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STUDIES ON COMBINING ABILITY THROUGH LINE X TESTER ANALYSIS IN MAIZE

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ABSTRACT

Combining ability analysis was carried out in 60 single cross hybrids derived from line x tester mating design (15 x 4) for grain yield and its component traits. The study revealed highly significant mean squares due to hybrids, lines, testers and line x tester for all the characters studied except anthesis silking interval and ear diameter in case of lines indicating significant contribution of lines and testers towards gca variance and line x tester towards sca variance. Higher magnitude of δ^2 sca in relation to δ^2 gca implied the greater importance of non-additive gene effects in the inheritance of grain yield plant^{-1} and its component traits. The parental lines L_{12}, L_1 and L_3 and testers T_1, T_2 and T_4 were excellent general combiners for grain yield plant^{-1} as well as major yield contributing traits and could be used in hybrid breeding programme for the development of superior hybrids. Considering the per se performance, sca effects and economic heterosis, six crosses viz., L_{12} x T_4, L_1 x T_1, L_1 x T_2, L_3 x T_1, L_3 x T_2 and L_{12} x T_2 could effectively be utilized for developing high yielding hybrids as well as for exploiting hybrid vigour. These crosses need to be evaluated for extensive testing to verify stability of their performance.

Key words: Combining ability, gene effects, grain yield, hybrid vigour, yield contributing traits

INTRODUCTION

Maize (*Zea mays* L.) also known as corn is one of the oldest and the third most important cereal food crop of the world after wheat and rice. It is a unique crop which can be used at any stage of its growth, and can be used as food, feed or fodder, in addition to hundreds of industrial uses. It is a highly cross pollinated crop and there is a wide scope for exploitation of hybrid vigour. Already this phenomenon has been successfully exploited and still there is a tremendous potential to develop several high yielding hybrids and composites. Combining ability analysis is one of the powerful tools in identifying the best combiners that may be used in crosses either to exploit heterosis or to accumulate productive genes. It also helps to understand the genetic architecture of parents, their mode of inheritance that enables the breeder to design appropriate breeding methodology to incorporate the traits in question. Line x tester analysis is one of the methods employed by which the genetic architecture of a given character, the combining ability and heterosis could be understood. Hence, in the present investigation, attempts have been made to evaluate nineteen parents (fifteen lines, four testers) and 60 hybrids generated through line x tester analysis along with four standard checks to bring out the best parents and cross combination with good general and specific combining abilities for grain yield and its component traits.

MATERIALS AND METHODS

Fifteen diverse yellow seeded inbred lines of maize *viz.*, L_1 (HKI 295), L_2 (HKI 536), L_3 (V 351), L_4 (HKI 3-4-8-5ER), L_5 (HKI 3-4-8-6ER), L_6 (HKI 323-8), L_7 (HKI 1332), L_8 (HKI 1532), L_9 (LM 13), L_{10} (LM 16), L_{11} (HKI 193-1), L_{12} (HKI 161), L_{13} (HKI 163), L_{14} (HKI 192) and L_{15} (LTP 1) were crossed with four testers *viz.*, T_1 (WI 241), T_2 (WI 249), T_3 (WI 263) and T_4 (WI 275) in a line x tester mating design to generate 60 hybrids during *rabi*, 2008-09. These 60 hybrids and 19 parental lines along with four standard checks *viz.*, Bio 9681, Prabal, PEHM 2 and Mahi Kanchan were evaluated in randomized block design with three replications, in a single row plot of 5.0 meters length having 60 cm x 25 cm crop geometry, at Agricultural Research Station, Banswara (Rajasthan) during *kharif*, 2009. The data were recorded on ten randomly selected competitive plants of each genotype in each replication for plant height, ear height, ear length, ear diameter, anthesis silking interval (ASI), leaves plant^{-1}, kernel rows ear^{-1}, 100-kernel weight, harvest index, stover yield plant^{-1} and grain yield plant^{-1}, while days to 50 per cent tesseling and days to 50 per cent silking were recorded on whole plot basis. Combining ability analysis was carried out according to the procedure given by Kempthorne (1957). Economic heterosis (against the standard check single cross hybrid Bio 9681) was estimated and tested according to Singh and Singh (1994).

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RESULTS AND DISCUSSION

The analysis of variance for combining ability (Table 1) indicated that mean squares due to hybrids, lines, testers and line x tester were significant for all the characters studied except anthesis silking interval and ear diameter in case of lines. These results revealed significant contribution of lines and testers towards gca variance and line x tester towards sca variance. Based on estimates, higher magnitude of δ^2 sca in relation to δ^2 gca implied the greater importance of non-additive gene effects in the inheritance of maturity related traits, grain yield plant^{-1} and its component traits. These results are in conformity with the findings of Dodiya and Joshi (2002), Amiruzzaman *et al.* (2010) and Sundararajan and Senthil Kumar (2011). Prevalence of greater magnitude of non-additive genetic component of variance in relation to additive gene effects in present study favours production of hybrid cultivars for increasing productivity in maize.

Table 1: Analysis of variance for different characters in maize

Source	d. f.	Days to 50 % tasseling	Days to 50% silking	ASI	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Kernel rows Ear^{-1}	100-grain weight (g)	Harvest index (%)	Grain yield plant^{-1} (g)
Replication	2	5.145	5.233	0.486*	58.640	8.108	1.176**	0.183	1.425	1.807**	5.792	31.114
Genotype	82	27.819**	30.943**	0.410**	702.480**	467.692**	3.921**	1.061**	4.491**	29.086**	40.564**	386.031**
Checks	3	100.444**	114.778**	0.556*	368.048*	398.701**	0.773**	0.250	0.626	18.318**	4.608	93.208**
Check v/s Parent	1	6.740	9.398	0.220	7134.633**	476.350**	0.572	5.254**	6.386**	3.578**	395.225**	3217.244**
Parent	18	10.754	11.086	0.351**	197.347	264.403**	2.936**	0.452*	1.433*	21.406**	10.336**	46.956**
Tester	3	2.889	4.556	0.556*	135.170	299.672**	2.664**	0.296	1.559	12.146**	7.966	30.860
Line	14	12.438	12.756	0.308*	214.147	273.099**	3.203**	0.511*	1.410	24.587**	11.494**	52.714**
Tester v/s Line	1	10.779	7.299	0.338	148.688	36.849	0.021	0.090	1.392	4.653**	1.235	14.628
Parent v/s Hybrid	1	4.878	4.381	0.013	15346.736**	99.774	0.850*	1.218*	0.778	31.689**	1980.083**	19623.256**
Hybrids	59	30.130**	33.610**	0.429**	606.911**	540.918**	4.497**	1.234**	5.601**	32.425**	19.160**	184.197**
Tester	3	43.748**	46.800**	0.222	6878.071**	5893.998**	4.591**	0.595	7.780**	71.432**	39.763**	408.018**
Lines	14	39.510**	41.796**	0.345**	402.744**	357.664**	7.424**	2.294**	10.296**	53.128**	33.998**	342.386**
Line x Tester	42	26.030**	29.939**	0.472**	227.027**	219.639**	3.514**	0.926**	3.880**	22.738**	12.742**	115.480**
Error	164	7.380	7.595	0.157	131.411	66.868	0.176	0.249	0.828	0.154	3.124	20.790
δ^2 gca		19.955	21.258	0.112	383.170	363.870	4.375	1.204	5.755	33.277	19.231	200.508
δ^2 sca		261.090	312.820	4.418	1338.600	2138.800	46.728	9.473	42.735	316.180	134.660	1325.700

** and ** significant at P = 0.05 and 0.01, respectively*

General combining ability (gca) effects:

The gca effects of the parents (lines and testers) revealed that none of the parents were found to be a good general combiner for all the characters studied (Table 2). A wide range of variability of gca effects was observed among the parents. In the present study, parents were classified as high, average and low combiners based on their effects. Parents with desirable significant gca effects (significantly different from zero) were considered as high combiners, while parents showing insignificant estimates were classified as average combiners. Low or poor combiners had significant estimates but negative (undesirable) gca effects. The good general combiner lines for major yield determining characters were L_1, L_{12} and L_3 for ear length, ear diameter, kernel rows ear^{-1} and 100-grain weight, while among testers T_4 and T_1 were good general combiners for ear length and 100-grain weight. Positive estimates for these traits are desirable since they directly contribute to yield in maize. The parental lines L_{12}, L_1 and L_3 and testers T_1, T_2 and T_4 were identified as the best general combiners for grain yield plant^{-1}. They also showed significant positive gca effects for major yield contributing characters and simultaneously possessed high mean values indicating that *per se* performance of the parent could prove as an useful index for combining ability. Hussain *et al.* (2003), Uddin *et al.* (2006) and Amiruzzaman *et al.* (2010) also observed the similar phenomenon. The overall study of gca effects suggested that parental lines L_{12}, L_1 and L_3 and testers T_1, T_2 and T_4 were excellent general combiners for yield and all the yield contributing traits and could be used extensively in hybrid breeding programme with a view to obtaining higher yield and desirable traits. Parental line L_{12} and tester L_{12} showed significant negative gca effects both for days to tasselling and days to silking and use of these parents might be useful in developing early hybrid varieties. Hussain *et al.* (2003) and Uddin *et al.* (2006) also found inbred line(s) as good general combiner for early maturity in their study.

Table 2: General combining ability effects of the parents for grain yield and its component traits in maize

Parents / Inbred lines	Days to 50 % tasseling	Days to 50% silking	ASI	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Kernel rows Ear^{-1}	100-grain weight (g)	Harvest index (%)	Grain yield plant^{-1} (g)
Lines											
L_1	1.32	1.16	-0.17	1.88	3.16	1.70**	0.89**	1.60**	4.51**	2.50**	9.16**
L_2	-0.01	-0.26	-0.25*	5.37	6.91**	-0.56**	-0.17	0.09	0.95**	0.22	-0.53
L_3	2.24**	2.66**	0.42**	-4.68	-5.21*	0.67**	0.38*	0.85**	2.20**	0.44	2.69*
L_4	2.57**	2.41**	-0.17	2.57	3.06	-0.10	-0.18	-0.36	-2.56**	1.23*	1.88
L_5	2.07*	2.07*	0.00	-8.92**	-5.04*	0.18	0.07	0.35	-0.66**	-0.29	-0.98
L_6	-0.09	-0.09	0.00	10.80**	5.46*	-0.37**	0.14	-0.08	0.48**	-0.59	-0.50
L_7	-1.01	-0.93	0.08	-3.43	-6.52**	-0.66**	-0.58**	-0.80**	-0.48**	-1.53**	-3.37*
L_8	-2.43**	-2.51**	-0.08	-7.98*	0.24	0.17	0.02	-0.06	1.51**	1.42**	2.40
L_9	-1.93*	-1.93*	0.00	-0.56	-3.99	-0.06	-0.05	-0.10	-1.44**	-0.15	-1.32
L_{10}	-0.43	-0.43	0.00	1.39	5.71*	-0.88**	-0.26	-0.40	-1.58**	-0.76	-1.44
L_{11}	2.16**	2.24**	0.08	0.27	2.28	0.10	-0.27	-0.35	-1.62**	0.17	-1.59
L_{12}	-2.43**	-2.59**	-0.17	-6.95*	-9.39**	1.37**	0.84**	1.84**	2.67**	2.88**	9.87**
L_{13}	-0.01	-0.01	0.00	6.58	4.13	-0.18	-0.11	0.20	-0.64**	-0.06	0.23
L_{14}	0.57	0.82	0.25*	-2.47	-6.14*	-1.30**	-0.67**	-1.71**	-3.38**	-3.94**	-13.06**
L_{15}	-2.59**	-2.59**	0.00	6.11	5.36*	-0.07	-0.05	-1.08**	0.04	-1.55**	-3.44*
SE ±	0.81	0.82	0.12	3.42	2.44	0.13	0.15	0.27	0.12	0.53	1.36
SE (g_i-g_j) lines	1.11	1.13	0.16	4.68	3.34	0.17	0.20	0.37	0.16	0.72	1.86
Testers											
T_1	-0.56	-0.49	0.07	17.18**	15.47**	0.20**	0.04	0.22	0.40**	0.98**	3.01**
T_2	-1.07*	-1.16*	-0.09	0.53	1.86	-0.42**	0.01	0.24	1.21**	0.47	1.73*
T_3	0.53	0.51	-0.02	-7.10**	-8.52**	-0.07	-0.16	-0.62**	-1.76**	-1.19**	-3.88**
T_4	1.09*	1.13*	0.04	-10.61**	-8.81**	0.29**	0.11	0.17	0.15*	-0.26	1.60*
SE ±	0.45	0.46	0.07	1.91	1.36	0.07	0.08	0.15	0.07	0.29	0.76
SE (g_i-g_j) testers	0.57	0.58	0.08	2.42	1.72	0.09	0.11	0.19	0.08	0.37	0.96

** and ** significant at P = 0.05 and 0.01, respectively*

Specific combining ability (sca) effects:

The sca effects of the crosses for yield and different yield contributing characters are presented in table 3. Out of 60 F_1s, eight crosses *viz.*, L_{12} x T_4, L_1 x T_1, L_1 x T_2, L_3 x T_1, L_3 x T_2, L_{12} x T_2, L_4 x T_1 and L_8 x T_4 showed significant positive sca effects for grain yield plant^{-1}. These eight crosses also possessed significant positive sca effects for other yield contributing traits like ear length, ear diameter, kernel rows ear^{-1} and 100-grain weight. The significant positive sca effects for ear length, ear diameter, kernel rows ear^{-1} and 100-grain weight are more frequently associated with significant estimates of sca effects of grain yield. The positive relationship of sca effects of grain yield and yield contributing traits were also observed by Rokadia and kaushik (2005) and Amiruzzaman *et al.* (2010). Among the eight promising crosses showing significant positive sca effects, six crosses viz., L_{12} x T_4, L_1 x T_1, L_1 x T_2, L_3 x T_1, L_3 x T_2 and L_{12} x T_2 involving high x high general combiners showed high sca effects and indicating the predominance of additive x additive type of gene effects and two crosses *viz.*, L_4 x T_1 and L_8 x T_4 exhibited significant sca effects which involved one good and one poor general combiners, indicating additive x dominance type of gene interaction involved in the expression of characters. Similar results have also been reported by Rokadia and kaushik (2005), Ojo *et al.* (2007), Amiruzzaman *et al.*

Table 3: Estimates of SCA effects of promising single cross hybrids for grain yield and its contributing traits with economic heterosis and *per se* performance in maize

Promising Hybrids	Days to 50% tasseling	Days to 50% silking	ASI	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Kernel rows ear^{-1}	100-grain weight (g)	Harvest index (%)	Grain yield plant^{-1} (g)	*Per se* Performance	gca effect		Heterosis	
													Female	Male	Heterobeltiosis	Economic heterosis (over Bio- 9681)
Promising Crosses																
L_{12} x T_4	0.16	0.28	0.12	16.22*	10.36	0.57*	0.47	0.25	3.74**	2.66*	11.50**	89.46	9.87** H	1.60* H	78.84**	25.58**
L_1 x T_1	0.06	0.16	0.10	-10.11	-10.34	-0.17	0.58	0.63	1.35**	1.24	5.29	86.28	9.16** H	3.01** H	58.84**	21.11**
L_1 x T_2	-1.43	-1.18	0.26	5.18	5.61	1.32**	0.46	1.01	1.23**	2.50*	4.55	84.13	9.16** H	1.73* H	54.89**	18.10**
L_3 x T_1	-4.53*	-4.68*	-0.15	0.08	-5.40	0.74**	0.76*	1.12	2.18**	2.27	6.71*	81.23	2.69* H	3.01** H	57.03**	14.02**
L_3 x T_2	-1.68	-2.01	-0.33	9.64	5.74	1.14**	0.84*	1.03	1.12**	2.00	6.93*	80.04	2.69* H	1.73* H	57.03**	12.36*
L_{12} x T_2	1.32	1.24	-0.08	0.48	-3.48	1.37**	0.08	0.45	-2.69**	0.72	-1.03	79.26	9.87** H	1.73* H	58.45**	11.26*
L_4 x T_1	-3.19	-3.43	-0.23	1.11	-5.30	1.13**	0.64	1.73**	3.36**	1.34	5.18	78.89	1.88 M	3.01** H	52.51**	10.74*
L_8 x T_4	1.49	2.20	0.71**	3.72	-8.80	0.65*	1.00**	2.15**	1.37**	3.09**	8.31**	78.81	2.40 M	1.60* H	52.44**	10.63*
SE ±	1.81	1.84	0.26	7.64	5.45	0.28	0.33	0.61	0.26	1.18	3.04					
SE (S_{ij}-S_{kl})	2.55	2.58	0.37	10.74	7.66	0.39	0.47	0.85	0.37	1.66	4.27					
Checks																
Bio 9681												71.24				
Prabal												69.16				
PEHM												62.43				
Mahi Kanchan												59.38				
SE ±	1.57	1.59	0.23	6.62	4.72	0.24	0.29	0.53	0.23	1.02	2.63					
F_1 Mean	46.51	49.84	3.33	173.78	76.21	13.63	4.31	13.28	26.00	37.55	68.83					
Check Mean	47.00	50.50	3.50	181.77	81.62	13.73	4.87	14.22	25.75	37.10	65.55					

** and ** significant at P = 0.05 and 0.01, respectively*

(2010) and Sundararajan Senthil Kumar (2011) and Panwar *et al.* 2013 in their study. The *per se* performance, gca effects of parents, heterobeltiosis and economic heterosis in eight superior cross combinations that exhibited significant positive sca effects (Table 3) indicated that high gca value of a parent is no guarantee of high sca effects of their crosses and *vice-versa*, confirming the earlier findings of Ali *et al.* (2007) and thus selection of parents should be based on their specific combining ability tests. L_{12} x T_4, L_1 x T_1, L_1 x T_2, L_3 x T_1, L_3 x T_2 and L_{12} x T_2 were identified as the most superior cross combinations that surpassed the best check (single cross hybrid Bio 9681) by a significant margin of 25.58%, 21.11%, 18.10%, 14.02% 12.36% and 11.26% for grain yield and at par with best check in respect of maturity related traits.

From the study, it can be concluded that parental lines L_{12}, L_1 and L_3 and testers T_1, T_2 and T_4 having good general combining ability for grain yield plant^{-1} as well as major yield contributing characters, could be extensively used in hybridization programme as a donor for the development of superior hybrids with high yield and desirable traits. The better performing cross combinations *viz.*, L_{12} x T_4, L_1 x T_1, L_1 x T_2, L_3 x T_1, L_3 x T_2 and L_{12} x T_2 manifested high *per se* performance with significant positive sca effects for grain yield plant^{-1}, high to moderate heterosis and both the parents of these crosses were good general combiners. These crosses also exhibited high sca effects for one or other component characters. These crosses could effectively be utilized for developing high yielding hybrids as well as for exploiting hybrid vigour. These crosses need to be evaluated for extensive testing to verify stability of their performance.

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