Pak J Sci Ind Res 2001 44 (4) 239-243

Inter-Racial Heterosis in Maize Hybrids

M Iqbal [ab]*, M Saleem [a] and O Rashid [a]

[a]Department of Plant Breeding and Genetics, NWFP Agricultural University, Peshawar, Pakistan

[b]H.No.353A, Sec.G-7/3-3, Islamabad, Pakistan

(Received 7 February 1999; accepted 29 December 2000)

Seventy-seven single cross maize hybrids alongwith four checks were evaluated at the NWFP Agricultural University Peshawar Research Farm during Kharif 1997 to determine the magnitude of heterosis and combining ability in elite inbred lines and to identify hybrids for commercial production. Hybrids CML40 x SY8-2 and K305 x CML66 produced the highest grain yields of 3995 and 3837 kg ha^{-1} showing 19% and 14% heterosis, respectively, over the best check Cargill 707. The top yielding hybrids had desirable plant heights (ranging 132-166 cm) and were observed in maturity (97-100 days) at par with the local check varieties. Inbred lines CML-40 and CML-66 were identified as good general combiners for grain yield while NC-298 and SW 49-2 showed good specific combining ability for the same trait.

Key words: Maize hybrids, *Zea mays* L, Heterosis, Combining ability.

Introduction

Maize (*Zea mays* L.) is an important and widely grown cereal throughout the world. It is used as food, feed and as a raw material in agro-based industries. In Pakistan, per hectare yield of maize is low as compared to that obtained in other developing countries. So there is a need to improve maize yield by using different breeding procedures and materials to develop improved cultivars/hybrids.

Maize hybrids are cultivated on a limited area in developing countries inspite of their higher yield potential than open-pollinated cultivars (Vasal *et al* 1944). Due to the increasing interest in hybrid maize production among national programmes and private seed companies in the developing world (Beck *et al* 1991), maize breeding is directed towards the development of inbred lines with superior combining ability. These inbred lines are then combined into hybrids, which are grown by farmers as commercial crop (Ordas 1991).

According to East and Hays (1912) and Chaudhri (1971), the amount of heterosis expressed in the F_1 hybrid is roughly proportional to the genetic diversity between two parental inbreds, provided the hybrid develops normally. Crossing maize germplasm from different adaptation groups (inter-racial) could result in better utilization of heterosis. Such heterotic response is rarely exploited due to problems in the adaptation of exotic material. Inter-racial hybridization has been an important factor in the evolution of maize. The hybrids developed through inter-racial hybridization could serve as useful source of new alleles to broaden the germplasm base and to further increase both the yield and stability in production.

The magnitude of heterosis and combining ability among tropical, sub-tropical and temperate maize inbred lines in hybrid combinations and identification of suitable germplasm for the development of commercial hybrids for different agro-climatic zones of Pakistan is reported here.

Materials and Methods

Ten locally developed inbred lines (sub-tropical) and 29 exotic lines (13 temperate and 16 tropical origin) were planted in Spring 1997. Ear shoots were covered with shoot bags before silk emergence for crossing and to avoid contamination. When silks were about 2-3 cm long, tassels were covered in the afternoon with tassel bags to avoid out crossing. Crosses were attempted the next morning. Inbred lines with the same maturity were crossed randomly in different combinations. Based on the amount of seed available, seventy-seven single crosses were selected for testing in yield trial.

During Kharif 1997, the hybrids alongwith four checks including two open-pollinated varieties, namely, Azam and Sarhad white and two commercial hybrids, namely, Cargill 707 and FRHW 12 were planted in 9 x 9 simple lattice design with two replications. Each entry was grown in one row plot measuring 5 m in length with plant to plant distance of 25 cm and row to row distance of 75 cm. Fertilizers were applied with the ratio of 120:50:0 NPK kg ha^{-1}. Sundaphos was sprayed to protect the crop from stem borer. Data were recorded on all plots for anthesis-silking interval (ASI), plant and ear heights, leaf area index (LAI), grain yield and days to harvest maturity. L A I was found out by the formula suggested by Francis *et al* (1969).

$$LAI = \frac{\text{Leaf length x width x 0.75 x No. of leaves plant}^{-1}}{\text{Land area occupied by that plant}}$$

*Author for correspondence. [b]Present address.

Grain yield was adjusted to 12% moisture content using the formula given below:

$$\text{Grain yield (kg ha}^{-1}\text{) at 12\% moisture content} = \frac{GY \times (100\text{-M.C.}) \times 10{,}000\ m^2}{3.75\ m^2 \times (100-12)}$$

Where;

GY	:	Fresh grain yield per plot in kgs.
M C	:	Moisture content of grains of that plot.
3.75 m^2	:	Plot size.
12	:	moisture % required.

Heterosis over the standard variety was calculated using the method suggested by Fehr (1987).

Results and Discussion

Significant differences existed in hybrids for all the important agronomic traits studied at 1 % level of probability (Table 1). The highest mean grain yield (3995 kg ha^{-1}) was obtained from the hybrid CML-40 x SY 8-2, showing 19%,85%, 109%, and 125% heterosis over the checks, Cargill 707, Azam, Sarhad White and FRHW 12, respectively. Its yield was significantly different from the four checks except Cargill 707. Hybrid K 305 x CML-66 out-yielded the checks Cargill 707, Azam, Sarhad White, and FRHW 12 by an increase of 14%, 78%, 103% and 116%, respectively. The lowest mean grain yield of 909 kg ha^{-1} was obtained from the hybrid SY 29-2 x SY15-1 indicating

Table 1
Performance of single cross maize hybrids for grain yield and other plant characteristics during Kharif 1997

S.NO	Hybrid	Grain yield (kg ha^{-1})	Plant height (cm)	Ear height (cm)	Anthesis-silking interval(days)	Maturity (days)	Leaf area index
1	CML-40 x SY8-2 (Tr* x ST*)	3995 A	166 B-F	88 A-C	2.0 C-E	100 B-J	3.12 A-G
2	K305 x CML-66 (Tm* x Tr)	3837 AB	132 G-Z	63 H-Z	2.0 C-E	97 E-S	3.53 A
3	Cargill 707 (Check)	3354 A-C	142 E-U	69 E-W	3.5 AB	96 H-U	2.77 A-K
4	NC298 x SW49-2 (Tm x ST)	3311 A-D	132 G-Z	58 N-\	2.5 B-D	97 D-R	2.65 A-K
5	CML-40 x CML-66 (Tr x Tr)	3241 A-E	139 E-V	70 E-W	2.0 C-E	101 A-I	3.29 A-E
6	NC300 x CML-66 (Tm x Tr)	3236 A-E	122 N-I	68 E-W	2.0 C-E	102 A-H	2.83 A-I
7	SY29-2 x CML-40 (ST x Tr)	3218 A-F	147 D-P	79 B-I	2.0 C-E	95 J-V	3.29 A-E
8	CML-66 x SW10-1 (Tr x ST)	3181 A-G	119 P-I	67 F-X	3.0 A-C	94 K-X	2.37 A-M
9	CML-899 xCML-23 (Tr x Tr)	3164 A-H	131 H-Z	68 E-X	2.5 B-D	99 C-K	2.12 B-M
10	Mo17Y x SY25-2 (Tm x ST)	3140 A-H	147 D-Q	73 C-P	2.0 C-E	96 E-T	2.51 B-L
11	K301 x Mo17W (Tm x Tm)	3103 A-I	137 F-W	63 I-\	2.0 C-E	102 A-H	2.49 A-L
12	Az21-1 x Sh2-3 (ST x ST)	3032 A-J	114 U-\	57 P-\	3.0 A-C	88 X-Z	2.18 A-M
13	Mo17Y x CML-23 (Tm x Tr)	3020 A-J	157 B-I	84 A-E	3.0 A-C	101 A-I	2.64 A-K
14	SY25-2 x B73Y (ST x Tm)	2993 A-J	150 C-O	74 B-O	2.5 B-D	92 Q-Z	2.61 A-K
15	CML-42 x SY8-2 (Tr x ST)	2974 A-K	182 A-B	88 A-C	3.0 A-C	103 A-C	2.92 A-H
16	K301 x CML-49 (Tm x Tr)	2973 A-K	173 A-D	83 A-F	1.5 DE	99 C-K	3.36 A-D
17	Sh18-2 x SW10-1 (Tm x ST)	2972 A-K	129 I-Z	64 H-Y	2.5 B-D	91 S-Z	2.22 A-M
18	Mo17Y x CML-49 (Tm x Tr)	2962 A-L	134 G-Z	70 E-U	2.0 C-E	102 A-E	2.59 A-K
19	NC250A x SW10-1 (Tm x ST)	2930 A-M	142 E-U	73 C-R	2.0 C-E	101 A-I	2.85 A-I
20	SY25-2 x CML-10 (ST x Tr)	2879 A-N	160 B-H	88 A-C	2.0 C-E	102 A-F	3.28 A-E
21	CML-42 x CML-62 (Tr x Tr)	2867 A-N	176 A-C	90 AB	2.5 B-D	102 A-G	3.44 A-C
22	CML-23 x B73Y (Tr x Tm)	2858 A-N	150 C-N	73 C-Q	3.0 A-C	97 C-Q	2.51 A-L
23	CML-66xCML-899 (Tm x Tm)	2856 A-N	141 E-V	79 B-H	2.5 B-D	97 E-S	2.55 A-L
24	Mo17W x Mo17Y (Tm x Tm)	2819 A-O	146 D-R	77 B-J	2.0 C-E	94 K-X	2.43 A-L
25	CML-30 x CML-63 (Tr x Tr)	2715 B-P	167 B-E	87 A-D	2.0 C-E	102 A-H	2.75 A-J
26	SY25-2x CML-899 (ST x Tr)	2666 B-P	161 B-G	82 B-G	2.0 C-E	94 J-W	2.80 A-I
27	SW10-1 x SY29-2 (ST x ST)	2655 B-Q	130 I-Z	65 G-Y	3.0 A-C	90 T-Z	2.00 D-M
28	CML-40 x SW10-1 (Tr x ST)	2650 B-Q	135 G-Y	65 H-Y	2.0 C-E	97 C-Q	2.29 A-M
29	Mo17W x CML-899 (Tm x Tr)	2574 C-Q	150 C-O	72 C-R	2.5 B-D	96 H-	2.60 A-K
30	K305 x SY25-2 (Tm x ST)	2527 C-Q	134 G-Z	57 P-\	2.0 C-E	93 L-Z	2.71 A-K
31	FR239Y x CML-40 (Tm x ST)	2484 C-R	145 D-S	76 B-L	1.0 E	97 E-S	1.80 G-M
32	SW10-1 x Mo17W (ST x Tm)	2459 C-R	150 C-N	70 E-V	2.0 C-E	92 P-Z	2.19 A-M
33	Az21-1 x CML-40 (ST x Tr)	2413 C-S	156 B-J	69 E-W	3.0 A-C	98 C-M	2.36 A-M

(Cont'd......)

(Table 1 Cont'd)

S.No	Hybrid	Grain yield (kg ha^{-1})	Plant height (cm)	Ear height (cm)	Anthesis-silking interval(days)	Maturity (days)	Leaf area index
34	CML-42 x CML-24 (Tr x Tr)	2374 C-S	197 A	98 A	2.0 C-E	105 AB	3.49 A-B
35	CML-38 x SY25-2 (Tr x ST)	2345 C-S	155 C-K	90 AB	2.0 C-E	102 A-H	3.32 A-E
36	YUZP212 xCML-23 (Tm x Tr)	2340 C-S	143 E-U	78 B-I	1.0 E	98 C-N	3.34 A-D
37	K301 x B73Y (Tm x Tm)	2300 C-T	154 C-I	75 B-N	3.0 A-C	92 P-Z	2.39 A-L
38	SY15-1x CML-899 (ST x Tr)	2296 C-T	139 E-V	61 J-I	2.0 C-E	95 J-V	2.70 A-K
39	Mo17Y x B73Y (Tm x Tm)	2256 C-V	139 E-V	72 C-S	3.0 A-C	98 C-O	2.21 A-M
40	Mo17W x B73Y (Tm x Tm)	2227 C-V	146 D-R	76 B-K	2.5 B-D	92 P-Z	2.63 A-K
41	K305 x Splenda (Tm x Tm)	2214 C-V	135 G-Y	64 H-Y	3.0 A-C	87 Z	2.22 A-M
42	Sh2-3 x Mo17W (ST x Tm)	2196 C-V	107 Y-\	47 /	2.0 C-E	92 M-Z	1.01 M
43	Azam (Check)	2155 C-V	126 K-Z	69 E-W	3.0 A-C	92 M-Z	2.22 A-M
44	SY29-2 x B73Y (ST x Tm)	2138 C-V	134 G-Y	66 G-Y	2.0 A-C	92 O-Z	2.00 D-M
45	K305 x FR239Y (Tm x Tm)	2132 C-V	132 G-Z	71 D-T	2.5 B-D	92 P-Z	2.12 C-M
46	Sh2-3 x SY25-2 (ST x ST)	2089 D-V	123 M-Z	53 W-\	2.0 C-E	89 V-Z	2.16 A-M
47	B73Y x SY15-1 (Tm x ST)	2071 D-V	124 M-Z	58 O-\	2.0 C-E	92 P-Z	2.16 A-M
48	Mo17W x B73Y (Tm x Tm)	2039 E-V	147 D-Q	75 B-M	2.5 B-D	92 P-Z	2.63 A-K
49	Mo17W x CML-51 (Tm x Tr)	2018 E-V	155 C-K	84 A-F	2.0 C-E	98 C-P	2.79 A-I
50	Sh2-3 x Mo17Y (ST x Tr)	2005 E-V	114 U-\	54 V-\	2.0 C-E	93 K-Y	1.83 G-M
51	CML-30 x CML-51 (Tr x Tr)	1990 E-V	144 E-T	64 H-Y	3.0 A-C	106 A	2.84 A-I
52	Sh2-3 x FR239Y (ST x Tm)	1979 E-V	115 T-\	61 J-	3.0 A-C	93 L-Z	2.15 B-M
53	NC250A x K302 (Tm x Tm)	1956 F-V	156 B-J	68 F-X	2.5 B-D	98 C-L	2.33 A-M
54	CML-127x FR239Y (Tr x Tm)	1949 G-V	128 J-Z	78 B-I	4.0 A	96 F-T	2.34 A-M
55	CML-40 x CML-26 (Tr x Tr)	1932 G-V	147 D-Q	76 B-J	2.0 C-E	99 C-K	2.58 A-L
56	Sarhad White (Check)	1915 H-V	147 D-P	73 C-R	3.5 AB	93 K-Y	2.55 A-L
57	K305 x Mo17Y (Tm x Tm)	1847 I-V	112 V-\	44 \]	2.0 C-E	98 C-M	1.66 H-M
58	Mo17Y x FR239Y (Tm x Tm)	1831 J-V	119 P-I	59 L-\	2.0 C-E	96 I-U	1.89 F-M
59	Az21-1 x K301 (ST x Tm)	1816 J-V	145 E-S	55 T-\	3.0 A-C	91 Q-Z	2.46 A-L
60	SW10-1 x Gracia (ST x Tm)	1790 J-V	132 G-Z	64 H-Z	2.0 C-E	91 R-Z	2.03 D-M
61	FRHW 12 (Check)	1770 J-V	130 I-Z	64 H-Y	1.5 D-E	91 Q-Z	1.86 D-M
62	K305 x SW10-1 (Tm x ST)	1726 K-V	121 N-I	57 Q-\	2.0 C-E	93 L-Z	1.58 H-M
63	Mo17W x CML-40 (Tm x Tr)	1705 L-V	152 C-M	84 A-F	2.5 B-D	95 J-V	2.26 A-M
64	Gracia x B73Y (Tm x Tm)	1687 M-V	136 G-X	61 J-\	1.5 D-E	88 YZ	1.71 H-M
65	SY15-1 x CML-26 (ST x Tr)	1655 N-V	133 G-Z	62 I-\	2.5 B-D	94 K-Y	2.81 A-I
66	CML-38 x CML-20 (Tr x Tr)	1652 N-V	125 L-Z	75 B-M	2.5 B-D	103 K-D	3.24 A-F
67	SW49-2 x FR239Y (ST x Tm)	1630 N-V	94 I\	51 W-I	2.0 C-E	94 J-W	1.22 LM
68	Az21-1 x Mo17Y (Tm x Tm)	1628 N-V	118 Q-I	56 R-\	2.0 C-E	96 G-T	1.48 I-M
69	SY29-2 x FR239Y (ST x Tm)	1586 O-V	120 P-I	60 J-	2.0 C-E	92 O-Z	1.73 H-M
70	Sh2-3 x Gracia (ST x Tm)	1538 P-V	121 O-I	58 O-\	2.5 D-E	89 V-Z	2.18 A-M
71	Sh2-3 x SW10-1 (ST x ST)	1527 P-V	117 S-I	55 S-\	3.0 A-C	90 U-Z	1.37 K-M
72	FR239Y x B73Y (Tm x Tm)	1484 P-V	109 W-\	54 U-\	2.0 C-E	94 K-X	1.85 G-M
73	Sh2-3 x SW18-1 (ST x ST)	1462 P-V	108 X-\	47 Z-	3.0 A-C	89 W-Z	1.68 H-M
74	CML-127xCML-899 (Tr x Tr)	1392 Q-V	127 K-Z	66 G-Y	2.0 C-E	102 A-G	2.21 A-M
75	Mo17W x SY25-2 (Tm x ST)	1259 R-V	137 F-W	62 I-	2.0 C-E	92 P-Z	1.95 E-M
76	K301 x FR239Y (Tm x Tm)	1250 R-V	117 S-I	49 Y-	2.0 C-E	99 C-K	2.04 D-M
77	K301 x YUZP212 (Tm x Tm)	1196 S-V	105 Z-\	47 \	2.0 C-E	92 N-Z	1.66 H-M
78	Mo17W xYUZP212 (Tm xTm)	1186 S-V	129 I-Z	60 K-\	3.0 A-C	92 P-Z	1.90 F-M
79	Gracia x B73Y (Tm x Tm)	1047 T-V	132 G-Z	63 H-Z	2.5 B-D	87 Z	2.10 C-M
80	FR239Y x Gracia (Tm x Tm)	1019 UV	118 R-I	59 M-\	2.0 C-E	88 X-Z	1.50 I-M
81	SY29-2 x SY15-1 (ST x ST)	908.6 V	89 \	37	2.0 C-E	90 U-Z	1.39 J-M
Mean		2452	135.1	67.5	2.33	95.0	2.37
CV		16.7%	6.5%	7.5%	16.7%	1.93%	17.4%

Means followed by different letters differ significantly at 1% level of probability; * Tr = Tropical, ST = Sub-tropical, Tm = Temperate.

no clear heterosis because both lines were derived from the same population, i.e. subtropical.

In general, crosses between tropical and subtropical inbred lines produced maximum mean grain yield of 2768 kg ha^{-1} (Table 2), followed by 2655 kg ha^{-1} for tropical x temperate crosses, 2426 kg ha^{-1} for tropical x tropical, 2112 kg ha^{-1} for sub-tropical x temperate, 2095 kg ha^{-1} for sub-tropical x sub-tropical and 1868 kg ha^{-1} for temperate x temperate crosses. The mean grain yields for tropical x subtropical and tropical x temperate crosses were significantly different from the rest of the groups.

The results indicated that hybrids between parents from different adaptation groups gave higher heterosis for grain yield than those derived from similar genetic back ground. These results are in agreement with Vasal *et al* (1992) and Zada *et al* (1997) who reported that diversity among parents contributed to high heterosis in hybrids.

Results further revealed that hybrids involving inbred lines CML66 or CML40 in their parentage were observed high yielders showing good general combining ability while inbred lines NC298 and SW49-2 were good specific combiners for grain yield. These inbred lines in specific hybrid combinations should be further studied for their potential as commercial hybrids.

Maximum plant height (197 cm) and maximum ear height (98 cm) were observed for the tropical single cross hybrid CML42 x CML24 (Table 1). The minimum plant height (89 cm) and ear height (37.2 cm) were obtained from hybrid SY 29-2 x SY 15-1 which is due to the involvement of local parents and early maturity. The highest yielding hybrids CML40 x SY8-2 and K305 x CML66 had relatively shorter plant height of 166 cm and 132 cm, respectively. Hybrid CML40 x SY8-2 had ears comparatively at higher positions of 88 cm (located in the upper half of the plant) which may make it vulnerable to lodging. However, hybrid K 305 x CML-66 had ear height of 63 cm (located in the lower half). So this hybrid may best suit under our production environment having lodging resistance. CIMMYT'S (International Maize and Wheat Improvement Center, Mexico) tropical maize lines tended to impart maximum plant height and showed later maturity than the sub-tropical or temperate lines which is in agreement with Vasal *et al* (1992).

Minimum Anthesis-Silking Interval (ASI) of 1 day was recorded for the hybrids YUZP212 x CML23 and FR 239Y x CML40, while the maximum ASI (4 days) was noted for the hybrid CML127 x FR239Y. The top yielding hybrids showed better synchronization of silk and pollen as compared to the adapted local checks, Azam and Sarhad White. Hybrids

Table 2
Mean grain yield of different heterotic groups of maize hybrids

S. No.	Heterotic group	Grain yield (kg ha^{-1})
1	Tropical x Subtropical	2768 A
2	Tropical x Temperate	2655 A
3	Tropical x Tropical	2426 AB
4	Subtropical x Temperate	2112 BC
5	Subtropical x Subtropical	2095 BC
6	Temperate x Temperate	1868 C
Mean		2320
CV		7.65%

Means followed by different letters differ significantly at 5% level of probability.

CML40 x SY 8-2 and K 305 x CML66 had an ASI value of 2 days. These hybrids showed potential for adaptation in our climatic conditions suggesting their future usefulness in hybrid breeding programmmes.

The earliest maturing hybrid Gracia x B73Y took 87 days to harvest maturity which was probably due to the temperate parents involved in the cross. But it showed low yield potential (1047 kg ha^{-1}). It could be a better choice as an early maturing hybrid but, if maximum yield potential is to be realized, slightly later maturing hybrids could offer a good alternative. Hybrid CML30 x CML51 involving CIMMYT'S tropical lines was the latest maturing hybrid (106 days). The top yielding hybrids CML40 x SY 8-2 and K 305 x CML66 took 100 and 97 days to maturity respectively and they were only 4 to 9 days later respectively in maturity as compared to local checks. Although these hybrids were slightly late maturing than the improved local checks yet yield differences were large enough to justify their commercial production.

Maximum leaf area index (LAI) of 3.53 was obtained from the hybrid K 305 x CML66 while the minimum LAI value (1.02) was observed for the hybrid Sh 2-3 x Mo17W. High yielding hybrid CML40 x SY8-2 had LAI value of 3.1 which is below the optimum value (3.5-4.5) for optimal grain production. All the hybrids including four checks produced lower LAI values, which may be due to the stressful and poor production environment in Kharif 1997. Lower LAI value resulted correspondingly in lower yields in these hybrids.

References

Beck D L, Vasal S K, Crossa J 1991 Heterosis and combining ability among sub-tropical and temperate intermediate maturity maize germplasm, *Crop Sci* **31** 68-73.

Chaudhri H K 1971 *Heterosis of Hybrid Vigour, Elementary*

Principles of Plant Breeding. Oxford and IBH, New Delhi, India, 2nd ed, pp 122.

Fehr W R 1987 *Heterosis, Principles of Cultivar Development*. Macmillan, New York, Vol 1 pp 115-119.

Francis C A, Rutger J N, Palmer A F E 1969 A rapid method for plant leaf area estimation in maize. *Crop Sci* **9** (5) 537-539.

Ordas A 1991 Heterosis in crosses between American and Spanish Populations of maize. *Crop Sci* **31** 931-935.

Vasal S K, Srinivasan G , Gonzalez C, Han G C, Pandey S, Beck D L, Crossa J 1992 Heterosis and combining ability of CIMMYT's tropical x subtropical maize germplasm. *Crop Sci* **32** (6) 1483-1489.

Vasal S K, Dhillon B S, Srinivasan G, McLean S D, Zhang S H, Gonzalez C F 1994 Breeding inter-synthetic hybrids to exploit heterosis in maize. *Maydica* **39** (3) 183-186.

Zada K, Saleem M, Salam A T 1997 Extent of inter-racial heterosis in short duration maize hybrids. *Book of Abstracts*. The genetics and exploitation of heterosis in crops, Mexico city, Mexico, August 17-22, 1997.