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Diallel analysis and estimation of heterosis in single cross maize hybrids

Abu Nayem Mohammad Sajedul Karim[1], Salahuddin Ahmed[1], Afsana Hoque Akhi[1], Md. Amiruzzaman[1] and A. N. Md. Anamul Karim[2]

[1]Plant Breeding Division, [2]Seed Technology Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh

✉ For any information: ask.author@journalbinet.com
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ABSTRACT

Heterosis and the nature of combining ability were studied in 28 F_1 hybrids made by selected 8 inbred lines using 8×8 diallel mating system (Griffing's Model I, Method IV) excluding reciprocals in maize for grain yield and yield contributing characters. The significant estimates of GCA and SCA variances suggested the importance of both additive and non-additive gene actions for the expression of the traits studied. The variances for general combining ability (GCA) were found significant for days to pollen shedding, days to silking, plant height, ear height, 1000-grain weight, and yield. Specific combining ability (SCA) was significant for all the characters except yield. Non-significant specific combining ability (SCA) variance for yield suggests that this trait predominantly controlled by the additive type of gene action. Variances due to GCA were much higher in magnitude than SCA for all the characters indicating the superiority of additive gene effects for the inheritance of this trait. Parents P_4 and P_6 were the best general combiner for high yield, P_5 for grain weight and parents P_7 and P_8 for earliness and dwarf plant type. Seven crosses $P_1×P_5$, $P_1×P_7$, $P_2×P_4$, $P_3×P_5$, $P_4×P_5$, $P_4×P_8$, and $P_6×P_7$ exhibited positive SCA effects for grain yield. Considering BHM9 as a check, the percent heterosis for grain yield varied from -85.76 to 10.83%. Three crosses exhibited significant and positive heterosis viz. $P_2×P_4$ (10.83%), $P_6×P_7$ (9.72%) and $P_4×P_6$ (1.78%) over the check BHM9. Considering the performance of SCA effects and heterosis, two crosses $P_2×P_4$ and $P_6×P_7$ could be utilized for developing high yielding hybrid varieties as well as for exploiting hybrid potency.

Key Words: *Diallel, crosses, evaluation, heterosis, GCA and SCA*

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I. Introduction

Among the cereals, maize ranked third globally. Concerning production, maize is the second most essential cereal crop in Bangladesh (Ferdoush *et al.*, 2017). In 2016-17, maize covered with 3.89 lac hectare of land and production was 3.02 million tons in Bangladesh (BBS, 2018). Maize continues to

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increase speedily because of a good combination of high market demands with comparatively low cost of production and high yield has generated remarkable interest among the farmers in maize cultivation. However, maize production growth in the country is frequently due to the fast advance of the poultry industry and the associated feed industry sector. In recent years, acreage, production, and productivity have been increased enormously. The theory of general combining ability (GCA) and specific combining ability (SCA) introduced by Sprague and Tatum (1942) and its scientific modeling was established by Griffing (1956) in his established paper in conjunction with the diallel crosses. General and specific combing ability linked to the type of gene action involved. Moreover, general combining ability is supportive for the selection efficiency in isolating populations (Bokanski *et al.*, 2009) and specific combining ability provide the performance of any two inbred in hybrid combination. However, variance due to GCA is a pointer of the extent of additive gene action though variance due to shows the extent of non-additive gene action (Hayman, 1954; Griffing, 1956). Combining ability analysis is of particular importance in cross-pollinated crops like maize as it helps in recognizing potential parents that can use for producing hybrids and synthetics (Vasal, 1998). The nature and magnitude of gene action is an essential factor in developing an effective breeding programme, which can understand through combining ability analysis. This information is helpful to plant breeders for formulating hybrid breeding programmes.

Heterosis and combining ability are prerequisites for developing a good economically viable maize variety. To maximize the effectiveness of hybrid development, information on the heterotic patterns and combing ability among maize germplasm is essential (Beck *et al.*, 1990). The phenomenon of heterosis has been exploited extensively in crop breeding, leading to a significant increase in yield. Heterosis is used to describe this phenomenon when the parents are taken from different populations of the same species (Charlesworth and Willis, 2009). Therefore, the present investigation with 8×8 half diallel crosses of maize undertaken to determine the better general combining parents and for isolating right cross combinations for evolving suitable hybrid(s) and determine the percent of heterosis using standard commercial check variety.

II. Materials and Methods

The experimental materials consisted of eight diverse maize inbred lines viz. P_1 (CL02450), P_2 (CML551), P_3 (CML223), P_4 (CML431), P_5 (CML451), P_6 (CLM285), P_7 (CLG1837) and P_8 (CML429) crossed in a diallel fashion excluding the reciprocals during the rabi season in 2015-16. The resulting 28 F_1 progenies evaluated along with two checks (BHM9 and 981) in an alpha lattice design with two replications at BARI, Gazipur in the following rabi season of 2016- 2017. Each entry planted in 2 rows of a 4m long plot. The spacing between rows was 60 cm and plant to plant distance was 25 cm. For the proper growth and development, fertilizers applied 250, 55, 110, 40, 5 and 1 kg/ha of N, P, K, S, Zn, and B, respectively. After germination, one plant per hill kept and maintained. However, data recorded on ten randomly selected plants from each plot for plant height (cm), ear height (cm), days to 50% pollen shedding, days to 50% silking and 1000-grain weight (g). Considering, grain yield recorded on the whole plot basis and finally converted to t/ha.

Data analyzed for the variance for all the characters studied. The mean performances of all characters analyzed using PB Tools software. Moreover, the combining ability analysis carried out Model I (fixed effects) and Method IV (one set of F_1 but neither parents nor reciprocal F_1 is included) described by Griffing (1956). The mean squares for GCA and SCA were verified against error variance desired using the mean data of all the single cross hybrids and check varieties were estimated and tested according to Singh and Singh (1994). On the other hand, percent heterosis was calculated by using the following formula:

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

Where, F_1 and CV represented the mean performance of hybrid and standard check variety.

The significance test for heterosis was done using the standard error of the value of check variety.

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III. Results and Discussion

The mean performances of all the crosses along with the checks (BHM9 and 981) are present in Table 01. Significant differences observed for days to 50% pollen shedding, days to 50% silking, plant height, ear height, 1000-grain weight and grain yield which indicating the sufficient genetic variability present among the materials. However, three crosses, $P_2 \times P_4$, $P_6 \times P_7$, and $P_4 \times P_6$ yielded higher than check variety BHM9.

Table 01. Mean performance of hybrid maize obtained from 8 × 8 half diallel crosses in maize evaluated at Gazipur during rabi 2016-2017

Crosses/ Hybrids	DP (day)	DS (day)	PH (cm)	EH (cm)	TGW (g)	GY (t/ha)
$P_1 \times P_2$	89	91	135	39	365.0	8.94
$P_1 \times P_3$	88	89	162	59	315.0	6.92
$P_1 \times P_4$	89	92	140	58	390.0	9.86
$P_1 \times P_5$	87	89	155	63	332.5	8.71
$P_1 \times P_6$	90	92	150	66	325.5	9.36
$P_1 \times P_7$	86	88	135	60	325.0	9.70
$P_1 \times P_8$	87	90	131	52	345.0	6.25
$P_2 \times P_3$	87	89	145	47	315.0	8.47
$P_2 \times P_4$	87	90	152	63	335.0	13.02
$P_2 \times P_5$	85	87	156	60	355.0	9.20
$P_2 \times P_6$	91	94	155	56	315.0	10.99
$P_2 \times P_7$	79	83	153	60	322.5	10.21
$P_2 \times P_8$	82	84	138	51	317.5	7.24
$P_3 \times P_4$	86	89	146	58	355.0	7.79
$P_3 \times P_5$	89	93	140	40	345.0	9.17
$P_3 \times P_6$	88	92	151	60	375.0	8.56
$P_3 \times P_7$	86	89	123	39	325.0	7.52
$P_3 \times P_8$	86	89	125	45	375.0	7.11
$P_4 \times P_5$	86	88	154	72	340.0	11.30
$P_4 \times P_6$	86	89	156	62	312.0	11.82
$P_4 \times P_7$	85	88	142	61	337.5	10.09
$P_4 \times P_8$	84	87	160	65	327.5	10.36
$P_5 \times P_6$	90	92	129	44	385.0	6.60
$P_5 \times P_7$	82	85	125	36	370.0	8.21
$P_5 \times P_8$	84	87	119	33	307.5	7.21
$P_6 \times P_7$	87	88	145	52	337.5	12.86
$P_6 \times P_8$	88	90	129	38	332.5	6.95
$P_7 \times P_8$	78	81	115	39	322.5	7.42
BHM9	82	85	177	58	357.5	11.61
981	88	90	164	75	322.5	12.36
F-test	**	**	**	**	**	**
CV (%)	2.39	2.27	8.25	9.86	3.83	8.65
LSD $_{(0.05)}$	4.22	4.13	24.02	22.94	26.82	1.60

*, ** indicated at 5% and 1% level of significance; DP=days to 50% pollen shedding, DS=days to 50% silking, PH=plant height, EH=ear height, TGW=1000-grain wt. (g), GY=grain yield (t/ha)

The degree of mean squares for general and specific combining abilities for considered characters showed significant differences among the GCA as well as SCA effects (Table 02). This suggested existence of remarkable genetic variability among the genotypes for the different characters studied. Moreover, the analysis of variance for combining abilities (GCA and SCA) showed significant variations for all the characters which indicate significant differences among the GCA and SCA effects. Karim *et al.*, (2018) also reported highly significant differences for all the sources of variation. 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 directed standing of both additive and non-additive components

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of genetic variance in controlling these characters. Derera *et al.*, (2007) found similar results for yield and yield components in maize. Rokadia and Kaushik (2005) stated the importance of both additive and non-additive gene effects in maize in their studied materials.

Table 02. Mean squares due to general and specific combining ability (GCA and SCA) for 7 characters in 8× 8 diallel cross in maize

Sources of variation	df	Mean of squares					
		DP (day)	DS (day)	PH (cm)	EH (cm)	TGW (g)	GY (t/ha)
Genotype	27	18.97**	16.91**	354.92**	220.12**	1355.60**	10.50**
GCA	7	25.15**	22.11**	351.28**	225.32**	386.53**	14.76**
SCA	20	4.00**	3.67**	116.62**	65.34**	779.74**	1.92
Error	27	2.11	2.02	69.52	8.54	85.21	0.52
GCA:SCA		6.28	6.02	3.01	3.44	0.49	7.68

*, ** indicated at 5% and 1% level of significance; DP= days to 50% pollen shedding, DS= days to 50% silking, PH=plant height, EH= ear height; TGW= 1000-grain wt. (g), GY= grain yield (t/ha)

In the present study, variances due to GCA were much higher in magnitude than SCA for all the characters indicating the preponderance of additive gene effects for the inheritance of these traits. Malik *et al.*, (2004) in their study also found higher GCA variances than SCA for days to pollen shedding, plant height, ear height, 1000-grain weight, and grain yield. Moreover, Muraya *et al.*, (2006) and Ahmed *et al.*, (2008) reported the prevalence of additive gene action for various quantitative traits in maize. The present result was different with Abdel-Moneam *et al.*, (2009) who observed GCA/SCA ratio was less than unity for 100-kernels weight and ear yield/plant, indicating non-additive gene action in controlling the traits.

General combining ability (GCA) effects

The assessments of general combining ability effects of the parents are presenting in Table 03. A wide range of variability of GCA effects was the presence among the different parents. For days to pollen shedding and silking, significant and negative estimates are considered desirable as those were observed to be related with earliness. The parents P_7 and P_8 showed significant and negative GCA effects for these traits. So, the use of these two parents may be useful in developing early hybrid variety(s). In the case of plant height and ear height, negative estimations are desirable for these characters. However, parent P_7 and P_8 were good combiners having significant and negative GCA affects both for plant and ear height. According to Singh and Singh (1979), generally, earliness associated with days to silk and the association of shorter plants with low ear height is resistance to lodging. Regarding 1000-grain weight, parent P_5 showed significant and positive GCA effect. Shengu *et al.*, (2016) also observed the similar result in their study.

Table 3. General combining ability (GCA) effects for different characters in 8×8 diallel cross in maize

Parent	DP (day)	DS (day)	PH (cm)	EH (cm)	TGW(g)	GY (t/ha)
P_1	2.12**	1.72**	2.77	1.29	1.97	-0.16
P_2	-0.62	-0.60	7.02*	-2.60	-10.10**	1.22
P_3	1.12	1.39	0.02	14.07**	6.56	-1.31
P_4	0.12	0.31	9.93	-2.32	1.97	2.37**
P_5	-0.12	-0.10	-2.22	-6.82**	11.14**	-0.73*
P_6	2.79**	2.47**	3.85	-2.54	5.31	0.77**
P_7	-3.29**	-3.18**	-8.97**	-7.85**	-7.18*	0.48
P_8	-2.12**	-2.02**	-12.39**	-8.93**	-9.68**	-2.63**
SE(gi)	0.55	0.54	3.18	3.02	3.52	0.27
$LSD_{(0.05)}$	1.08	1.06	6.23	5.92	6.90	0.53
$LSD_{(0.01)}$	1.42	1.39	8.20	7.79	9.08	0.70

*, ** indicated at 5% and 1% level of significance; DP=days to 50% pollen shedding, DS=days to 50% silking, PH=plant height, EH=ear height; TGW=1000-grain wt. (g), GY=grain yield (t/ha)

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Parents P_4 and P_6 were the best general combiner for yield and also possessed significant and positive GCA effect. Ahmed *et al.*, (2008) and Abdel-Moneam *et al.*, (2009) has given similar views. So, these two parents might use extensively in hybrid breeding program intending to increase the yield level. From the GCA effect, none of the parents individually showed good general combiner for all the characters studied. The overall study of GCA effects suggests that parents P_7 and P_8 were excellent general combiner for earliness and short stature; P_5 for 1000 grain weight and P_4 and P_6 for grain yield. These parents could be used in the future breeding program to increase maize yield with the wanted trait.

Specific combining ability (SCA) effects

The estimates of specific combining ability (SCA) effects for the 28 F_1's are presented in Table 04. Considering, the days to 50% pollen shedding, 3 crosses exhibited significant and negative sca effects and for days to 50% silking 4 crosses showed significant and negative SCA, indicates quick flowering of the hybrids. Moreover, four crosses viz. $P_1 \times P_2$, $P_1 \times P_4$, $P_4 \times P_5$, and $P_6 \times P_7$ showed significant negative SCA effects for plant height indicating the better specific combinations of these hybrids for plant height, which is desirable as short-statured plants are mostly lodging tolerant. But Begum *et al.*, (2018) found no significant and negative SCA effects for plant height.

Table 4. Specific combining ability (SCA) effects for different characters in 8×8 diallel cross in maize

Crosses	DP (day)	DS (day)	PH (cm)	EH (cm)	TSW(g)	Yi (t/ha)
$P_1 \times P_2$	1.32	1.00	-16.20*	-18.49**	32.32**	-0.79**
$P_1 \times P_3$	-2.42*	-2.5*	17.79*	-3.49	-34.34**	-0.27
$P_1 \times P_4$	1.07	1.08	-14.11*	4.90	45.23**	-1.02**
$P_1 \times P_5$	-1.67	-1.5	12.54	-7.60	-21.42**	0.93**
$P_1 \times P_6$	-1.09	-1.08	1.96	10.45	-23.09**	0.07
$P_1 \times P_7$	1.49	1.08	-0.70	1.73	-10.59**	0.70**
$P_1 \times P_8$	1.32	1.91	-1.28	2.51	11.90**	0.37
$P_2 \times P_3$	0.32	-0.16	-3.95	-1.94	-22.26**	-0.11
$P_2 \times P_4$	1.32	1.41	-6.86	-2.88	2.32	0.74**
$P_2 \times P_5$	-0.42	-0.66	9.79	19.95	13.15**	0.04
$P_2 \times P_6$	2.65	2.75	2.21	-4.66	-21.01**	0.31
$P_2 \times P_7$	-3.26**	-2.58*	12.54	2.29	-1.01	-0.17
$P_2 \times P_8$	-1.92	-1.75	1.46	-4.27	-3.51	-0.01
$P_3 \times P_4$	-0.92	1.08	-5.36	2.45	5.65	-1.21**
$P_3 \times P_5$	2.32	2.33	0.29	7.95	-13.51**	1.82**
$P_3 \times P_6$	-2.09	-1.25	5.21	0.01	42.32**	0.41
$P_3 \times P_7$	1.99	1.91	-9.95	3.95	-15.17**	-0.32
$P_3 \times P_8$	0.32	0.75	-4.03	-8.94	37.32**	-0.31
$P_4 \times P_5$	-0.67	-1.08	-14.88*	-21.33**	-13.92**	0.98**
$P_4 \times P_6$	-3.09*	-2.66*	0.79	-0.60	-35.59**	-0.01
$P_4 \times P_7$	1.99	2.50*	-0.36	10.01	1.90	-1.43**
$P_4 \times P_8$	0.32	-0.16	21.04**	7.45	-5.59	1.94**
$P_5 \times P_6$	1.15	0.75	-14.03**	-15.56*	42.73**	-3.38**
$P_5 \times P_7$	-0.76	-0.58	-5.70	-2.49	27.73**	-0.21
$P_5 \times P_8$	0.07	0.75	-7.78	-2.05	-34.76**	-0.19
$P_6 \times P_7$	0.82	0.33	-8.21	-15.77**	-1.42	2.92**
$P_6 \times P_8$	1.65	1.16	-4.3	-5.01	-3.92	-0.32
$P_7 \times P_8$	-2.26	-2.66**	-5.03	0.29	-1.42	-1.40**
SE(ij)	1.22	1.20	7.04	6.70	3.52	0.27
LSD $_{(0.05)}$	2.39	2.35	13.80	13.13	6.90	0.53
LSD $_{(0.01)}$	3.15	3.10	18.16	17.29	9.08	0.70

*, ** indicated at 5% and 1% level of significance; DP=days to 50% pollen shedding, DS=days to 50% silking, PH=plant height, EH=ear height, TGW=1000-grain wt. (g), GY=grain yield (t/ha)

Considering yield, seven crosses performed significant and positive SCA effects for grain yield (Table 04) and most of them also possessed high mean values for the trait (Table 01). Out of 28 crosses, seven

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crosses viz. $P_1 \times P_5$, $P_1 \times P_7$, $P_2 \times P_4$, $P_3 \times P_5$, $P_4 \times P_5$, $P_4 \times P_8$, and $P_6 \times P_7$ exhibited significant and positive SCA effects for yield. Begum *et al.*, (2018) found 9 significant and positive SCA effects in their crossed materials. The significant and positive SCA effect involved parents where one or both the parents were related to good combiners, indicating GCA of the parental lines plays a vital role for high yield. Xingming *et al.*, (2002) also described a similar conclusion. These crosses also possessed high *per se* performances (Table 01). Vasal (1998) also suggested to include one good combiner (especially female parent) during the crossing to obtain higher heterosis.

Heterosis

The heterosis of 28 F_1 hybrids was considered to the standard check BHM9 (commercial hybrid) for different characters are presented in Table 05. Days to pollen shedding and silking regulate the earliness of flowering of the hybrid. Moreover, negative heterosis is desirable for these characters. Considering BHM9 as a check, 2 crosses $P_2 \times P_7$ and $P_7 \times P_8$ showed significant and negative heterosis for days to pollen shedding and ranged from -4.46 to 9.89%. For days to silking, none of the crosses showed significant and negative heterosis but two crosses exhibited negative values and ranged from -3.03 to 9.09% (Table 05).

Table 05. Percent heterosis over the check variety BHM9 for different characters in 8×8 diallel crosses in maize

Crosses/ Hybrids	DT (day)	DS (day)	PH (cm)	EH (cm)	TGW	GY (t/ha)
$P_1 \times P_2$	7.87**	6.59*	-30.63**	-17.17**	2.05	-29.87**
$P_1 \times P_3$	6.57**	5.03	-8.92**	2.52	-13.49**	-67.77**
$P_1 \times P_4$	8.38**	7.61**	-25.98**	0.85	8.33	-17.75**
$P_1 \times P_5$	5.31	4.49	-14.19**	8.66**	-7.52	-33.30**
$P_1 \times P_6$	8.89**	7.61**	-17.61**	12.78**	-9.83*	-24.04**
$P_1 \times P_7$	5.20**	3.95	-31.11**	3.33	-10.00*	-19.69**
$P_1 \times P_8$	6.29**	6.08*	-35.11**	-10.48**	-3.62	-85.76**
$P_2 \times P_3$	5.75**	5.03**	-22.07**	-22.11**	-13.49**	-37.07**
$P_2 \times P_4$	5.75**	5.56	-16.45**	8.66**	-6.72	10.83**
$P_2 \times P_5$	3.53**	2.86	-13.10**	3.33	-0.70	-26.13**
$P_2 \times P_6$	9.89**	9.09**	-14.19**	-2.65	-13.49**	-5.64**
$P_2 \times P_7$	-3.80**	-3.03	-15.31**	3.33	-10.85*	-13.71**
$P_2 \times P_8$	-0.61	-0.59	-28.26**	-13.73**	-12.60**	-60.36**
$P_3 \times P_4$	5.20**	5.03	-20.82**	0.85	-0.70	-49.04**
$P_3 \times P_5$	8.38**	8.11**	-26.43**	-43.21**	-3.62	-26.61**
$P_3 \times P_6$	6.82**	7.10**	-17.22**	3.33	4.67	-35.63**
$P_3 \times P_7$	4.65**	4.49	-43.90**	-46.84**	-10.00*	-54.39**
$P_3 \times P_8$	4.65**	4.49	-41.04**	-27.47**	4.67	-63.29**
$P_4 \times P_5$	4.09**	3.41	-14.56**	19.44**	-5.15	-2.74**
$P_4 \times P_6$	4.65**	4.49	-13.10**	7.20**	-14.58**	1.78**
$P_4 \times P_7$	3.53**	3.95	-24.21**	5.07*	-5.93	-15.06**
$P_4 \times P_8$	2.96**	2.86	-10.28**	10.77**	-9.16*	-12.07**
$P_5 \times P_6$	8.89**	7.61**	-36.68**	-31.82**	7.14	-75.91**
$P_5 \times P_7$	0.00	0.00	-41.60**	-61.11**	3.38	-41.41**
$P_5 \times P_8$	2.38**	2.86	-48.12**	-75.76**	-16.26**	-61.03**
$P_6 \times P_7$	5.20**	3.95	-22.07**	-10.48**	-5.93	9.72**
$P_6 \times P_8$	7.34**	6.08*	-37.21**	-50.65**	-7.52	-67.05**
$P_7 \times P_8$	-4.46**	6.59*	-53.25**	-46.84**	-10.85*	-56.47**
Mean	4.76	4.69	-25.84	-13.22	-5.78	-34.27
Min	-4.46	-3.03	-53.25	-75.76	-16.26	-85.76
Max	9.89	9.09	-8.92	19.44	8.33	10.83
SE	0.56	2.74	2.71	1.99	4.21	0.36
$CD_{(0.05)}$	1.15	5.61	5.55	4.08	8.61	0.73
$CD_{(0.01)}$	1.55	7.56	7.48	5.49	11.60	0.98

*, ** indicated at 5% and 1% level of significance; DP=days to 50% pollen shedding, DS=days to 50% silking, PH=plant height, EH=ear height, TGW=1000-grain wt. (g), GY=grain yield (t/ha)

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Negative heterosis is desired for plant height and ear height which supports for evolving short statured plant. Considering commercial hybrid BHM9 as a check, all the 28 crosses exhibited significant and negative heterosis for plant height indicates dwarfness of the hybrids which ranged from -53.25 to -8.92% (Table 05). Conversely, 13 crosses exhibited significant and negative heterosis for ear height (Table 05). For 1000-grain weight, positive heterosis is necessary for bold grain hybrids. Considering this, 6 crosses viz. $P_1×P_2$, $P_1×P_4$, $P_3×P_6$, $P_3×P_8$, $P_5×P_6$, and $P_5×P_7$ expressed significant and positive heterosis (Table 05). The percent heterosis for grain yield varied from -85.76 to 10.83% (Table 05). Moreover, Karim *et al.*, (2018), Talukder *et al.*, (2016) and Begum *et al.*, (2018) found 5.25%, 12.53 % and 9.9% significant positive heterosis in their studied materials, respectively. Among the 28 F_1, three crosses revealed positive heterosis for grain yield. The highest heterosis 10.83% was showed by the cross $P_2×P_4$ followed by $P_6×P_7$ (9.72%) and $P_4×P_6$ (1.78%).

IV. Conclusion

The study revealed that parent P_6 and P_7 for earliness, P_6 and P_7 for the dwarf plant, P_5 for bold grain and P_4 and P_6 for high yield may be used as donor parent for combining high yield with desirable traits. Two crosses namely $P_2×P_4$ and $P_6×P_7$ showed significant positive SCA effect with significant positive heterosis for yield compared to the check BHM9 and could be more satisfying in a hybrid breeding program after the thorough investigation at the different location.

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