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ESTIMATE OF MAGNITUDE OF HETERO SIS FOR GRAIN YIELD AND ITS CONTRIBUTING CHARACTERS IN MAIZE(Zea mays L.)

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ABSTRACT

Estimate of heterosis experiment for grain yield and its contributing characters was carried out in maize (Zea mays L.) through line × tester mating design using 60 hybrids developed by crossing 15 inbred lines and four testers along with parents and three standard checks 30B07, NAH-1137 and NAH-2049. The 60 hybrids along with 19 parents and three standard checks were grown in Randomized Completely Block Design with two replications and were evaluated for grain yield and its 12 contributing characters at Zonal Agricultural Research Station, V. C. Farm, Mandya, University of Agricultural Sciences, Bangalore, Karnataka state, India, during Rabi 2010. The results on heterosis studies indicated marked variations in the expression of relative mid-parent, better-parent and standard heterosis for grain yield and its contributing characters. The manifestation of mid-parent heterosis for grain yield per plot ranged from -16.50 to 361.16 % while for better-parent heterosis ranged between -44.98 to 310.29 per cent. The standard heterosis over 30B07, NAH-1137 and NAH-2049 ranged from -22.39 to 142.29%, -43.68 to 75.81% and -35.80 to 100.00%, respectively. Among 60 crosses, 12 showed significant standard heterosis over best check NAH-1137 in the positive direction of which MAI45 × CM202 recorded maximum heterosis (75.81%). Considering per se performance grain yield standard heterosis more than 20%, as well as significant sca effects for major grain yield contributing characters, the crosses MAI45 × CM202, MAI33 × CM202, MAI27 × CM202, MAI48 × MAI105, MAI29 × CM202 and MAI28 × CM500 which are superior to the recently released single cross hybrid NAH-1137 were most promising combinations. They have to be evaluated across locations and seasons for future release.

Keywords: Heterosis, Mid-parent, Better parent, Standard Heterosis, sca effects, line × tester mating design

INTRODUCTION

Maize (Zea mays L.) is important cereal crop in many developed and developing countries of the world for its production and economic returns. It has a wider genetic variability and can be cultivated successfully worldwide covering tropical, subtropical and temperate agro-climatic conditions (Morris et al., 1999). The United States of America produces over 40% of the world total production. The next largest maize producers countries are China followed by Brazil, Mexico, France, Argentina, India and Italy. The United States of America and China accounts for 60% of the world total production (Sleper and Poelman, 2006). In many countries the importance of maize corresponds to its availability for human consumption, animal feeds and the source of supply of raw materials and their utilization in different processing and manufacturing activities (Morris et al., 1999). Given the great economic importance of maize, genetic breeding in this crop is very intense and mostly targeted at increasing grain yield. A frequent method used in maize breeding is to obtain inbred lines that are later crossed in order to develop different types of hybrids, which exhibit high heterosis when the inbred lines are complementary (Sleper and Poelman, 2006).

The potential of heterosis is just beginning to be exploited in developing countries through expansion of hybrid seeds. It has the highest potential of per day carbohydrate productivity. The invention of heterosis phenomenon, the development of hybrid breeding technology and successful commercial exploitation of heterosis in maize are considered to be significant achievements and land marks in the history of biological sciences during the present century (Shull 1952). Heterosis describes the superior performance of heterozygous F1-hybrid plants compared to the average of their homozygous parental inbred lines (Falconer and Mackay 1996) and is of notable importance in maize breeding. The hybrid development program in maize involves development and evaluation of inbred lines, crossing of selected inbreeds based on their combining ability and production of hybrids. The analysis of general combining ability and specific combining ability helps in identifying potential parents/inbreeds for the production of superior hybrids. It is important to know the performance of F1 hybrids before exploitation in commercial scale and this identification is expensive process. Thus a present investigation was aimed to evaluate the newly developed maize hybrids for grain yield and its contributing characters for future successful commercial utilization.

MATERIALS AND METHODS

The present study consists of 15 inbred lines (MAI23, MAI2, MAI28, MAI29, MAI31, MAI32, MAI33, MAI35, MAI38, MAI40, MAI42, MAI43, MAI44, MAI45 and MAI48) which were crossed to 4 testers (CM 500, CM 202, MAI 105 and NAI 137) in line × tester mating design during Kharif 2010 at Zonal Agricultural Research Station, V. C Farm, Mandya, University of Agricultural Sciences, Bangalore, Karnataka state, India. The 60 F1's along with 19 parents (15 lines and four testers) and three standard checks viz., 30B07, NAH-1137 and NAH-2049 were evaluated in randomized complete block design with two replications each during Rabi 2010. Each genotype was sown in two rows of two meters length with as spacing of 60 x 20 cm. The cultural practices, fertilizer levels and protection measures were followed to grow a good crop. The data were recorded on days to 50 per cent tasseling, days to 50 per cent silking, days to 50 per cent brown husk maturity, plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), number of kernel rows per cob, number of kernels per row, shelling percentage, 100-grain weight (g), grain yield (kg/plot) and fodder yield (kg/plot).

Mean values of the 13 quantitative characters recorded on the hybrids and parents were subjected for statistical analysis and variances due to different sources were estimated following the method of Panse and Sukhatme (1961). The combining ability analysis was done according to the procedure developed by Kempthorne (1957). Heterosis expressed as per cent increase or decrease of F1 hybrid over mid-parent (average or relative heterosis), better-parent (heterobeltiosis) and the best commercial check (standard heterosis) were computed as per the method of Tuner (1953) and Hayes et al., (1955). Out of the three checks, the mean performance of the best check for a given character was considered to work out the standard heterosis.

$$\text{a) Heterosis over mid-parent (relative heterosis)} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \text{ X } 100$$

$$\text{b) Heterosis over better parent (Heterobeltiosis)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \text{ X } 100$$

$$\text{c) heterosis over check (standard heterosis)} = \frac{\overline{F_1} - \overline{CC}}{\overline{CC}} \text{ X } 100$$

Where,

$\overline{F_1}$	=	mean performance of F_1
$\overline{MP}$	=	mean mid-parental value = $(P_1 + P_2)/2$
P_1	=	mean performance of parent one
P_2	=	mean performance of parent two
$\overline{BP}$	=	mean performance of better parent
$\overline{CC}$	=	mean performance of the best commercial check

Test of significance for heterosis

To test the significance of heterosis, the following formula proposed by Arunachalam (1974) was used.

$$\text{MP Heterosis } 't_{cal}' = \frac{\overline{F_1} - \overline{MP}}{SE}$$

$$\text{BP Heterosis } 't_{cal}' = \frac{\overline{F_1} - \overline{BP}}{SE}$$

$$\text{SH Heterosis } 't_{cal}' = \frac{\overline{F_1}-\overline{SC}}{SE}$$

To compute the standard error (SE) of estimates of heterosis, mean squares due to error (M_4) from RCBD analysis was considered

$$\text{S.E (Mid parent heterosis)} = \sqrt{\frac{3M_4}{2r}}$$

$$\text{S.E (Better parent heterosis)} = \sqrt{\frac{2M_4}{r}}$$

$$\text{S.E (Standard parent heterosis)} = \sqrt{\frac{2M_4}{r}}$$

Where,

r = Number of replications
Me = Error mean sum of square from analysis of variance table

Based on the performance of hybrids as well as significance of heterosis, we will list out hybrids with superior performance. The number of crosses deviating significantly MP indicate operation of non-additive gene action in such crosses and the remaining crosses confirm to additive gene action. Similarly, the number of crosses deviating significantly from BP indicate operation of over dominance gene action in such crosses and partial or additive gene action in the remaining crosses. The number of crosses deviating significantly from SH or CC can go for evaluation in multi-location trails years before final release.

RESULTS AND DISCUSSION

The percent heterosis have been assessed and expressed by the F1 hybrids over the mid-parent, better-parent and commercial checks, viz., 30B07, NAH-1137 and NAH-2049 for grain yield and its contributing characters are presented in Table 1. The degree of heterosis in F1 hybrids varied from character to character or from cross to cross.

Negative heterosis was considered desirable for days to 50 per cent tasseling, days to 50 per cent silking and days to 50 per cent brown husk maturity. The percentage of heterosis over mid-parent, better-parent and over the commercial checks 30B07, NAH-1137 and NAH-2049 ranged from -12.35 to 6.28%, -16.03 to 2.40%, -20.86 to -7.91%, -11.29 to 3.23% and -12.70 to 1.59%, respectively for days to 50% tasseling. Thirty one and 33 crosses showed significant mid-parent heterosis and better-parent heterosis in the desired direction (negative) respectively. Twenty two crosses took less number of days for tasseling over the best check NAH-1137 of which three crosses MAI48 × CM500 (-11.29%), MAI40 × CM500 (-8.87%) and MAI38 × CM500 (-8.87%) exhibited highly significant standard heterosis. The earlier workers including Hassaballa et al. (1980), Turgut et al. (1995) and Premlatha and Kalamani (2010) also reported highly significant heterotic effects for early tasselling. Among 60 crosses 30 exhibited significant negative heterosis over mid-parent and the magnitude ranged from -11.52% to 5.51% for days to 50% silking trait. Forty four crosses exhibited significant negative heterosis over better-parent and the magnitude of this heterosis varied from -15.11% to 2.38%. The magnitude of this heterosis over 3 commercial checks ranged from -19.18% to -6.16% (30B07), -9.92% to 4.58 % (NAH-1137) and -11.94 % to 2.24% (NAH-2049). Twenty six crosses showed significant negative standard heterosis over best check NAH-1137 of which MAI35 × CM500 (-9.92 %), MAI48 × CM500 (-9.92 %) and MAI40 × CM500 (-9.16 %) were very early to silk. Ganguli et al. (1989), Vasal et al. (1993) and Premlatha and Kalamani (2010) also reported highly significant heterotic effects for early silking. The percentage of heterosis over mid-parent, better-parent and three commercial checks ranged from -10.66 to 10.93%, -14.98 to 6.84%, -17.37 to 3.7% (30B07), -12.56 to 3.02% (NAH-1137) and -14.71 to 0.49% (NAH-2049) respectively for 50% brown husk maturity trait. Thirty eight crosses showed significant negative standard heterosis over NAH-1137 and MAI40×CM500 (-12.56%), MAI48 × CM500 (-11.56%) and MAI35 × CM500 (-11.06%) recorded highest significant negative standard heterosis. The expression of negative heterosis in this trait was also reported by Kalsy and Sharma (1970) while investigating on genetic parameters and heterotic effects in crosses of maize (Zea mays L.) varieties with varying chromosome numbers and Murthy et al. (1981) on his analysis of yield and maturity components in maize

Table 1: Estimation of heterosis percentage over mid-parent, better-parent and standard heterosis for grain yield and its contributing characters for best hybrids

Character	Hybrid	Mid-parent	Better-parent	Standard heterosis		
				30B07	NAH-1137	NAH-2049
Days to 50% tasseling	MAI48 × CM500	-12.35 **	16.03 **	-20.86 **	-11.29 **	-12.70 **
	MAI40 × CM500	-11.37 **	13.08 **	-18.71 **	-8.87 **	-10.32 **
	MAI38 × CM500	-5.69 **	-7.20 **	-16.55 **	-6.45 **	-7.94 **
Days to 50% silking	MAI35×CM500	-7.09 **	-11.28 **	-19.18 **	-9.92 **	-11.94 **
	MAI48 × CM500	-10.94 **	-15.11 **	-19.18 **	-9.92 **	-11.94 **
	MAI40 × CM500	-11.52 **	-14.39 **	-18.49 **	-9.16 **	-11.19 **
Days to 50% brown husk maturity	MAI40 × CM500	-7.94 **	-8.42 **	-18.31 **	-12.56 **	-14.71 **
	MAI48 × CM500	10.66 **	-14.98 **	-17.37 **	-11.56 **	-13.73 **
	MAI35× CM500	-5.09 **	-8.76 **	-16.90 **	-11.06 **	-13.24 **

Plant height (cm)	MAI45 × CM202	62.51 **	51.43**	16.92**	19.62 **	37.00 **
	MAI40 × MAI105	39.39 **	27.56**	5.34 **	7.77 **	23.43 **
	MAI29 × CM202	42.75 **	31.69**	0.34	2.66 *	17.57 **
Ear height (cm)	MAI45 × CM202	102.69 **	84.75 **	36.92 **	37.39 **	69.14 **
	MAI38 × NAI137	40.19 **	19.74 **	15.98 **	16.39 **	43.28 **
	MAI48 × NAI137	88.44 **	49.73 **	14.93 **	15.34 **	41.98 **
Ear length (cm)	MAI23 × MAI105	36.68 **	36.15**	8.59 *	20.41 **	52.59 **
	MAI43 × CM202	36.96 **	36.43**	7.98	19.73 **	51.72 **
	MAI23 × CM500	19.72 **	18.49**	6.13	17.69 **	49.14 **
Ear diameter (cm)	MAI28 × NAI137	46.40 **	38.89 **	4.84	2.20	27.45 **
	MAI29 × NAI137	29.60 **	29.60 **	4.52	1.89	27.06 **
	MAI45 × CM202	27.27 **	25.78 **	3.87	1.26	26.27 **
Kernel rows per cob	MAI35× CM202	29.32 **	21.13 **	21.13 **	6.17	22.86 **
	MAI31 × CM202	39.59 **	25.74 **	20.42 **	5.56	22.14 **
	MAI48 × MAI105	43.22 **	30.00 **	19.01 **	4.32	20.71 **
Kernels per row	MAI45 × CM202	40.96 **	28.57 **	22.94 **	37.11 **	65.57 **
	MAI43 × CM202	31.82 **	26.55 **	21.89 **	35.94 **	64.15 **
	MAI23 × MAI105	26.00 **	14.55 **	10.33 **	23.05 **	48.58 **
Shelling (%)	MAI48 × CM202	9.41 **	5.12 **	5.70 **	8.86 **	8.12 **
	MAI28 × CM202	8.40 **	4.58 **	5.15 **	8.30 **	7.56 **
	MAI42 × CM202	6.72 **	4.34 *	4.91 *	8.05 **	7.32 **
100- grain weight (g)	MAI42 × CM500	41.67 **	33.33 **	4.62 *	33.33 **	30.77 **
	MAI45 × CM500	24.07 **	13.56 **	3.08	31.37 **	28.85 **
	MAI28 × NAI137	40.43 **	34.69 **	1.54	29.41 **	26.92 **
Fodder yield/plot (kg)	MAI45 × CM202	156.52 **	118.52**	73.53 **	84.38 **	47.50 **
	MAI32 × CM202	168.29 **	150.00**	61.76 **	71.87 **	37.50 **
	MAI28 × CM500	84.62 **	77.78 **	41.18 **	50.00 **	20.00 **
Grain yield/plot (kg)	MAI45 × CM202	310.97 **	224.67 **	142.29 **	75.81 **	100.41 **
	MAI33 × CM202	86.44 **	17.02 **	91.54 **	38.99 **	58.44 **
	MAI27 × CM202	155.41 **	152.00 **	88.06 **	36.46 **	55.56 **

*Significant at P = 0.05 level **Significant at P = 0.01 level

In maize, tall types are preferred over dwarf types. Therefore positive heterosis is considered desirable for plant height. Out of evaluated 60 crosses, 47 and 37 crosses exhibited significant positive heterosis over the mid-parent and better-parent, respectively. Two crosses exhibited significant positive heterosis over best standard check 30B07. The highest positive standard heterosis was registered by MAI45 × CM202, MAI40 × MAI105 and MAI29 × CM202. This expression of high heterosis and sca effects also indicated the role of non-additive gene action in the inheritance of this trait. Gupta et al. (1994) and Singh et al. (2002) reported the heterosis in desirable direction for this trait (Table 1).

The extent of heterosis for ear height exhibited by crosses over their corresponding mid-parent ranged from –21.58 to 10.69% and –27.88 to 84.75% over better-parent. Over checks it ranged from –36.22 to 36.92% (30B07), –35.99 to 37.39% (NAH-1137) and -21.21 to 69.14% (NAH-2049). Out of 60 hybrids, 38 hybrids over mid-parent, 30 hybrids over better-parent showed significant heterosis in positive direction. Eleven crosses showed significant heterosis in positive direction over best check 30B07 of which MAI45 × CM202 (36.92%), MAI38 × NAI137 (15.98%) and MAI48 × NAI137 (14.93%) exhibited maximum heterosis(Table 1). Ganguli et al. (1989) and Premlatha and Kalamani (2010) reported positive heterosis over the better-parent, but Beck et al. (1990) reported low heterosis for this trait. For ear length the extent of heterosis exhibited by crosses over their corresponding mid-parent ranged from –7.44 to 62.98%, over better-parent ranged from –15.51 to 48.99%, over checks the range was from –18.10 to 8.59% (30B07), –9.18 to 20.41% (NAH-1137) and 8.62 to 52.59% (NAH-2049). Out of 60 hybrids, 39 hybrids over mid-parent, 25 hybrids over better parent showed significant heterosis in positive direction. These results were in accordance with those of Verma and Singh (1980), Debnath (1987), Turgut et al. (1995). Positive standard heterosis was expressed in many of the crosses but only one crosses viz., MAI23× MAI105 (8.59%) exhibited positive standard heterosis over best check 30B07 for this character (Table 1). From this study, the importance of non-additive gene action in the inheritance of ear length was evident as reported earlier by Ali and Topara (1986) and Debnath (1999). Superior performance of hybrids for ear diameter was desirable for increasing grain yield per plot. The magnitude of heterosis over mid-parent ranged from –7.34 to 46.40% and 6.71 to 38.89% over best parent. Over checks it ranged from -22.58 to 3.87% (30B07), -24.53 to 1.26% (NAH-1137) and -5.88 to 26.27% (NAH-2049). Significant positive mid-parent heterosis and better-parent heterosis was expressed by 49 and 33 crosses, respectively, but none of crosses expressed significant positive standard heterosis over checks. Debnath (1987) reported low mid-parent heterosis for ear diameter (Table 2). However, considerable heterotic effects for this trait were reported by Turgut et al. (1995).

As number of kernel rows per cob trait is concerned the heterosis was observed in the range of –1.40 to 45.92% over mid-parent, –9.63 to 56.88% over better-parent and –10.56 to 21.13 % (30B07), -21.60 to 6.17% (NAH-1137), -9.29 to 22.86% (NAH-2049) over respective checks. Five crosses exhibited positive but not significant heterosis over best check NAH-1137(Table 1) and this was in line with the findings of Presolska and Kamara (1991) who reported the expression of heterosis in this trait. In contrast, Salillari and Hoxha (1998) reported no heterosis for this trait. Twenty one out of 60 crosses exhibited significantly positive heterosis over mid-parent and the magnitude ranged from -24.95 to 47.47% for number of kernels per row. Eight crosses had significantly better-parent heterosis in positive direction which varied from -30.98 to 34.50%. Among sixty crosses a modest number five crosses showed significant positive standard heterosis over the best check 30B07 of which MAI45 × CM202 (22.94%), MAI43 × CM202 (21.89 %) and MAI23 × MAI105 (10.33 %) recorded highest positive significant standard heterosis (Table 1). Presolska and Kamara (1991) and Salillari and Hoxha (1998) also reported considerable heterosis for this character.

Among 60 crosses, 43 and 25 crosses showed significant positive mid-parent heterosis and better-parent heterosis for shelling percentage respectively, while seven crosses exhibited positive standard heterosis over best standard check 30B07 for this trait. The mid-parent heterosis for this trait ranged between -5.45 to 11.16 % and -7.60 to 8.90% over better-parent heterosis. The standard heterosis ranged from -4.73 to 5.70% over best check 30B07 of which MAI48 × CM202 (5.70 %) recorded maximum heterosis followed by MAI28 × CM202 (5.15 %) and MAI42 × CM202 (4.91 %). The relatively less number of crosses with significant sca effects indicates the lower contribution of additive gene action (Table 1).

The extent of heterosis for test (100-grain) weight exhibited by crosses over their corresponding mid-parent ranged from –15.38 to 41.67, over better-parent ranged from –20.34 to 34.69, over checks it ranged from –32.21 to 4.62% (30B07), –13.73 to 33.33% (NAH-1137) and -15.38 to 30.77% (NAH-2049). Out of 60 hybrids, 33 hybrids over mid-parent, 21 hybrids over better-parent showed significant heterosis in positive direction. Three crosses showed positive heterosis of which only one cross MAI42 × CM500 (4.62 %) showed significantly heterosis in positive direction over best check (30B07) (Table 1). Considerable heterotic effect for this trait was noticed by Turgut et al. (1995) and Salillari and Hoxha (1998).

The mid-parent heterosis for fodder yield per plot ranged between -26.32 to 168.16% and for better-parent it ranged between -31.58 to 150.00%. On the other hand the standard heterosis over 30B07, NAH-1137 and NAH-2049 ranged from -38.24 to 73.53%, -34.38 to 84.38% and -47.50 to 47.50% respectively. Among 60 crosses, six crosses showed significant standard heterosis over best check NAH-2049 in the positive direction of which MAI45 × CM202 (47.50 %) recorded maximum heterosis followed by MAI32 × CM202 (37.50 %) and MAI28 × CM500 (20.00%) (Table 1). These findings were in agreement with Bassey (2002) and Jha et al. (2002) findings.

The mid-parent heterosis for grain yield per plot ranged from -16.50 to 361.16 % while for better-parent heterosis it ranged between -44.98 to 310.29 per cent. On the other hand the standard heterosis over 30B07, NAH-1137 and NAH-2049 ranged from -22.39 to 142.29%, -43.68 to 75.81% and -35.80 to 100.00%, respectively. Among 60 crosses, 12 showed significant standard heterosis over best check NAH-1137 in the positive direction, of which MAI45 × CM202 (75.81%) recorded maximum heterosis followed by MAI33 ×CM202 (38.99 %) and MAI27 × CM202 (36.46%)(Table 2). Such high heterosis levels were also reported by Verma and Singh (1980), Debnath (1984), Jha and Khera (1992) and Larish and Brewbaker (1999) for grain yield per plot.

Table 2: Promising single cross hybrids for grain yield and its contributing characters

Sl. No.	Hybrids	Mean	*sca effects*	30B07	NAH-1137	NAH-2049	Type of cross
1	MAI45 × CM202	2.24	1.00**	42.29**	75.81**	100.41**	H × L
2	MAI33 × CM202	1.92	0.63**	1.54**	38.99**	58.44**	L × L
3	MAI27 × CM202	1.89	0.18**	8.06**	36.46**	55.56**	H × L
4	MAI48× MAI105	1.80	0.23**	9.10**	29.96**	48.15**	H × L
5	MAI29 × CM202	1.70	0.13**	8.66**	22.38**	39.51**	L × L
6	MAI28 × CM500	1.69	0.29**	7.66**	21.66**	38.68**	H × L

*Significant at P=0.05 level **Significant at P=0.01 level

For exploiting hybrid vigor, per se performance, sca effects and the extent of heterosis of hybrids are important. Selection based on any one of these criteria alone may not be effective. The hybrids with high per se performance need not always reveal high sca effect and vice versa. So selection must be based on all the three parameters. In the present study also, the hybrids were evaluated on the basis of the above said three parameters.

CONCLUSION

Among the 60 hybrids evaluated, MAI45 × CM202 was identified as the best hybrid since it possessed desirable per se performance, sca effects and heterosis for grain yield per plot along with plant height, ear height, number of kernels per row and fodder yield per plot. Considering, grain yield per plot trait to which all characters contribute and based on above three parameters the present study has resulted in the identification of six promising hybrids MAI45 × CM202, MAI33 × CM202, MAI27 × CM202, MAI48 × MAI105, MAI29 x CM202, MAI28 x CM500 which are superior to the newly released hybrids 30B07, NAH-1137 and NAH-2049 (Table 2).

These hybrids could be further evaluated across locations and over seasons to select best hybrids for commercial exploitation.

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