Combining Ability and Heterosis for Yield and Quantitative Traits in Maize, Zea mays (L.)

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Combining Ability and Heterosis for Polygenic Characters in Maize (*Zea mays* L.)

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Combining ability analysis was conducted using line x tester design in maize inbred lines for yield and yield contributing traits. The *sca* variance was observed to be more important for all the traits studied. The inbreds DMR-201, CM-119 and CM-121 were good general combiners for grain yield per plant and most of their yield contributing traits. The cross CM-121 x DMR-201 showed high *sca* effects and heterosis for grain yield and early maturity and thus, can be tested over the locations for assessing its consistent performance over the wide range of environments. Other crosses *viz.,* CM-119 x DMR-40E, CM-104 x AML-420 and CM-119 x DMR-201 also showed high heterosis and *sca* effects for grain yield.

Key words: Line x tester, Combining ability, Heterosis, Maize, Polygenic traits.

Maize (*Zea mays* L.) is one of the most important cereal crop. Maize is used as human food, industrial raw material and animal feed. This indicates the importance of maize in the ever-increasing demand for food and warrants the development of new high yielding varieties and hybrids of maize. Maize is highly allogamous crop and it has been successfully exploited in the production of hybrids. Venkatesh *et al.* (2003) reported that maize researchers in India were currently focusing their efforts on the development of single cross hybrids. The Combining ability analysis is an important tool to identify parents with better potential to transmit desirable characteristics to the progenies and to identify the best specific cross(s) for yield. Paul and Duara (1991) pointed out that the combining ability gave useful information on the choice of parents, in terms of expected performance of the hybrids and their progenies.

The exploitation of heterosis in maize (*Zea mays* L.) can be accomplished through the development and identification of high *per se* performance vigorous parental lines and their subsequent evaluation for combining ability in cross combinations to identify the hybrids with high heterotic effects. The grain yield and maturity are the primary traits targeted for the improvement of maize productivity. The information about the heterotic patterns and combining ability of the parents and crosses facilitate the breeders in the selection and development of the single cross hybrids. Considering the grain yield and maturity as major traits, the present study was conducted to estimate the magnitude of heterosis and combining ability in maize.

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Materials and Methods

Ten elite inbred lines of maize *viz.,* CM-104, CM-105, CM-114, CM-115, CM-118, CM-119, CM-120, CM-121, CM-130 and CM-131 lines were crossed with four testers *viz.,* KI-109, DMR-40E, AML-420 and DMR-201 at Maize Research Station, Amberpet, Hyderabad during *Kharif*, 2007 to generate 40 crosses. These 40 crosses along with 14 parents and two standard checks (DHM-103 and DHM-105) were raised in randomized block design with three replications in experimental field at College farm, College of Agriculture, Rajendranagar, Hyderabad during *Rabi*, 2007-08. Each entry was raised in single row of 5 metre length with a spacing of 75 x 20 cm. The standard check DHM-103 was used to estimate the heterosis. Five competitive plants from each genotype were randomly selected from each replication for recording biometrical observations on days to 50 per cent tasselling, days to 50 per cent silking, days to maturity, plant height (cm), ear height (cm), and grain yield per plant (g). However, observations for the characters *viz*., days to 50 per cent tasselling, days to 50 per cent silking and days to maturity were recorded on plot basis.

Line x tester analysis was carried out according to Kempthorne (1957). The heterosis was estimated over the check as per the standard procedure. Mean values per replication for all traits were subjected to analysis of variance according to Panse and Sukhatme (1985) for randomized block design. The estimates of general and specific combining ability and their variances were obtained by using covariance of half sibs and full sibs.

Results and Discussion

In the present investigation, the analysis of variance (Table1) revealed highly significant differences among themselves. The parents as well as crosses exhibited significant differences for all the traits studied, where as parents vs. crosses also exhibited significant differences for all the six traits under study. When the effects of crosses was partitioned into lines, testers and line x testers effects, the effects of lines were found to be significant for plant height, ear height and grain yield, where as the effects of testers were significant for all the traits studied. The interaction effects (limes x testers) were found to be significant for all the traits under study.

Table 1. Analysis of variance for parents and hybrids of different characters in Maize

Genotypes	d.f.	Days to 50% tasseling	Days to 50% Silking	Days to Maturity	Plant Height (cm)	Ear Height (cm)	Grain Yield per plant (g)
Replications	2	0.518	0.796	0.320	32.899	21.235	13.638
Treatments	53	49.514**	51.225**	31.080**	2257.479**	902.824**	2053.904**
Parents	13	12.675**	24.448**	26.287**	979.650**	326.131**	178.797**
Parent vs. crosses	1	285.358**	243.911**	150.252**	26709.446**	24545.458**	37228.833**
Crosses	39	55.747**	55.210**	29.623**	2056.447**	488.834**	1777.018**
Lines	9	11.848	13.262	9.459	3263.742**	711.260**	1304.227**
Testers	3	547.422**	525.022**	249.900**	12424.526**	3069.968**	11869.578**
Line x Testers	27	15.638**	16.991**	11.869**	502.006**	127.8991**	813.220**
Errors	106	2.141	3.542	2.351	100.281	27.052	9.105

*Significant at 5 per cent level; ** Significant at 1 per cent level

Similarly, analysis of variance for combining ability (Table 2) exhibited non significant differences for days to 50 per cent tasseling, days to 50 per cent silking and days to maturity traits in lines and significant differences were observed for all the six traits in testers and line x testers. Thereby suggesting that the experimental material possessed considerable variability and that both *gca* and *sca* were involved in genetic expression of these traits. A higher proportion of s^2 *sca* than s^2 *gca* also indicates that the additive x non-additive interactions were significantly higher among the hybrids, which would be important for their exploitation. Higher *sca* variance than *gca* variance exhibiting preponderance of non-additive gene effects reported earlier by Singh and Mishra (1996), Venkatesh *et al.* (2000), Joshi *et al.* (2002), Alamnie-Atanaw (2003), Lata *et al.* (2006), Kumari *et al.* (2006), Gowhar Ali Ishfaq *et al*. (2007), Jyothi kumari *et al.* (2008), Lata *et al.* (2008), Singh *et al.* (2010), Dan Mankumbi *et al.* (2011) and Premlatha *et al.* (2011).

Table 2. Analysis of variance for combining ability

Source	d.f.	Days to 50% tasseling	Days to 50% Silking	Days to Maturity	Plant Height (cm)	Ear Height (cm)	Yield plant
Replications	2	0.408	0.508	0.258	5.293	33.651	5.806
Lines	9	11.848	13.262	9.459	3263.742**	711.260**	1304.227**
Testers	3	548.422**	525.022**	249.900**	12424.526**	3069.968**	11869.580**
Lines x Testers	27	15.638**	16.991**	11.869**	502.007**	127.899**	813.221**
Error	78	0.288	0.431	0.335	90.266	32.772	10.207
σ^2 gca		0.658	0.627	0.291	25.51	5.924	15.819
σ^2 sca		5.125	5.540	3.845	133.908	33.615	268.038

* Significant at 5 per cent level; ** Significant at 1 per cent level

The *gca* estimates showed that the best general combining inbreds for grain yield were DMR-201, CM-119 and CM-121 (Table 3). Inbred KI-109 and CM-104 were poor general combiner for grain yield. Among the parents studied, KI-109, AML-420 and CM-131 were found to have negative *gca* effects for days to 50% tasseling, days to 50% silking and days to maturity. Jayakumar and Sundaram (2007) indicated usefulness of bringing out earliness in crosses. The inbreds DMR-201, CM-131 and CM-121 for plant height, for ear height the inbreds DMR-201 and CM-131 recorded good general combining ability. The two inbreds KI-109 and AML-420 were recorded very poor general combining ability for the all the traits. The parents having high *gca* effects would be useful since the *gca* effect is due to additive gene action and is fixable (Sprague and Tatum, 1942). Thus, inbreds DMR-201, CM-119 and CM-

Table 3. Estimates of general combining ability (*gca*) effects for lines and testers for different characters in Maize

Genotypes	Days to 50% tasseling	Days to 50% Silking	Days to Maturity	Plant Height (cm)	Ear Height (cm)	Grain Yield per plant (g)
PARENTS						
Lines						
CM-104	-0.933 **	-1.133 **	0.267 **	-26.168 **	-13.316 **	-14.068 **
CM-105	0.317 **	1.200 **	0.683 **	-22.277 **	-6.691 **	-9.751 **
CM-114	-0.600 **	-0.717 **	-1.400 **	-12.318 **	-6.208 **	-12.343 **
CM-115	0.817 **	0.783 **	1.017 **	2.357	-1.341 **	1.424
CM-118	1.317 **	1.367 **	0.350 **	-0.443 **	-2.516 **	0.449
CM-119	1.150 **	0.450 **	0.350 **	3.115	-0.274 **	18.341 **
CM-120	-0.350 **	0.117	-0.400 **	1.640	3.626	2.374
CM-121	0.733 **	0.533 **	1.100 **	15.298 **	8.234	12.516 **
CM-130	-0.933 **	-0.883 **	-0.900 **	11.973 **	6.709	4.491 *
CM-131	-1.517 **	-1.717 **	-1.067 **	26.823 **	11.776 *	-3.434 **
Testers						
KI-109	-4.933 **	-4.500 **	-2.350 **	-17.333 **	-10.218 **	-15.539 **
DMR-40E	0.900 **	0.367 **	1.517 **	2.267	1.863	-3.063 **
AML-420	-1.267 **	-1.367 **	-2.483 **	-12.757 **	-4.884 **	-10.233 **
DMR-201	5.300 **	5.500 **	3.317 **	27.823 **	13.239 **	28.834 **

* Significant at 5 per cent level; ** Significant at 1 per cent level

121 were good general combiners for grain yield per plant and most of their yield contributing traits.

The cross CM-118 x DMR-201 and CM-119 x DMR-40E showed negatively significant *sca* effect for days to 50% tasseling and days to 50% silking respectively. For days to maturity cross CM-104 x DMR-201 and CM-121 x DMR-201 recorded negative significant *sca* effects coupled with high heterosis (Table 4).

A perusal of first seven best hybrids revealed that the cross CM-121 x DMR-201 performed best on the basis of high *sca* effects for grain yield coupled with high economic heterosis. The cross was desirable for early maturity with significant *sca* and heterosis with least number of days for maturity. The next best crosses observed for high heterosis and *sca* effects for grain yield were CM-119 x DMR-40E, CM-104 x AML-420 and CM-119 x DMR-201.

Table 4. Specific combining ability and heterosis of best performing crosses

Characters		CM-104 x AML-420	CM-104 x DMR-201	CM-115 x DMR-201	CM-118 x DMR-201	CM-119 x DMR-40E	CM-119 x DMR-201	CM-121 x DMR-201
Days to 50 % tasseling	sca	1.433**	-0.133	3.117**	-0.717*	-0.483	1.450**	4.533**
	heterosis	-0.46	6.48 **	13.43 **	8.80 **	2.78 **	11.57 **	15.28 **
Days to 50 % silking	sca	1.200**	-0.333	2.417**	-0.5	-0.783*	1.083**	4.000**
	heterosis	0.44	7.46 **	13.60 **	10.53 **	2.19 **	11.40 **	15.35 **
Days to maturity	sca	2.233**	-1.900**	2.683**	0.35	-0.517	2.350**	-3.067**
	heterosis	0.00	1.47 **	6.19 **	3.54 **	1.18 **	5.31 **	7.37 **
Plant height	sca	10.482	-5.398	21.777**	23.643**	0.742	18.818*	11.235
	heterosis	-23.55 **	-8.28	26.15 **	25.57 **	-2.18	24.79 **	27.63 **
Ear height	sca	1.876	4.353	9.911**	7.119*	2.021	6.811*	1.736
	heterosis	-6.64	22.25 **	46.84 **	41.28 **	21.32 **	43.99 **	48.81 **
Grain yield per plant	sca	14.591**	-25.376**	31.966	27.308	18.713**	11.949**	21.441**
	heterosis	-14.89 **	-16.04 **	77.18 **	69.97 **	41.04 **	73.21 **	77.90 **

* Significant at 5 per cent level; ** Significant at 1 per cent level

These results are in similarity with the earlier findings of Dubey *et al.* (2001), Srivastava and Singh (2003), Lata *et al.* (2006), Kumari *et al.* (2006), Lata *et al.* (2008) Dhliwayo *et al.* (2009), Cruz Lazaro *et al.* (2010) and Singh *et al.* (2010).

A comparison of combining ability effects of parents and their corresponding crosses indicated that the *gca* effects of the parents were reflected in the *sca* effects of most of crosses for several of the characters studied.

Conclusion

Among the lines CM-119, and CM-121 had positive *gca* effects for grain yield. Thus they can be used as parents for production of high yielding single cross hybrids. The cross CM-121 x DMR-201 recorded significantly high positive heterosis and positive *sca* effects for grain yield and days to maturity traits. Hence, this cross may be tested for its performance over the locations and years. Other hybrids CM-119 x DMR-40E, CM-104 x AML-420 and CM-119 x DMR-201 showed high heterosis and *sca* effects for grain yield and were identified for further multilocation evaluation.

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