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Relationship between heterosis, potence ratio and genetic distance for yield traits in maize (*Zea mays*)

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ABSTRACT

An experiment was conducted during 2014–18 at Agricultural Research Station, Professor Jayashankar Telangana State Agricultural University, Karimnagar, Telangana to find out the relationship between heterosis, potence ratio and genetic distance for yield contributing characters in maize (*Zea mays* L.). Heterosis was trait dependent exhibiting high level for plant height, ear height, ear length, kernels/row, 100-kernel weight, grain yield and fodder yield. Two hybrids BML-51 × BML-14 (22.1%) and BML-51 × BML-6 (13.2%) recorded heterosis of greater than 10% over the check NK6240 and exhibited negative heterosis for flowering and maturity traits and positive heterosis for the remaining traits. Potence ratio indicated that majority of the traits in the hybrids had over dominance gene effect and expressed over dominance for ear length, ear diameter, kernels/row, fodder yield and grain yield suggesting heterosis breeding is an appropriate strategy for improvement of these traits. Standard heterosis of greater than 5% was observed in 7 crosses and out of these 6 belonged to mid parental divergence group. Five crosses, viz. BML-51 × BML-14, BML-51 × BML-7, BML-51 × BML-6, BML-32 × BML-13 and BML-32 × BML-6 with yield ranging from 7637 to 8733 kg/ha belonged to the medium parental divergence group comprising of high yielding inbreds, viz. BML-51 or BML-32 as parents. Grain yield heterosis was found significant and positively correlated with heterosis for ear length and 100-kernel weight. Therefore to maximize the full genetic potential of hybrids, inbreds with high *per se* performance and intermediate genetic divergence are to be involved in maize crop improvement programmes.

Keywords: Heterosis, Maize, Potence ratio, Parental divergence, Single crosses

Globally maize (*Zea mays* L.) is an important cereal crop because of its diverse uses mainly as food, feed and raw material for industrial products. In recent years the maize crop registered impressive production gains (both at global and national level) and this could be attributed largely to successful adoption of single cross hybrid technology. However, to match the growing requirement of the consumer across the globe there is an urgent need to further improve the productivity level especially in developing nations including India.

Maize in Telangana state is an important crop occupying consistently an area of 6.5 lakh ha for the past 5–6 years but had shown a quantum jump of 3.0 t/ha in productivity (i.e. from 3.34 t/ha to 6.30 t/ha). This gain in productivity is attributed to post-rainy maize cultivation. Since the option for further increase in area is limited, a vibrant breeding programme needs to be adopted in hybrid development to enhance productivity across a range of production ecologies. Considering the above facts, the performance of single cross hybrids developed by involving newly developed potential inbreds was evaluated to estimate heterosis in comparison with mid and better parents along with popular hybrid check. Based on this data potence ratio was also determined during 2019 and an attempt has been made to find out the relationship between heterosis, potence ratio and genetic distance.

MATERIALS AND METHODS

Seven newly developed inbreds, viz. BML 51, BML 32, BML 14, BML 13, BML 10, BML 7 and BML 6 were crossed in diallel fashion (Griffing 1956 Method I Model II) to synthesize 21 single crosses in rainy (*kharif*) season, 2014 and the details of the inbreds used in this study have already been published in earlier paper (Sumalini *et al.* 2018). Using these 21 single crosses, 105 each of three-way and double cross hybrids were produced during post-rainy season, 2014–15. The performance of 21 single crosses and 105 each of three-way and double cross hybrids along with parents was tested during rainy season, 2015 against 18 hybrid checks at 3 locations, viz. Regional Agricultural

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Research Station, Palem, Telangana (E1), Maize Research Centre, ARI, Rajendranagar, Hyderabad, Telangana (E2) and Agricultural Research Station, Karimnagar, Telangana (E3) representing diverse ecologies. A balanced lattice (16 × 16) design was adopted with two replications at each location in a plot size of 3.6 m^2 at spacing of 60 cm × 20 cm. The crop was managed as per the recommended production practices to raise a good crop.

In this paper, however, data pertaining to seven inbreds, 21 single crosses and NK6240 a highly adapted check hybrid from Syngenta Pvt Ltd. was used to estimate heterosis, potence ratio and genetic distance and the results of the same are discussed and reported.

Observations: A total of 13 yield and yield contributing characters were recorded out of which 7 traits, viz. days to 50% pollen shed, days to 50% silk emergence, days to 75% dry husk, shelling percentage (%),100-kernel weight (g), grain yield (kg/ha) and fodder yield (kg/plot) were measured on plot basis while rest of the six i.e. plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), kernel rows/ear and kernels/row were scored on 10 randomly selected plants during 2017–18.

Statistical analysis: The ANOVA for balanced lattice indicated higher intra block variation over the block differences and hence, the efficacy of this design couldn't be confirmed. Therefore, data were reanalyzed using randomized block design (Eberhart *et al.* 1964). Plot means were used for statistical analysis. The Bartlett's test for homogeneity of variances was computed to test the homogeneity of error variance among the 3 locations for single crosses for all the characters and the data were subjected to analysis of variance (ANOVA) for pooled environments. To test the normal probability distribution of the data, Shapiro-Wilk test (1965) was done using RStudio.

Average heterosis, heterobeltiosis and standard heterosis for different characters were estimated as per Mather and Jinks (1971).

To determine the degree of dominance, potence ratio was estimated as (Mather 1949, Smith 1952):

$$P= (F_1\text{-}MP)/0.5\ (P_2\text{-}P_1)$$

where, P, relative potence of gene set; F_1, first generation mean; P_1, the mean of lower parent; P_2, the mean of higher parent; MP, mid-parents value $(P_1 + P_2)/2$.

Complete dominance was indicated when Potence ratio = ±1, Partial dominance is indicated when Potence ratio is between −1 and +1, Over dominance is indicated when potence ratio exceeds ±1. Absence of dominance is indicated when Potence ratio = 0. The positive and negative signs indicate the direction of dominance of either parent (Mahesh *et al.* 2017).

Phenotypic distance between the parents was estimated using Hierarchical cluster method (RStudio Team 2020) and based on these values parents were classified into 3 categories. Phenotypic distance greater than (m+SD) indicated high divergence group while (m-SD) represented lower divergence group and values falling in between these two classes was considered under medium divergence group (Datta *et al.* 2004). Correlations of yield with potence ratio, phenotypic distance and heterosis were computed (RStudio Team 2020).

RESULTS AND DISCUSSION

The Bartlett's test revealed homogeneous error variances for majority of the yield and its contributing characters hence, pooled analysis was carried out. Further, the data were subjected to Shapiro-Wilk test for normality and it was ascertained that all the characters followed normal distribution.

Heterosis: Data pertaining to the performance of 21 single crosses evaluated at three locations against the check NK6240 was earlier reported (Sumalini *et al.* 2019). Perusal of the data revealed significant differences among the hybrids for all traits indicating the presence of heterosis and heterotic effects. Of the 21 single crosses, none of crosses expressed standard heterosis over check NK6240 at pooled locations for days to 75% dry husk, ear diameter and grain yield (data not shown). It becomes evident from the study that the amount of heterosis in any hybrid was trait dependent and to unravel the mechanism of heterosis a deep insight into specific traits is necessary to predict better heterotic hybrids with maximum productivity (Flint-Garcia *et al.* 2009). Only 2 crosses BML-51 × BML-14 (22.1%) and BML-51 × BML-6 (13.2%) exhibited standard heterosis

Table 1 Performance of hybrids over DHM-117 for yield contributing traits pooled over years, *rabi* 2017–18 and 2018–19

Hybrid	DT (50%)	DS (50%)	PLHT (cm)	EHT (cm)	EL (cm)	ED (cm)	KR	KRR	Sh (%)	GY (kg/ha)
BML-51 × BML-14	57.3	59.7	207.5	101.0	18.5	4.49	14.3	33.7	79.4	9625
BML-51 × BML-7	57.7	59.8	207.7	103.0	17.8	4.01	14.3	34.7	80.9	9051
BML-51 × BML-6	58.0	60.3	202.8	97.2	17.8	4.20	15.0	33.2	80.3	8309
BML-32 × BML-13	56.8	59.2	195.2	94.8	17.3	3.95	13.7	37.7	79.0	7864
BML-32 × BML-6	57.3	60.0	206.7	103.5	16.8	3.84	13.7	31.0	79.9	6974
DHM-117 (Check)	62.0	63.7	199.7	99.3	17.3	4.53	14.0	32.5	79.5	8485
LSD (0.05) (Treatments)	1.1	1.3	10.4	9.1	1.7	5.4	1.7	4.7	3.4	927

LSD, Least Significant Difference; DT (50%), Days to 50% pollen shed; DS (50%), Days to 50% silking; PLHT, Plant height; EH, Ear height; EL, Ear length; ED, Ear diameter; KR, Kernel rows/ear; KRR, Kernels/row; Sh%, Shelling percentage; GY, Grain yield.

over the check NK6240.The high yielding hybrid BML-51 × BML-14 had either on par or significantly lower values for traits such as ear length, ear diameter, shelling %, kernel rows/ear as compared to the check NK6240. On the contrary, 100-kernel weight in this hybrid was highly significant suggesting the existence of yield compensating mechanism. These two hybrids displayed negative heterosis for days to 50% pollen shed, days to 50% silking and kernel rows/ear. BML-51 × BML-14 had highly significant heterosis for 100-kernel weight (29.0^{**}%) and BML-51 × BML-6 had significant heterosis for kernels/row (17.1^{*}%). It indicates that negative heterotic expression for kernel rows/ear is countered by positive heterosis of the characters like 100-kernel weight and kernels/row resulting in no yield loss. Further, these two hybrids were ideal in plant height as ear position was at half of the plant height. Results of the studies carried out by Ghosh *et al.* (2018) and Anilkumar and Lohithaswa (2018) on similar aspects also confirmed the findings of this investigation.

Further, 5 high yielding hybrids as discussed above were evaluated in post-rainy seasons of 2017-18 and 2018-19 to know the consistency of performance at Agricultural Research Station, Professor Jayashankar Telangana State Agricultural University, Karimnagar, Telangana. Pooled analysis was carried out and it was observed that only one hybrid i.e. BML-51 × BML-14 (9625 kg/ha) exhibited significant grain yield over the check DHM-117 (8485 kg/ha) while the hybrid BML-32 × BML-6 was found to be inferior (6974 kg/ha). Rest of the 3 hybrids BML-51 × BML-7 (9051 kg/ha), BML-51 × BML-6 (8309 kg/ha) and BML-32 × BML-13 (7864 kg/ha) were found on par (Table 1).

The values of heterobeltiosis and standard heterosis in respect of different yield components were analysed for their association with grain yield through correlation studies and the data revealed that the cob characters, viz. ear length, kernels/row, 100-kernel weight are significant and positively correlated with the grain yield in single crosses (data not shown). Interestingly, significant and negative association was observed between ear length and 100-kernel weight. Of the five cob characters except 100-kernel weight, all other characters exhibited significant and positive association among them. On the strength of these observations, it can be inferred that heterosis for grain yield can be predicted.

Potence Ratio: The potence ratios of various traits of single crosses indicated the presence of various degrees of dominance effects (Table 2). Of the 13 traits, 5 traits, viz. ear length, ear diameter, kernels/row, fodder yield

Table 2 Potence ratio of 21 single crosses for yield contributing traits in maize

Cross	DT (50%)	DS (50%)	DM (75%)	PLHT (cm)	EHT (cm)	EL (cm)	ED (cm)	KR	KRR	Sh (%)	100 KW (g)	FY (kg/plot)	GY (kg/ha)
BML 51 × BML 32	-10.0	-9.3	-1.2	2.6	1.5	83.3	9.3	1.9	12.2	-0.1	3.2	3.7	17.8
BML 51 × BML 14	-16.0	-7.8	-1.8	1.6	1.2	7.3	68.1	14.7	3.5	0.4	2890.0	8.1	10.9
BML 51 × BML 13	-1.3	-1.7	-1.1	1.0	0.9	16.8	6.6	2.7	19.1	-1.4	1.5	2.9	10.6
BML 51 × BML 10	-0.9	-0.7	-0.2	0.9	0.7	4.4	15.7	1.7	4.3	0.2	1.7	3.6	11.2
BML 51 × BML 7	-68.9	-13.8	-4.2	1.9	1.4	16.3	4.9	0.8	6.3	0.4	2.6	5.7	12.5
BML 51 × BML 6	-21.0	-67.0	-11.0	1.8	2.1	16.2	5.0	1.2	18.8	0.7	1.4	14.4	21.2
BML 32 × BML 14	-3.0	-1.9	0.4	1.6	1.0	7.7	12.3	3.0	6.3	1.9	3.1	46.3	13.0
BML 32 × BML 13	-0.4	-0.3	3.6	1.0	1.1	19.1	5.2	9.6	51.9	1.9	1.5	10.8	34.8
BML 32 × BML 10	-0.3	-0.1	1.2	1.4	1.4	5.7	7.4	6.0	9.7	3.4	1.0	12.9	46.8
BML 32 × BML 7	-0.6	0.1	1.2	4.5	2.7	28.5	6.4	1.4	15.5	1.6	2.4	133.9	29.4
BML 32 × BML 6	-18.0	-3.6	0.8	1.9	4.9	18.2	8.1	2.9	9.4	1.8	1.3	5.3	409.8
BML 14 × BML 13	-1.2	-1.4	-0.7	1.7	3.8	11.5	8.9	2.3	3.9	0.8	2.3	21.0	29.3
BML 14 × BML 10	-1.0	-0.9	-0.5	2.7	7.6	9.4	25.2	2.1	14.1	1.9	1.3	13.2	20.1
BML 14 × BML 7	-7.9	-9.0	-3.7	4.6	6.5	4.9	5.2	1.3	9.3	6.3	3.0	39.5	30.5
BML 14 × BML 6	-7.0	-7.7	-2.4	6.2	1.5	3.6	3.1	1.2	2.6	5.5	0.8	6.4	13.0
BML 13 × BML 10	-2.7	-2.4	11.0	4.8	7.4	4.6	11.9	4.0	5.5	0.3	16.0	7.1	66.2
BML 13 × BML 7	-1.0	-1.2	-0.8	0.9	1.9	7.8	2.7	0.7	9.5	0.6	3.1	9.3	1248.9
BML 13 × BML 6	-1.9	-1.8	0.1	3.1	2.3	7.0	2.9	1.5	10.1	0.8	16.9	4.9	27.1
BML 10 × BML 7	-0.4	-0.2	-0.3	1.9	4.4	3.6	3.6	8.3	20.0	2.3	4.5	23.8	96.5
BML 10 × BML 6	-0.2	0.1	0.1	4.7	2.3	1.9	3.1	5.5	3.4	1.6	6.1	8.5	32.3
BML 7 × BML 6	-14.3	-7.5	-3.0	3.5	9.0	49.0	42.4	5.8	4.7	7.6	1.2	5.1	22.0

DT (50%), Days to 50% pollen shed; DS (50%), Days to 50% silking; DM (75%), Days to 75% dry husk; PLHT, Plant height; EH, Ear height; EL, Ear length; ED, Ear diameter; KR, Kernel rows/ear; KRR, Kernels/row; Sh%, Shelling percentage; 100 KW, 100 kernel weight; GY, Grain yield; FY, Fodder yield.

Table 3 *Per se* performance of inbreds, standard heterosis for grain yield and genetic distance of high yielding hybrids

Cross	GY (kg/ha) of crosses	Parental *per se* yield (kg/ha)	SH (%) over NK 6240	GD	PDC
BML 51 × BML 14	8733	3829, 2837	22.1	5.88	M
BML 51 × BML 6	8096	3829, 3406	13.2	4.74	M
BML 32 × BML 6	7801	3385, 3406	9.1	3.75	M
BML 51 × BML 7	7798	3829, 3139	9.1	5.13	M
BML 32 × BML 13	7637	3385, 3134	6.8	4.19	M
BML 14 × BML 7	7585	2837, 3139	6.1	3.70	M
BML 51 × BML 32	7559	3829, 3385	5.7	3.15	L

GY, Grain yield; SH %, Standard heterosis; GD, Genetic distance; PDC, Parental divergence class; Genetic divergence, > 5.90 = High (H), Between 3.64 – 5.90 = Medium (M), < 3.64 = Low (L).

and grain yield had positive potence ratio values of greater than one for all the 21 hybrids emphasizing the major role of overdominance for the inheritance of these traits (Begum *et al.* 2018, Rohman *et al.* 2019). Shelling percentage and flowering, and maturity traits, viz. days to 50% pollen shed, days to 50% silking and days to 75% dry husk were controlled by both partial and overdominance gene effects. On the other hand, two hybrids for days to 50% pollen shed and plant height and one hybrid for ear height and 100-kernel weight expressed complete dominance in gene action with potence ratio equal ±1. Overdominance is an intra-allelic interaction in which presence of multiple alleles lead to greater performance than homozygosity for either of the allelic state. In the present study, higher magnitude of heterosis for ear length, ear diameter, kernels/row, grain and fodder yield appears to be due to preponderance of overdominance gene effect. Hence, heterosis breeding can be assorted to improve these traits. Russell *et al.* (1978) also emphasized the importance of overdominance in the expression of heterotic effects for majority of the traits.

Genetic distance: Perusal of the data on mean grain yield, standard heterosis and genetic divergence showed a genetic distance of inbred parents ranging from 2.78 to 6.58 and mean grain yield (kg/ha) ranged from 2837 to 3829 kg/ha (data not shown). Inbred BML-51 (3829 kg/ha) had highest grain yield followed by BML-32 (3829 kg/ha) while minimum grain yield was observed in BML-6 (2837 kg/ha). Standard heterosis of greater than 5% was recorded in 7 crosses and of these 6 belonged to mid parental divergence group (between 3.70 to 5.88) (Table 3). High yielding inbreds BML-51 and BML-32 were involved in high heterotic cross combinations as one of the parent while other inbreds belonged to medium divergence group. In fact the high yielding 5 single cross hybrids, viz. BML-51 × BML-14, BML-51 × BML-7, BML-51 × BML-6, BML-32 × BML-13 and BML-32 × BML-6 (yield ranging from 7637 to 8733 kg/ha) belonged to the medium parental divergence group. The hybrids BML-51 × BML-14 and BML-51 × BML-7 gave grain yields over 90 q/ha over two seasons of evaluation. This shows a general trend where high yielding inbreds with medium parental divergence tend to produce high heterotic combinations. Similar results were reported by Ghosh *et al.* (2018). Based on the findings of the present investigation it is suggested to avoid parental lines with low and extremely high genetic divergence so that promising hybrid could be developed. Therefore it is further reiterated that medium parental divergence coupled with high *per se* performance of inbreds is more important than merely high genetic diversity to tap the full yield potential.

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