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Study of combining ability and heterosis analysis for yield traits in maize (*Zea mays* L.)

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Abstract
Combining ability and heterosis for yield and its contributing traits was studied in 7 parental in a diallel scheme. The purpose of the study was to identify and select superior parents and best hybrid combinations on the basis of estimates of general and specific combining abilities. The highest percentage of economic heterosis for grain per ear was observed by the cross CML-49 x DMR-3010. Crosses CML-80 x BVM-2 and DMR-3010 x BVM-2 showed significant negative heterosis for days to maturity.Both general combing ability (GCA) and specific combing ability (SCA) variances were significant for grain yield and all yield component characters, except GCA variances for ear height. Almost equal role of additive and non-additive gene actions was observed for days to maturity. Additive genetic variance was preponderant for grains per ear and 1000-grain weight and non-additive gene action was involved in plant height, ear height, days to silking and days to maturity. The combining ability effects revealed that parents DMR-3010, DMR-3004 and Local 99-B were identified as good general combiners for grain yield and for most of the characters. The crosses, BVM-2 x Chandan-3, BVM-2 x DMR-3004 and BVM-2 x Local 99-B were good specific combiner for grain yield and either two or more component traits. Considering the overall performances, the inbred lines/genotypes DMR-3010 and DMR-3004 may be utilized for the development of F_1 hybrid in maize.

Keywords: Maize, Combining ability, Heterosis, yield

Introduction
Maize (*Zea mays* L.) is one of the most widely grown global cereal and is the primary staple food in many developing countries (Morris *et al*., 1999) [9]. It is a versatile crop with wider genetic variability and able to grow successfully throughout the world covering tropical, subtropical and temperate agro-climatic conditions. Maize acreage and production have an increasing trend with the inclusion of hybrids due to its high yield potential.

In order to achieve this target one should be aware of genetic makeup and nature of gene action involved in controlling plant responses to different environments. For the breeding programme aiming at hybridization, information about better combiner possessing desirable traits is a pre-requisite. Information on the heterotic patterns and combining ability among maize germplasm is essential in maximizing the effectiveness of hybrid development by Beck *et al.* (1990) [3]. In maize, appreciable percentage of heterosis for yield and combining ability were studied by several workers like, Roy *et al.* (1998) [13], Paul and Debnath (1999) [12] and Rokadia and Kaushik (2005) [10]. Knowledge of the combining ability is important in selecting suitable parents for hybridization, understanding of inheritance of quantitative traits and also in identifying the promising cross combinations for further use in breeding programmes. Keeping in view, present investigation was undertaken to study the combining ability of varieties/lines for yield, its contributing traits.

Material and Methods
The present study was conducted at the Zonal Research Station, Birsa Agricultural University, Chianki, Palamau. The experimental material of the study consisted of seven maize lines parental genotypes/inbred i.e. CML-49, DMR-3010, CML-80, BVM-2, DMR-3004, Chandan-3 & Local-99B and their 21 F_{1s}. The F_{1s} were made by crossing all the seven parents in half diallel fashion during *Kharif*2006. These crosses were then evaluated along with the parents and check, Suwan Composite-1 during 2007.The experiment was laid out in a Randomized Block Design (RBD) with three replications. Each plot consisted of four rows of 5.0 meter long with a row to row distance of 75 cm. The plant to plant distance was maintained at 45 cm by dibbling the seeds manually. Eight morphological characters namely, days to 75% heading, days to maturity, plant height at maturity (cm), ear cob height (cm), cob length (cm), number of rows per cob, grain per line, 100 grain weight, seed yield per plant were studied. Analysis of

variance was carried out according to Fisher (1918) to determine the significant differences among genotypes. Combining ability analysis in diallel scheme was carried out following the method given by Griffing's (1956) [5] model l method 2.

Results and Discussion

Heterosis for all the 11 traits studied was found with all crosses. A wide variation of heterosis range, heterosis mean, number of desired hybrids and best hybrid was found for most of the traits (Table 1). Rokadia and Kaushik (2004) stated that the superiority of hybrids particularly over high parent is more useful for commercial exploitation of heterosis and also indicated the parental combinations capable of producing the highest level of transgressive segregants. However, for grain yield per plant, economic and average heterosis ranged from -29.38 to 81.33 and from -35.01 to 94.69 with mean value of 49.22 and 60.92, respectively. Early maturity is the desirable traits in maize in which the cross combination BVM-2 x Chandan-3 showed highest negative heterosis for days to maturity both over economic variety and mid parent. Significantly highest positive economic and average heterosis was observed in CML-49 x DMR-3010 and CML-49 x BVM-2 for grain yield/plant, respectively. Appreciable percentage of heterosis for grain yield in maize was also reported by Lonnquist and Gardner (1961) [8] and, Akhtar and Singh (1981) [1]. General and specific combining ability variances and effects were estimated with a view to decipher the genetic architecture of the characters under study. Combining ability describes the breeding value of parental lines to produce hybrids (Romanus *et al.* 2008) [11]. The general combining ability has been equated with additive gene action and specific combining ability with non-additive gene action (Griffing 1956) [5]. The analysis of variance for combining ability was done for all the 14 characters (Table 2). Highly significant variances, of both general and specific combining ability, were observed which indicated the importance of both additive and non-additive gene effects for all the traits except ear length (where only sca variance was highly significant indicating non-additive gene action), ear diameter and kernel rows per ear. The estimated value of $\sigma^2 gca$ was higher than its $\sigma^2 sca$ for days to maturity which indicated the predominance of additive gene action as the ratio of $\sigma^2 gca/\sigma^2 sca$ was more than unity while rest of the traits showed preponderance of non-additive gene action. The value of average degree of dominance $(\sigma^2 sca / \sigma^2 gca)^{0.5}$ for days to maturity indicated partial dominance while rest of the traits showed over dominance. In the same way, preponderance of non-additive gene effects were reported by several researchers (Izhar and Chakarborty, 2013 andSuthamathi and Nallathambi, 2015) [6, 14].

While considering *gca* effects of the parents, it was found that none of the parents was observed as good general combiner for all the 11 traits. However, Local 99-B and DMR-3010 for early maturity, DMR-3004 for ear length and ear diameter, kernel rows per ear, CML-49 for kernel per ear, Local 99-B and CML-80 for 100-seed weight, DMR-3010, DMR-3004 and Local 99-B for grain yieldper plant (Table 3). Kabdal *et al.* (2003) [7] and Amiruzzaman *et al.* (2010) [2] also reported similar trends

The estimates of sca presented in Table 4 reveal that the cross BVM-2/ Chandan-3 had the highest specific combining ability for yield per plant followed by the cross and BVM-2/Local 99-B involved high x low general combiners. While the cross While the cross DMR-3004 x Local 99-B had high specific combining ability for ear height and both the parents involved were found to be the best general combiners for the same characters. There are chances of recovering transgressive segregants from these combinations in later generations. In the present findings, best combinations mostly involved high × low and low × low general combiners for the characters under study. There was very rare case in which high × high general combiners were involved for best combinations. The same type of result was also observed by Vasal *et al.* (1992) [15] and Izhar and Chakraborty. (2013) [6]. Thus, it is evident that high specific combiners are not always obtained between high general combiners but may occur between low × low or high × low general combiners. This might be probably due to the presence of dominant and epistatic gene interactions

Table 1: Heterosis range, heterosis mean. Number of desirable hybrids and best hybrids [over standard variety (Suwan composite-1) and mid-parent (MP) for 10 traits in maize]

Traits	Heterosis hybrids	Heterosis range (%)	Heterosis mean	No. of desirable hybrids	Best Hybrids
Days to 50% tasselling	Standard heterosis	-24.86 to 12.18	-6.00	16	BVM-2 x Chandan-3
	Mid-parent heterosis	-10.12 to 22.98	4.68	8	CML-49 x DMR-3010
Days to 50% silking	Standard heterosis	-22.36 to 10.42	-5..82	15	CML-49 x BVM-2
	Mid-parent heterosis	-9.34 to 19.84	7.75	8	BVM-2 x Chandan-3
Days to 75% dry husk	Standard heterosis	-34.12 to 8.74	-9.74	19	BVM-2 x Chandan-3
	Mid-parent heterosis	-7.55 to 28.32	6.12	6	CML-49 x DMR-3010
Plant height	Standard heterosis	-36.52 to 32.45	16.68	6	CML-49 x DMR-3004
	Mid-parent heterosis	-45.92 to 40.19	12.52	11	DMR-3010 x CML-80
Ear height	Standard heterosis	-31.16 to 32.95	12.95	7	CML-49 x DMR-3004
	Mid-parent heterosis	-41.01 to 35.72	8.61	11	DMR-3010 x CML-80
Ear length	Standard heterosis	-19.11 to 12.16	10.12	12	CML-49 x DMR-3010
	Mid-parent heterosis	-14.15 to 28.32	14.72	15	CML-49 x BVM-2
Ear diameter	Standard heterosis	-11.23 to 16.18	9.12	10	DMR-3004 x Local-99B
	Mid-parent heterosis	-17.44 to 18.74	11.96	6	Chanda-3 X Local-99B
Kernel rows/ear	Standard heterosis	-22.41 to 28.55	18.12	8	DMR-3004 x Local-99B
	Mid-parent heterosis	-20.53 to 39.72	25.56	9	CML-49 x DMR-3010
Kernel/ear	Standard heterosis	-17.21 to 12.68	32.44	17	CML-49 x DMR-3010
	Mid-parent heterosis	-12.55 to 18.72	40.56	19	CML-49 x BVM-2
100-kernel weight	Standard heterosis	-20.16 to 22.83	11.95	7	CML-80 x BVM-2
	Mid-parent heterosis	-16.68 to 26.88	14.73	9	CML-49 x DMR-3010
Grain yield (q/ha)	Standard heterosis	-29.38 to 81.33	49.22	14	CML-49 x DMR-3010
	Mid-parent heterosis	-35.01 to 94.69	60.92	15	CML-49 x BVM-2

Table 2: Analysis of variance (ANOVA) for combining ability along with estimates of genetic components of variance and degree of dominance for 11 characters in maize

Source of variation	D.F.	Days to 50% tasselling	Days to 50% silking	Days to maturity	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Kernel rows/ear	Kernel/ear	100-kernel weight (g)	Yield (q/ha)
GCA	6	40.83**	35.25**	455.23**	35.64**	23.56**	0.61	0.6	1.22	16.98**	18.45*	6.45**
SCA	21	9.15**	8.64**	42.68**	64.68**	45.84**	1.45	3.89**	1.11	32.65**	21.78**	15.18**
Error	54	0.03	0.04	0.03	0.04	0.03	0.01	0.02	0.03	0.12	0.02	0.14
σ^2gca		5.08	4.68	52.10	4.02	3.52	0.06	0.04	0.12	1.89	4.89	0.69
σ^2sca		9.56	8.67	42.65	60.23	45.38	1.4	3.89	1.0	32.12	87.91	14.85
σ^2gca/σ^2sca		0.50	0.48	1.18	0.05	0.04	0.04	0.01	0.11	0.05	0.05	0.03
$(\sigma^2sca/\sigma^2gca)^{1/2}$		1.3	1.2	0.92	4.01	3.94	3.69	8.65	2.58	4.21	8.45	4.58

* Significant at 5% level, ** significant at 1% level; gca, general combining ability; sca, specific combining ability; **σ^2gca/σ^2sca** ratio of gca variance to sca variance;, **$(\sigma^2sca/\ \sigma^2gca)^{1/2}$** degree of dominance

Table 3: Estimates of general combining ability effects of the parents for yields and its important attributes in maize

Entries	Days to 50% tasselling	Days to 50% silking	Days to maturity	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Kernel rows/ear	Kernel/ ear	100-kernel weight (g)	Yield (q/ha)
CML-49	2.76**	2.83**	-0.92**	-4.89**	1.20**	0.16	0.01	-0.05	6.95**	-0.95**	-0.60
DMR-3010	-1.09**	-0.90**	-1.69**	-5.03**	-0.86*	-0.51**	-0.02	0.36**	9.17**	-0.44*	2.55**
CML-80	3.92**	-3.65	-0.86**	-1.79**	-0.36	-1.37**	-0.02	0.04	-1365**	0.76**	0.84
BVM-2	-0.74**	-0.67**	-0.59*	7.52**	-0.05	0.91**	0.07*	-0.70**	-1.14	-0.43*	-0.79
DMR-3004	-0.70**	-0.80	0.74**	-0.55	0.60	0.83**	0.07*	0.59**	-1.13	1.59**	2.11*
Chandan-3	1.40**	-0.81**	0.21	-1.62**	1.01*	-0.31**	-0.08	-0.21	-15.23**	-0.04	0.79
Local 99 B	1.02**	-0.94**	-3.10**	-9.01**	-6.10**	-0.12	-0.06*	0.54**	-13.54**	2.34**	0.91**
SE (gi)±	0.05	0.04	0.25	0.50	0.41	0.10	0.06	0.12	0.08	0.20	0.80
SE (gi-gj)±	0.07	0.06	0.38	0.76	0.62	0.15	0.09	0.18	0.11	0.30	1.21

Table 4: SCA effects of crosses for different characters in Maize

Particulars	Days to 50% tasselling	Days to 50% silking	Days to maturity	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Kernel rows/ear	Kernel/ ear	100-kernel weight (g)	Yield (q/ha)
CML-49 x DMR-3010	3.42**	1.44**	2.42**	-4.46*	5.27**	0.45	0.54**	0.88*	2.23	-4.35**	3.65
CML-49 x CML-80	2.22**	1.34**	1.82*	-9.10**	3.36**	0.59	0.98**	0.18	5.60**	-2.34**	3.99
CML-49 x BVM-2	0.83	-1.01**	0.89	0.66	-3.95**	-0.02	-0.50**	1.32**	-0.91	-0.93	-7.37**
CML-49 x DMR-3004	-1.25	-1.48**	-0.44	3.99*	-4.81**	0.06	-1.04**	0.30	-0.56	1.02	2.56
CML-49 x Chandan-3	0.08	-1.60**	-0.24	0.20	-2.75**	0.53	-0.54**	-0.10	2.03	-0.20	0.50
CML-49 X Local 99-B	1.69*	2.86**	0.39	1.01	7.77**	-0.06	1.18**	-0.07	-4.90**	2.64**	1.46
DMR-3010 x CML-80	-2.31**	-0.77**	-0.81	-2.07	-3.10**	0.57	-0.18**	-0.09	-0.43	-2.26**	4.18
DMR-3010 x BVM-2	-1.48*	-0.02	1.59*	-5.10**	-1.11**	0.12	0.24**	0.52	-2.04	-4.45**	-2.96
DMR-3010 x DMR-3004	-1.54*	0.34**	1.59*	0.99	0.93**	-0.07	-0.07	-0.50	-2.50	0.53	-0.33
DMR-3010 x Chandan-3	1.12	-1.85**	-0.21	-3.40*	-2.82**	-0.43	-0.43**	0.56	0.50	-2.24**	-2.36
DMR-3010 x Local 99-B	-0.94	-3.62**	0.09	3.94*	-7.26**	0.08	-1.38**	0.33	-3.73**	-3.46**	-4.55
CML-80 x BVM-2	2.06**	-2.30**	-1.24	0.16	-4.27**	-0.15	-1.09**	1.36**	1.55	-0.01	-2.34
CML-80 x DMR-3004	-0.68	-1.50**	-0.58	-0.65	-1.86**	-0.60	-0.47**	-0.05	-2.50	-2.48**	-2.02
CML-80 x Chandan-3	-3.01**	-1.79**	-0.71	0.89	-3.81**	0.33	-0.74**	0.74	0.29	1.92**	0.65
CML-80 X Local 99-B	1.26	-0.96**	1.26	2.43	-2.01**	0.74*	0.05	-0.02	-1.84	0.64	4.90
BVM-2 x DMR-3004	-0.84	0.78**	-0.51	5.22**	1.83**	-0.22	0.26**	-0.08	-0.11	6.47**	10.61**
BVM-2 x Chandan-3	-0.18	-0.50**	1.02	-3.54*	2.55**	0.72*	-0.14*	-0.72	1.88	3.61**	12.34**
BVM-2 x Local 99-B	0.09	3.52**	0.66	0.66	7.75**	0.59	1.21**	-1.68**	4.85**	0.20	10.21**
DMR-3004 x Chandan-3	0.42	0.22**	0.69	0.99	-2.54**	1.53**	-0.09	-0.33	-0.77	-4.59**	-1.48
DMR-3004 x Local 99-B	2.36**	2.75**	0.66	-4.74**	11.59**	0.58	1.30**	0.90*	6.20**	-3.26**	-1.89
Chanda-3x Local 99-B	0.36	2.17**	0.52	-0.13	2.57**	1.08**	0.50**	0.36	7.09**	1.68**	-2.44
SE(Sij)±	0.32	0.08	0.76	1.54	0.21	0.30	0.06	0.37	1.25	0.60	2.45
SE(Sij-Skl) ±	0.92	0.11	1.07	0.45	0.29	0.42	0.09	0.52	1.75	0.84	3.42

, - significant at 5 and 1% respectively*

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