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COMBINING ABILITY AND HETEROSIS ON YIELD AND ITS COMPONENT TRAITS IN MAIZE (*Zea mays* L.)

M. Z. A. TALUKDER[1], A. N. M. S. KARIM[2]
S. AHMED[3] AND M. AMIRUZZAMAN[4]

Abstract

Combining ability and heterosis were studied in a 7×7 half diallel cross in maize for grain yield and yield contributing characters. Significant general and specific combining ability variances were observed for all the characters studied. The significant estimates of GCA and SCA variances suggested the importance of both additive and non-additive gene actions for the expression studied traits. In these studies, variances due to SCA were higher than GCA for all charactesr, which revealed the predominance of non additive gene action (dominance and epistasis) for controlling these traits. Parents P_1 and P_4 were excellent general combiner for days to tasseling and silking while P_1 and P_5 for early maturity. P_4 for short height and, P_4 and P_7 for higher thousand kernel weight. The parents P_4 and P_6 having good combining abilities for yield. Heterosis estimation was carried out using two commercial varieties NK40 and 900MG. When standard commercial check NK40 was used, the percent heterosis for kernel yield varied from -51.39 to 12.53%. Among the 21 F_1s, 3crosses exhibited significant positive heterosis for kernel yield. The highest heterosis was exhibited by the cross $P_4 \times P_6$ (12.43%), $P_6 \times P_7$ (10.89%) and $P_2 \times P_3$ (9.87%) respectively. Compared with 900MG as check, the percent heterosis for kernel yield varied from -53.73 to 7.01%. Among the 21 F_1s, none of the crosses exhibited significant positive heterosis for kernel yield. The highest heterosis were exhibited by the crosses $P_4 \times P_6$ (7.01%), P_6 x P_7 (5.55%) and $P_2 \times P_3$ (4.57%). The crosses showed significant positive SCA values could be used for variety development after verifying them across the agro-ecological zones of Bangladesh.

Keywords: Combining ability, heterosis, GCA, SCA, maize (*Zea mays* L.), nature of gene action.

Introduction

Maize is becoming an important crop in the rice based cropping system. Maize continues to expand rapidly at an average rate of 20% year^{-1} (CIMMYT, 2008). A combination of high market demand with comparatively low cost of production and high yield has generated tremendous interest among the farmers in maize cultivation. The estimated average national grain yield is 5.7 t ha^{-1}, is the highest in Asia, and that compares with average on-farm grain yield of

[1]Senior Scientific Officer, Plant Breeding Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, [2]Scientific Officer, Plant Breeding Division, BARI, Gazipur, [3&4] Principal Scientific Officer, Plant Breeding Division, BARI, Gazipur, Bangladesh.

around 2 t ha^{-1} for wheat or 3-4 t ha^{-1} with boro rice (CIMMYT, 2008). Day by day it is gaining popularity in the country due to huge demand, particularly for poultry feed industry. The acreage and production of maize have an increasing tendency with the introduction of exotic hybrids due to high yield potentials. The farmers are mostly cultivating imported hybrid maize, but they are very expensive. The local hybrids are cheap and farmers can get it easily.

Combining ability estimation are important genetic attributes for maize breeders in anticipating improvement in productivity *via* hybridization and selection. Maize exhibits heterosis for all traits and the extent of heterosis vary significantly depending on the choice of parents and the trait(s) measured. Maize unveiled excessive ability for heterotic expression, even several inbred lines exhibit enough variability to find out appropriate genotypes for a successful breeding program and generating stable inbred lines for production of commercial hybrids. Genetic variability and harboring of excessive hybrid vigour makes maize as a model crop for all kind of studies. Furthermore, the input cost of hybrids can easily be minimized by avoiding losses of resources and time in production of desirable inbred lines, as it is obvious that the breeding community always preferred hybrid maize rather than Open pollinated variety (OPV) or synthetic variety because of its high productivity. Combining ability studies provide information on the genetic mechanisms controlling the inheritance of quantitative traits and enable the breeders to select suitable parents for further improvement or use in hybrid breeding for commercial purposes. In biometrical genetics two types of combining abilities are considered i.e. general combining ability (GCA) and specific combining ability (SCA). General combining ability refers to the average performance of the genotype in a series of hybrid combinations and is a measure of additive gene action whereas; specific combining ability is the performance of a parent in a specific cross in relation to general combining ability (Sharief *et al.*, 2009). Combining ability analysis is of special importance in cross pollinated crops as it helps in identifying potential inbred parents that can be used for producing hybrids. Such studies also help in elucidating the nature and magnitude of different types of gene action governing the expression of quantitative characters of economic importance (Pal and Prodhan, 1994).

Inbred lines are pre-requisite for hybrid development in maize. Combining ability analysis is of special importance in cross-pollinated crops like maize as it helps in identifying potential parents that can be used for producing hybrids and synthetics (Vasal, 1998). The nature and magnitude of gene action is an important factor in developing an effective breeding program, which can be understood through combining ability analysis. This information is helpful to plant breeders for formulating hybrid breeding program.

Heterosis and combining ability are prerequisites for developing a good economically viable maize variety. Information on the heterotic patterns and combing ability among maize germplasm is essential in maximizing the effectiveness of hybrid development (Beck *et al*., 1990). The phenomenon of heterosis has been exploited extensively in crop breeding, leading to significant increase in yield. Heterosis is used to describe this phenomenon when the parents are taken from different populations of the same species; hybrid vigor is used when the parents are taken from different species (Charlesworth and Willis, 2009).

Therefore, the present investigation with 7×7 half diallel cross was undertaken for isolating superior inbred lines and thereby to identify better combining parents to obtain suitable hybrids and determine percent of heterosis using standard commercial checks.

Materials and Method

Seven diverse maize inbred lines *viz.* P_1 (BIL 79), P_2 (BIL 31), P_3 (CML 468-2-B), P_4 (CA03130-1-2-B-B-B), P_5 (CML 481-1-B), P_6 (CML 20-2-B) and P_7 (CML 487-2-B) were crossed in a diallel fashion excluding the reciprocals during the *rabi* season in 2012-13. The resulting 21 F_1's and their 7 parents were evaluated along with three checks (BARI hybrid maize 9, NK40 and 900MG) in a alpha lattice design with two replications at BARI, Gazipur in the following *rabi* season of 2013- 2014. Each entry planted in one rows of 5 m long plot. The spacing between rows was 75 cm and plant to plant distance was 20 cm. One plant per hill was maintained after proper thinning. Data were recorded on ten randomly selected plants from each plot for plant height (cm), ear height (cm), days to tasseling and silking, days to maturity, yield and 1000 kernel weight. Kernel yield was recorded on whole plot basis and finally converted to t/ha.

Data were analyzed for variance for all the characters studied. The mean performances of all characters were analyzed using Crop Stat software. General combining ability (GCA) and specific combining ability (SCA) were estimated following Model I, Method II of Griffing (1956). The mean squares for GCA and SCA were tested against error variance desired using the mean data of all the single cross hybrids and check variety, was estimated and tested according to Singh and Singh (1994). Percent heterosis was calculated by using the following formula:

Standard heterosis (%) = $[(\overline{F_1} - \overline{CV}) / \overline{CV}] \times 100$

Where, $\overline{F}_1$ and $\overline{CV}$ represented the mean performance of hybrid and standard check variety. The significance test for heterosis was done by using standard error of the value of check variety.

Results and Discussion

The mean performances of all the crosses along with the checks are presented in Table 1. Significant differences were observed for all the characters except days to maturity and 1000 kernel weight, indicating sufficient genetic variability present among the materials.

Table 1. Mean performance of hybrid maize obtained from 7 × 7 half diallel crosses of maize evaluated at Gazipur during rabi 2013-2014.

Cross/ Hybrids	Days to tassel	Days to silk	Plant ht. (cm)	Ear ht. (cm)	Days to maturity	1000 kw	Yield (t/h)
$P_1 \times P_2$	95	98	196	96	148	310	10.09
$P_1 \times P_3$	93	96	202	90	144	300	6.75
$P_1 \times P_4$	86	89	183	99	144	340	7.67
$P_1 \times P_5$	95	99	191	99	144	250	4.65
$P_1 \times P_6$	96	100	215	106	148	305	7.59
$P_1 \times P_7$	94	98	200	103	149	295	6.73
$P_2 \times P_3$	93	96	228	112	147	300	10.51
$P_2 \times P_4$	85	88	178	94	145	360	8.46
$P_2 \times P_5$	94	97	229	112	149	325	7.35
$P_2 \times P_6$	95	99	204	104	149	355	9.22
$P_2 \times P_7$	102	107	182	91	149	380	4.71
$P_3 \times P_4$	85	88	208	91	144	360	8.94
$P_3 \times P_5$	93	97	232	110	145	235	6.63
$P_3 \times P_6$	94	98	192	100	148	290	10.07
$P_3 \times P_7$	89	93	211	103	143	280	7.30
$P_4 \times P_5$	90	94	212	107	142	360	8.70
$P_4 \times P_6$	87	91	180	104	145	360	10.76
$P_4 \times P_7$	90	94	215	99	146	330	8.67
$P_5 \times P_6$	96	100	185	101	148	310	8.74
$P_5 \times P_7$	92	94	201	107	145	295	7.78
$P_6 \times P_7$	93	97	183	98	149	300	10.61
BHM9	94	97	198	107	145	305	8.33
NK 40	89	92	210	100	146	415	9.57
900MG	91	95	202	106	149	370	10.05
F-test	**	**	**	**	-	-	**
CV(%)	2.5	2.8	10.4	9.8	2.3	20.4	11.5
$LSD_{(5\%)}$	3.74	4.08	26.08	15.7	5.4	129.80	1.84

*, ** indicated at 5% and 1% level of significance, KW = Kernel Weight.

The magnitude of mean squares for general and specific combining abilities for studied characters indicated significant differences among the GCA as well as SCA effects. This suggested presence of notable genetic variability among the genotypes for the characters studied. Furthermore, the analysis of variance for combining abilities (GCA and SCA) showed significant variations for all the characters except GCA of 1000 kernel weight, which indicate significant differences among the GCA as well as SCA effects. Highly significant differences for most of the sources of variation were also reported by Narro *et al.* (2003). The significant differences for gca and sca variances for different traits in maize have been reported earlier (Mathur and Bhatnagar, 1995). The mean squares of genotypes (diallel hybrids) were highly significant for all the traits. This indicated an adequate amount of variability present in the materials for these traits. Further, analysis of variance for combining ability showed that estimates of mean squares due to GCA and SCA were highly significant for all the characters. This indicated importance of both additive and non-additive components of genetic variance in controlling these traits. This was confirmed by Debnath and Sarker (1990) and Derera *et al.*, (2007) who reported similar results for yield and yield components in maize. Importannce of both additive and non-additive gene effects in maize were also reported by Rokadia and Kaushik (2005).

Table 2. Mean squares due to general and specific combining ability (GCA and SCA) for 7 characters in a 7 × 7 diallel cross of maize

Sources of variation	df	Mean of squares						
		Days to tassel	Days to silk	Plant ht. (cm)	Ear ht. (cm)	Days to maturity	1000-KW (g)	Yield (t/h)
Genotype	27	41.22**	49.83**	1631.83**	767.05**	43.29**	7690.14*	11.10**
GCA	6	38.12**	38.88**	905.27*	309.48**	33.997**	3971.16	5.67**
SCA	21	43.15**	52.96**	1839.43**	897.78**	45.95**	8752.71*	12.65**
Error	27	2.03	2.74	260.16	81.88	6.34	3197.55	0.78
GCA: SCA		0.88	0.73	0.49	0.34	0.74	0.45	0.45

In these studies, variances due to SCA were higher than GCA for all character, which revealed the predominance of non additive gene action (dominance and epistasis) for controlling these traits. Predominant role of SCA effect i.e. non-additive gene actions in the inheritance of kernel yield was also reported by several workers (Khotyleva *et al.*, 1986, Zelleke, 2000, Lee, 1987 and Singh and Kumar, 2008). The genetic control of different yield contributing characters is finally projected through kernel yield. Therefore, non-additive gene action for kernel yield is expected.

General combining ability (GCA) effects

The estimates of general combining ability effects of the parents are presented in Table 3. For days to tasseling and silking, negative estimates are considered desirable as those were observed to be associated with earliness. The parents P_1 and P_4 showed negative GCA effects for this trait. In case of plant height and ear height, negative estimates are desirable since they are correlated with shorter plant height. Parent P_4 was good combiner having significant negative GCA effects both for plant and ear height. According to Singh and Singh (1979), generally earliness is associated with days to silk and the shorter plants with low ear height are associated with resistance to lodging.

Parents P_4 and P_6 were the best general combiner for yield and also possessed significant positive gca effect. This was supported by Singh *et al.*, (1995) and Hussain *et al.*, (2003). From the GCA effect it was observed that, none of the parents individually showed good general combiner for all the yield component.

The overall study of GCA effects suggests that parents P_1 and P_4 were excellent general combiner for early tasseling and silking, parents P_1 and P_5 were excellent for early maturity and parents P_4 for short height, parents P_4 and P_6 for yield. These parents could be used in future breeding program to improve maize yield with desirable traits.

Specific combining ability (SCA) effects

The SCA effects of the crosses for seven characters are presented in Table 4. For days to 50% tasseling, 5 crosses exhibited significant negative sca effects and for days to 50% silking 5 crosses showed significant negative SCA, indicates early flowering of the hybrids. The SCA effect of the cross P4×P5 was positive significant indicating for higher 1000 kernel weight.

For considering yield, among 21 hybrids 8 crosses performed significant positive SCA effects for kernel yield (Table 4) and most of them also possessed high mean values for the same trait (Table 1). Out of 21 crosses eight viz. $P_1 \times P_2$, $P_2 \times P_3$, $P_3 \times P_6$, $P_4 \times P_5$, $P_4 \times P_6$, $P_4 \times P_7$, $P_5 \times P_7$ and $P_6 \times P_7$ showed significant positive SCA effects for yield. The significant positive SCA effect involved parents where one or both the parents were related to good combiners, indicating GCA of the parental lines plays a key role for high yield. Xingming *et al.*, (2002) also drew similar conclusion. These crosses also possessed high *per se* performances (Table 1). Vasal (1998) also suggested to include one good combiner (especially female parent) during crossing to obtain higher heterosis.

Table 3. General combining ability (GCA) effects and mean performances (in parenthesis) for different characters in a 7 × 7 diallel cross of maize

Parents	Days to tasseling		Days to silking		Plant ht. (cm)		Ear ht. (cm)		Days to maturity		1000-KW (g)		Yield (t/h)	
	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean
P1	-1.47**	91	-1.54**	95	-2.89	190	-1.05	94	-1.33*	141	-6.19	267	-0.94**	3.11
P2	1.42**	93	1.40**	97	-1.67	193	-2.61	94	1.81*	147	23.81	303	0.38	4.45
P3	0.23	91	0.29	94	11.05*	205	-0.44	95	0.14	145	-11.2	261	0.01	4.20
P4	-2.13**	88	-1.98**	92	-8.89*	186	-6.0*	90	-0.80	144	4.92	291	0.49*	4.61
P5	-0.08	92	-0.26	96	2.89	199	4.12	100	-1.36*	140	-12.3	261	-0.40	3.49
P6	1.98**	94	2.13**	97	-6.61	186	-0.62	95	1.92**	147	3.97	265	0.77**	5.18
P7	0.003	92	-0.03	96	6.11	196	6.52*	99	-0.41	145	14.92	286	-0.10	4.13
SE(gi)	0.31		0.36		3.51		1.97		0.54		12.34		0.19	
$LSD_{(5\%)}$	0.76		0.88		8.59		4.82		1.32		30.20		0.46	
$LSD_{(1\%)}$	1.08		1.26		12.28		6.89		1.88		43.17		0.66	

*, ** indicated at 5% and 1% level of significance, KW = Kernel Weight.

Table 4. Specific combining ability (SCA) effects for different characters in 7 × 7 diallel cross in maize

Cross	Days to tassel	Days to silk	Plant ht. (cm)	Ear ht. (cm)	Days to maturity	1000-KW (g)	Yield (t/ha)
$P_1 \times P_2$	3.08**	3.15**	12.43	8.23	3.65*	7.92	3.46**
$P_1 \times P_3$	2.25*	2.26*	5.71	-0.44	1.31	32.92	0.50
$P_1 \times P_4$	-2.36*	-2.46*	6.65	14.55	2.26	56.81	1.11
$P_1 \times P_5$	5.08**	5.32**	2.88	4.50	2.32	-15.97	-1.20**
$P_1 \times P_6$	4.02**	4.43**	35.88**	16.24	3.54	40.69	0.57
$P_1 \times P_7$	3.97**	4.10**	8.15	5.59	6.38**	1.81	0.58
$P_2 \times P_3$	-0.64	-1.18	30.49**	23.61**	1.21	2.92	2.94**
$P_2 \times P_4$	-5.75**	-6.40**	0.43	10.60	-0.35	46.81	0.58
$P_2 \times P_5$	1.19	0.88	39.65**	19.06**	4.71**	29.03	0.18
$P_2 \times P_6$	0.14	0.48	23.65*	15.79*	0.93	60.69	0.89
$P_2 \times P_7$	8.58**	10.65**	-11.07	-4.85	3.76*	56.81	-2.75**
$P_3 \times P_4$	-5.08**	-5.79**	17.21	5.93	0.82	81.81	1.43
$P_3 \times P_5$	1.36	1.49	29.43**	14.89*	2.37	-25.97	-0.16
$P_3 \times P_6$	-0.19	0.60	-0.51	9.13	2.10	30.69	2.10**
$P_3 \times P_7$	-2.75**	-2.24*	5.21	4.98	-0.57	-8.19	0.21
$P_4 \times P_5$	0.25	0.76	29.87**	17.38**	0.32	82.91*	1.61**
$P_4 \times P_6$	-4.30**	-4.63**	7.37	19.01**	0.04	4.58	2.49**
$P_4 \times P_7$	0.64	0.54	29.15	6.67	3.37*	25.69	1.26*
$P_5 \times P_6$	2.63**	3.15**	0.60	6.07	3.60*	51.80	1.18*
$P_5 \times P_7$	0.08	-0.68	3.38	4.43	-0.07	7.91	1.10
$P_6 \times P_7$	-0.47	-0.57	-5.13	0.16	3.15	14.58	2.76*
SE(ij)	0.91	1.05	10.24	5.74	1.60	35.89	0.56
LSD $_{(5\%)}$	1.90	2.19	21.36	11.97	3.34	74.87	1.17
LSD $_{(1\%)}$	2.59	2.99	29.13	16.33	4.35	102.10	1.59

*, ** indicated at 5% and 1% level of significance, KW = Kernel Weight.

The desirable significant SCA effects observed for different characters were exhibited by the crosses involved high × high, high × average, average × average or high × low and low × low general combining parents. High SCA effects manifested by different crosses were of good combiner parents might be attributed to sizeable additive × additive gene action. The high × low combinations, besides expressing the favorable additive effect of the high parent, manifested some complementary gene interaction effects with a higher SCA. An appreciable amount of the SCA effects expressed by low × low crosses might be ascribed to dominance × dominance type of non-allelic gene action produced over dominance and are non-fixable. It appears that superior performance of most hybrids may be largely due to epistatic interaction. The SCA effects of the crosses exhibited no specific trends in cross combinations between parents having high, medium and low gca effects. Any combination among the parents may produce hybrid vigour over the parents which might be due to dominant, over dominant or epistatic gene action. So, the crosses which showing desirable SCA effects can be used in future breeding program.

Heterosis

The standard heterosis expressed by the F_1 hybrids over the two standard checks namely NK40 and 900MG (commercial hybrid)) for different characters are presented in Tables 5 and 6. The percent of heterosis in F_1 hybrids varied from character to character or from cross to cross.

Days to tasseling and days to silking

Days to tasseling and silking determine the earliness of flowering of the hybrid. Negative heterosis is desirable for these characters. Considering commercial hybrid NK40 as a check 4 crosses showed significant negative heterosis for days to tasseling and ranged from -0.506 to 14.04%. For days to silking, 3 crosses also showed significant negative heterosis and ranged from -4.37 to 14.97(Table 5). When we considered 900MG as check, 4 crosses exhibited significant negative heterosis for 50% tassel date which ranged were -6.63 to 12.15. For 50% silk date 4 crosses showed significant negative heterosis out of 21 and ranged were -7.41 to 13.23 (Table 6).

Plant height and ear height

Negative heterosis is desirable for plant height and ear height which helps for developing short statured plant leads to less lodging. Considering commercial hybrid NK40 as a check 11 crosses exhibited significant negative heterosis for plant height indicate dwarfness of the hybrids (Table 5). Some crosses also showed significant positive heterosis for this trait. For ear height, 5 crosses showed significant negative heterosis others are positive (Table 5).

To compare with check variety 900MG, 8 crosses performed significant negative heterosis for plant height. For ear height, 11 crosses expressed significant negative heterosis.

Days to maturity

Negative heterosis is also desirable for days to maturity which helps for adjusting cropping pattern. Considering commercial hybrid NK40 as a check 6 crosses expressed significant negative heterosis (Table 5). Compare with 900MG as check, 12 crosses expressed significant negative heterosis for the trait (Table 6).

Table 5. Percent heterosis over the check variety NK40 for different characters in 7×7 diallel crosses of maize

Cross/ Hybrids	Days to tassel	Days to silk	Plant ht. (cm)	Ear ht. (cm)	Days to maturity	1000-KW (g)	Yield (t/h)
P_1×P_2	6.18**	7.10**	-6.67**	-4.00**	1.72**	-25.30	5.46
P_1×P_3	3.93**	4.92**	-3.81*	-10.50**	-1.03**	-27.71	-29.44**
P_1×P_4	-3.93**	-2.73*	-12.86**	-1.00	-1.03**	-18.07	-19.87**
P_1×P_5	6.74**	7.65**	-9.05**	-1.00	-1.37**	-39.76	-51.39**
P_1×P_6	7.87**	9.29**	2.14	6.00**	1.72**	-26.51	-20.68**
P_1×P_7	5.62**	6.56**	-5.00**	2.50	2.06**	-28.92	-29.69**
P_2×P_3	3.93**	4.37**	8.57**	12.00**	1.03**	-27.71	9.87*
P_2×P_4	-4.49**	-3.83**	-15.24**	-6.50**	-0.69	-13.25	-11.56**
P_2×P_5	5.62**	6.01**	9.05**	12.00**	2.41**	-21.69	-23.19**
P_2×P_6	6.74**	8.20**	-3.10	4.00*	2.06**	-14.46	-3.57
P_2×P_7	14.04**	16.94**	-13.57**	-9.50**	2.41**	-8.43	-50.76**
P_3×P_4	-5.06**	-4.37**	-1.19	-9.00**	-1.03**	-13.25	-6.51
P_3×P_5	4.49**	5.46**	10.24**	10.00**	-0.34	-43.37	-30.64**
P_3×P_6	5.06**	7.10**	-8.57**	-0.50	1.72**	-30.12	5.23
P_3×P_7	0.00	1.64	0.24	2.50	-1.72**	-32.53	-23.73**
P_4×P_5	0.56	2.19	0.95	7.00**	-2.41**	-13.25	-9.02*
P_4×P_6	-2.25*	-1.09	-14.29**	3.90*	-0.34	-32.53	12.43**
P_4×P_7	1.12	2.19	2.14	-1.30	0.34	-20.48	-9.39*
P_5×P_6	7.87**	9.29**	-11.90**	1.00	1.72**	-25.30	-8.63*
P_5×P_7	2.81*	2.73*	-4.52	6.50**	-0.69	-28.92	-18.68**
P_6×P_7	4.49**	5.46**	-13.10**	-2.50	2.06**	-27.71	10.89*
Mean	3.40	4.53	-4.26	1.03	0.41	-24.73	-14.42
Minimum	-5.06	-4.37	-15.24	-10.50	-2.41	-43.37	-51.39
Maximum	14.04	16.94	10.24	12.00	2.41	8.43	12.43
Std. Error	1.03	1.09	1.73	1.45	0.34	1.97	3.98
$CD_{(0.05)}$	2.14	2.28	3.61	3.03	0.71	4.11	8.31
$CD_{(0.01)}$	2.92	3.10	4.93	4.14	0.97	5.60	11.34

*, ** indicated at 5% and 1% level of significance, KW = Kernel Weight.

Kernel yield

When standard commercial check was NK40, the percent heterosis for kernel yield varied from -51.39 to 12.53%. It showed that among the 21 F_1s, 3 crosses exhibited significant positive heterosis for kernel yield (Table 5). The highest heterosis 12.43% was exhibited by the cross $P_4 \times P_6$ followed by $P_6 \times P_7$ (10.89%) and $P_2 \times P_3$ (9.87%).

Table 6. Percent heterosis over the check variety 900MG for different characters in 7×7 diallel cross of maize

Cross/ Hybrids	Days to tassel	Days to silk	Plant ht. (cm)	Ear ht. (cm)	Days to maturity	1000-KW (g)	Yield (t/h)
$P_1 \times P_2$	4.42**	3.70**	-2.97	-9.0**0	-0.34	-16.22**	0.38
$P_1 \times P_3$	2.21*	1.59	0.00	-15.17**	-3.03**	-18.92**	-32.84**
$P_1 \times P_4$	-5.52**	-5.82**	-9.41**	-6.16**	-3.03**	-8.11**	-23.73**
$P_1 \times P_5$	4.97**	4.23**	-5.45**	-6.16**	-3.37**	-32.43**	-53.73**
$P_1 \times P_6$	6.08**	5.82**	6.19**	0.47	-0.34	-17.57**	-24.50**
$P_1 \times P_7$	3.87**	3.17**	-1.24	-2.84	0.00	-20.27**	-33.08**
$P_2 \times P_3$	2.21*	1.06	12.87**	6.16**	-1.01**	-18.92**	4.57
$P_2 \times P_4$	-6.08**	-6.88**	-11.88**	-11.37**	-2.69**	-2.7	-15.82**
$P_2 \times P_5$	3.87**	2.65*	13.37**	6.16	0.34	-12.16**	-26.89**
$P_2 \times P_6$	4.97**	4.76**	0.74	-1.42	0.00	-4.05	-8.22*
$P_2 \times P_7$	12.15**	13.23**	-10.15**	-14.22**	0.34	2.7	-53.13**
$P_3 \times P_4$	-6.63**	-7.41**	2.72	-13.74**	-3.03**	-2.7	-11.02**
$P_3 \times P_5$	2.76*	2.12	14.60**	4.27**	-2.36**	-36.49**	-33.99**
$P_3 \times P_6$	3.31**	3.70**	-4.95*	-5.69**	-0.34	-21.62**	0.16
$P_3 \times P_7$	-1.66	-1.59	4.21*	-2.84	-3.70**	-24.32**	-27.40**
$P_4 \times P_5$	-1.10	-1.06	4.95*	1.42	-4.38**	-2.7	-13.41**
$P_4 \times P_6$	-3.87**	-4.23**	-10.89**	-1.52	-2.36**	-2.7	7.01
$P_4 \times P_7$	-0.55	-1.06	6.19*	-6.45**	-1.68**	-10.81**	-13.75**
$P_5 \times P_6$	6.08**	5.82**	-8.42**	-4.27**	-0.34	-16.22**	-13.03**
$P_5 \times P_7$	1.10	-0.53	-0.74	0.95	-2.69**	-20.27**	-22.59**
$P_6 \times P_7$	2.76*	2.12	-9.65**	-7.58**	0.00	-18.92**	5.55
Mean	1.68	1.21	-0.47	-4.24	-1.62	-15.57	-18.55
Minimum	-6.63	-7.41	-11.88	-15.17	-4.38	-36.49	-53.73
Maximum	12.15	13.23	14.60	6.16	0.34	2.7	7.01
Std. Error	1.01	1.06	1.80	1.38	0.33	2.21	3.79
$CD_{(0.05)}$	2.11	2.20	3.75	2.87	0.70	4.61	7.91
$CD_{(0.01)}$	2.88	3.01	5.12	3.92	0.95	6.28	10.79

*, ** indicated at 5% and 1% level of significance, KW = Kernel Weight.

When estimated with 900MG as check, the percent heterosis for kernel yield varied from -53.73 to 7.01%. It showed that among the 21 F_1s, none crosses exhibited significant positive heterosis for kernel yield (Table 6). The highest heterosis 7.01% was exhibited by the cross P_4xP_6 followed by P_6xP_7 (5.5%) and $P_2 \times P_3$ (4.57%). Debnath (1988) and Roy *et al.*, (1998) reported 43.05 to 96.74% and -16.42 to 71.82% heterobeltiosis.

Conclusion

From the study, the parents like P_1 (for early flowering and short duration), P_4 (for yield, early flowering, short plant and ear height), P_5 (short duration) and P_6 (for yield) may be used as donor for combining high yield with desirable traits. The crosses ($P_2 \times P_3$, $P_4 \times P_6$ and $P_6 \times P_7$) showed the highest heterosis for yield compared to the checks (NK40 and 900MG). The cross combinations manifested significant high SCA effects coupled with *per se* performance and could be more rewarding in a hybrid breeding program after intensive investigation at different agro ecological zones.

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