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Combining ability for polygenic traits in early maturing hybrids of maize (*Zea mays* L.)

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Abstract

Combining ability analysis using line × tester design was conducted in white seed colour early maturing maize (*Zea mays* L.) inbred lines for yield and yield contributing characters. There was greater contribution of lines towards $\sigma^2 gca$ for all the traits. Inbred lines *viz.*, X_1W-1627-1-1 and X_2W-3997-2-1-7 were good general combiners for all the characters except 100-grain weight. Tester CD(W) was good general combiner for grain yield per plant, grain cob ratio and straw yield per plant. Among the selected hybrids, two parent (TP) conventional single cross hybrid exhibited highest magnitude of positive significant sca effect with highest magnitude of significant positive economic heterosis for grain yield per plant and it was followed in descending order by the multiparent (MP) conventional three way cross and nonconventional two parent (TP) top cross hybrid.

Key words : Maize, combining ability, conventional & non-conventional hybrids.

Introduction

The exploitation of heterosis in maize (*Zea mays* L.) can be accomplished through the development and identification of high *per se* performing vigorous parental lines and their subsequent evaluation for combining ability in cross combinations to identify hybrids with high heterotic effects. The grain yield is the primary trait targeted for improvement of maize productivity in both favourable and unfavourable environments from its present level. In unfavourable environments early maturing genotypes may play an important role for improvement in grain yield. The present investigation was therefore, undertaken to assess both gca and sca effects for yield and yield contributing traits in early maturing lines of X_1W, X_2W, CD(W), Pop.49, Pop.30 and SS3 gene pool to identify best general combiner inbred lines and also the best hybrids among the category of conventional and non-conventional type with respect to sca effect and economic heterosis for grain yield.

Material and methods

Fifteen diverse early maturing white seed colour inbred lines of maize *viz.*, L_1 to L_{15} (Table 2) and three testers *viz.*, T_1, T_2 and T_3 were crossed in line x tester design during *rabi* 1994-95 to generate a total of 45 hybrids. These 45 hybrids with 18 parents and four standard checks *viz.*, Arun, Kiran, Mahi Kanchan and Deccan-107 were planted in randomized block design with three replications in a single row plot of 5 meters length having 60 × 25 cm crop geometry in four environments of soil types and fertility levels under rainfed conditions in *kharif* 1995. The data were recorded on yield and yield contributing traits on ten randomly selected competitive plants. Pooled economic heterosis over environments was calculated as per standard procedure [1] and combining ability analysis was done according to procedure of Kempthorne [2].

Results and discussion

Both two parent (TP) and multiparent (MP) conventional and non-conventional maize hybrids are under cultivation in different parts of the world [3]. In India nonconventional hybrids are more popular in many parts of the country because of their high productivity, much easier seed production and less problems in maintenance of open pollinating male parent than the inbred lines. Recently in India, research strategies are being diverted to produce two parent single cross hybrids to achieve quantum jump in production and productivity of maize on a pattern similar to that achieved in USA and in many other European countries. In the present investigation the pooled analysis of variance for combi- ning ability revealed that the mean squares due to lines, testers and lines × testers were significant for most of the characters except due to lines for grain yield per plant and number of rows per ear, due to testers for grain yield per plant, ear length, number of rows per ear, 100-grain weight and grain cob ratio and due to lines × testers for ear length (Table 1), thereby sugges- ting that the experimental material possessed conside- rable variability and that both gca and sca were involved in the genetic expression of these traits. The non

Table 1. Pooled analysis of variance (mean squares) of combining ability for different traits in a line × tester cross of maize

Source	d.f.	Grain yield/plant	Ear length	Ear girth	No. of rows/ear	100-grain weight	Grain cob ratio	Straw yield/plant
Environment	3	288556.954**	379.957**	31.670**	26.012**	460.499**	38.543**	22083.099**
Line	14	434.284	8.232**	4.052**	5.092	69.598**	2.923*	812.368**
Tester	2	99.202	0.672	2.965*	0.520	75.439	4.069	1206.785**
Line × Tester	28	321.339**	2.732	2.356**	3.274*	31.953**	1.668**	278.277**
Line × E	42	259.719**	3.917**	2.236**	2.285	6.813*	0.767**	244.981**
Tester × E	6	199.239	3.650	0.248	1.809	12.202	1.118*	54.138
L×T × E	84	128.765**	1.924**	1.139**	1.887**	4.327**	0.468**	111.130**
Error	252	1.337	0.30	0.021	0.021	0.294	0.115	0.612
σ^2 L		4.849	0.120	0.051	0.078	1.740	0.060	15.761
σ^2 T		-0.556	-0.017	0.015	-0.007	0.351	0.016	6.404
σ^2 *gca*		0.08	0.01	0.00	0.00	0.04	0.00	0.68
σ^2 *sca*		16.05	0.07	0.10	0.12	2.30	0.10	13.93
$\sigma^2 sca/\sigma^2 gca$		200.62	7.00	H	H	57.50	H	20.48

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

Table 2. Pooled mean performance for different traits in a line × tester cross of maize

Parents/ Hybrids	Grain yield per plant (g)	Ear length (cm)	Ear girth (cm)	No. of rows per ear	100-grain weight (g)	Grain cob ratio	Straw yield per plant (g)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Parents							
T_1	48.9	12.1	14.0	12.1	20.8	4.8	65.7
T_2	48.1	11.9	13.1	12.9	17.4	5.0	62.1
T_3	43.5	12.2	20.9	12.3	18.1	4.4	58.6
L_1	58.0	11.9	13.4	13.2	21.3	5.2	60.9
L_2	53.2	11.9	13.1	13.2	19.4	5.1	59.2
L_3	55.2	11.7	12.7	13.4	19.7	5.0	57.2
L_4	58.6	12.1	11.8	13.1	18.2	5.4	66.6
L_5	53.7	12.6	12.4	13.4	20.9	4.0	55.3
L_6	57.1	12.3	12.4	13.0	19.8	4.1	71.5
L_7	51.1	12.1	13.0	12.6	19.9	4.6	69.7
L_8	52.3	11.5	13.6	12.9	18.4	5.0	65.2
L_9	40.5	10.7	12.0	12.2	16.3	4.2	58.5
L_{10}	58.3	13.4	13.6	14.0	17.6	4.7	68.8
L_{11}	50.3	11.7	12.0	12.7	16.9	4.9	67.9
L_{12}	44.2	10.9	12.6	12.0	17.0	4.8	51.7
L_{13}	54.2	12.1	14.5	14.1	19.0	4.9	57.5
L_{14}	48.3	12.1	12.3	12.6	16.9	5.0	56.5
L_{15}	48.9	12.3	13.6	11.5	17.2	4.2	58.1
Hybrids							
L_1 x T_1	60.0	13.5	13.7	12.9	19.8	5.8	73.1
L_2 x T_1	74.8	14.1	14.6	14.2	22.9	5.5	78.8
L_3 x T_1	59.3	13.3	13.5	13.3	19.5	5.7	80.3
L_4 x T_1	66.3	14.0	14.1	12.6	22.1	4.9	74.4
L_5 x T_1	58.7	12.5	12.8	11.9	19.3	4.7	62.7
L_6 x T_1	63.1	12.6	13.6	13.4	18.3	5.8	74.4
L_7 x T_1	62.2	12.7	13.3	12.6	20.5	4.7	70.5
L_8 x T_1	63.9	12.3	12.8	12.2	20.4	5.6	68.4
L_9 x T_1	65.1	12.8	13.9	13.3	21.2	4.9	74.2
L_{10} x T_1	54.2	11.6	12.9	12.8	18.2	5.2	63.6
L_{11} x T_1	65.2	13.1	13.9	13.4	24.2	5.0	78.7
L_{12} x T_1	57.0	13.7	14.3	13.7	21.8	4.6	68.6
L_{13} x T_1	63.0	12.7	13.2	12.5	20.5	4.7	77.2
L_{14} x T_1	56.6	12.9	13.6	13.2	20.8	4.9	74.2
L_{15} x T_1	52.7	12.9	13.6	13.1	20.3	4.7	66.3
L_1 x T_2	64.8	12.9	13.1	13.8	20.3	4.7	72.1
L_2 x T_2	61.9	13.9	13.3	13.4	20.3	5.5	84.2
L_3 x T_2	59.4	13.7	14.0	13.1	19.5	5.6	80.0
L_4 x T_2	61.5	13.4	13.0	13.1	20.9	4.8	70.2
L_5 x T_2	58.1	13.6	13.8	13.5	21.8	4.6	74.9
L_6 x T_2	53.6	13.2	12.9	12.6	20.3	4.3	70.0
L_7 x T_2	57.2	12.2	12.8	13.0	20.3	4.6	68.7
L_8 x T_2	61.6	12.7	13.8	13.5	24.2	5.4	61.0
L_9 x T_2	64.2	12.7	13.4	12.9	23.2	4.7	77.6
L_{10} x T_2	65.6	12.7	13.3	13.4	19.2	5.2	69.5
L_{11} x T_2	54.0	13.2	13.4	13.7	20.2	5.2	78.7
L_{12} x T_2	70.2	13.6	14.4	12.6	23.5	4.7	72.8
L_{13} x T_2	63.7	13.5	13.7	13.1	26.2	4.7	75.7
L_{14} x T_2	50.8	12.7	13.7	12.8	18.2	4.8	69.8
L_{15} x T_2	59.7	12.4	13.1	12.4	19.7	4.9	64.6
L_1 x T_3	77.5	14.0	14.5	14.1	22.7	5.0	71.7
L_2 x T_3	59.8	13.7	14.7	13.9	18.8	5.0	72.5
L_3 x T_3	64.7	14.1	14.3	12.8	19.0	4.7	79.6
L_4 x T_3	60.1	13.0	13.7	12.8	20.4	5.9	71.4
L_5 x T_3	52.8	12.0	13.1	12.4	17.2	4.5	63.0
L_6 x T_3	58.4	12.1	13.5	12.1	18.5	5.3	74.7
L_7 x T_3	56.4	12.3	13.1	13.7	19.0	4.6	60.9
L_8 x T_3	62.7	12.9	14.0	13.6	20.6	4.5	58.3
L_9 x T_3	56.5	12.9	13.6	13.6	20.3	4.4	56.7
L_{10} x T_3	59.3	13.3	13.6	13.4	20.9	5.1	76.8
L_{11} x T_3	58.5	13.2	13.6	13.7	19.6	4.6	65.1
L_{12} x T_3	56.5	13.5	13.9	12.5	21.2	4.4	70.2
L_{13} x T_3	63.7	13.5	13.5	13.1	24.6	5.1	71.7
L_{14} x T_3	56.7	12.1	13.5	12.8	17.5	4.8	63.2
L_{15} x T_3	57.3	13.1	13.1	12.0	20.2	4.5	64.7
Checks							
Arun	57.0	12.5	12.5	12.7	18.4	4.7	64.8
Kiran	50.8	12.5	12.30	13.7	17.5	4.7	65.3
Mahi kanchan	48.2	12.2	13.6	13.4	17.4	5.0	71.1
D-107	44.2	11.6	13.2	13.1	17.1	4.7	66.2
G.M.	57.8	12.7	13.4	13.0	19.9	4.9	68.3
Sem±	0.61	0.10	0.09	0.10	0.31	0.19	0.44

significance of variance for grain yield in lines and high mean value for the trait suggest that the lines chosen had high and comparable yield potential (Table 2). The results on pooled analysis further revealed the presence of significant differences among the environments. The interactions of lines × environments, testers × environments and lines × testers × environments were significant for most of the characters except due to lines × environments for number of rows per ear, due to testers × environments for grain yield per plant, ear length, ear girth, number of rows per ear and straw yield per plant. This indicated that the expression of both *gca* and *sca* were influenced by the environmental fluctuations for these traits. A higher proportion of $\sigma^2 sca$ between $\sigma^2 sca$ and $\sigma^2 gca$ also

Table 3. Pooled estimates of *gca* effects for different traits in lines and testers of maize

Pedigree	Code name	Grain yield/plant	Ear length	Ear girth	No. of rows/ear	100grain weight	Grain cob ratio	Straw yield/plant
X_1W-1627-1-7	L_1	6.79**	0.41	0.18**	0.50*	0.29	0.23*	1.26**
X_2W-3997-2-1-7	L_2	4.87**	0.82**	0.61**	0.74**	0.01	0.37**	7.51**
CD(W)-89-1-1-2-1	L_3	0.48	0.66**	0.34**	-0.01	-1.35**	0.40**	8.95**
CD(W)-49-1-1-4-1	L_4	1.98**	0.42**	0.00	-0.27**	1.12**	0.26*	0.98**
CD(W)-125-2-2-1-2	L_5	-4.10**	-0.31**	-0.36**	-0.49**	-1.21	-0.38**	-4.16**
Pop. 49-1-1-2	L_6	-2.30**	-0.44**	-0.27**	-0.36**	-1.63**	0.20	2.04**
X_2W-80-29-2	L_7	-2.02**	-0.60**	-0.50**	0.04	-0.74**	-0.35**	-4.30**
SS_3-35-2-1-1-1-1	L_8	2.06**	-0.40**	-0.05	0.03	1.07**	0.20	-8.44**
Pop. 49-77-1-3-1	L_9	1.26**	-0.23**	0.04	0.20**	0.90**	-0.27*	-1.52**
X_2W-3121-1-1-2	L_{10}	-0.96**	-0.50**	-0.30**	0.12*	-1.24**	0.23*	-1.05**
Pop. 49-87-1-1-1	L_{11}	-1.41**	0.11	0.07	0.52**	0.62**	-0.02	3.15**
Pop. 49-104-1-2-2	L_{12}	0.56	0.55**	0.63**	-0.13**	1.51**	-0.38**	-0.49
Pop. 30-128-2-15-1	L_{13}	2.79**	0.20**	-0.13**	-0.18	3.07**	-0.13	3.81**
SS_3-35-3-1-2-2-1	L_{14}	-5.96**	-0.46**	0.04	-0.16**	-1.82**	-0.10	-1.941**
X_2W-11046-1	L_{15}	-4.05**	-0.24**	-0.30**	-0.57**	0.60**	-0.27*	-5.82**
Testers								
CD(W)	T_1	0.83**	-0.06*	0.00	-0.06**	-0.02	0.16*	1.35**
CIMMYT-66 × X_2W-4001	T_2	-0.24	0.06*	-0.13**	0.04	0.66**	-0.04	1.64**
SLT-11	T_3	-0.60**	0.00	0.13**	0.02	-0.64**	-0.13*	-2.99**

*Significant at 5% level, **Significant at 1% level

Table 4. Pooled *sca* estimates for yield and yield contributing traits showing highest *sca* effects for grain yield per plant with economic heterosis and *per se* performance in maize

Pedigree	*sca* effects							Economic heterosis for grain yield/plant (%)	*per se*						
	Grain yield/ plant	Ear length	Ear girth	No. of rows/ ear	100-grain weight	Grain cob ratio	Straw yield/ plant		Grain yield/ plant (g)	Ear length (cm)	Ear girth (cm)	No. of rows/ ear	100-grain weight (g)	Grain cob ratio	Straw yield/ plant (g)
($L_1 \times T_1$-SC) X_2W-1627-1-1 × SLT-11	10.65**	0.52**	0.65**	0.46**	2.42**	-0.06	2.37**	35.96**	77.5	14.0	14.5	14.1	22.7	5.0	71.7
($L_{12} \times T_2$-TWC) Pop. 49-104-1-2-2 × CIMMYT-66 × X_2W-4001	9.18**	0.07	0.35**	-0.35**	0.65**	0.20	0.67	23.10**	70.2	13.6	14.4	12.6	23.5	4.7	72.8
($L_{10} \times T_2$-TWC) X_2W 3121-1-1-2 × CIMMYT-60 × X_2W-4001	6.12**	0.12	0.17*	0.17*	-0.85**	0.09	- 2.11**	15.06**	65.6	12.7	13.3	13.4	19.2	5.2	69.5
($L_{11} \times T_1$-TC) Pop. 49-87-1-1-1-1 × CD(W)	5.17**	-0.04	0.27**	-0.18*	2.88**	-0.03	3.24**	14.47**	65.2	13.1	13.9	13.2	24.2	5.1	78.7
($L_8 \times T_1$-TC) SS_3-35-2-1-1-1-1 × CD(W)	4.49**	-0.32**	-0.76**	-0.78**	-1.32**	0.25	-0.74**	12.13**	63.9	12.3	12.8	12.3	20.4	5.6	68.4
L_1									58.0	11.9	13.4	12.2	21.3	5.2	60.9
L_8									52.3	11.5	13.6	12.9	18.4	5.0	65.2
L_{10}									58.3	13.4	13.6	14.1	17.6	4.7	68.8
L_{11}									50.3	11.7	12.0	12.7	16.9	4.9	67.9
L_{12}									44.2	10.9	12.6	12.1	17.0	4.8	65.7
T_1									48.9	12.1	14.0	12.1	20.8	4.8	65.7
T_2									40.1	11.9	13.1	12.9	17.4	5.0	62.1
T_3									43.5	12.7	12.9	12.3	18.1	4.4	58.6
Check															
Arun									57.0	12.5	12.5	12.2	18.4	4.7	64.2
Kiran									50.8	12.9	13.0	13.7	17.5	4.7	65.3
Mahi Kanchan									48.2	12.2	13.6	13.4	17.4	5.0	71.1
D-107									44.2	11.6	13.2	13.1	17.1	5.7	66.2

*Significant at 5% level, **Significant at 1% level indicated that the additive × non additive and non additive interactions were significantly higher among the hybrids which would be important in the hybrids.

A perusal of *gca* effects revealed that the two inbred lines *viz.*, X_1W-1627-1-1 and X_2W-3997-2-1-7 were good general combiners for all the characters except 100grain weight. Among the testers CD(W) was good general combiner for crain yield per plant, grain cob ratio and straw yield per plant (Table 3).

A perusal of first five best hybrids on the basis of *sca* effect for grain yield per plant in relation to economic heterosis for grain yield per plant revealed that the conventional single cross hybrid X_1W-1627-1-1 × SLT-11 exhibited highest magnitude of positive significant *sca* effect for grain yield per plant alongwith positive significant *sca* effects for other directly contributing characters (Table 4). This single cross hybrid also exhibited highest magnitude of significant positive economic heterosis for grain yield per plant against the best check 'Arun' with good *per se* performance for other yield contributing characters. The multiparent (MP) three way cross hybrid (Pop. 49-104-1-2-2 × CIMMYT-66) × X_2W-4001 and (X_1W-3121-1-1-2 × CIMMYT-66) × X_2W-4001 ranked next to single cross hybrid in terms of magnitude of significant positive *sca* effect for grain yield per plant with high magnitude of positive significant economic heterosis for grain yield per plant. These two three way cross hybrids also exhibited significant positive sca effects for some yield contributing traits with good *per se* performance. The non-conventional two parent (TP) top cross hybrids Pop.49-87-1-1-1 × CD(W) and SS_3-35-2-1-1-1-1 × CD(W) were lowest in terms of magnitude of significant positive *sca* effects and magnitude of significant positive economic heterosis for grain yield per plant. However, top cross hybrid Pop. 49-87-1-1-1 × CD(W) also exhibited significant positive *sca* effects for ear girth, 100-grain weight and straw yield per plant with highest *per se* performance for 100-grain weight and straw yield per plant. The top cross hybrid SS_3-35-2-1-1-1-1 × CD(W) exhibited significant negative *sca* effects for ear length, ear girth, number of rows per ear, 100-grain weight and straw yield per plant with highest *per se* performance for grain cob ratio.

The female parental inbred line of the single cross hybrid X_1W-1627-1-1 × SLT-11 possessed high *per se* performance for yield and other yield contributing traits and the single cross hybrid was in fact a cross of good × poor *gca* effect parents for grain yield per plant. The best three way cross hybrid (Pop.49-1-2-2 × CIMMYT-66) × X_2W-4001 was a cross of poor × poor *gca* effect parents for grain yield per plant and the best top cross hybrid Pop.49-87-1-1-1 × CD(W) was a cross of poor × good gca effect parents for grain yield per plant. The parental lines and testers in this study were having diverse genetic background of their source populations and hence exhibited high sca effects for yield and yield contributing traits which resulted into expression of significant economic heterosis for grain yield per plant. Among the two parent (TP) and multiparent (MP) hybrids it was the two parent conventional single cross hybrid which exhibited highest heterotic response and it was followed in the descending order by conventional multiparent three way cross hybrids and nonconventional two parent top cross hybrid. These findings as such support the views of earlier workers (3-7) regarding the superiority of conventional single cross hybrids in terms of yield and other attributes and it would encourage the development and cultivation of single cross hybrids even in early maturity group.

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