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Studies on the Assessment of Combining Ability and Heterosis in Maize Inbreds

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ABSTRACT

The present study was carried out to determine the combining ability for yield and yield components by crossing six diverse maize inbreds in a half diallel mating design. Combining ability analysis for grain yield and its components in maize inbreds were carried out in 6×6 half diallel cross. 15 F_1 progenies along with their 6 parents were planted in RCBD with 3 replications. Combining ability analysis revealed that both GCA and SCA variances were significant for all the characters indicating the importance of both additive and non-additive gene action. The parents P_1 (IL12), P_3 (IL_{19}) and P_5 (IL_{20}) were good general combiners for grain yield and some yield contributing traits. The crosses $P_1 \times P_2$, $P_1 \times P_5$, $P_3 \times P_5$, $P_3 \times P_6$, and $P_5 \times P_6$ estimated significant and positive SCA effects for yield and some of the yield contributing traits.

KEYWORDS: Maize, Combining ability, Heterosis, Inbred lines, Diallel cross, Grain yield

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INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop in the world after rice and wheat, and it is being a cross pollinated crop has a higher yield potential compared to other cereals. Maize is a versatile crop grown over a range of agro climatic zones and is an important food and forage crop with abundant natural diversity.

Every part of the plant has economic value; the grain, leaves, stalk, tassel are used to produce hundreds of food and non-food products (Haddadi *et al*., 2012). High yield potentiality and its multipurpose use as food can be reduced the wheat production area and maize imports. Maize is also the most demandable cereal food of the poultry industry in Bangladesh (Zaman and Alam, 2013). The main purpose of maize breeding is to develop new inbred lines and hybrids that will outperform the existing hybrids with respect to a few traits. Maize is one of the important cereal crops of Bangladesh. Its area and production are increasing gradually, and the crop is becoming popular among the farmers. It is well established that hybrid maize has more yield potential than composite and synthetic varieties. Due to yield advantages and other agronomical characters growers are very much interested in cultivating hybrid maize. But most of the hybrid varieties are imported from foreign countries. The imported hybrid maize is very costly, and farmers are not getting seed timely. Due to the import of hybrid seeds farmers are losing valuable foreign currency each year. Besides this, poor viability of imported seeds has also been reported. With this view in mind, the present study was undertaken to evaluate locally developed hybrids in Bangladesh conditions and to select the best inbrds. Heterosis and combining ability is prerequisite for developing a good economically viable maize variety (Karim *et al*., 2023). Development of commercial maize hybrid generally requires a good knowledge of combining ability and heterosis of the breeding materials to be used.

The result of commercial production of hybrid maize depends up on the availability of productive diverse inbred lines and clear knowledge of gene action for specific characters. Eventually, the present investigation was undertaken to study the combining ability and estimate the extent of heterosis. The objectives of the present study were to evaluate GCA and SCA effects of six maize inbred lines to determine superior breeding lines and cross combinations. The main objectives of this study are to identify superior parental lines, predict hybrid performance, classify heterotic groups and maximize grain yield and to determine the underlying genetic architecture; additive vs. non-additive variance governing key agronomic traits.

MATERIALS AND METHOD

The parental materials were sown in crossing block during November 2024 at the Research Field of the Department of Botany, University of Rajshahi, Bangladesh. The genetic materials used in this experiment were 6 parents (IL_{12}=P_1, IL_7=P_2, IL_{19}=P_3, IL_{14}=P_4, IL_{20}=P_5 and IL_{18}=P_6) among the 25 inbred lines and their F_1 which were P_1×P_2, P_1×P_3, P_1×P_4, P_1×P_5, P_1×P_6, P_2×P_3, P_2×P_4, P_2×P_5, P_2×P_6, P_3×P_4, P_3×P_5, P_3×P_6, P_4×P_5, P_4×P_6 and P_5×P_6.

The present investigation was carried out during 15 November 2022 and 28 November 2023 seasons at the experimental field, Department of Botany, University of Rajshahi, Bangladesh. Plants at flowering stage (just before anthesis) were selected and crossed in half diallel fashion on 26 November 2024, excluding reciprocals and obtaining the F_1 seeds. The F_1 seeds of all the crosses with their parents were planted in the field on 28 November 2025 for evaluation in a randomized block design with three replications. The experimental unit was single row of 3 m long. Inter-plant and inter-row distances were 10 and 30 cm, respectively.

Data Collection

Five plants from each row were randomly selected for recording data on the studied characters such as ear height, cob length, cob diameter, number of rows/cob, number of kernels/row, number of kernels/cob and grain yield/plant.

Techniques of Statistical Analysis of Data

The collected data were analyzed following the biometrical techniques of analyses according to the Method 1 (Parents+F_1s = half diallel) given by Griffings (1956). In this study, six parents (n=6) were involved in the diallel, producing 15 F_1s [n (n-1)/2] and without reciprocals i.e., there were 21 total entries, 15 crosses and 6 parents. Data was analyzed using R software (2017).

RESULTS AND DISCUSSION

The parents P_4 and P_5 with mean value for most of the characters are more profitable for improving respective characters (Table 1). Due to lower plant height, it makes the plant more tolerant to lodge. Therefore, the parents P_1, P_3 and P_4 with mean values of ear height, cob length and cob diameter, respectively were suitable parents for these characters. The mean of grain yield ranged from 98.548 to 118.950g and the parents P_4 and P_5 with113.245 and 118.950g mean of grain yield had high meaning values for this character. The results agreed with those of Karim *et al.,* (2018), Karim *et al*., (2023) and Mishra *et al.,* (2024)

The F_1 crosses, P_2× P_4 and P_2× P_5 showed the lowest ear length, cob diameter and length, kernels numbers and grain yield compared with the other crosses. The F_1 crosses, P_4×P_5, P_4×P_5 and P_5× P_6 showed the highest grain yield compared with the other crosses. These results agree with the results of Afshar and Bahram (2012), Karim *et al*., (2021), Karim *et al*., (2023) and Mishra et al., (2024).

The analysis of variance revealed highly significant differences for all the characters, indicating the existence of wider genetic variability among the lines. Both general combining ability (GCA) and specific combining ability (SCA) variances were found to be highly significant (Table 2) for all the characters studied which indicated that both additive and non-additive gene action played predominant role for expression of these characters. The variance due to GCA of line being higher than the variance due to SCA indicating preponderance of additive gene effects. The estimated ratio between GCA and SCA was more than unity, indicating the predominance of additive gene action for cob length, cob diameter and row per cob numbers. Grain yield and its contributing characters were suggested to be controlled by additive and non-additive gene actions in maize inbreds. The variance due to GCA of inbreds being higher than the variance due to SCA indicating preponderance of additive gene effects. These results were agreement with the results of (Karim *et al*., (2023). Relative importance of GCA and SCA was calculated. Closer the ratio is to unity greater the predictability is based on GCA alone. The Highly significant differences for the analysis of variance between the inbreds for most of the characters and combining ability of variance indicated that inbreds were significantly different.

General and specific ability combining effects of inbreds and crosses were also significantly different for most of the characters (Table 3 and Table 4). In this study, for ear height, grain numbers/cob and grain yield the inbreds with significant and negative general combining ability effects were considered as good general combiners. On the other hand, for and other yield components i.e. number of grains/cob those with significant and positive GCA effects were considered as good general combiners. Similar inbreds difference for ear length, grain yield and other traits were reported by Karim *et al. (*2023) and Mishra et al., (2024). In the present study GCA/SCA variance was observed to be unity for cob length, cob diameter and number of rows/cob indicating equal importance of both additive and non-additive gene effects. The estimates of GCA effects showed that the parent P_1 was the best combiner of ear height, grains/cob, grain yield and also for earliness. Parents P_4 and P_5 had significant positive GCA effects for ear height making them good combiners for improving the trait. Thus, the inbred lines which exhibited good general combining ability for at least one character can be used as donor parents for the accumulation of favorable genes. These findings are in accordance with Khalil *et al*. (2010) and Singh *et al*. (2012) and Haddadi *et al.* (2012).

Specific combining ability effects of some crosses showed positive significant performance for many characters under study (Table 4). Among the crosses, P_1×P_2, P_1×P_5, P_2×P_5 and P_3×P_5 possessed significant SCA effect for ear height, number rows/cob, grain number/cob and grain yield/plant exhibited best specific combiner for these characters. For grain yield, most of the crosses exhibited significant and positive SCA effects. The most promising crosses for improving the grain number and grain yield were (P_1×P_2) and (P_2×P_5), because it gave the highest positive significant SCA for the above-mentioned characters. High specific combination for grain yield was observed in low × high general combiners as in the crosses $P_1 \times P_5$ and $P_3 \times P_5$.The crosses $P_2 \times P_5$ and $P_3 \times P_5$ were also good for grain yield and involved low × average general combiners. These crosses could be selected and used in breeding programs for improving these characters. Results obtained from this study agree with the results obtained by Singh *et al.* (2012), Karim *et al*. (2018), Karim *et al*., (2023) and Mishra *et al*., (2024).

The better parent heterosis expressed by the F_1 hybrids for yield and yield related characters are shown in Table 5. Most of the characters showed significant negative heterosis in many crosses. For grain, yield/plant $P_1 \times P_2$ cross showed significant and positive heterosis was found in 4.150 and rest of the characters are shown in significant negative heterosis. Karim et al 2018 and Karim et al 2023 in their study found 2.89 to 5.25 standard heterosis for grain yield, respectively. Significant and negative heterosis was shown by most of the characters. Significant and negative heterosis for both days to pollen shedding and days to silking indicating earliness was reported by Singh *et al.* (2012), Karim *et al*. (2018), Karim *et al*., (2023) and Mishra et al., (2024).

CONCLUSION

Parents with good positive GCA for yield (P_1, P_2 and P_5), negative GCA for ear height, cob length and cob diameter (P_1, P_2 and P_4), dwarf short ear and cob length (P_5) may be extensively used in hybridization programs as a donor. The better performing four crosses ($P_1 \times P_2$, $P_1 \times P_5$, $P_2 \times P_3$ and $P_3 \times P_5$) can be utilized for developing high yielding hybrid varieties as well as exploiting hybrid vigor. These crosses also need to be evaluated through multiplications.

Table 1. Mean performance of parents and crosses.

Parents/Crosses	EH	CL	CD	NRC	NKR	NGC	GY
P_1	53.336	14.633	12.185	13.405	26.658	357.263	111.141
P_2	56.933	12.632	12.451	13.048	26.905	351.210	98.548
P_3	54.355	12.805	11.573	13.194	28.441	375.186	106.215
P_4	60.889	12.796	12.193	13.009	30.063	390.906	113.245
P_5	61.650	12.763	11.587	13.042	31.411	410.633	118.950
P_6	66.991	12.616	12.176	13.056	29.961	391.014	110.695
SE of mean	1.434	0.240	0.185	0.088	0.529	7.321	2.072
$P_1 \times P_2$	45.200	13.586	12.300	13.910	27.616	383.670	108.617
$P_1 \times P_3$	55.083	14.536	13.683	13.716	24.983	342.503	96.9623
$P_1 \times P_4$	61.966	16.700	12.243	13.490	27.216	366.843	103.853
$P_1 \times P_5$	48.766	16.263	10.500	13.616	29.200	400.020	113.245
$P_1 \times P_6$	56.516	11.883	12.933	12.500	28.616	356.886	101.034
$P_2 \times P_3$	57.983	11.666	12.883	13.033	27.000	351.803	99.595
$P_2 \times P_4$	65.120	10.950	13.016	12.533	26.783	335.610	95.011
$P_2 \times P_5$	59.083	13.250	12.506	12.350	25.600	316.326	89.551
$P_2 \times P_6$	48.966	13.000	12.316	13.133	27.016	353.620	100.109
$P_3 \times P_4$	56.550	14.460	8.850	12.666	28.916	367.386	104.007
$P_3 \times P_5$	47.283	11.100	12.316	13.083	29.916	390.903	110.664
$P_3 \times P_6$	63.430	12.200	12.123	12.950	28.400	367.680	104.089
$P_4 \times P_5$	53.716	10.600	12.216	13.133	33.983	448.513	126.973
$P_4 \times P_6$	70.883	12.700	12.883	13.183	31.350	410.883	116.321
$P_5 \times P_6$	81.883	12.783	11.150	13.403	33.433	449.136	127.150
SE of mean	6.573	1.102	0.849	0.404	2.428	33.549	9.497

. EH: ear height, CL: cob length, CD: cob diameter, NRC: number of rows/cob, NKR: number of kernels/row, NGC: number of grains/cob and GYP: grain yield/plant.

Table 2. Mean squares due to GCA and SCA on grain yield and yield components of inbreds

Items	df	EH	CL	CD	NRC	NKR	NGC	GYP
GCA	5	706.745**	11.733**	4.024**	2.655*	93.452**	13112.520**	1123.209**
SCA	15	250.432**	6.135**	3.928**	2.246**	11.872**	3490.124**	290.805**
Crosses	20	129.636	7.939**	4.702**	1.750*	34.905**	6114.124**	481.762**
Error	40	2.8225	3.644	2.162	3.574	16.657	3295.608	255.439
GCA: SCA		2.822	1.912	1.024	1.182	7.871	3.757	3.862

*, ** indicate significant at p«0.05 and p« 0.01, respectively, *, ** indicate significant at p«0.05 and p« 0.01, respectively, GCA: General combining ability, SCA: Specific combining ability. EH: ear height, CL: cob length, CD: cob diameter, NRC: number of rows/cob, NKR: number of kernels/row, NGC: number of grains/cob and GYP: grain yield/plant.

Table 3. Estimates of GCA effects of the parents for yield & yield contributing characters in Inbreds

Parents	EH	CL	CD	NRC	NKR	NGC	GYP
P1	-8.450**	-0.051	0.056	0.415	-0.258	19.150**	-9.102**
P2	-0.225	-0.024	0.412	0.158	-0.915	7.550**	-7.120**
P3	-1.425	0.258	-0.295	0.800	1.058	20.155**	0.405
P4	-0.924	-0.250	0.355	-0.241	-1.812	-16.415**	3.905**
P5	6.975**	-0.620	-0.385	-0.205	0.915	3.125**	9.120**
P6	3.955**	0.820	-0.075	-0.224	0.355	-3.151**	3.156**
S.E(gi)	2.850	0.425	0.315	0.195	0.845	9.510	4.102

Table 4. SCA effects of the crosses for yield and yield contributing characters in inbreds

Crosses	EH	CL	CD	NRC	NKR	NGC	GYP
P1 × P2	6.458**	0.09	-0.114	7.713**	3.985**	57.914**	14.548**
P1 × P3	7.156**	0.215	2.314**	0.274	-1.434	-10.164**	-3.455**
P1 × P4	6.586**	0.846	-0.259	2.315*	-0.361	3.348**	0.991
P1 × P5	-7.984**	2.198*	-3.648**	3.453*	4.162**	16.295**	4.915**
P1 × P6	-6.125**	-0.847	0.794	-4.914**	1.294	-5.745**	-1.915
P2 × P3	5.984**	-3.484**	1.253	-2.910**	-0.061	-6.360**	-1.518
P2× P4	6.254**	4.458**	0.315	-0.416	-3.56**	-32.514**	-9.642**
P2 × P5	-3.149**	0.548	0.657	-0.634	-4.293**	-71.930**	19.458**
P2 × P6	-16.448**	3.02*	-0.167	0.099	-1.315	-13.545**	4.190**
P3× P4	2.148*	0.298	-3.152**	-0.464	-1.243	-26.795**	-7.948**
P3× P5	-9.158**	-3.481*	4.451**	-5.348**	-1.548	-23.411**	-6.153**
P3× P6	1.258*	-2.952*	0.661	-5.324*	-2.451**	-25.542**	-7.459**
P4× P5	-10.194**	-4.584*	0.283	0.256	3.248**	24.238**	7.914**
P4× P6	2.798**	-0.198	0.351	0.227	4.232**	7.699**	2.640**
P5× P6	9.589**	-0.297	-0.541	0.463	2.940**	25.821**	6.948**
S.E.(Sij)	5.146	0.143	0.743	0.369	2.783	27.905	8.154

Table 5. Heterosis of the crosses for different characters in inbreds

Crosses	EH	CL	CD	NRC	NKR	NGC	GYP
P1 × P2	14.128**	-1.641*	2.068*	2.617*	0.974*	16.512**	4.150*
P1 × P3	1.715**	-0.325	2.950*	0.818*	1.941*	-87.308**	-24.190**
P1 × P4	3.985**	1.945*	-1.123*	0.645*	0.324	-50.150**	-15.487**
P1 × P5	39.845**	1.971*	-0.142*	0.497*	4.378**	58.145**	-15.187**
P1 × P6	24.258**	-3.042*	1.150*	0.514	-3.741**	-50.130**	-12.428**
P2 × P3	3.590**	-1.954*	1.480*	0.066	2.148**	-80.151**	-24.185**
P2× P4	0.950	-2.471*	-0.193*	0.197	2.943**	-81.846**	-17.148**
P2 × P5	35.158**	-0.010	0.893*	0.914*	3.740**	-140.147**	-34.185**
P2 × P6	19.250**	-0.378	0.713*	0.294	0.414	-52.190**	-18.194**
P3× P4	9.255**	1.945*	-4.951*	0.729*	0.064	-60.895**	-21.297**
P3× P5	30.192**	-1.847*	1.648*	0.814*	-3.189*	-69.580**	-14.580**
P3× P6	15.208**	-0.987*	0.541	0.790*	0.064	-61.854**	-14.187**
P4× P5	32.158**	-1.912*	-1.847*	0.816*	7.491**	-12.458**	-2.319*
P4× P6	11.058**	-0.494	-1.944*	0.512	2.128*	-5.784*	-1.6.48*
P5× P6	13.158**	-0.390	-0.545*	0.197	0.614	-9.894**	-3.1804*
LSD(5%)	3.45	5.36	0.42	1.24	2.82	3.95	8.25

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