for grain yield were calculated using line x tester analysis. Twenty-one of the 34 lines from Population 21 had positive GCA estimates for yield. Of the nine lines tested from Population 43, seven showed positive GCA effects for yield. The four testers behaved differently for GCA effects in different sets except Tester 3 (Pop. 25) which showed positive GCA effects for yield in all the sets and in the combined data. SCA effects for yield were significant in each set. Several line x tester hybrid combinations yielded more than 7 t/ha. Generally, crosses of lines from Population 43 to Populations 32 or 25 had higher grain yields. Interpopulation crosses were usually superior to intrapopulation crosses. A few crosses within Population 21 and Population 25 gave yields comparable to some of the best interpopulation combinations. Based on the testcross data, two tropical heterotic groups THG "A" and THG "B" were formed which will be useful for future hybrid development work at CIMMYT and national programs in the tropics. Several of the lines included in this study were announced as CIMMYT maize lines (CML) during 1991, and are available to both public and private breeders. Twelve of the 20 top-yielding crosses (five from each set) involved CML lines.

KEY WORDS: *Zea mays* L.; Heterotic patterns; Tropical germplasm; Combining ability.

INTRODUCTION

From over 250 races of maize reported in the literature and a wide spectrum of maize germplasm developed by national research programs worldwide, only a few heterotic groups or racial complexes have been identified and exploited for hybrid development work (GOODMAN, 1978; VASAL and TABA, 1988). Breeders from private and public sectors have exploited the already known heterotic groups while constantly looking for newer ones (DUVICK, 1985). WELLHAUSEN (1988) noted the heterotic patterns between Tuxpeño and the Cuban and Coastal Tropical flints of the Caribbean which could be fruitfully exploited for improvement of maize in the lowland tropics. CROSSA *et al.* (1990a) studied the heterotic patterns among 25 Mexican maize races with varying grain color, texture, and endosperm types, and suggested ways of exploiting them in population improvement and hybrid development programs.

Efforts in hybrid development are not limited to interpopulation interline hybrids. A few programs have developed intrapopulation interline hybrids successfully from Suwan-1 (CHUTKAEW *et al.*, 1985) and Iowa Stiff Stalk Synthetic (HALLAUER and MIRANDA, 1988). Considering the genetic constitution of CIMMYT materials, and their inherent broad genetic base, there is considerable potential to derive superior intrapopulation hybrids from them (HAN *et al.*, 1991; VASAL and SRINIVASAN, 1991a). However, use of complementary heterotic germplasm is often essential for conducing efficient hybrid development programs. Efforts towards identifying or forming new heterotic groups are few and also not well documented. Limited attempts made in this direction by CIMMYT have been reported by VASAL and SRINIVASAN (1991b).

CIMMYT's hybrid maize program conducted a series of population diallels during 1985 and 1986 in México, U.S.A., and other countries to ascertain the het-

TABLE 1 - *Description of the nine CIMMYT tropical late white maize gene pools and populations from which the lines used in this study were derived.*

Population/ Pool Number	Population/ Pool Name	Germplasm description
Population 21	Tuxpeño 1	White, dent, late maturity. Includes Tuxpeño racial collections Veracruz 48, Veracruz 143, Veracruz 174, Michoacan 137, Michoacan 166, V-520C, Colima Group 1-Mix. 1 and 16 families from tropical late white dent pool (Pool 24).
Population 22	Mezcla Tropical Blanco	White, dent to semi dent, late maturity. Includes Tuxpeño, ETO Blanco, Antigua Group 2 white selection, ETO, Pfister hybrids, Central American composite, lines from El Salvador, V-520C and 13 families from Pool 24.
Population 25	Blanco Cristalino-3	White, flint, late maturity. Improved for stalk rot resistance. Derived from Pool 23 which includes materials from México, Colombia, Caribbean, Guatemala, Panama, India, Thailand and the Philippines.
Population 29	Tuxpeño Caribe	White, dent, late maturity. Includes Tuxpeño, Cuban flints, ETO.
Population 32	ETO Blanco	Tropical-subtropical, intermediate to late, white, flint grain, short plant type, improved for ear rot resistance. Includes tropical and temperate germplasm. Derived from crosses of Colombia 1 x Venezuela 1 (Cuban yellow flints), recombined with germplasm from Argentina, Brazil, Cuba, México, Puerto Rico, USA and Venezuela.
Population 43	La Posta	Late, tall, white dent, has been improved for streak resistance and reduced plant height in cooperation with IITA, Nigeria. Derived from Tuxpeño Synthetic of 16 lines.
Population 73	Tropical Late White Dent	Improved for resistance to stunt. Tuxpeño based material.
Pool 23	Tropical Late White Flint	Includes materials from México, Colombia, the Caribbean area, Guatemala, Panama and other Central American countries, India, Thailand and the Philippines. Selection being practiced for increased stalk-rot resistance.
Pool 24	Tropical Late White Dent	Based mainly on Tuxpeño germplasm from México. Includes some materials from Central America, the Caribbean and Zaire. Being improved for resistance to fall armyworm.

erotic patterns of CIMMYT's tropical maize populations and pools (VASAL *et al.*, 1987, 1992a; CROSSA *et al.*, 1990b; BECK *et al.*, 1990). JOHNSON and FISHER (1981) evaluated the performance of various CIMMYT materials in crosses with Tuxpeño P.B. (Blanco Dentado-2, Population 49) and ETO Blanco (Population 32), representing two widely known heterotic patterns in the tropics. Combining ability information of CIMMYT's maize germplasm was reported elsewhere also (NASPOLINI FILHO *et al.*, 1981; OYERVIDES-GARCIA *et al.*, 1985). CIMMYT's hybrid maize program initiated further studies to determine the heterotic patterns of its tropical inbred lines and to use this information to identify other heterotic groups.

The objectives of this study were 1) to characterize the combining ability and heterotic patterns of 92 tropical inbred lines developed at CIMMYT and 2) to classify the lines into contrasting heterotic groups for future hybrid development work.

MATERIALS AND METHODS

Ninety-two tropical, late, white, inbred lines at S3 to S6 levels of inbreeding derived from nine CIMMYT tropical maize populations and pools were used for this study. Descriptions of the materials used in the study are presented in Table 1. The 92 lines were divided into four sets of 23 lines each for easier management, efficient testing, and statistical analysis. Each of the 23 lines constituting a set was crossed to four tester lines for a total of 92 line x tester hybrid combinations in each set. The pedigree and line codes of the inbred lines included in each set are presented in Table 2. Several of the lines included in this study were later announced as CIMMYT maize lines (CML) for which corresponding CML code numbers are provided. Eight common checks were included for a total of 100 entries. The checks were deleted from the line x tester statistical analysis. The checks include six superior experimental hybrids (single cross) identified from ongoing hybrid research at CIMMYT, one commercial hybrid (H-507) from INIFAP, México, and an experimental variety (EV) from Population 43 (Across 8243).

Each set was planted with three replications using a split plot design with lines as main plots and testers as subplots. The four sets were planted in three common locations: Cuyuta, Guatemala; Poza Rica, México; and Tlaltizapan, México. The fourth and fifth locations were planted in different countries in South America. The number of trials conducted for each set, and their locations and year are presented in Table 3.

The experimental unit consisted of one 5.5 m long row spaced 75 cm apart between rows. Planting in the row was done at a spacing of 50 cm between hills. Each hill was overplanted and later thinned to 2 plants per hill for a plant density of 53,000 plants/ha. Data on plant height, ear height, days to 50% pollen shed and silk, and root and stalk lodging were recorded before harvest. Fresh ear weight and percentage of grain moisture were taken at harvest in individual plots. Grain yield (t/ha.) was calculated using plot data, assuming 80% shelling and adjusting the grain moisture to 15%.

Analyses of variance were computed for each location (referred to as environments hereafter) separately and combined across envi-

TABLE 2 - *Line code and pedigrees of 92 tropical late white inbred lines and four tester parents used in this study.*

Line code and pedigree (Set 1)	Line code and pedigree (Set 2)	Line code and pedigree (Set 3)	Line code and pedigree (Set 4)
1 Pop. 21 C5 FS21-S5	24 Pop. 29 C5 FS238-S6	47 P. 24 C20 HS119-S4	70 Pop. 21 C5 FS57-S4-3 (CML 1)
2 Pop. 21 C5 FS57-S5-1	25 ACR 7529-S5	48 P. 24 C20 HS46-S4	71 Pop. 21 C5 FS78-S4 (CML 2)
3 Pop. 21 C5 FS218-S6-1 (CML 8)	26 ACR 7529-S4-1	49 P. 24 C20 HS54-S4	72 Pop. 29 C5 FS172-S4 (CML 34)
4 Pop. 21 C5 FS191-S5	27 ACR 7529-S5-2	50 P. 24 C20 HS63-S4	73 Pop. 32 C4 FS20-S4 (CML 36)
5 Pop. 21 C5 FS109-S6-1 (CML 4)	28 Pop. 32 C5 FS7-S4-1	51 P. 24 C20 HS94-S4-1	74 Pop. 21 C5 FS25-S4
6 Pop. 21 C5 FS117-S6	29 Pop. 32 C5 FS7-S4-2	52 P. 24 C20 HS94-S4-2	75 Pop. 21 C5 FS38-S4
7 Pop. 21 C5 FS219-S6 (CML 10)	30 Pop. 32 C5 FS61-S4	53 P. 24 C20 HS94-S4-3	76 Pop. 21 C5 FS44-S4
8 Pop. 21 C5 FS84-S4-1 (CML 3)	31 Pop. 32 C5 FS71-S5-1	54 P. 24 C20 HS449-S4	77 Pop. 21 C5 FS129-S4
9 Pop. 21 C5 FS84-S4-2	32 Pop. 32 C5 FS71-S5-2	55 Tux. Seq. 35-S3-1	78 ACR 7522-S4-1 (CML 15)
10 Pop. 21 C5 FS133-S4-1	33 ACR 7643-S4-1 (CML 42)	56 Tux. Seq. 35-S3-2	79 ACR 7522-S4-2
11 Pop. 21 C5 FS128-S6	34 ACR 7643-S4-2 (CML 45)	57 Tux. Seq. 35-S3-3 (CML 14)	80 Pop. 32 C5 FS230-S4
12 Pop. 21 TSR(S2)-S4	35 ACR 7843-S4-1 (CML 43)	58 Tux. Seq. 100-S3	81 ACR 7643-S5-3
13 Pop. 22 C6 FS100-S4-1	36 ACR 7843-S4-2 (CML 44)	59 Tux. Seq. 115-S3	82 P. 23 C20 HS268-S4
14 Pop. 22 C6 FS100-S4-2 (CML 16)	37 ACR 7843-S4-3	60 Tux. Seq. 134-S3	83 P. 23 C20 HS25-S4
15 Pop. 22 TSR(S2)5-S4-1	38 Pop. 43 C6 FS133-S5 (CML 47)	61 Tux. Seq. 142-S3	84 P. 24 C20 HS200-S4
16 Pop. 22 TSR(S2)5-S4-2	39 Pop. 43 C6 FS108-S5	62 Tux. Seq. 171-S3	85 P. 24 C20 HS119-S4
17 Pop. 22 TSR(S2)5-S4-3	40 Pop. 43 C6 FS82-S5	63 Tux. Seq. 187-S3	86 STA. ROSA 8073-S4 (CML 49)
18 Pop. 22 TSR(S2)40-S4-1 (CML 17)	41 P. 24 TSR-19-S3	64 Tux. Seq. 219-S3	87 PORILLO 8073-S4 (CML 48)
19 Pop. 22 TSR(S2)40-S4-2	42 P. 24 TSR-24-S3	65 ACR 7729-193-S6	88 Pop. 21 C5 FS109-S6-2
20 Pop. 22 C6 FS242-S4	43 P. 24 TSR-45-S3	66 PR7722(SR)-42-S6	89 Pop. 21 C5 FS195-S6
21 Pop. 25 C0 FS20-S6	44 P. 24 C20 HS27-S4	67 Pop. 29 TSR(S2)-S4	90 ACR 7421-S4
22 Pop. 25 C0 FS31-S6 (CML 22)	45 P. 24 C20 HS6-S4-1	68 Pop. 21 C5 FS218-S4-2 (CML 8)	91 Pop. 21 C5 FS133-S3-2 (CML 5)
23 Pop. 25 C0 FS57-S5-2	46 P. 24 C20 HS6-S4-2	69 Pop. 32 C4 FS218-S4 (CML 37)	92 Pop. 25 C0 FS118-S4
	Tester		
	93 T1 Pop. 21 C5 FS219-S4 (CML 9)		
	94 T2 Pop. 32 C4 FS142-S4 (CML 38)		
	95 T3 Pop. 25 C0 FS128-S4 (CML 24)		
	96 T4 P. 24 TSR-29-S3 (CML 56)		

* Pedigree is given in a standard format with Population/Pool number and level of inbreeding at which the lines were tested. Lines coming out of the same family are serially numbered. CML codes for public lines available from CIMMYT are given in parentheses wherever applicable. Abbreviations used: Pop. = Population; P. = Pool; FS = Full-sib; HS = Half-sib; TSR = Tar spot resistant; SR = Streak resistant; Tux. Seq. = Tuxpeño Sequia (Drought tolerant version of Pop. 21); ACR = Across (Variety formed based on across location performance); PR = Poza Rica, México; CML = CIMMYT maize line.

ronments. In the combined analysis, environment (E) effects were treated as random effects and crosses as fixed effects. Line (L) x tester (T) analyses were done using the method described by KEMPTHORNE (1957). General combining ability (GCA) and specific combining ability (SCA) effects for grain yield were calculated according to the line x tester model. Based on their GCA effects, two testers were chosen for classifying the 92 lines into two contrasting heterotic groups. The selected lines within each heterotic group were recombined followed by two more cycles of recombination through bulk-sibbing. Two new tropical late white heterotic populations were thus formed which will undergo further improvement for enhancing their level of heterotic response to each other.

RESULTS AND DISCUSSION

Combined analyses of variance across environments for grain yield, days to 50% silking, plant height, and ear height are presented for the four sets individually (Tables 4 to 7).

Location effects were significant ($P < 0.05$) for all traits in each set (Tables 4 to 7). Line effects were significant for grain yield in each set except set 1. For the other three characters, significant differences were detected among lines in each set. Combined analyses failed to show significant differences among the four testers for grain yield, although for the other three traits, there were significant differences. Differences in SCA (L x T) effects for grain yield and days to silking were significant in each set. For plant and ear height, non-significant differences were observed in set 4 with the other three sets showing significant differences.

Mean grain yield across environments and entries ranged from 6.5 t/ha in set 2 to 5.6 t/ha in set 4. For days to silking, the range was from 71.2 days in set 4 to 66.8 days in set 1. Set 4 had the shortest plant

TABLE 3 - *Environments where the four sets of 92 line x tester cross combinations were evaluated.*

Set No.	Location	Year
1	Cuyuta, Guatemala	1988
	Poza Rica, México	1988
	Pichilingue, Ecuador	1989
	Tlaltizapan, México	1990
2	Cuyuta, Guatemala	1988
	Poza Rica, México	1988
	Tarapoto, Peru	1989
	Palmira, Colombia	1989
	Tlaltizapan, México	1990
3	Cuyuta, Guatemala	1988
	Poza Rica, México	1988
	Tlaltizapan, México	1990
4	Cuyuta, Guatemala	1988
	Poza Rica, México	1988
	Tlaltizapan, México	1990

height (209.3 cm), while set 1 was the tallest (277.7 cm). A similar trend was observed for ear height also. CV for yield ranged from 10 to 12% while the other characters had lower CV (Tables 4 to 7).

General combining ability estimates for grain yield

Set 1: Mean grain yield in set 1 averaged across environments was 6.3 t/ha with a CV of 11.6% (Table 4). Highest yield (6.9 t/ha) in crosses was recorded by L 3 and L 14 with a significantly positive GCA effect of 0.53 t/ha (Table 8). Six of 13 lines (L 1 to L 12 and L 23) from Population 21, had positive GCA effects for yield. Only three of the eight lines from Population 22 (L 13 to L. 20), had positive GCA effects. The two lines from Population 25 had negative GCA effects for yield. Among the testers, T 3 (Pop. 25) had positive GCA effects, whereas T 1 (Pop. 21) and T 2 (Pop. 32) were negative. (Fig. 1).

Set 2: Mean grain yield for set 2 averaged across five environments was 6.5 t/ha with a CV of 11.4%. Highest yields (7.2 t/ha.) in crosses within set 2 were recorded by L 34, L 35 and L 36 from Population 43, which had significantly positive GCA effects. Of the 23 lines included in this set, only one line each from Populations 29 and 32 and none from Pool 24 showed positive GCA effects for yield. Out of the eight lines from Population 43 tested, all but one had positive GCA effects for grain yield. Among the testers, T 1 and T 3 had positive GCA effects while T 2 and T 4 were negative (Fig. 1).

Set 3: Mean grain yield for this set was lower than the first two sets (6.1 t/ha). Line 50 from Pool 24 had the highest mean yield in crosses (6.9 t/ha) and had significantly positive GCA effects for yield. Of the eight lines (L 47 to L 54) derived from Pool 24, three lines (L 48, L 50, and L 53) had positive GCA effects for yield. Two lines (L 47 and L 51) were neutral while the other three had negative GCA effects. Eight out of ten lines derived from Tuxpeño Sequía (L 55 to L 64) showed positive GCA effects for yield, although

TABLE 4 - *Combined line x tester analysis for grain yield, days to 50% silking, plant height and ear height for Set 1 tested in four environments.*

Source	Mean squares					
	df	Yield (t/ha.) (4 environments)	Days to 50% silking (4 environments)	df	Plant height (cm) (3 environments)	Ear height (cm) (3 environments)
Env.	3	448.59**	83037.33**	2	192927.35**	84422.75**
Rep (Env.)	8	4.77	8.54	6	957.33	1056.36
Line (GCA line)	22	3.89	57.23**	22	3283.30**	2212.36**
Line* Env.	66	3.24**	5.60**	44	488.22**	195.30
Line* Rep (Env.)	176	1.15	3.20	132	274.85	139.61
Tester (GCA Tester)	3	13.45	302.99**	3	6184.29**	11863.30**
Tester* Env.	9	11.00**	12.58**	6	725.75**	710.22**
Line* Tester (SCA)	66	2.05**	4.36**	66	290.96**	158.39**
Line* Tester* Env.	198	0.78*	1.27	132	162.59	76.51*
Pooled Error	552	0.54	1.10	414	161.19	59.90
Mean		6.33	66.82		227.70	114.20
CV, %		11.59	1.57		5.58	6.78

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

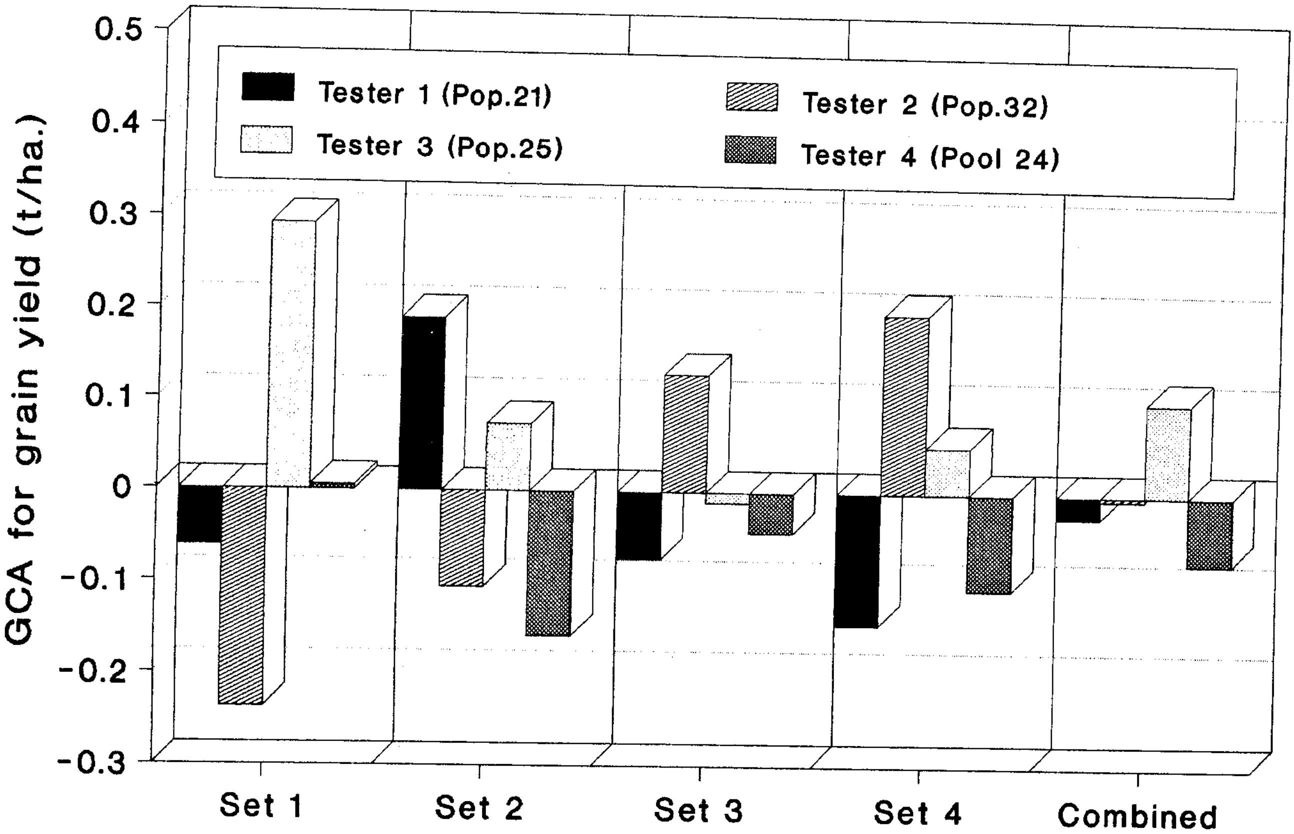

FIGURE 1 - GCA effects for grain yield (t/ha.) of the four testers used in this study. GCA values given for each set separately and for sets combined.

the magnitude was small in many cases. This material is the original Tuxpeño (Pop. 21) germplasm that has been improved for drought tolerance at CIMMYT for eight cycles. All the other entries from Population 29 (L 65 and L 67), Population 22 (L 66) and Population 32 (L 69) had negative GCA effects for yield. Only T 2

TABLE 5 - *Combined line x tester analysis for grain yield, days to 50% silking, plant height and ear height for Set 2 tested in five environments.*

Source	Mean squares: df	Yield (t/ha.) (5 environments)	df	Days to 50% silking (4 environments)	Plant height (cm) (4 environments)	Ear height (cm) (4 environments)
Env.	4	1003.18**	3	88711.33**	311676.33**	140577.33**
Rep (Env.)	10	3.10	8	53.29	1874.53	669.52
Line (GCA line)	22	10.40**	22	55.18**	2832.81**	1186.54
Line* Env.	88	2.59**	66	12.90**	886.68**	448.18**
Line* Rep (Env.)	220	1.54	176	6.09	439.79	248.63
Tester (GCA Tester)	3	8.97	3	166.63**	4224.42**	9799.59**
Tester* Env.	12	7.34**	9	15.74**	228.21**	239.10**
Line* Tester (SCA)	66	2.65**	66	11.93**	239.41**	190.87**
Line* Tester* Env.	264	0.84**	198	1.51	70.23	78.82
Pooled Error	690	0.55	552	1.43	60.14	65.49
Mean		6.54		67.68	215.17	
CV, %		11.36		1.77	3.60	

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

TABLE 6 - *Combined line x tester analysis for grain yield, days to 50% silking, plant height and ear height for Set 3 tested in three environments.*

Source	df	Yield (t/ha.) (3 environments)	Days to 50% silking (3 environments)	df	Plant height (cm) (2 environments)	Ear height (cm) (2 environments)
Env.	2	532.78**	114325.45**	1	447963.09**	207215.63**
Rep (Env.)	6	3.78	14.21	4	5713.22	3275.91
Line (GCA line)	22	3.52**	33.04**	22	2355.18**	1223.46**
Line* Env.	44	1.27**	8.09**	22	275.21	189.20**
Line* Rep (Env.)	132	0.68	3.27	88	194.10	152.23
Tester (GCA Tester)	3	1.68	220.93**	3	4083.50**	4041.95**
Tester* Env.	6	5.72**	12.89**	3	790.75**	108.02**
Line* Tester (SCA)	66	2.07**	5.58**	66	112.35**	90.53**
Line* Tester* Env.	132	0.78**	2.26**	66	54.51	52.05
Pooled Error	414	0.37	1.24	276	46.32	42.51
Mean		6.13	70.71		212.67	102.16
CV, %		9.97	1.57		3.20	6.38

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

showed positive GCA effects out of the four testers. Set 2 was represented mostly by dent lines (eight from Pool 24 and 11 from Pop. 21), and, hence, the flint testers from Populations 25 and 32 performed better compared to the two dent testers (Fig. 1).

Set 4: This set had the lowest mean grain yield (5.6 t/ha). Line 73 derived from Population 32 had the highest yield in crosses (6.3 t/ha) and a significantly positive GCA of 0.66 t/ha. Set 4 included lines from all the nine populations and pools tested. Population 21 had the major share with ten lines while the rest were represented by one or two lines (Table 2). As in other sets, lines from Tuxpeño (Pop. 21) performed reasonably well with seven out of ten lines showing positive GCA effects for yield. Lines from Pool 23 (L 82 and L 83) and Population 25 (L 92) had negative GCA effects for yield while L. 72 (Pop. 29) had positive GCA effects. One out of two lines from Pop. 32, Pop. 22, Pool 24 and Pop. 73 had positive GCA effects. The two flint testers (T 2 and T 3) showed positive GCA effects.

Performance of the four testers across all the four

TABLE 7 - *Combined line x tester analysis for grain yield, days to 50% silking, plant height and ear height for Set 4 tested in three environments.*

Source	df	Yield (t/ha.) (3 environments)	Days to 50% silking (3 environments)	df	Plant height (cm) (2 environments)	Ear height (cm) (2 environments)
Env.	2	243.18**	129868.90**	1	706277.22**	307338.09**
Rep (Env.)	6	5.99	9.50	4	979.44	278.28
Line (GCA line)	22	3.60**	55.46**	22	2402.86**	1062.39**
Line* Env.	44	1.66**	8.83**	22	508.47	322.94*
Line* Rep (Env.)	132	0.86	3.82	88	309.74	163.59
Tester (GCA Tester)	3	5.16	132.70**	3	2510.07**	3716.83**
Tester* Env.	6	8.91**	12.98**	3	583.50**	51.73
Line* Tester (SCA)	66	1.47**	6.12**	66	78.88	69.17
Line* Tester* Env.	132	0.69**	2.47**	66	61.72	58.18
Pooled Error	414	0.42	1.49	276	67.78	52.02
Mean		5.61	71.22		209.32	103.03
CV, %		11.60	1.72		3.93	7.00

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

TABLE 8 - *GCA, SCA and mean grain yield (t/ha.) for 368 line x tester crosses divided into four sets and evaluated in multiple environments.*

Lines	Yield@	GCA	Tester 1		Tester 2		Tester 3		Tester 4	
			Yield§	SCA	Yield	SCA	Yield	SCA	Yield	SCA
Set 1										
1	6.3	–0.00	6.1	–0.16	5.9	–0.19	6.7	0.04	6.7	0.32
2	6.3	0.00	6.0	–0.28	6.4	0.31	7.0	0.42	5.9	–0.45
3	6.9	0.53*	6.7	–0.08	6.7	0.03	7.5	0.37	6.6	–0.31
4	6.6	0.27	6.6	0.07	7.2	0.84**	6.9	–0.02	5.7	–0.88**
5	6.4	0.07	6.4	0.07	6.2	0.04	6.6	–0.12	6.4	0.01
6	6.6	0.22	6.5	0.02	6.3	–0.05	6.6	–0.26	6.9	0.30
7	6.2	–0.12	6.7	0.59*	5.9	–0.10	6.4	–0.10	5.8	–0.40
8	6.7	0.34	5.9	–0.75**	6.5	0.10	7.7	0.78**	6.6	–0.13
9	6.4	0.07	5.3	–1.01**	6.0	–0.18	7.2	0.48	7.1	0.71**
10	6.2	–0.16	6.4	0.29	6.0	0.07	6.3	–0.12	5.9	–0.24
11	6.3	–0.07	6.4	0.16	6.1	0.08	6.5	–0.06	6.1	–0.17
12	6.3	–0.06	6.3	0.13	6.3	0.22	6.1	–0.45	6.4	0.10
13	5.9	–0.40	5.7	–0.15	5.7	–0.01	6.4	0.20	5.9	–0.03
14	6.9	0.53*	6.4	–0.43	6.6	0.02	7.7	0.58*	6.7	–0.17
15	6.0	–0.35	5.9	–0.07	5.8	0.09	6.2	–0.12	6.1	0.10
16	6.5	0.16	6.4	–0.05	6.3	0.01	6.6	–0.14	6.7	0.17
17	6.6	0.22	6.0	–0.45	6.4	0.10	7.0	0.19	6.7	0.15
18	6.4	0.03	6.5	0.16	6.0	–0.10	6.4	–0.29	6.6	0.23
19	5.7	–0.62*	6.4	0.70**	5.0	–0.49	5.8	–0.20	5.7	–0.01
20	6.2	–0.09	6.3	0.08	6.5	0.45	5.6	–0.91**	6.6	0.38
21	6.1	–0.24	6.0	0.00	5.7	–0.20	6.4	0.05	6.2	0.15
22	6.4	0.02	6.8	0.48	5.7	–0.43	6.3	–0.33	6.6	0.28
23	6.0	–0.35	6.6	0.69**	5.2	–0.59*	6.3	0.01	5.9	–0.11
Set 2										
24	7.0	0.47*	7.2	–0.05	7.0	0.11	7.1	0.05	6.7	–0.11
25	6.5	–0.04	6.3	–0.44	6.7	0.26	6.8	0.23	6.3	–0.06
26	6.3	–0.23	6.6	0.06	6.5	0.28	6.3	–0.10	5.9	–0.23
27	6.5	–0.03	6.1	–0.61*	6.6	0.17	6.5	–0.04	6.8	0.48*
28	6.4	–0.16	6.8	0.18	5.8	–0.44*	6.5	–0.01	6.5	0.27
29	6.3	–0.24	5.4	–1.07**	6.1	–0.09	6.5	0.14	7.2	1.03**
30	6.8	0.26	7.2	0.18	6.3	–0.36	6.7	–0.17	7.0	0.35
31	6.4	–0.12	6.7	0.04	5.6	–0.74**	6.7	0.21	6.8	0.50*
32	5.9	–0.64**	6.5	0.38	5.4	–0.36	6.0	0.07	5.7	–0.09
33	6.6	0.06	7.0	0.22	5.9	–0.61*	6.7	–0.02	6.8	0.41
34	7.2	0.69**	7.1	–0.36	7.1	–0.03	7.7	0.35	7.1	0.05
35	7.2	0.61**	7.0	–0.36	7.4	0.39	7.2	–0.01	7.0	–0.02
36	7.2	0.62**	7.2	–0.15	7.2	0.15	7.2	–0.02	7.0	0.02
37	6.9	0.40	7.2	0.07	6.6	–0.28	7.3	0.30	6.7	–0.09
38	6.9	0.40	7.6	0.47*	6.9	0.04	6.7	–0.31	6.6	–0.21
39	6.0	–0.57*	6.2	0.07	5.6	–0.23	6.2	0.19	5.8	–0.03
40	6.8	0.29	7.0	–0.07	6.6	–0.10	7.3	0.35	6.5	–0.17
41	6.6	0.02	6.7	–0.02	6.6	0.11	7.0	0.38	5.9	–0.47*
42	6.2	–0.33	6.4	0.00	6.3	0.18	6.2	–0.09	6.0	–0.09
43	6.4	–0.17	6.5	–0.11	6.9	0.62*	6.2	–0.26	6.0	–0.26
44	6.5	–0.04	6.8	0.08	6.5	0.10	6.9	0.35	5.8	–0.53*
45	6.1	–0.46*	7.1	0.83**	6.1	0.17	5.3	–0.81**	5.7	–0.18
46	5.7	–0.80**	6.6	0.68**	6.3	0.66**	5.0	–0.77**	5.0	–0.57*
Set 3										
47	6.1	0.02	6.3	0.22	6.4	0.08	6.1	–0.00	5.8	–0.30
48	6.4	0.32	7.0	0.65*	6.6	0.04	6.0	–0.45	6.2	–0.23
49	5.7	–0.40*	5.7	0.00	5.4	–0.41	5.8	0.07	6.0	0.34
50	6.9	0.77**	6.6	–0.22	7.1	0.08	6.9	0.00	7.0	0.13
51	6.1	0.02	5.7	–0.33	6.2	–0.12	6.4	0.27	6.3	0.18
52	5.8	–0.32	5.6	–0.11	5.9	–0.04	5.7	–0.10	6.0	0.25
53	6.3	0.19	6.3	0.06	6.8	0.33	6.8	0.53	5.4	–0.92**

TABLE 8 - *Continued.*

Lines	Yield@	GCA	Tester 1		Tester 2		Tester 3		Tester 4	
			Yield§	SCA	Yield	SCA	Yield	SCA	Yield	SCA
54	5.8	−0.35	6.1	0.35	5.7	−0.22	6.0	0.19	5.4	−0.32
55	5.7	−0.47*	6.6	1.06**	5.1	−0.69*	4.3	−1.38**	6.6	1.02**
56	6.1	0.02	6.0	−0.02	6.5	0.23	6.5	0.34	5.6	−0.54
57	6.5	0.41*	5.8	−0.63*	7.8	1.10**	7.0	0.48	5.5	−0.96**
58	5.9	−0.24	5.8	−0.02	5.3	−0.75*	6.6	0.76*	5.9	0.02
59	6.2	0.05	5.5	−0.58*	6.6	0.34	6.0	−0.15	6.5	0.40
60	6.2	0.07	5.8	−0.28	6.4	0.09	6.0	−0.19	6.5	0.38
61	6.2	0.10	5.8	−0.39	6.8	0.41	6.2	0.01	6.2	−0.02
62	6.3	0.12	6.7	0.53	6.2	−0.16	5.9	−0.35	6.2	−0.03
63	6.4	0.28	6.5	0.18	6.2	−0.37	6.3	−0.11	6.7	0.29
64	6.2	0.08	5.9	−0.26	6.7	0.35	6.1	−0.12	6.2	0.03
65	6.1	−0.01	6.3	0.30	5.9	−0.34	6.0	−0.09	6.2	0.13
66	6.1	−0.05	5.9	−0.15	6.2	−0.01	6.0	−0.04	6.2	0.20
67	5.7	−0.44*	5.5	−0.07	5.9	0.09	6.0	0.30	5.3	−0.32
68	6.4	0.29	5.8	−0.51	6.7	0.16	6.7	0.26	6.5	0.09
69	5.7	−0.43*	5.9	0.22	5.7	−0.18	5.5	−0.23	5.8	0.18
Set 4										
70	5.7	0.07	5.3	−0.19	6.2	0.31	5.9	0.19	5.3	−0.31
71	5.7	0.05	4.9	−0.64*	6.5	0.59*	5.9	0.17	5.4	−0.11
72	5.9	0.33	6.3	0.50	6.1	−0.08	5.8	−0.22	5.6	−0.20
73	6.3	0.66**	6.4	0.27	5.7	−0.73**	6.4	0.07	6.6	0.40
74	5.4	−0.21	4.9	−0.33	5.8	0.25	5.2	−0.27	5.6	0.35
75	5.9	0.28	5.7	−0.05	6.5	0.36	5.8	−0.13	5.6	−0.19
76	5.7	0.09	5.4	−0.12	6.1	0.22	5.9	0.14	5.4	−0.24
77	5.5	−0.13	5.2	−0.15	5.9	0.26	5.4	−0.08	5.3	−0.03
78	5.4	−0.23	5.0	−0.21	5.7	0.14	5.1	−0.34	5.7	0.41
79	5.7	0.08	5.5	−0.07	6.3	0.39	5.8	0.03	5.2	−0.35
80	5.2	−0.41	5.7	0.60*	5.2	−0.19	5.2	−0.04	4.7	−0.37
81	5.6	−0.04	5.3	−0.14	5.6	−0.22	5.7	0.10	5.7	0.25
82	5.2	−0.37	5.9	0.81**	5.5	0.10	4.0	−1.28**	5.5	0.37
83	5.0	−0.58*	5.0	0.08	4.9	−0.36	5.2	0.12	5.1	0.15
84	6.1	0.44*	5.4	−0.49	6.1	−0.19	6.7	0.58*	6.1	0.11
85	5.5	−0.13	5.1	−0.28	5.8	0.14	6.4	0.87**	4.7	−0.73
86	5.5	−0.07	5.7	0.27	5.7	−0.00	5.4	−0.23	5.4	−0.04
87	5.8	0.23	5.9	0.20	5.5	−0.53	6.3	0.39	5.7	−0.05
88	5.2	−0.43	5.3	0.25	5.2	−0.19	5.4	0.14	4.9	−0.20
89	5.9	0.33	5.5	−0.28	6.0	−0.15	6.0	−0.01	6.3	0.44
90	5.7	0.10	5.4	−0.16	6.1	0.22	5.8	0.07	5.5	−0.14
91	5.9	0.31	5.4	−0.35	6.2	0.03	6.1	0.11	6.0	0.20
92	5.2	−0.37	5.6	0.48	5.1	−0.39	4.9	−0.38	5.4	0.29

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.
@ Grain yield (t/ha.) of each line averaged over four testers and multiple environments.
§ Grain yield (t/ha.) averaged over each line x tester cross over multiple environments.s

sets showed that T 3 had positive GCA effect, T 4 had negative GCA effect and T 1 and T 2 basically neutral (Fig. 1). Across sets, Tuxpeño germplasm (Pop. 21 and Pop. 43) provided a higher percentage of lines with positive GCA effects for yield, while Pools 23 and 24 provided the least. VASAL *et al.* (1992a) obtained similar results from diallel studies involving CIMMYT's tropical pools and populations and concluded that Populations 43 and 21 showed higher GCA effects for yield.

Specific combining ability (SCA) estimates for grain yield

Set 1: Set 1 included 13 lines (L 1 to L 12 and L 23) from Population 21. Generally these lines combined well with the flint testers from Populations 25 and 32

TABLE 9 - *SCA means and grain yield (t/ha.) at the source population level for the 368 line x tester crosses divided into four sets and evaluated in multiple environments.*

		Tester 1 (Pop. 21)		Tester 2 (Pop. 32)		Tester 3 (Pop. 25)		Tester 4 (Pop. 24)	
Population/Pool	Set No.	Yield§	SCA	Yield	SCA	Yield	SCA	Yield	SCA
Pop. 21	Set 1 (13)§	6.3	−0.02	6.2	0.04	6.8	0.07	6.3	−0.10
	Set 3 (11)	6.0	−0.08	6.4	0.06	6.1	−0.04	6.2	0.06
	Set 4 (10)	5.3	−0.20*	6.0	0.19*	5.7	0.03	5.5	−0.02
	Mean (34)	5.9	−0.10	6.2	0.10	6.2	0.02	6.0	−0.02
Pop. 32	Set 2 (5)	6.5	−0.06	5.9	−0.40**	6.5	0.05	6.6	0.41**
	Set 3 (1)	5.9	0.22	5.7	−0.18	5.5	−0.23	5.8	0.18
	Set 4 (2)	6.0	0.43*	5.5	−0.46*	5.8	0.01	5.6	0.01
	Mean (8)	6.1	0.20	5.7	−0.35	5.9	−0.05	6.0	0.20
Pop. 25	Set 1 (2)	6.4	0.24	5.7	−0.32	6.4	−0.14	6.4	0.22
	Set 4 (1)	5.6	0.48	5.1	−0.39	4.9	−0.38	5.4	0.29
	Mean (3)	6.0	0.36	5.4	−0.35	5.6	−0.26	5.9	0.25
Pool 24	Set 2 (6)	6.7	0.24*	6.4	0.31**	6.1	−0.20	5.7	−0.35**
	Set 3 (8)	6.2	0.08	6.3	−0.03	6.2	0.06	6.0	−0.11
	Set 4 (2)	5.2	−0.39*	5.9	−0.02	6.5	0.72**	5.4	−0.31
	Mean (16)	6.0	−0.02	6.2	0.08	6.3	0.20	5.7	−0.26
Pool 23	Set (4) 2	5.4	0.45*	5.2	−0.13	4.6	−0.58**	5.3	0.26
Pop. 22	Set 1 (8)	6.2	−0.03	6.0	0.01	6.5	−0.09	6.4	0.10
	Set 3 (1)	5.9	−0.15	6.2	−0.01	6.0	−0.04	6.2	0.20
	Set 4 (2)	5.3	−0.14	6.0	0.27	5.4	−0.16	5.5	0.03
	Mean (11)	5.8	−0.10	6.1	0.09	6.0	−0.09	6.0	0.11
Pop. 29	Set 2 (4)	6.5	−0.26*	6.7	0.21	6.7	0.03	6.4	0.02
	Set 3 (2)	5.9	0.11	5.9	−0.13	6.0	0.10	5.8	−0.09
	Set 4 (1)	6.3	0.50	6.1	−0.08	5.8	−0.22	5.6	−0.20
	Mean (7)	6.3	0.12	6.2	0.00	6.2	−0.03	6.0	−0.09
Pop. 43	Set 2 (8)	7.0	−0.01	6.7	−0.08	7.0	0.10	6.7	−0.01
	Set 4 (1)	5.3	−0.14	5.6	−0.22	5.7	0.10	5.7	0.25
	Mean (9)	6.2	−0.08	6.1	−0.15	6.4	0.10	6.2	0.12
Pop. 73	Set 4 (2)	5.8	0.23	5.6	−0.26	5.8	0.08	5.5	−0.05

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.
§ Number in parentheses represents number of lines in each set derived from the particular population/pool.

(T 2 and T 3). There were a few intrapopulation hybrids that performed well. For example, the cross L 7 x T 1, an intrapopulation hybrid from Population 21 yielded 6.7 t/ha and had a significantly positive SCA of 0.59 t/ha. Both parents were derived from the same full sib family, FS 219 of Population 21. This family in particular has given rise to some of the best inbred lines in our program and is noted for its vigor, lodging resistance and good stalk quality (VASAL *et al.*, 1992b). The top-yielding hybrid combination in this set was L 8 x T 3 (Pop. 21 x Pop. 25) with grain yield of 7.8 t/ha and a significantly positive SCA of 0.78 t/ha. (Table 8).

Eight lines from Population 22 (L 13 to L 20) were represented in set 1. These lines crossed well with T 3 and T 4. Except for L 19, the rest showed negative SCA effects in crosses with T 1. These lines produced some good specific combinations with T 3, a flint tester from Population 25. Lines 14 and 17 in particular performed well for grain yield, exceeding 7 t/ha and depicting positive SCA effects. In general, yields realized with T 3 were higher than with other testers for these lines from Population 22. The two lines from Population 25 (L 21 and L 22) crossed well with the two dent testers (T 1 and T 4), while they showed negative SCA effects with the two flint testers. (T 2 and T 3).

Set 2: Set 2 included lines from Populations 29, 32, 43 and Pool 24 (Table 2). Lines from Population 29 (L 24 to L 27), performed well with all testers. The five lines from Population 32 (L 28 to L 32) had negative SCA effects with T 2 from the same population, while they performed well in crosses with the two dent testers, T 1 and T 4. Lines from Population 43 had positive GCA effects and produced some of the high-yielding crosses. These lines crossed well with all testers, though there was a slight yield advantage in crosses with the flint testers (T 2 and T 3) over the dent testers. Many of the hybrid combinations from this group yielded in excess of 7 t/ha. (Table 8). Lines from Pool 24 (L 41 to L 46) crossed well with T 1 and T 2 and had positive SCA effects for yield.

Set 3: Eight lines from Pool 24 and 11 from Tuxpeño Sequía (drought tolerant version of Pop 21) were the major constituents in set 3. There were two lines from Population 29 and one line each from Populations 22 and 32. Lines from Pool 24 (L 47 to L 54) crossed well with all testers. The tester from Pool 24 (tar spot resistant-TSR) performed reasonably well with lines derived from Pool 24. Lines from Tuxpeño Sequía showed good yield potential in crosses with T 2 and T 4 and poor yield when crossed with T 1 and T 3 (Table 8). There were a few superior hybrid combinations in this set that yielded more than 7 t/ha. Line 57, from Tuxpeño Sequía crossed with T 2 and with T 3 produced yields that exceeded 7 t/ha.

Set 4: Set 4 included lines from all the nine populations and pools. Lines from Population 21 had negative SCA effects with T 1 from the same population but crossed well with T 2 from Population 32. The yield levels of set 4 were comparatively lower than in the other three sets. The best hybrid in set 4 was L 84 x T 3 (Pool 24 x Pop. 25) which yielded 6.7 t/ha and had a significantly positive SCA of 0.58 t/ha (Table 8).

Results from the combining ability studies among CIMMYT maize germplasm were summarized by VASAL *et al.* (1987). Some of the possible heterotic partners for CIMMYT's tropical pools and populations were listed therein. Results from the current study, conducted at the inbred line level confirmed our earlier results obtained at the population level. In general, the dent x flint heterotic pattern observed in the temperate cornbelt germplasm was observed in the tropical material as well. BECK *et al.* (1990) observed similar heterotic patterns between materials of different grain types with CIMMYT's tropical early and intermediate maturity germplasm. However, some superior dent x dent heterotic patterns between Population 43, Population 21 and Pool 24 (all Tuxpeño based) could very well be successfully exploited. WELLHAUSEN (1956) suggested that the Tuxpeño germplasm introgressed into the Southern Dent parentage might have contributed to the high yield potential of the U.S. Corn Belt maize.

Intra vs Interpopulation inter-line combining ability

A total of 92 tropical inbred lines developed at CIMMYT were used in this study. Population 21 (Tuxpeño-1) contributed 34 lines followed by Pool 24 with 16 lines and Population 22 with 11 lines, with the remaining lines coming from six populations and pools. Since the populations/pools that the testers were derived from were also included in the lines studied, it was possible to look at the cross performance from an intra vs. interpopulation perspective. Mean SCA effects and yields for all the lines from the same population/pool for each set and combined for all the sets are presented in Table 9. The first four populations/pools given are in the same order as the testers used. Hence the diagonal of this 4 x 4 matrix would represent intrapopulation interline crosses whereas the off-diagonal values would represent interpopulation interline crosses. For the remaining five populations and pools listed thereafter, all combinations would be largely interpopulation interline crosses as they are not directly represented in the testers used.

Intrapopulation crosses involving Populations 21, 25, 32 and Pool 24 were lower yielding and had negative SCA effects compared with the interpopulation crosses (Table 9). However, the interpopulation cross of Population 25 x Population 32 (flint x flint) had negative SCA effects and lower yields. Similar results were obtained with dent x dent crosses involving Pool 24 and Population 21.

Among interpopulation crosses, Pool 23 combined well with Population 21 and Pool 24 and combined poorly with Population 25. Populations 22, combined well with Population 32 and Pool 24. Both the Populations 29 and 43 combined equally with all the four testers showing no particular preference for any tester.

HAN *et al.* (1991) studied the heterosis among 58 S3 lines derived from CIMMYT maize germplasm. They observed large positive SCA effects and good interpopulation cross superiority in Population 21 x Population 32 cross and Population 32 x Population 25 cross. Similar results were obtained in the present study, which involved 92 lines that were tested at a higher level of inbreeding (S3-S6).

From the 368 line x tester crosses evaluated, performance of five high-yielding crosses from each set are summarized in Table 10, alongwith the performance of the checks. For comparison purposes, the yields of three best checks are provided. They are: (1) the commercial hybrid from INIFAP, Mexico (H 507), (2) Best CIMMYT single cross hybrid check, and (3)

TABLE 10 - *Grain yield, days to silk, plant height, and grain moisture content of five best line x tester crosses from the four sets evaluated in two environments at Poza Rica and Tlaltizapan, Mexico during 1988 and 1990.*

Hybrid code@	Grain yield (t/ha.)	Grain yield % over ACR 8243	Days to 50% silk	Plant height (cm)	Grain moisture (%)
Set 1					
L 3 x T 3 (CML 8 x CML 24)	8.37	120.1	75.5	210	25.6
L 3 x T 2 (CML 8 x CML 38)	8.18	117.5	78.3	220	27.7
L 2 x T 3	8.06	115.7	75.0	210	22.8
L 6 x T 3	7.94	113.9	74.8	212	24.8
L 7 x T 1 (CML 10 x CML 9)	7.91	113.6	78.3	197	31.0
Check (H 507)	5.29	–	87.0	225	25.8
Best check hybrid	7.76	–	76.3	190	28.6
Best OPV (ACR 8243)§	6.96	–	76.8	205	25.5
Set 2					
L 34 x T 3 (CML 45 x CML 24)	8.34	123.7	79.6	213	22.0
L 38 x T 1 (CML 47 x CML 9)	8.13	120.7	77.5	210	32.6
L 30 x T 1	8.10	120.1	75.5	182	29.1
L 34 x T 1 (CML 11 x CML 9)	8.05	119.5	76.7	198	27.9
L 37 x T 3	7.99	118.6	76.3	195	25.2
Check (H 507)	5.12	–	84.0	225	26.5
Best check hybrid	7.69	–	81.4	198	28.4
Best OPV (ACR 8243)§	6.74	–	77.0	210	24.0
Set 3					
L 57 x T 2 (CML 14 x CML 38)	8.20	138.3	78.8	197	29.1
L 62 x T 1	7.89	133.0	79.8	175	26.6
L 50 x T 2	7.86	132.6	76.7	173	28.4
L 57 x T 3 (CML 14 x CML 24)	7.77	131.0	77.0	197	24.7
L 48 x T 1	7.75	130.7	76.7	198	24.9
Check (H 507)	5.29	–	85.3	222	26.3
Best check hybrid	7.15	–	77.5	185	25.2
Best OPV (ACR 8243)§	5.93	–	79.3	202	23.7
Set 4					
L 73 x T 4 (CML 36 x CML 56)	7.33	124.7	75.7	178	27.0
L 71 x T 2 (CML 2 x CML 38)	7.18	122.1	78.7	182	26.8
L 70 x T 2 (CML 1 x CML 38)	7.15	121.7	80.5	163	26.8
L 73 x T 1 (CML 36 x CML 9)	7.02	119.4	78.8	177	28.8
L 84 x T 3	6.98	118.7	74.3	187	23.7
Check (H 507)	4.23	–	79.0	180	27.3
Best check hybrid	7.43	–	84.7	195	27.8
Best OPV (ACR 8243)§	5.88	–	78.2	173	24.8

§ ACR 8243 stands for EV developed from 10 best full-sib families of Pop. 43 based on across site performance in international testing at six locations during 1982.

@ For line and tester code refer to Table 2. CML stands for CIMMYT Maize line which are announced lines from CIMMYT. CML code given for applicable crosses.

best across EV from Population 43 (ACR.8243). Data on root and stalk lodging though taken, are not included, as there was very little lodging in these materials in the environments tested. Yield superiority of some crosses over the EV check was as high as 39%. H 507, a popular hybrid from INIFAP was taller and later than the other entries in the trial and did not perform well in these environments. Grain moisture content at harvest, ranged from 22.8 to 32.6% in the crosses listed (Table 10). Twelve of the 20 high-yielding crosses listed, involved crosses between CML lines that were announced. This information on the specific top-performing cross-combinantions will be of great value to our cooperators in the public and private seed industry, who are starting to make use of these lines in their hybrid program.

Formation of tropical maize heterotic groups

The results provided detailed information on the heterotic patterns of the tropical lines with respect to the four testers used. Based on the general combining ability information for yield, Tester 1 (Population 21 - Dent) and Tester 3 (Population 25 - Flint) were selected. The 92 lines tested were examined for their SCA effects and actual yield with the two testers. Lines which showed divergent combining abilities with the two testers were included into two different groups. Lines showing negative SCA with Tester 1 (Pop. 21) and positive SCA with Tester 3 (Pop. 25) were classified under Tropical Heterotic Group "A" (THG "A"). These were mostly comprised of dent lines. Lines showing positive SCA with Tester 1 and negative with Tester 3 were classified under the second Tropical Heterotic Group "B" (THG "B"). These were mostly made up of flint lines, although there were a few lines which were dent to semi-dent. Lines from each group were recombined separately followed by selection and further recombination to develop two new heterotic groups. These two new populations are expected to exhibit a high level of heterosis between them and also would serve as superior hybrid-oriented germplasm for further hybrid development work.

Maize breeders worldwide constantly desire new genetic diversity that could be profitably exploited in their breeding programs, but very few organizations have the resources or expertise to work on it (DUVICK, 1985). The hybrid maize program at CIMMYT started seven years ago, took upon the task of developing new heterotic groups and improving the source germplasm required for hybrid development work. We feel that the study presented here is a step in the right direction in achieving that goal.

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