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Use of inbred testers for evaluating combining ability in modified single cross hybrids of maize

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Abstract

Modified single cross hybrids were derived and tested at two diverse locations. Line × Tester analysis was carried out to determine the combining ability of parents through their crosses. Over all combining ability studies across all the characters were studied namely days to 50 percent tasseling, days to 50 per cent silking, plant height and ear traits like kernel rows per ear, kernels per row and grain yield per plot. From the present study it is inferred that among the sister line crosses used as female parents, ($A_1 \times A'_1$), ($A_7 \times A'_7$), ($A_8 \times A'_8$), ($A_{10} \times A'_{10}$) and ($A_{11} \times A'_{11}$) are the best general combiners. Among the exotic testers that were used CML290 was found to be the best combiner. The indigenous tester CM111 widely used in the Indian Maize programme also showed its potential as a good tester. Among the crosses [($A_4 \times A'_4$) × CML247], [$A_8 \times A'_8$) × CML247], [($A_5 \times A'_5$) × CML254] and the crosses of [($A_9 \times A'_9$) × CML254], [($A_1 \times A'_1$) × CML290] [($A_{10} \times A'_{10}$) × CML290] and [($A_{11} \times A'_{11}$) × CML290] showed high specific combining ability status.

Key words: Modified single cross hybrids, inbred testers, sisterline crosses, combining ability, *Zea mays* L.

Introduction

Modified single cross hybrids are obtained by crossing sister line crosses (A × A') as female parent with an inbred line. The sister line cross is used to obtain a higher seed yield from the female parent. This is a way of overcoming the limitation of poor yield of inbred lines *per se* in commercial seed production. In the present study, inbred lines and sister lines were derived and consequently sister line crosses were developed from them. The combining ability of these sister line crosses was subsequently assessed using different inbred testers. This was to provide useful information on the performance of these SLCs in combination with diverse inbred testers and ultimately to identify the best combining ones.

Materials and methods

At the Directorate of Maize Research, a narrow based pool of full season maturity, CMIP 2-7 (> 120 days duration) of yellow grain type was developed in the early nineties. This pool had desirable characters like relative tolerance to stem borer (*Chilo partellus*), and Sorghum Downy mildew (*Sclerospora graminicola*) the major pests affecting Maize crop in India. This pool had been improved by S1 recurrent selection for desirable agronomic traits like standability, vigor and inbreeding tolerance. In this pool, selfing was carried out for three generations. The families were raised in an ear-to-row manner and in S2 generation, sister lines were developed in promising families. These lines and sister lines were advanced further for three more cycles. Based on the test cross performance in S3, the lines and sister lines of 11 promising families were selected. Subsequently lines and corresponding sister lines were crossed to derive 11 sister line crosses (SLCs) in the Rabi season of 1995-96. In Kharif 1996, these SCLs were raised and crossed to four promising diverse inbred testers namely CML247, CML254, CML290 (exotic testers from CIMMYT, Mexico) and CM 111 (an indigenous tester widely used in the Indian Maize program). Thus 44 Modified Single cross hybrids were derived. In Rabi 1996-97, these 44 MSCHs were grown in a Completely Randomized Block design at two diverse locations namely Hyderabad and Karimnagar. Each entry was raised in a 5 M long row with a inter row spacing of 0.75 M and an intra row spacing of 0.25m. Fertilizer was applied @ 120:60:60 kg/ha with N (in 3 split doses) : P_2O_5 (basal): K_2O (basal). Hyderabad location has deep black loam soils while Karimnagar has red sandy loam soils. The data was recorded on traits like days to 50 percent tasseling, days to 50 per cent silking, plant height and ear traits like kernel rows per ear, kernels per row and grain yield per plot (kg). The grain yield was adjusted to 20 plants per plant stand and 15% grain moisture.

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Combining ability analysis was carried out using Linex Tester analysis of Kempthorne (1962). The Bartlett's Test of homogeneity of error variances was carried out to pool the data across the two locations for each of the characters studied.

To get an over all picture of combining ability estimates, the pooled estimates of combining ability were used to work out the over all combining ability as given by Arunachalam and Bandyopadhyay (1979). Here for each character, the combining ability effects that were found to be statistically significant were given a value of '1' with the commensurate sign. The non significant combining ability estimates were given a '0' value. Finally for each entry, across the characters studied, these '0' and '1' values were added up. In the cumulative marginal score thus obtained for each entry, the sum of scores was calculated. Those of the entries which had a cumulative score equal to or more than the sum of scores were considered to have high over all combining ability status. The entries with scores less than the score mean were considering to have low over all combining ability status.

Results and discussion

In the trial of the Modified single cross hybrids, at both the locations, the ANOVA exhibited significant differences for yield and associated characters studied. The data across the two locations for each character studied were pooled after carrying out the Bartlett's test and verifying the homogeneity of error variances to enable combined analysis.

An important consideration in determining the utility of inbred lines developed is their combining ability. Starting from a general description, the concept of combining ability was subsequently refined into General and Specific combining ability by Sprague and Tatum (1942). Hayes (1963) defined general Combining ability (gca) as the comparative ability of a group of inbreds to combine with a tester or a group of testers. GCA expressed as a statistic shows the extent of deviation of the mean yield of the single crosses involving each inbred from the averages of all single crosses. He defined Specific Combining Ability (sca) as the deviation in performance of a specific single cross from the performance expected on the basis of gca. The statistical constant for sca expresses the extent of deviation of individual crosses in which this inbred is one parent, from the mean of all Single crosses of that inbred with other inbreds. The method seems of greatest interest as a means of comparing the relative magnitude of gca and sca in a group of inbreds. General and Specific combining ability have had a significant impact on inbred line evaluation and population improvement in maize breeding (Hallauer and Miranda, 1988).

Line × Tester analysis carried out to estimate the combining ability effects also showed significant differences between lines (sister line crosses), testers and Line × Tester interaction (modified single cross hybrids) for most of the characters studied (Table 1) except plant height.

The studies on pooled General combining ability effects summarised in Table 2 showed that among the Sister line crosses used as the female parents, ($A_1 \times A'_1$), ($A_6 \times A'_6$), ($A_9 \times A'_9$) and ($A_{10} \times A'_{10}$) showed positive and significant gca effects for grain yield and most of the related characters studied. ($A_2 \times A'_2$), ($A_3 \times A'_3$) and ($A_5 \times A'_5$) showed negative and significant gca effects for most of the characters studied. Among the testers, CML 290 and CM111 showed positive and significant gca effects for majority of the characters studied. CML247 and CML251 showed negatively significant differences for grain yield and many other traits studied.

Studies on pooled specific combining ability effects are summarised in the Tables 3 and 4. The crosses of the SLCs ($A_5 \times A'_5$) and (A_8 and A'_8) with the tester CML247 showed significant and positive sca effects for yield and most of the related traits. The crosses of the tester CML254 showed significant and positive sca effects for yield in respect of the SLCs

Table 1. Line x Tester analysis for various characters pooled across the two locations

Source	df	Mean Squares					
		Days to 50% Tasseling	Days to 50% silking	Plant height	Kernel rows per ear	kernels per row	Grain yield per plot
Locations	1	438.30*	283.50*	469656**	15.35	1581.60**	3.64**
RWL+	4	46.77*	26.14**	1198.7**	4.05	44.12*	1.69**
Treatments	43	35.61**	33.49**	458.6*	5.97**	58.66**	3.13**
Lines (L)++	10	110.47**	90.34**	518.59	17.92**	191.46**	3.12**
Testers (T)	3	77.95**	123.95**	265.17	6.51*	55.81*	5.89**
L × T	30	6.43**	5.49**	457.79**	1.93**	14.68**	0.75**
Pooled error	172	0.79	0.74	37.55	0.25	1.88	0.05

+ Replications within locations; ++Sister line crosses; *,**Significant at P = 0.01 & 0.05 respectively.

Table 2. General combining ability effects of parents for various characters pooled across the locations

Parents	GCA effects					
	Days to 50% tasseling	Days to 50% silking	Plant height (cm)	Kernel rows per ear	Kernels per row	Grain yield per plot (Kg)
Sister line cross						
$(A_1 \times A'_1)$	2.23**	1.88**	5.39**	1.54**	2.45**	0.56**
$(A_2 \times A'_2)$	0.44*	0.34**	1.58	–0.16	–.87**	–0.19**
$(A_3 \times A'_3)$	–0.98**	–1.21**	–3.73**	1.13**	–0.61*	–0.16**
$(A_4 \times A'_4)$	–0.61**	–1.05**	–1.98	–0.73**	–3.45**	–0.06
$(A_5 \times A'_5)$	–.19**	–4.29**	–0.93	–0.68**	–1.52**	–0.62**
$(A_6 \times A'_6)$	–1.19**	–0.91**	4.13**	–1.36**	–0.79**	0.42**
$(A_7 \times A'_7)$	2.52**	2.09**	–5.25**	0.60**	–1.19**	–0.08
$(A_8 \times A'_8)$	0.35	–0.03	–0.57	0.18	3.75**	–0.08
$(A_9 \times A'_9)$	–0.44**	–0.37*	4.7**	–0.16	–0.33	0.33**
$(A_{10} \times A'_{10})$	1.89**	2.63**	–3.31**	–0.69**	4.23**	0.18**
$(A_{11} \times A'_{11})$	0.98**	0.92**	9.38**	0.31**	1.12**	0.08
Testers						
CML247	–0.07	0.41**	–2.82**	–0.33**	–0.58**	–0.27**
CML254	–0.19**	–1.42**	1.73*	–0.14*	–0.09	–0.22**
CML290	–0.18	0.71**	1.05	0.40**	1.33**	0.38**
CM111	1.44**	1.72**	0.05	0.07	0.65**	0.12**

*,**Significant at P = 0.01 & 0.05 respectively

Table 3. Pooled Specific combining ability effects for Days to 50 percent tasseling, silking and plant height

Parent	SCA Effects of crosses with											
	Days to 50% Tasseling				Days to 50% silking				Plant height (cm)			
	CML47	CML254	CML290	CM111	CML247	CML254	CML290	CM111	CML247	CML254	CML290	CM111
$(A_1 \times A'_1)$	0.86*	–0.35	–0.03	–0.49	–0.12	0.05	0.17	–0.09	0.86	–3.11	–1.47	3.72
$(A_2 \times A'_2)$	0.65	–0.89*	–0.24	0.47	0.75	–1.08**	0.04	0.28	6.32*	–2.16	–9.95**	5.79*
$(A_3 \times A'_3)$	0.57	0.53	0.44	–0.44	–0.20	1.29**	–0.42	–0.67	0.44	0.41	–6.17*	5.33*
$(A_4 \times A'_4)$	1.86**	–1.68**	–0.03	–0.15	1.29**	–1.54**	0.42	–0.17	–7.68**	1.63	3.74	2.29
$(A_5 \times A'_5)$	–1.89**	0.07	0.39	1.43**	0.54	–0.79*	–0.17	0.41	12.24**	–5.38*	–5.74	–1.12
$(A_6 \times A'_6)$	–0.22	1.40**	–0.45	–0.74*	0.50	0.84*	–0.87*	–0.47	–17.88**	3.41	6.11*	8.35**
$(A_7 \times A'_7)$	0.91*	–0.47	0.01	–0.44	0.17	0.17	0.63	–0.97**	4.49	3.99	–0.35	–8.14**
$(A_8 \times A'_8)$	0.24	0.19	–1.16**	0.72*	–0.04	0.29	–1.08**	0.83	16.09**	–2.04	4.83	–.88**
$(A_9 \times A'_9)$	–1.14**	–0.18	0.47	0.85*	–0.21	–0.87*	0.08	0.99**	6.98**	–1.48	–4.65	–0.84
$(A_{10} \times A'_{10})$	0.03	0.82**	0.14	–0.98*	–0.04	0.79*	–0.08	–0.67	–9.50**	0.38	12.24*	–3.12
$(A_{11} \times A'_{11})$	–1.89**	0.57	–1.55**	–0.23	–2.66**	0.84*	1.29**	0.53	–12.39**	4.35	1.41	6.63**

*,**Significant at P = 0.01 & 0.05 respectively

$(A_4 \times A'_4)$, $(A_7 \times A'_7)$ and $(A_9 \times A'_9)$. The crosses of the tester CML290 showed significant and positive sca effects for yield and some related traits with the SLCs $(A_{10} \times A'_{10})$ and $(A_{11} \times A'_{11})$. For the crosses with the tester CM111, the SLCs $(A_2 \times A'_2)$ and $(A_3 \times A'_3)$ showed positive and significant sca effects for grain yield and some of the related traits studied. Thus in the material under study diverse combining ability effects of parents reflects the inherent genetic variation for yield and its component traits.

Over all combining ability status of parents and crosses

After the estimates of general and specific combining ability effects were obtained for each character separately the general picture of the combining ability of parents and crosses pooled over all the characters studied was obtained from an assessment of he overall combining ability status of parents and crosses carried out following the method given by Arunachalam and Bandhyopahyay (1979). The score

Table 4. Pooled spceific combining ability effects of crosses for kernel rows per ear, kernels per row and grain yield per plot

Parent	SCA effects of crosses with											
	CML247	CML254	CML290	CM111	CML247	CML254	CML290	CM111	CML247	CML254	CML290	CM111
	Kernel rows per ear				Kernels per row				Grain yield per plot			
$(A_1 \times A'_1)$	–0.42*	–0.40	0.59**	0.23	0.29	–1.13*	0.12	0.71	0.02	–0.54**	–0.11	0.63**
$(A_2 \times A'_2)$	–0.12	–0.04	–0.41*	0.56**	–0.41	–0.67	0.99	0.09	0.06*	–0.27**	–0.08	0.28**
$(A_3 \times A'_3)$	0.45*	0.28	–0.60*	–0.13	0.64	1.67**	0.13	–2.44**	–0.10*	–0.10	–0.32**	0.45**
$(A_4 \times A'_4)$	0.41*	0.15	–0.50*	–0.06	–1.74**	–0.10	–0.54	2.39**	–0.04	0.29**	–0.19*	0.06
$(A_5 \times A'_5)$	0.01	0.26	–0.11	–0.17	0.02	–0.97	1.23*	–0.28	0.42**	0.09	–0.41	–0.10
$(A_6 \times A'_6)$	0.32	–0.24	–0.73**	0.65**	2.39**	0.31	–2.52**	–0.19	0.42**	0.04	–0.35**	–0.11
$(A_7 \times A'_7)$	–0.15	0.20	–0.07	0.02	–3.65**	1.72**	1.57**	0.36	–0.15	0.23*	–0.18	–0.11
$(A_8 \times A'_8)$	–0.19	–0.19	–0.16	0.26	0.09	0.38	–0.13	1.20*	–1.45**	0.34**	–0.17	0.08
$(A_9 \times A'_9)$	0.03	1.19**	–0.47*	–0.75**	2.14**	0.10	–2.49**	0.24	–0.45**	0.74**	–0.08	–0.21*
$(A_{10} \times A'_{10})$	0.06**	–0.45*	0.53*	–0.14	–1.04	0.19	0.51	0.34	–0.21*	–0.14	0.61**	–0.26**
$(A_{11} \times A'_{11})$	–0.42*	–0.78**	1.51**	–0.30	0.97	–0.99	–0.20	0.23	–0.31**	0.04	0.27**	0.01

*,**Significant at P = 0.05 & 0.01 respectively

Table 5. Over all general combining ability status of parents based on six Quantitative characters pooled over two locations

Status	Scores	Parents
Sister line crosses (Female parents)		
HIGH	6	$(A_1 \times A'_1)$
	5	$(A_{11} \times A'_{11})$
	2	$(A_{10} \times A'_{10})$
	1	$(A_7 \times A'_7)$
		$(A_8 \times A'_8)$
LOW	0	$(A_2 \times A'_2)$
	0	$(A_9 \times A'_9)$
	–2	$(A_6 \times A'_6)$
	–4	$(A_3 \times A'_3)$
		$(A_4 \times A'_4)$
	– 5	$(A_5 \times A'_5)$
Testers (Male parents)		
HIGH	4	CML290
	4	CM111
Low	–3	CML254
	–3	CML247

and status presented in tables 5 and 6 were based on six quantitative characters averaged over the two locations which indicate that the female parents $(A_1 \times A'_1)$, $(A_7 \times A'_7)$, $(A_8 \times A'_8)$, $(A_9 \times A'_9)$, $(A_{10} \times A'_{10})$ and $(A_{11} \times A'_{11})$ as also the testers CML 290 and CM111 received scores above the norm and are classified as having high overall combining ability status. All the best combining female parents had different highest scores while among the male parents the best combining tester CML290 shared the same highest score [4] with the tester CM111. Among SLCs (A5 × A'_5) [–5] and among testers CML247 [–4] and CML254 [–2] got the lowest scores. CML247 and CML254 are among the best combining lines at CIMMYT. The results from this study confirm that combining ability is a relative term specific to the material under study.

Table 6. Overall specific combining ability status of crosses based on six quantitative characters pooled over two locations

Status	Scores	Crosses
HIGH	5	$[(A_5 \times A'_5) \times$ CML247]
	4	$[(A_4 \times A'_4 \times$ CML254], $[(A_9 \times A'_9) \times$ CML254], $[(A_2 \times A'_2) \times$ CM111]
	3	$[(A_8 \times A'_8) \times$ CML247], $[(A_{10} \times A'_{10} \times$ CL290], $[(A_6 \times A'_6) \times$ CM111]
	2	$[(A_2 \times A'_2) \times$ CML247], $[(A_7 \times A'_7) \times$ CML254], $[(A_1 \times A'_1) \times$ CML290], $[(A_8 \times A'_8) \times$ CML290], $[(A_{11} \times A'_{11}) \times$ CML290], $[(A_3 \times A'_3) \times$ CM111], $[(A_5 \times A'_5) \times$ CML254], $[(A_1 \times A'_1) \times$ CM290]
	1	$[(A_1 \times A'_1) \times$ CM111], $[(A_{10} \times A'_{10}) \times$ CM111], $[(A_{11} \times A'_{11}) \times$ CM111]
Low	0	$[(A_3 \times A'_3) \times$ CML247], $[(A_6 \times A'_6) \times$ CML247], $[(A_9 \times A'_9) \times$ CML247], $[(A_{10} \times A'_{10}) \times$ CML247111]
		$[(A_2 \times A'_2) \times$ CML 254], $[(A_5 \times A'_5) \times$ CML254], $[(A_8 \times A'_8) \times$ CML254], $[(A_6 \times A'_6) \times$ CML290], $[(A_7 \times A'_7) \times$ CML290], $[(A_4 \times A'_4) \times$ CM111]
	–1	$[(A_7 \times A'_7) \times$ CML247], $[(A_1 \times A'_1) \times$ CML254], $[(A_9 \times A'_9) \times$ CML290], $[(A_5 \times A'_5) \times$ CM111]
	–2	$[(A_4 \times A'_4) \times$ CML247], $[(A_{11} \times A'_{11}) \times$ CML247], $[(A_3 \times A'_3) \times$ CML254], $[(A_{11} \times A'_{11}) \times$ CML 254], $[(A_2 \times A'_2) \times$ CML290], $[(A_3 \times A'_3) \times$ CML290], $[(A_5 \times A'_5 \times$ CML290]
	–3	$[(A_1 \times A'_1) \times$ CML247], $[(A_6 \times A_6) \times$ CML 254], $[(A_4 \times A'_4) \times$ CML290]
	–4	$[(A_{10} \times A'_{10}) \times$ CML254], $[(A_8 \times A'_8) \times$ CM111]
	–5	$[(A_9 \times A'_9) \times$ CM111]

When overall combining ability status of the crosses was carried out it was noticed that as many as 18 of the 44 crosses were found in the high category (Table 6). The crosses [(A_5 × A'_5) × CML247], [(A_4 × A'_4) × CML254], [(A_9 × A'_9) × CML254] and [(A_2 × A'_2) × CM111] received the highest score of 4 while the cross [(A_9 × A'_9) × CM111] received the lowest score [–5]. Combined analysis showed that of the 18 best specific combining crosses, seven crosses had both parents with high combining ability status (H × H), six crosses had one high combining parent and one low combining parent (H × L) and five crosses had both low combining parents (L × L).

In most of the cases, the final selection of parents or crosses is mostly influenced by results on grain yield though it has been established that the other characters are much more heritable than grain yield and have significant direct bearing on yield. This method of determining the overall combining ability status would help to detect the potential of a parent or a cross based on all the important characters. In the present investigation, the genetic worth of parents and crosses were assessed following this method.

Diverse testers were used in the study and these testers in general differentiated well among the lines and crosses. Among the exotic testers CML290 was the best combiner. The indigenous tester CM111 also combined well and differentiated the female parents being tested.

Conclusion

From the present study it is inferred that among the sister line crosses (SLCs) (A_1 × A'_1), (A_7 × A'_7), (A_8 × A'_8), (A_{10} × A'_{10}) and (A_{11} × A'_{11}) are the best combiners. Among the exotic inbred testers used from CIMMYT, CML290 was found to be the best combiner. The indigenous inbred tester CM111 also reinforced its utility as a good tester. Among the crosses [(A_5 × A'_5) × CML247], [(A_4 × A'_4) × CML254], [(A_9 × A'_9) × CML254], [(A_{10} × A'_{10}) × CML290], (A_{11} × A'_{11}) × CML290] and [(A_2 × A'_2) × CM111], were the best over all specific combiners. These SLCs and promising crosses can be tested extensively over environments in the future and good performers can be utilised profitably by the Maize breeders. Combination of these Sister line crosses can be tried with newer lines to develop more potential Modified Single cross hybrids.

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