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Short Communication

Heterosis and combining ability for quality, yield and maturity traits in conventional and non-conventional hybrids of maize (*Zea mays* L.)

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Fifteen diverse early maturing white seeded inbred lines of maize viz., L_1, L_2, L_3, L_4, L_5, L_6, L_7, L_8, L_9, L_{10}, L_{11}, L_{12}, L_{13}, L_{14} and L_{15} were crossed with three testers T_1, T_2 and T_3 in a line × tester mating design during *rabi* 1994-95 to generate 45 hybrids (30 conventional and 15 non-conventional hybrids). These 45 hybrids and 18 parental lines with four standard checks viz., Arun, Kiran, Mahi Kanchan and D-107 were grown in Randomized Block Design with three replications, in a single row plot of 5 meters length having 60 cm × 25 cm crop geometry, in four environments during *Kharif* 1995. The data were recorded on quality, grain yield and maturity traits on ten randomly selected competitive plants. Total oil content of dry seeds was determined by Soxhlet method [1]. Starch content was estimated by the Anthrone reagent method. Pooled economic heterosis over environments was calculated as per standard procedure and combining ability analysis was carried out as per procedure given by Kempthorne [2].

Mean squares due to lines for days to 50% silk and 100-grain weight, due to testers for days to 50% silk and oil content and, due to lines × testers for all the characters under study were significant (Table 1). Thus both gca and sca variances were important for these traits. The mean square due to lines × environments was significant for oil content, grain yield per plant, 100-grain weight and harvest index, due to testers × environments was significant for 100-grain weight and due to lines × testers × environments was significant for all the characters which indicated that both gca and sca were influenced by the environmental fluctuations for these traits. The ratio of σ^2 sca/σ^2 gca was greater than one for all the characters. This indicated the preponderance of non-additive variance in the expression of traits under study (Table 1). Similar results have also been reported by earlier workers [3, 6].

Table 1. Pooled combining ability ANOVA for different characters in a line × tester cross of maize

Source	d.f.	Oil content	Starch content	Grain yield per plant	100-grain weight	Harvest index	Days to 50% silk
Environment	3	0.71**	4.8*	288556.9**	460.4**	688.0**	56.0**
Line	14	6.51	99.1	434.2	69.5**	31.8	34.2**
Tester	2	13.96**	167.8	99.2	75.0	17.7	34.4**
Line × Tester	28	4.54**	80.8**	321.3**	31.9**	22.6**	5.8**
Line × E	42	0.1**	2.0	259.7**	6.8**	25.9**	3.3
Tester × E	6	0.01	2.2	199.2	12.2**	25.5	6.0
L × T × E	84	0.04**	1.6**	128.7**	4.3**	0.6**	3.017**
Pooled error	352	0.003	0.020	1.337	0.294	0.133	0.688
σ^2 sca/σ^2 gca		H	220.33	200.62	57.50	100.00	7.66

*Significant at 5% level, **Significant at 1% level; H Mainly contributed by sca

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Table 2. Pooled estimates of gca effects for different traits in inbred lines of maize

Pedigree	Code	Oil content	Starch content	Grain yield per plant	100-grain weight	Harvest index	Days to 50% silk
Lines							
X_1W-1627-1-1	L_1	–0.84**	2.35**	6.79**	0.29	1.30**	1.33**
X_2W-3997-2-1-7	L_2	0.65**	–2.76**	4.87**	0.01	0.94**	1.61**
CD(W)-89-1-1-2-1	L_3	–0.06**	–1.15**	0.48	–1.35**	0.38**	0.39
CD(W)-49-1-1-4-1	L_4	–0.01	0.45**	1.98**	1.12**	1.10**	0.06
CD(W)-125-2-2-1-2	L_5	–0.16**	0.01	–4.10**	–1.21**	–0.99**	–0.72**
Pop. 49-1-1-2	L_6	0.70**	–2.00**	–2.30**	–1.63**	–0.68**	–1.19**
X_2W-80-29-2	L_7	–0.35**	2.08**	–2.02**	–0.74**	–0.51**	0.22
SS_3-35-2-1-1-1-1	L_8	0.19**	0.23**	2.06**	1.07**	1.79**	–1.19**
Pop. 49-77-1-3-1	L_9	0.44**	–1.65**	1.26**	0.90**	–0.21	–0.11
X_2W-3121-1-1-2	L_{10}	–0.03	0.59**	–0.96*	–1.24**	0.24	–0.67**
Pop. 49-87-1-1-1	L_{11}	–0.47**	2.60**	–1.41**	0.62**	–0.42**	0.33
Pop. 49-104-1-2-2	L_{12}	0.09**	–0.72**	0.56	1.51**	–0.15	–1.00
Pop. 30-128-2-15-1	L_{13}	0.39**	–1.81**	2.79**	3.07**	–0.62**	–0.56**
SS_3-35-3-1-2-2-1	L_{14}	–0.19**	0.50**	–5.96**	–1.82**	–1.59**	1.83**
X_2W-11046-1	L_{15}	–0.34**	1.28**	–4.05**	–0.60**	–0.57**	–0.33
Testers							
CD(W)	T_1	–0.01	0.19**	0.83**	–0.02	0.19**	–0.40**
CIMMYT-66 × X_2W-4001	T_2	–0.27**	0.85**	–0.24	0.66**	–0.36**	–0.07
SLT-11	T_3	0.29**	–1.05**	–0.60**	–0.64**	0.17**	0.47**

*Significant at 5% level; **Significant at 1% level

Table 3. Pooled sca estimates for different quality yield and maturity traits showing highest sca effects for oil content with economic heterosis and *per se* performance in maize

Pedigree	sca effects						Economic heterosis for oil content	*per se*					
	Oil content	Starch content	Grain yield per plant	100-grain weight	harvest index	Days to 50% silk		Oil content (%)	Starch content (%)	Grain yield per plant (g)	100-grain weight (g)	Harvest index (%)	Days to 50% silk
(L_{12} × T_2-TWC) (Pop. 49-104-1-2-2 × CIMMYT-66) × X_2W-4001	1.27**	–5.17**	9.18**	0.65*	1.98**	–0.57	12.90**	5.25	56.77	70.17	23.50	32.62	48.42
(L_3 × T_2-TWC) (CD(W)-89-1-1-2-1 × CIMMYT-66) × X_2W-4001	0.97**	–1.98**	–1.49**	–0.49	–0.30	0.38	3.41**	4.81	60.07	59.42	19.50	30.88	50.00
(L_{11} × T_1-TC) (Pop. 49-87-1-1-1 × CD(W)	0.82**	–2.81**	5.17**	2.88**	0.97**	0.34	-	4.50	62.34	65.25	24.17	31.90	50.33
(L_2 × T_3-SC) X_2W-3997-2-1-7 × SLT-11	0.75**	–1.99**	–5.10**	–1.22**	–1.64**	–0.05	25.81**	5.85	56.56	59.83	18.83	30.63	52.08
(L_7 × T_3-SC) X_2W-80-29-2 × SLT-11	0.62**	–0.69**	–1.63**	–0.31	–0.15	–1.08*	1.61**	4.72	62.70	56.42	19.00	30.67	49.67
L_2								4.42	62.30	53.17	19.42	30.79	53.00
L_3								3.80	64.69	55.25	19.67	31.95	51.92
L_7								5.82	55.68	51.08	19.92	28.28	52.00
L_{11}								4.42	61.32	50.33	16.92	28.55	51.42
L_{12}								3.89	64.58	44.17	17.00	28.65	51.42
T_1								4.57	60.07	48.92	20.83	28.85	49.08
T_2								4.47	60.94	48.08	17.42	28.58	48.75
T_3								4.49	59.79	43.50	18.08	27.62	52.33
Check													
Arun								4.58	60.01	57.00	18.42	31.70	50.42
Kiran								4.47	62.62	50.83	17.50	29.53	50.58
Mahi Kanchan								3.84	64.36	48.17	17.42	28.86	49.92
D-107								4.65	61.87	44.17	17.08	26.60	53.92

*Significant at 5% level; **Significant at 1% level

The inbred line SS_3-35-2-1-1-1-1 was a good general combiner for oil content and starch content along with grain yield per plant, 100-grain weight and days to 50% silk. Inbred line X_2W-3997-2-1-7 was good general combiner for oil content, grain yield per plant and harvest index, while inbred line X_1W-1627-1-1 was good general combiner for starch content, grain yield per plant and harvest index. Another inbred line Pop. 30-128-2-15-1 was good general combiner for oil content, grain yield per plant, 100-grain weight and days to 50% silk (Table 2).

Three-way cross hybrid (Pop. 49-104-1-2-2 × CIMMYT-66) × X_2W-4001 exhibited highest magnitude of positive significant sca effect for oil content along with positive significant sca effect for grain yield per plant, 100-grain weight and harvest index but negative significant sca effect for starch content and non-significant sca effect for days to 50% silk and highest estimate of economic heterosis for oil content against the best check D-107 (Table 3). This three-way cross conventional hybrid also revealed good *per se* performance for oil content, grain yield per plant, 100-grain weight and harvest index and lesser number of days to 50% silk. Another three-way cross hybrid (CD(W)-89-1-1-2-1 × CIMMYT-66) × X_2W-4001 showed significant positive sca effect for oil content along with negative significant sca effect for starch content, grain yield per plant and negative non significant sca effect for 100-grain weight, harvest index and days to 50% silk with poor significant economic heterosis for oil content along with reasonably good *per se* performance for other traits. The single cross hybrid X_2W-3997-2-1-7 × SLT-11 showed positive significant sca effect for oil content but negative significant sca effect for starch content, grain yield per plant, 100-grain weight and harvest index and non-significant negative sca effect for days to 50% silk with highest estimate of economic heterosis for oil content along with good *per se* performance for other traits. Thus among the selected conventional and non-conventional two parent (TP) and multiparent (MP) hybrids on the basis of sca effect for oil content, it was the two parent single cross hybrid which exhibited highest magnitude of economic heterosis for oil content and it was a cross of good × good gca effect parents for oil content. The *per se* performance of parental inbred lines of this cross was also good. The multiparent conventional three-way cross hybrid ranked next to single cross hybrid in terms of expression of economic heterotic response for oil content and it was a cross of good × poor gca effect parents for oil content. The non-conventional two parent top cross hybrid Pop. 49-87-1-1-1 × CD(W) although exhibited significant positive sca effect for oil content, grain yield per plant, 100-grain weight, harvest index and negative significant and non-significant sca effect for starch content and days to 50% silk respectively, did not exhibit economic heterosis for oil content. Thus top cross hybrid was a cross of poor x poor gca effect parents for oil content. The parental lines in this study were having origin from the diverse genetic background and hence exhibited high sca effect which resulted into significant heterotic response for oil content. Similar results have also been reported by Joshi [6].

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