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Gene Action and Combining Ability for Yield and Yield Attributes in Maize (*Zea mays* L.)

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ABSTRACT

The studies on gene action and combining ability using eight inbreds for grain yield and its components in maize through diallel analysis revealed that the component due to *sca* variance ($\sigma^2 sca$) was higher than *gca* variance ($\sigma^2 gca$) in all the characters and also the ratio $\sigma^2 gca$ to $\sigma^2 sca$ was less than unity, which indicated the preponderance of non-additve gene action in controlling the expression of all the traits. Based on both *per se* and *gca* effects, the genotypes CM 209, CM 149 and BML 15 among parental lines were identified as good general combiners for yield and most of the yield components. High *per se* and significant *sca* effects were exhibited by two hybrids *viz.,* CM 149 x BML 6 and CM 148 x BML 15 which could be exploited in the recombinant breeding programme.

Key words : General combining ability, Maize, Specific combining ability

Maize is the third most important cereal grain in the world. In India, maize ranks among the top four cereal crops occupying an area of 7.89 million ha with a production of 15.09 million tonnes and 1904 kg ha^{-1} productivity and in Andhra Pradesh, it covers an area of 0.85 million hectares with a production of 4.15 million tonnes and productivity of 4073 kg ha^{-1} (CMIE, 2010). Though many synthetics and composites have contributed to maize production in India in the initial stages of maize improvement programme, of late, hybrids are playing a vital role due to their high yielding potential. However, there is a continuous need to evolve new hybrids, which should exceed the existing hybrids in yield. In maize, the scope of exploitation of hybrid vigour will depend on the type of gene action besides the direction and magnitude of heterosis. Information on combining ability also provide guidelines to the plant breeder in selecting the elite parents and desirable cross combinations and at the same time reveals the nature of gene action involved in the expression of traits and thereby helps in formulating breeding methodology to be used to improve the yield. Hence, the present investigation was carried out to understand the nature and magnitude of gene action besides combining ability, which would assist in identifying the best inbreds as well as single cross hybrids of maize in the present material.

MATERIAL AND METHODS

Eight ined lines of maize (CM 209, CM 132, CM 133, CM 148, CM 149, BML 6, BML 7 and BML 15) were crossed in a half diallel during *kharif*, 2010 at S.V Agricultural college farm, Tirupati. All the twenty eight cross combinations and their eight parental inbred lines were evaluated during *rabi*, 2010-2011, grown in a Randomized Block Design (RBD) with three replications. The crop was raised as per the recommended cultural practices. The row-to-row and plant to plant distance was 75 and 20 cm, respectively. The data was recorded on randomly selected five plants on leaf area index, plant height, cob length, cob girth, number of kernel rows per ear, number of kernels per row, SPAD (measured using SPAD meter), tassel length, number of branches per tassel, 100-seed weight, grain yield per plant. However, the data for the traits *viz.,* days to 50 per cent tasseling, days to 50 per cent silking, anthesis-silking interval and days to 50 per cent maturity were recorded as per plot basis. The data was subjected to preliminary analysis of variance (Panse and Sukhatme, 1985) and the combining ability analysis as per the procedure of Method 2 and Model I of Griffing's (1956).

Table 1. Analysis of variance for combining ability for yield and yield components in maize

Character	General ANOVA			ANOVA for combining ability					
	Replications (df=2)	Genotypes (df=35)	Error (df=70)	*gca* (df=7)	*sca* (df=28)	error (df=70)	s^2*gca*	s^2*sca*	s^2*gca* / *sca*
Days to 50 % tasseling	3.01	68.42**	1.65	74.40**	9.91**	0.55	7.38	9.36	0.79
Days to 50% silking	4.39	62.87**	1.73	65.91**	9.72**	0.58	6.53	9.14	0.72
Anthesis-silking interval	1.01	2.88**	0.53	2.27**	0.63**	0.18	0.21	0.46	0.46
Leaf area index	0.34	2.41**	0.25	1.75**	0.56**	0.08	0.17	0.48	0.35
Days to 50% maturity	5.11	75.04**	2.63	80.19**	11.22**	0.88	7.93	10.34	0.77
Plant height (cm)	395	1278.67**	67.61	1081.19**	262.48**	22.54	105.86	239.95	0.44
No. of kernel rows per ear	1.06	6.99**	0.47	6.22**	1.36**	0.16	0.61	1.20	0.51
No. of kernels per row	21.93	98.04**	8.96	34.09**	32.33**	2.99	3.11	29.34	0.11
Cob length (cm)	2.76	22.77**	1.53	11.95**	6.05**	0.51	1.14	5.99	0.19
Cob girth (cm)	0.55	5.84**	0.39	1.80**	1.98**	0.13	0.17	1.86	0.09
SPAD chlorophyll	24.74	83.41**	9.91	84.81**	13.55**	3.30	8.15	10.25	0.80
Tassel length (cm)	10.45	73.04**	6.62	47.45**	18.57**	2.21	4.52	16.36	0.23
No. of branches per tassel	9.08	40.67**	4.24	19.25**	12.13**	1.41	1.78	10.72	0.17
100-seed weight (g)	5.53	42.53**	2.69	18.24**	13.16**	0.90	1.73	12.26	0.14
Yield per plant (g)	500.31	3884.18**	206.91	388.49**	1521.29**	68.97	31.95	1452.32	0.02

** Significant at 1% level; *gca* – general combining ability; *sca* – specific combining ability; s^2*gca* – variance due to gca ; s^2*sca* – variance due to *sca*.

Table 2: Estimates of general combining effects (*gca*) of inbreds for yield and yield components in maize

Character	CM 209	CM 132	CM 133	CM 148	CM 149	BML 6	BML 7	BML 15
Days to 50 % tasseling	-2.65**	-0.68**	-0.38	-1.98**	-3.32**	1.75**	3.48**	3.78**
Days to 50% silking	-2.76**	-0.32	-0.39	-1.33**	-3.52**	2.04**	3.44**	2.84**
Anthesis-silking interval	-0.11	0.36**	-0.01	0.66**	-0.21	0.29*	-0.04	-0.94**
Leaf area index	-0.74**	-0.07	0.01	-0.34**	-0.12	0.43**	0.33**	0.50**
Days to 50% maturity	-4.94**	0.62*	0.32	-2.97**	-0.47	2.19**	3.96**	1.29**
Plant height (cm)	-11.80**	1.50	2.71	-16.02**	-4.53**	2.90*	11.21**	14.02**
No. of kernel rows per ear	1.26**	0.30*	0.57**	-0.73**	-0.60**	0.46**	-0.15	-1.10**
No. of kernels per row	-2.51**	-0.89	3.19**	-1.11*	-0.38	-0.02	-0.51	2.23**
Cob length (cm)	-2.18**	0.15	0.41	-0.64**	-0.42*	0.53*	0.76**	1.41**
Cob girth (cm)	0.28*	-0.20	0.40**	-0.80**	0.02	0.22*	0.42**	-0.35**
SPAD chlorophyll	3.16**	-2.86**	2.30**	2.78**	2.03**	-1.79**	-1.21*	-4.41**
Tassel length (cm)	-1.60**	1.21**	-0.81	4.76**	-1.57**	-0.79	0.41	-1.61**
No. of branches per tassel	0.20	0.83*	-1.87**	-0.53	2.73**	-1.03**	-0.60	0.27
100-seed weight (g)	-2.29**	0.74*	-1.51**	0.06	1.94**	-0.15	0.91**	0.32
Yield per plant (g)	-9.07**	-2.93	9.16**	-7.59**	1.52	0.89	2.58	5.45*

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

Table 3. Estimates of specific combining ability effects (*sca*) for yield and yield contributing characters in maize

S.No.	Crosses	Days to 50 % tasseling	Days to 50 % silking	Anthesis-silking interval	Leaf area index	Days to 50% maturity	Plant height (cm)	No. of kernel rows per ear	No. of kernels per row
1.	CM 209 × CM 132	-1.80*	-2.69**	-0.89*	0.24	-3.66**	0.67	1.38**	0.96
2.	CM 209 × CM 133	-1.43*	-1.62*	-0.19	-0.03	-4.02**	7.18	1.58**	-0.13
3.	CM 209 × CM 148	1.50*	1.98**	0.48	-0.03	0.28	8.38	-0.91*	3.77*
4.	CM 209 × CM 149	-1.50*	-1.82*	-0.32	0.66*	-1.89*	5.49	0.36	0.58
5.	CM 209 × BML 6	-3.56**	-3.05**	0.51	0.17	-1.22	9.19*	0.63	2.88
6.	CM 209 × BML 7	-1.96**	-2.12**	-0.16	-0.51	-0.99	7.08	-1.69**	2.17
7.	CM 209 × BML 15	-2.93**	-2.85**	0.08	0.27	-2.32*	7.81	-0.34	4.24*
8.	CM 132 × CM 133	-0.40	-0.05	0.34	0.35	-0.26	0.88	-0.46	2.52
9.	CM 132 × CM 148	-0.46	-1.45*	-0.99*	0.55*	-2.29*	1.68	1.44**	3.62*
10.	CM 132 × CM 149	3.54**	3.75**	0.21	0.63*	-2.79**	28.05**	-0.76*	3.50*
11.	CM 132 × BML 6	-2.53**	-1.82*	0.71	0.14	2.88**	9.69*	1.32**	3.94*
12.	CM 132 × BML 7	-4.26**	-3.55**	0.71	0.19	0.11	4.31	0.46	2.42
13.	CM 132 × BML 15	-3.23**	-3.29**	-0.06	-0.25	-3.56**	4.51	-0.59	1.56
14.	CM 133 × CM 148	-2.10**	-2.05**	0.04	-0.02	-2.32*	13.66**	-0.09	0.34
15.	CM 133 × CM 149	0.90	2.15**	1.24**	-0.24	1.51	-5.50	0.44	-2.46
16.	CM 133 × BML 6	-2.16**	-1.42*	0.74	0.40	-2.16*	-4.06	1.72**	1.98
17.	CM 133 × BML 7	-0.56	-1.15	-0.59	0.25	-1.59	21.09**	-0.07	4.34**
18.	CM 133 × BML 15	-0.86	-1.22	-0.36	0.97**	0.08	5.42	0.08	3.20
19.	CM 148 × CM 149	-1.83*	-3.25**	-1.42**	-0.08	0.14	4.83	0.28	2.24
20.	CM 148 × BML 6	-2.90**	-2.49**	0.41	0.45	-6.19**	7.41	-0.04	3.68*
21.	CM 148 × BML 7	0.04	0.45	0.41	1.44**	4.38**	5.76	0.30	1.50
22.	CM 148 × BML 15	0.74	-0.29	-1.02*	0.24	2.04*	17.75**	0.98*	5.77**
23.	CM 149 × BML 6	-1.56*	-1.95**	-0.39	-0.14	4.98**	10.45*	-0.84*	4.02*
24.	CM 149 × BML 7	-2.63**	-1.35	1.28**	0.56*	-0.46	-3.93	0.17	0.24
25.	CM 149 × BML 15	-1.26	-0.75	0.51	0.74**	-2.79**	1.39	1.38**	4.58**
26.	BML 6 × BML 7	0.64	1.41*	0.78	-0.17	-1.79*	-12.76**	2.04**	1.15
27.	BML 6 × BML 15	-1.33	-1.65*	-0.32	0.39	-2.46**	1.63	0.06	2.62
28.	BML 7× BML 15	0.27	-0.39	-0.66	0.74**	0.78	20.32**	0.01	4.10*
	SE (s_{ij})	0.67	0.69	0.38	0.26	0.85	4.30	0.36	1.56

Table 3. cont.......

S. No.	Crosses	Cob length (cm)	Cob girth (cm)	SPAD chlorophyll	Tassel length (cm)	No. of branches per tassel	100-seed weight (g)	Grain yield per plant (g)
1.	CM 209 × CM 132	-0.47	1.07**	-1.39	-1.36	0.63	0.15	13.29
2.	CM 209 × CM 133	0.37	0.21	0.49	-0.34	-1.33	0.80	19.22*
3.	CM 209 × CM 148	0.92	-0.40	-3.05	0.85	4.33**	1.36	0.33
4.	CM 209 × CM 149	0.24	0.38	2.13	0.63	1.07	1.48	5.71
5.	CM 209 × BML 6	1.29	1.48**	5.30**	2.45	2.50*	1.74	18.37*
6.	CM 209 × BML 7	0.95	0.35	1.25	4.38**	1.40	2.26*	18.21*
7.	CM 209 × BML 15	1.04	0.65	1.98	2.34	-0.47	2.19*	22.4**
8.	CM 132 × CM 133	1.34*	0.31	2.28	-0.36	0.70	-1.67	6.40
9.	CM 132 × CM 148	1.96**	0.44	4.49*	4.88**	-2.3*	-1.27	15.45*
10.	CM 132 × CM 149	1.24	-0.04	-5.80**	2.41	2.43*	1.98*	9.99
11.	CM 132 × BML 6	2.19**	0.82*	3.12	2.83*	1.53	0.22	15.82*
12.	CM 132 × BML 7	1.86**	0.79*	0.61	3.29*	1.10	1.91*	26.05**
13.	CM 132 × BML 15	1.34*	0.13	4.43*	2.12	-0.77	4.49**	24.05**
14.	CM 133 × CM 148	1.23	0.68*	-1.70	2.97*	4.73**	4.04**	24.19**
15.	CM 133 × CM 149	-0.08	-0.51	-1.03	-1.04	-2.20	-1.19	-15.27
16.	CM 133 × BML 6	-0.33	0.86*	2.04	0.38	3.57**	0.28	7.71
17.	CM 133 × BML 7	1.30	0.66	-4.25*	1.78	3.47**	2.16*	22.87**
18.	CM 133 × BML 15	1.59*	0.56	3.07	1.67	1.60	0.83	18.04*
19.	CM 148 × CM 149	0.43	0.69*	0.75	-2.40	5.8**	1.65	16.58*
20.	CM 148 × BML 6	1.65*	0.69*	4.80**	2.75	0.23	3.27**	30.49**
21.	CM 148 × BML 7	1.92**	0.79*	1.47	3.65*	-1.87	3.51**	6.64
22.	CM 148 × BML 15	2.20**	1.16**	-0.37	-1.63	2.93*	1.37	37.5**
23.	CM 149 × BML 6	2.30**	1.87**	-0.90	4.48**	-1.03	6.33**	51.37**
24.	CM 149 × BML 7	0.36	0.30	0.91	3.95**	2.20	1.15	4.34
25.	CM 149 × BML 15	1.82**	1.51**	0.81	3.84**	2.00	1.81*	37.08**
26.	BML 6 × BML 7	0.55	0.94**	0.39	-0.83	1.30	-1.74	10.41
27.	BML 6 × BML 15	1.20	0.14	3.60*	2.92*	1.77	1.77*	12.43
28.	BML 7× BML 15	0.90	0.31	-0.83	2.05	0.67	-1.13	18.37*
	SE (s_{ij})	0.65	0.32	1.65	1.34	1.07	0.85	7.53

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

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant differences for yield and its components, indicating the existence of sufficient variation in the material studied. Analysis of variance for combining ability (Table 1) revealed significance of both *gca* and *sca* variances for all the characters under study, thus indicating the importance of both additive and non-additive genetic variances in the inheritance of the characters. It is also evident that the component due to *sca* variances was higher than *gca* variance in all characters and also the ratio of *gca* to *sca* variances was less than unity, which indicated the predominance of non-additive gene action in controlling the expression of these traits. Similar results were also reported by Fan *et al.,* (2010) and Wannows *et al.,* (2010).

Based on the estimates of *gca* effects (Table 2), the inbred CM 133 recorded highly significant *gca* effect for grain yield per plant and number of kernels per row. Similarly, the inbred CM 149 was identified as the best general combiner for early tasseling, silking and high test weight. Therefore, these two inbreds *viz.,* CM 133 and CM 149 could be utilized in hybrid breeding programme to develop hybrids with high yielding ability coupled with earliness. The other inbreds *viz.,* CM 209 for early maturity, number of kernel rows per ear and SPAD chlorophyll; CM 148 for tassel length; BML 7 for cob girth and BML 15 for reduced anthesis-silking interval, high leaf area index, tall plant height and increased cob length were identified as the best general combiners in the present material. Based on *gca* effects and *per se* performance, the inbreds CM 209, CM 149 and BML 15 were recognized as the best parental lines for most of the traits under study. The inbreds with high *gca* could produce superior segregants in F_2 and later generations. The lines CM 209, CM 149 and BML 15 recorded high *gca* effects in desirable direction for most of the yield contributing characters studied. Therefore, these inbred lines may be utilized in the hybridization programme for selecting superior recombinants.

The estimates of *sca* effects revealed (Table 3) that the hybrids *viz.,* CM 149 x BML 6 for cob length, cob girth, yield per plant and 100-seed weight and the cross CM 132 x BML 7 for early tasseling and silking recorded the highest desirable *sca* effects and could be utilized to develop superior recombinants for yield and earliness in later generations. The other crosses which exhibited highly significant *sca* effects in desirable direction were, CM 148 x CM 149 for anthesis-silking interval and number of branches per tassel; CM 148 x BML 7 for leaf area index; CM 148 x BML 6 for days to 50 per cent maturity; CM 132 x CM 149 for plant height; CM148 x BML 15 for number of kernels per row; BML 6 x BML 7 for number of kernel rows per ear; CM 209 x BML 6 for SPAD chlorophyll and CM 132 x CM 148 for tassel length. Based on both *per se* performance and *sca* effects the crosses *viz.,* CM 149 x BML 6 and CM 148 x BML 15 were identified as the best crosses for yield and most of the yield related traits. In these crosses, combination of favourable genes from parents for the corresponding traits might have resulted in high *sca* effects. These two cross combinations are ideally suitable for commercial exploitation after testing their performance in multi-location and on farm trials. Similar results were also reported by Premalatha and Kalamani (2010).

To conclude that the combining ability analysis indicated predominance of non-additive gene action in all the characters. Hence, by following recycling procedures such as recurrent selection and/or reciprocal recurrent selection, the frequency of favourable alleles could be increased in segregating generations and thereby superior inbreds could be isolated (Debnath, 1987).

The inbreds CM 209, CM 149 and BML 15 in the present material were identified as the best general combiners for most of the traits under study and could be exploited in hybrid breeding programme to develop superior cross combinations and/or for the development of synthetic varieties after confirming their combining ability in later generations. The crosses *viz.,* CM 149 x BML 6 and CM 148 x BML 15 were identified as the best crosses for yield and most of the yield related traits and hence, these hybrids could be exploited for commercial cultivation after testing their performance in multi-location trials.

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