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Estimation of Combining Ability of Maize Inbreds

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ABSTRACT

The present study was conducted to assess the combining ability for grain yield and its related components by crossing six diverse maize inbred lines using a half-diallel mating design. A total of 15 F_1 hybrids, along with their six parental lines, were evaluated in a randomized complete block design (RCBD) with three replications. Combining ability analysis indicated that both general combining ability (GCA) and specific combining ability (SCA) variances were significant for all studied traits, highlighting the importance of both additive and non-additive gene actions. Grain yield was found to be influenced by both types of gene effects. Most of the crosses exhibited significant and positive SCA effects for several traits, particularly those involving low × average and average × average general combiners. Parent P_4 showed high GCA effects and demonstrated good general combining ability for most traits, except for number of rows per cob and number of grains per row. A comparison of SCA effects with the GCA effects of the respective parents revealed that crosses with high SCA effects for maturity, number of grains per cob, and grain yield per plant generally involved high × low general combiners. The majority of high-yielding crosses with superior SCA effects for grain yield and grains per cob also involved high × low GCA parents. Based on GCA performance, parents P_3 and P_4 were identified as promising genotypes and may be utilized as potential sources in future maize hybridization programs.

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INTRODUCTION

Maize (*Zea mays* L.) plays a vital role in human and livestock nutrition worldwide. It is one of the highest-yielding cereal crops and is valued for its high productivity, low production cost, reduced risk, and multipurpose uses compared with many other crops. The combination of high market demand, relatively low input costs, assured market availability, and high yield potential has generated considerable interest among farmers in maize cultivation. In Bangladesh, maize is gaining increasing popularity, particularly due to its extensive demand in the poultry feed industry (Karim et al., 2018).

Despite the growing demand, Bangladesh relies heavily on imported hybrid maize seeds, which are expensive and often not available to farmers in a timely manner. Maize is the third most important cereal crop in the country after rice and wheat, accounting for approximately 4.8% of the total cropped area and 3.5% of the total value of agricultural output (Ahmad et al., 2011). During the 2014-15 cropping season, maize was cultivated on about 3.25 lakh hectares, producing nearly 22.72 lakh tons of grain (BBS, 2016). The high cost of imported inbred lines and seed supply constraints highlight the urgent need for developing locally adapted, high-yielding, and early-maturing maize hybrids. Farmers would benefit significantly if such hybrids could be produced and distributed domestically.

In this context, the present study was undertaken to evaluate locally developed maize hybrids under Bangladesh conditions and to identify superior inbred lines for hybrid development. Combining ability analysis, specifically general combining ability (GCA) and specific combining ability (SCA), provides valuable information on the breeding potential of inbred lines and their performance in hybrid combinations. Differences in GCA effects are mainly attributed to additive gene action and additive × additive interactions, whereas differences in SCA effects are associated with non-additive genetic variance, including dominance and epistatic interactions (Falconer, 1981). The concepts of GCA and SCA have become increasingly important in plant breeding due to the widespread adoption of hybrid cultivars across many crops (Wilson et al., 1978).

The evaluation of crosses among inbred lines is a crucial step in the development of superior maize hybrids (Hallauer, 1990). Ideally, this involves the assessment of all possible crosses among selected parents through diallel mating designs, which allow breeders to estimate the genetic potential of individual inbred lines. Diallel analysis provides insights into genetic architecture, including dominance-recessive relationships and other gene interactions. Such analyses have been widely used to study trait inheritance and to identify superior parents for hybrid and cultivar development (Yan and Manjit, 2003).

The primary objectives of combining ability and heterosis studies in plant breeding are to identify elite parental lines, select superior cross combinations, exploit hybrid vigor, and understand the underlying gene action governing yield and its components. General combining ability aids in the identification of superior parents, while specific combining ability facilitates the selection of promising hybrid combinations. Heterosis analysis helps quantify the superiority of F_1 hybrids over their parents and assists in the formation of heterotic groups. Therefore, the present investigation employed a 6 × 6 half-diallel mating design to identify good general combiners and superior cross combinations for the development of suitable maize hybrids under local conditions in Bangladesh.

MATERIALS AND METHODS

Materials

The genetic materials used in this experiment consisted of six maize inbred lines selected from a pool of 25 inbreds, namely IL_4 (P_1), IL_5 (P_2), IL_{18} (P_3), IL_{10} (P_4), IL_{23} (P_5), and IL_1 (P_6). These six parents were crossed in a half-diallel mating design to produce 15 F_1 hybrids: $P_1 \times P_2$, $P_1 \times P_3$, $P_1 \times P_4$, $P_1 \times P_5$, $P_1 \times P_6$, $P_2 \times P_3$, $P_2 \times P_4$, $P_2 \times P_5$, $P_2 \times P_6$, $P_3 \times P_4$, $P_3 \times P_5$, $P_3 \times P_6$, $P_4 \times P_5$, $P_4 \times P_6$, and $P_5 \times P_6$.

Methods

The experiment was laid out in a randomized complete block design (RCBD) with three replications. Crosses were made in a half-diallel fashion during the 2023-2024 growing season. Plants at the flowering stage, just before anthesis, were selected for controlled pollination.

Collection of Data

Data were recorded from five randomly selected plants from each row for the following traits: days to tasseling (DT), days to silking (DS), number of rows per cob (NRC), number of grains per row (NGR), number of grains per cob (NGC), and grain yield per plant (GYP).

Statistical Analysis

The collected data were analyzed using standard biometrical techniques of combining ability analysis following Method 1 (parents + F_1s; half-diallel without reciprocals) as described by Griffing (1956). In this study, six parents (n = 6) were involved in the diallel mating system, resulting in 15 F_1s [n(n-1)/2]. Thus, a total of 21 entries comprising six parents and 15 crosses were evaluated**.**

RESULTS AND DISCUSSION

The analysis of variance revealed that both general combining ability (GCA) and specific combining ability (SCA) variances were highly significant for all the studied characters (Table 1), indicating the involvement of both additive and non-additive gene actions in the expression of these traits. The ratio of GCA to SCA variances was greater than unity for most of the characters, suggesting that additive gene effects played a more predominant role than non-additive effects. A higher GCA/SCA ratio implies greater predictability of performance based on GCA alone.

The importance of both GCA and SCA variances for grain yield and its contributing traits in maize has also been reported by Moneam et al. (2009) and Karim et al. (2018). In the present study, however, GCA variances were considerably higher than SCA variances for most characters, except for number of rows per cob, indicating the predominance of additive gene action for the inheritance of these traits. Karim et al. (2018) similarly reported higher GCA than SCA variances for days to pollen shedding, plant height, ear height, and grain yield. In contrast, Moneam et al. (2009) and Karim et al. (2018) observed GCA/SCA ratios less than unity for kernels per row, 100-kernel weight, and ear yield per plant, suggesting the predominance of non-additive gene action. The present findings therefore indicate that additive gene effects were more influential for most traits, except number of rows per cob.

Effects of General Combining Ability (GCA): The estimates of GCA effects along with the mean performance of the parents are presented in Table 2. Among the six parents, P_4 emerged as the best general combiner for most of the traits studied, whereas the remaining parents showed good combining ability for specific characters only. A wide range of GCA effects was observed among the parental lines, reflecting substantial genetic variability.

For days to tasseling, days to silking, maturity, number of grains per cob, and grain yield per plant, parents P_1, P_2, and P_4 exhibited significant positive GCA effects along with superior mean performance, indicating that parental mean performance could serve as a useful indicator of combining ability. These parents may therefore be effectively utilized in hybrid breeding programs aimed at improving grain yield and adjusting flowering and maturity duration. Estimates of GCA effects further revealed that parents P_1 and

P_2 were good general combiners for grain yield, while P_4 and P_5 showed desirable GCA effects for reduced plant stature, suggesting their potential use in breeding for short-statured, high-yielding genotypes.

Overall, parent P_4 was identified as the most promising general combiner for days to tasseling, days to silking, grains per cob, and earliness. Parents P_4 and P_5 also exhibited significant positive GCA effects for ear height, making them suitable donors for improving this trait. Inbreds with good general combining ability for one or more traits can be effectively used as donor parents to accumulate favorable alleles in breeding populations.

Effects of Specific Combining Ability (SCA): The estimates of SCA effects revealed that crosses showing significant positive SCA effects for grain yield generally also exhibited high mean performance, whereas crosses with significant negative SCA effects had lower mean values (Table 3). This relationship indicates the effectiveness of SCA in identifying superior hybrid combinations. The high mean performance and significant positive SCA effects observed in crosses such as $P_1 \times P_2$ and $P_3 \times P_4$ highlight their potential as promising hybrids. These crosses involved high × low and low × low general combiners, demonstrating that high SCA effects can arise from diverse parental combinations.

The cross $P_1 \times P_2$ exhibited one of the highest significant positive SCA effects for grain yield and related traits, whereas some high × high general combiner crosses showed relatively lower SCA effects and mean performance. For days to maturity, crosses $P_3 \times P_5$ and $P_3 \times P_6$ showed significant negative SCA effects, indicating earliness, and involved low × low general combiners. Parents P_3, P_4, and P_5, which showed significant positive GCA effects for grain yield and negative GCA effects for days to tasseling, silking, and maturity, may be extensively utilized as donor parents in hybridization programs.

Among the hybrids, $P_1 \times P_2$ and $P_1 \times P_5$ exhibited significant and desirable SCA effects for days to tasseling and silking, number of grains per cob, and grain yield per plant, and were identified as the best specific combiners for these traits. These were followed by crosses $P_3 \times P_5$ and $P_3 \times P_6$, which showed favorable SCA effects for days to silking and maturity along with several yield components. The most promising crosses for improving grain number and grain yield were $P_1 \times P_2$ and $P_5 \times P_6$, as they exhibited the highest significant positive SCA effects for these traits. Additionally, crosses $P_4 \times P_5$ and $P_5 \times P_6$ also showed good performance for grain yield and involved low × average general combiners.

Parents with desirable GCA effects for grain yield (P_4), reduced grain number per cob (P_1), and early maturity (P_4) may be effectively used as donor parents in hybrid breeding programs. Overall, the superior crosses $P_1 \times P_2$, $P_4 \times P_5$, and $P_5 \times P_6$ showed excellent potential and can be utilized for the development of high-yielding maize hybrids and for the exploitation of heterosis.

Table 1. ANOVA (MS value) for combining ability of seven characters of maize inbreds in a 6;6 diallel cross

Sources of variation	df	DT	DS	DM	NRC	NGR	NGC	GYP
Inbreds	24	7.348**	5.938**	77.896**	5.463*	9.395**	947.161**	68.778**
GCA	5	15.009**	10.473**	180.405**	1.433*	94.069**	12916.598**	1035.173**
SCA	15	4.795**	4.427**	45.030**	2.581**	12.116**	3571.143**	286.216**
Crosses	20	7.348**	5.938**	77.789**	1.544*	32.604**	5907.507**	473.455**
Error	40	4.236	3.242	5.0989	3.489	17.689	3376.707	270.629
GCA/SCA		3.159	2.365	4.414	0.745	7.764	3.6169	3.6167
F value		**	**	***	**	***	***	***

*, ** indicate significant at p=0.05 and p= 0.01, respectively.

Table 2. Estimation of GCA of parents for different characters in maize inbreds

Parents	DT		DS		DM		NRC		NKR		NKC		GYP	
	Mean	gca	Mean	gca	Mean	gca	Mean	gca	Mean	gca	Mean	gca	Mean	gca
P_1	91.00	1.422	93.00	1.265	145.30	-4.448**	12.134	0.388	14.650	0.237	68.750	18.422**	65.575	-8.301**
P_2	90.75	-0.743	97.75	-0.134	152.90	2.659**	11.865	0.132	13.530	-0.846	66,240	7.419**	79.535	-7.018**
P_3	92.06	-0.428	95.06	-0.267	148.25	2.975**	11.685	0.173	14.500	1.045	69.240	19.055**	78.540	0.358
P_4	90.70	-3.547*	90.70	-2.487*	150.60	-5.402**	11.330	-0.198	15.350	-1.071	66.855	-15.88**	82.900	3.178**

P_5	89.50	0.452	92.50	0.114	149.90	-0.576	10.750	-0.252	14.750	0.789	65.900	2.703**	81.950	8.877**
P_6	91.20	-0.155	93.90	-0.491	149.95	0.793	12.350	-0.242	14.350	0.311	65.350	-2.880**	75.120	2.906**
SE (gi)	0.345		0.335		0.420		0.130		0.783		10.828		3.065	
LSD, 5%	1.532		1.831		15.279		1.112		1.843		1.749		1.749	

Table 3. Estimation of SCA of crosses for different characters in maize inbreds

Crosses	**DT**		**DS**		**DM**		NRC		NKR		NKC		GYP	
	Mean	sca	Mean	sca	Mean	sca	Mean	sca	Mean	sca	Mean	sca	Mean	sca
$P_1 \times P_2$	97.840	0.054	100.110	4.757**	146.223	2.244*	14.666	7.61**	28.780	3.034**	383.670	56.096**	108.617	15.880**
$P_1 \times P_3$	97.280	-0.313	98.890	0.671	149.473	3.178**	14.386	0.253	31.000	-1.253	342.503	-11.127**	96.962	-3.150**
$P_1 \times P_4$	95.356	-0.569	98.613	0.614	142.110	0.192	13.776	2.248*	28.166	-0.324	366.843	3.251**	103.853	0.920
$P_1 \times P_5$	96.556	0.958	99.943	-2.343**	144.473	-0.270	13.723	3.398*	27.360	4.124**	400.020	16.295**	113.245	4.613**
$P_1 \times P_6$	94.750	1.035	97.610	-0.384	151.276	7.163**	12.712	-4.80**	24.583	1.300	356.886	-5.745**	101.034	-1.626
$P_2 \times P_3$	93.610	0.078	97.973	2.153**	156.723	3.319**	13.610	-2.80**	27.583	-0.058	351.803	-6.360**	99.595	-1.800
$P_2 \times P_4$	94.943	-0.008	97.526	0.927	152.416	1.391	13.220	-0.457	24.140	-3.58**	335.610	-32.514**	95.011	-9.205**
$P_2 \times P_5$	94.223	-0.230	96.946	-0.254	150.833	0.981	12.470	-0.617	28.556	-4.30**	316.326	-71.930**	89.551	20.363**
$P_2 \times P_6$	93.473	0.946	95.916	-0.678	148.526	-2.694**	13.001	0.093	27.890	-1.121	353.620	-13.545**	100.109	3.834**
$P_3 \times P_4$	93.140	-0.569	94.946	-3.519**	143.803	3.185**	13.026	-0.480	29.610	-1.101	367.387	-26.795**	-15.360	-7.585**
$P_3 \times P_5$	95.443	0.958	97.77	0.708	146.723	-6.364**	12.886	-5.04**	28.831	-1.635	390.903	-23.411**	110.664	-6.627**
$P_3 \times P_6$	95.136	1.035	97.890	-3.427**	144.750	-4.813**	12.776	-5.247*	29.723	-2.40**	367.680	-25.542**	104.089	-7.231**
$P_4 \times P_5$	94.443	0.078	96.693	-3.154**	149.890	-1.039	13.250	0.231	24.556	3.126**	448.883	24.238**	126.973	6.861**

$P_4\times P_6$	93.973	-0.008	95.666	-0.154	**147.125**	1.730	12.640	0.208	30.290	4.253**	410.883	7.699**	116.321	2.181**
$P_5\times P_6$	94.526	-0.230	96.696	2.146**	148.176	0.191	13.223	0.451	31.193	2.801**	449.137	25.821**	127.150	7.309**
SE (gi)	0.946		0.921		1.155		0.357		2.152		29.738		8.418	
LSD ()5%	**ns**		**ns**		*		**ns**		**		***		***	

CONCLUSION

Parents exhibiting significant positive general combining ability (GCA) for grain yield (P_1 and P_4), negative GCA effects for days to silking and maturity (P_1 and P_3), and lower grain number (P_5) may be effectively utilized as donor parents in hybridization programs. The four superior crosses, namely $P_1\times P_2$, $P_1\times P_5$, $P_3\times P_5$, and $P_3\times P_6$, demonstrated promising performance and can be exploited for the development of high-yielding maize hybrids as well as for the utilization of hybrid vigor. These crosses should be further evaluated through multi-location and advanced-generation trials to confirm their stability and yield potential.

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