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COMBINING ABILITY AND HETEROSIS IN DIALLEL CROSSES OF MAIZE (*Zea mays* L.) FOR YIELD AND YIELD CONTRIBUTING CHARACTERS

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Abstract

A field research was carried out durig 2014-15and 2015-16, using eight white maize inbred lines (CML154, VL109196, CML491, VL05590, CML502, CLRCWQ10, CLRCWQ26 and CML511) designated as P1, P2, P3, P4, P5, P6, P7 and P8 respectively, to estimate the combining ability effects and heterosis of 28 crosses produced following half diallel mating design at Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. Assessment was done for eight characters viz. days to pollen shedding, days to silking, plant height, ear height, ear length, number of grains/ear, 1000 -grain weight and yield. Considering overall performance of GCA effects observed that parent P_6 was the best general combiner for both yield and earliness while parent P_2 and P_8 for dwarfness. Two hybrids namely, $P_3 \times P_5$ and $P_6 \times P_8$ exhibited significant positive SCA effects and significant positive heterosis for grain yield. These two hybrids were selected for future trial.

Introduction

Maize is considered as a major cereal crop in the world because of its high yield, abundant diversity and for essential nutrient element. In Bangladesh, maize emanates as a second most important cereal crop after rice and gaining popularity among the farmers because of its high yield.The maize area in Bangladesh is increasing to 0.444 million hectare during 2017-18 (DAE, 2018Plant breeder plays a vital role to make better cross combinations through selection of desirable inbreds. In the time of inbred selection plant breeder should have combining ability information of all inbred used in the experiment (Burt *et al.* 2011). Combining ability also provides information about the nature of the crosses. The average performance of an inbred line in its cross combination is defined as general combining ability (GCA) and specific combining ability (SCA) clarify that based on average performance some cross combinations showed superior or inferior performance than expected (Sprague and Tatum 1942). Diallel mating designs works well for getting genetic information of desired trait from fixed or random

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selected parental lines (Griffing 1956). The presence of additive variance is very important for the development of crop through selection because only this variance shows reaction for selection. Additive gene effect is quantified through general combining ability of a parent that means important for parent selection and dominance and/or non-additive genetic is quantified through specific combining ability and is important for hybrid development (Nadaranjan *et al.*, 2005). Both additive and non-additive variances played a vital role in genetic control of different agronomic traits in maize (Estakhr *et al.*, 2012). In Bangladesh farmers are more interested in high yielding hybrid with short plant height. The main objective of the study was to develop high yielding hybrid having with short plant height. So, best parents with desirable characters and crosses showing heterosis could be find out for fulfilling the objectives.

Material and methods

Eight white maize inbred lines, namely CML154, VL109196, CML491, VL05590, CML502, CLRCWQ10, CLRCWQ26 and CML511 were received from CIMMYT and selected based on their agronomic performances for making half diallel (8×8) crosses (Table 1). All inbred lines were mated by hand pollination and 28 crosses were produced during rabi season of 2014-15 at Bangladesh Agricultural Research Institute (BARI), Gazipur and in the next rabi season of 2015-16, all the cross combinations were evaluated along with four commercial checks. The soil of the experiment sites were homogenous so randomized complete block design were followed with three replications. All evaluating materials were grown in two rows of 4m long. Row to row spacing was 60cm and plant to plant spacing was 25 cm. Each row consisted of 17 plants after thinning and all standard agronomic practices were followed for quick growing of plants. Data were recorded on plant height, ear height, ear length, grains per ear and 1000 -grain weight from five randomly selected plants from each treatment. Grain yield were finally converted in ton/ha.

Table 1. Parents used in diallel crosses and their important features

Parents	Origin	Source
P_1	CML154	CIMMYT
P_2	VL109196	CIMMYT
P_3	CML491	CIMMYT
P_4	VL05590	CIMMYT
P_5	CML502	CIMMYT
P_6	CLRCWQ10	CIMMYT
P_7	CLRCWQ26 and	CIMMYT
P_8	CML511	CIMMYT

The ANOVA and combining ability was analyzed using PB Tools software following Model I (fixed effect) method IV (without reciprocals and parents) following Griffing (1956). Heterosis percentages of crosses for different characters were calculated using standard checks described by Mather and Jinks (1971) as follows:

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

Where, F_1 is the mean performance of the cross and SC is the mean of the Standard check varieties. The significance test for heterosis was done by using standard error of the value of check variety.

Results and Discussion

Combining ability analysis

Primary analysis of variance disclosed that highly significant to significant variation were observed for some of the characters indicating existence of noticeable amount of genetic variability among the parents and their hybrids (Table 2). So there is a scope of improvement by using these characters of maize. This results is in concurrence with Amiruzzaman *et al.,* (2013). In keeping with above mentioned result comprehensive analysis of combining ability and type of gene action was therefore suitable for guessing the characters investigated through this research. ANOVA for combining ability (Table 2) of parents and crosses showed significant GCA and SCA variances, respectively. As reported by Griffing (1956), GCA variance contains additive epistasis effect, while SCA variance contains non-additive epistasis effect. So, significant GCA and SCA variance suggested that there is an importance of both additive and non-additive gene effects for governing these characters in maize. These results agree with the findings by Estakhr *et al.,* (2012). However, GCA/SCA ratio of mean squares for all characters except yield in this study was higher than unity. That is variances due to GCA was higher than SCA for all characters except yield indicating additive gene action plays significant role for controlling these characters. Selection would be useful for improvement of these characters. But in grain yield SCA variances showed higher value than GCA variances indicating grain yield is controlled by non-additive gene effects. Khotyleva *et al.* (1986) reported dominant gene effects are more responsible for controlling grain yield than additive gene effects. Dass *et al.* (1997) also noted that supremacy of non-additive gene action for governing the grain yield of maize. Recently Archana *et al.,* (2018) reported non-additive gene action for heat stress conditions.

Estimate of general combining ability (GCA) effects of eight parents for different characters are presented in Table 3. GCA analysis revealed that, three parents ($P_{1,}$ P_6 and P_8) showed highly significant and negative GCA effect for days to pollen shedding and silking indicating good combiner for earliness. Similar findings reported by Archana *et al.*, (2018) in their studies and they identified parental lines having good general combiner for days to 50% anthesis, days to 50% silking. Earliness of the hybrid depends on days to pollen shedding and silking, so significant negative value is desirable. The parents P_2 (-7.29), P_8 (-11.01) and P_5 (-6.82), P_8 (-8.93) exhibited highly significant negative value for plant height and ear height, respectively. These parents proved to be a good general combiner for developing dwarf hybrid because plant height and ear height ~~is~~ are the indicator of dwarfness. Ear length, no of grain/ear, 1000 grain weight are the yield contributing characters and significant positive value is desirable. Among the parents $P_{6,}$ P_7 showed highly significant positive value for ear length and P_8 possess significant positive value for no. of grain/ear. Therefore, these parents considered to be a good combiner for improving yield. But none of the parents exhibited significant positive value for 1000 grain weight. Only two parents P_3 and P_6 had significant positive value for yield. Hence P_3 and P_6 parents could be treated as good general combiner for improving maize yield. Therefore, it may be concluded that for development of high yielding hybrid and desirable traits these parental genotype could be productively used in future breeding program. Archana *et al.*, (2018) identified two parents ZL 11953 and VL128 in their study having significant *GCA* effects for grain yield. Dinesh *et al.* (2016) reported that three inbreds *viz.*, L78, L73, and L37 as good general combiners for grain yield among 145 inbred lines.

Specific combining ability effects of 28 crosses for studied characters are presented in Table ~~3~~ 4. Among the crosses, none showed significant value for days to pollen shedding. For days to silking only one cross $P_4 \times P_6$ (-1.00) showed desirable significant negative value and considered as a good specific combiner for improving this character. Two crosses namely $P_4 \times P_5$ and $P_6 \times P_7$ exhibited highly significant negative value for plant height (-16.54, -15.43) and ear height (-21.33, -15.77), respectively may be treated as good specific combiner for improving this traits. Therefore, these crosses can be effectively used in hybrid breeding program for developing dwarf hybrid. Regarding no. of grain/ear none of the parent showed significant positive effect but two crosses $P_2 \times P_5$ and $P_4 \times P_7$ had significant positive value for 1000 grain weight. The crosses $P_3 \times P_5$ and $P_6 \times P_8$ was the best specific combiner for grain yield because of significant positive SCA value. Begum *et al.* (2018), Jodage *et al.* (2018) also drew similar conclusion for grain yield. Grain yield is the reflection of high yielding hybrid development. Again GCA effects helps to bring out effective parent for developing desired profitable hybrid and SCA effects associated with heterosis. Result of in this study revealed that, there is a relation between GCA effects and SCA value of their resembling crosses, hence two parents P_3(0.62) and P_6 (0.69) having positive GCA value for grain yield, and therefore, some crosses of these two parents, namely $P_3 \times P_5$ (1.69) and $P_6 \times P_8$ (1.23) produced significant positive SCA effect.

Table 2. Analysis of variance for combining ability for eight characters in maize

Source of variation	df	DPS	DS	PH (cm)	EH (cm)	EL (cm)	NG/E	TGW (g)	Y (t/ha)
Genotype	27	9.08**	8.36**	428**	474**	1.53*	12062**	2028**	2.80*
GCA	7	9.90**	9.14**	314.91**	384.03**	1.00*	4367	1195	0.82
SCA	20	0.62	0.56	82.17*	91.53	0.34	3900	495**	3.86**
Error	54	1.31	1.1	142.72	188.29	0.86	1918	146	1.49
GCA:SCA	83	15.97	16.32	3.83	4.19	2.94	1.12	2.41	0.21

*, ** indicated at 5% and 1% level of significance; DPH (Days to pollen shed), DS (Days to silk), PH (Plant height), EH (Ear height), EL (Ear length), NG/E (No. of grain/ear), TGW (1000 grain weight), Y (Yield).

Table 3. Estimate of general combining ability (GCA) effects of parents for different characters in maize crosses

Parents	DPS	DS	PH (cm)	EH (cm)	EL (cm)	NG/E	TGW (g)	Y (t/ha)
P_1	-1.42**	-1.35**	0.1	1.29	0.24	-48	0.75	-0.48
P_2	0.25	0.32	-7.29**	-2.6	-0.76*	29	-50.75	0.01
P_3	2.3**	1.89**	12.25**	14.07**	0.35	-54	27.53	0.62*
P_4	0.47	0.49**	3.99	-2.32	-0.71	35	31.53	0.03
P_5	0.92**	0.93**	-3.46	-6.82**	-0.38	-66	1.69	-0.62*
P_6	-1.58**	-1.74**	2.71	-2.54	0.43*	34	0.14	0.69**
P_7	-0.19	0.14	2.71	7.85**	0.51*	24	16.75	0.15
P_8	-0.75**	-0.68**	-11.01**	-8.93**	0.32	46*	-27.64	-0.4
SE (gi)	0.25	0.23	2.63	3.02	0.21	18	16.72	0.27
LSD (5%)	0.49	0.45	5.15	5.92	0.41	39.33	31.60	0.49
LSD (1%)	0.65	0.59	6.79	7.79	0.54	58.20	48.79	0.65

*, ** indicated at 5% and 1% level of significance; DPH (Days to pollen shed), DS (Days to silk), PH (Plant height), EH (Ear height), EL (Ear length), NG/E (No. of grain/ear), TGW (1000 grain weight), Y (Yield).

Table 4. Estimate of specific combining ability effects of crosses for different characters in maize.

Cross	DPS	DS	PH (cm)	EH (cm)	EL (cm)	NG/E	TGW (g)	Y (t/ha)
$P_1 \times P_2$	-0.52	-0.56	-4.48	-8.49	0.3	-0.46	30.86	0.08
$P_1 \times P_3$	0.42	0.39	-5.71	-3.49	-0.14	41.54	11.41	0.09
$P_1 \times P_4$	0.59	0.61	6.57	4.9	-1.09*	-49.13	-6.59	-0.02
$P_1 \times P_5$	-0.86	-0.83	-10.98	-7.6	0.25	-9.46	17.3	-0.76
$P_1 \times P_6$	-0.36	-0.17	4.85	10.45	-0.53	-34.68	-131.59**	-0.46
$P_1 \times P_7$	0.92	0.78	3.52	1.73	1.02*	38.1	31.52	0.79
$P_1 \times P_8$	-0.19	-0.22	6.24	2.51	0.19	14.1	32.08	0.28
$P_2 \times P_3$	0.09	0.06	-8.65	-1.94	0.19	-67.46	-36.92	-0.06
$P_2 \times P_4$	1.25*	1.28*	-9.71	-2.88	0.58	28.54	-23.58	-0.58
$P_2 \times P_5$	-0.86	-0.83	16.07**	19.95**	-0.75	-21.79	96.96*	0.14
$P_2 \times P_6$	-0.02	0.17	1.57	-4.66	0.47	-21.02	24.08	0.26
$P_2 \times P_7$	-0.08	0.11	11.57	2.29	-0.98*	6.43	-122.14**	-0.41
$P_2 \times P_8$	0.14	-0.22	-11.37	-4.27	0.19	75.76	15.75	0.58
$P_3 \times P_4$	-0.8	-0.78	4.74	2.45	-0.2	-15.46	1.3	0.54
$P_3 \times P_5$	-0.25	-0.22	7.85	7.95	0.47	39.54	13.86	1.69**
$P_3 \times P_6$	-0.08	-0.22	4.68	0.01	0.02	-25.68	31.3	-0.75
$P_3 \times P_7$	0.53	0.72	-3.32	3.95	0.25	51.1	-15.92	0.23
$P_3 \times P_8$	0.09	0.06	3.4	-8.94	-0.59	-23.57	-20.03	-1.74**
$P_4 \times P_5$	0.92	0.65	-16.54**	-21.33**	-0.48	-24.46	-50.81	-1.06

Cross	DPS	DS	PH (cm)	EH (cm)	EL (cm)	NG/E	TGW (g)	Y (t/ha)
$P_4 \times P_6$	-0.91	-1.00*	-0.71	-0.6	0.41	72.32	-1.03	0.7
$P_4 \times P_7$	0.03	-0.06	6.63	10.01	0.3	33.1	122.76**	-0.35
$P_4 \times P_8$	-1.08	-0.72	4.02	7.45	0.47	-44.9	-42.03	0.76
$P_5 \times P_6$	1.31*	1.22*	5.07	5.56	0.08	-28.02	18.47	-0.69
$P_5 \times P_7$	-0.41	-0.5	0.4	-2.49	-0.03	-32.57	-52.03	0.9
$P_5 \times P_8$	0.14	0.5	-1.87	-2.05	0.47	76.76	-6.81	-0.23
$P_6 \times P_7$	-0.91	-0.83	-15.43**	-15.77**	-0.14	19.54	47.74	-0.3
$P_6 \times P_8$	0.98	0.83	2.96	5.01	-0.31	17.51	26.01	1.23*
$P_7 \times P_8$	-0.08	-0.22	-3.37	0.29	-0.42	-115.68**	-11.92	-0.86
SE (ij)	0.56	0.51	5.83	6.70	0.45	39.75	37.01	0.60
LSD (5%)	1.10	1.00	11.43	13.13	0.88	77.91	69.94	1.10
LSD (1%)	1.44	1.32	15.04	17.29	1.16	102.56	110.66	1.44

*, ** indicated at 5% and 1% level of significance; DPH (Days to pollen shed), DS (Days to silk), PH (Plant height), EH (Ear height), EL (Ear length), NG/E (No. of grain/ear), TGW (1000grain weight), Y (Yield).

Using BHM9 as a standard check the percent standard heterosis was calculated and presented in table 4 5. The hybrid $P_1 \times P_6$ (-2.25), $P_1 \times P_8$ (1.12), $P_4 \times P_6$ (0.75) and $P_6 \times P_7$ (-1.50) had desirable significant negative heterosis for days to pollen shedding. Morphologically earliness is measured by days to pollen shedding and silking, hence, negative heterosis value is desirable. Since, these four hybrids exhibited significant negative heterosis, they can be used for short duration hybrid development. Depending on calculated value of heterosis, negative heterosis produced in eight crosses for plant height and sixteen crosses for ear height, respectively. These crosses can be extensively used for developing dwarf hybrid. Significant positive heterosis is desirable for yield contributing characters i.e ear length, no. of grain/ear and1000 grain weight. Considering ear length maximum crosses had significant positive (22 crosses) heterosis. Meanwhile, no. of grain/ear and 1000 grain weight of maximum crosses had significant negative value of heterosis. Only one crosses ($P_3 \times P_6$) and three crosses ($P_1 \times P_{3,}$ $P_1 \times P_{7,}$ $P_2 \times P_6$) showed significant positive value for no. of grain/ear and1000 grain weight, respectively. Significant positive heterosis is desirable for grain yield, and in this study among 28 crosses, two crosses namely $P_3 \times P_5$ (6.25%) and $P_6 \times P_8$ (11.29%) showed significant positive heterosis for grain yield. Debnath (1992) and Roy *et al.* (1998) found appreciable percentage of heterosis for grain yield in maize. Similar kind of results were also reported by Kumar *et al.*, (2016), Amiruzzaman *et al.*, (2013), Begum *et al.*, (2018) in their study.

Table 5. Percent heterosis over the check variety BHM9 for different characters in 8×8 diallel crosses of maize

Parents	DPS	DS	PH (cm)	EH (cm)	EL (cm)	NG/E	TGW (g)	Y (t/ha)
$P_1 \times P_2$	0.00	1.49**	-4.74**	-12.93**	4.44**	-8.83**	-3.68*	-32.14**
$P_1 \times P_3$	3.00**	4.48**	3.67**	5.75**	6.67**	-0.71	5.76**	-26.23**
$P_1 \times P_4$	1.12**	2.99**	5.50**	-1.15	-4.44**	-3.42	-11.24**	-32.93**
$P_1 \times P_5$	0.00	1.87**	-5.96**	-15.80**	4.44**	-5.22*	-7.46**	-31.72**
$P_1 \times P_6$	-2.25**	-0.37	4.13**	3.45	4.44**	-33.72**	-13.13**	-30.84**
$P_1 \times P_7$	0.75*	2.61**	3.52**	4.89*	15.56**	1.10	8.59**	-24.12**
$P_1 \times P_8$	-1.12**	0.75**	-1.53	-8.91**	4.44**	-7.03**	-9.35**	-34.20**
$P_2 \times P_3$	4.49**	5.97**	-1.07	3.74	4.44**	-19.66**	-1.79	-23.05**
$P_2 \times P_4$	3.75**	5.60**	-3.06**	-11.21**	2.22**	-16.31**	-13.13**	-33.46**
$P_2 \times P_5$	1.87**	3.73**	3.06**	4.60*	-6.67**	0.58	-7.46**	-32.76**
$P_2 \times P_6$	0.00	1.87**	-0.76	-12.93**	6.67**	-13.22**	9.54**	-19.29**
$P_2 \times P_7$	1.50**	3.73**	3.82**	2.01	-2.22*	-38.23**	-6.52**	-30.75**
$P_2 \times P_8$	1.12**	2.61**	-13.00**	-18.10**	0.00	-19.79**	-6.52**	-26.75**
$P_3 \times P_4$	3.75**	5.22**	10.24**	7.76**	2.22*	3.29	-9.35**	-17.21**
$P_3 \times P_5$	4.87**	6.34**	8.26**	8.62**	6.67**	-0.71	-9.35**	6.25**
$P_3 \times P_6$	2.25**	3.36**	8.26**	5.46**	8.89**	5.87*	-11.24**	-23.13**

Parents	DPS	DS	PH (cm)	EH (cm)	EL (cm)	NG/E	TGW (g)	Y (t/ha)
P_3×P_7	4.49**	6.34**	5.96**	17.82**	11.11**	-2.90	-2.74	-18.91**
P_3×P_8	3.37**	4.85**	2.75*	-7.76**	0.00	-11.93**	-15.01**	-42.81**
P_4×P_5	4.12**	5.60**	-6.73**	-30.75**	-4.44**	-12.44**	-22.57**	-39.25**
P_4×P_6	-0.75*	0.75**	3.36**	-9.20**	6.67**	-2.51	-1.79	-15.02**
P_4×P_7	1.87**	3.73**	6.73**	8.91**	6.67**	24.69**	-13.13**	-30.04**
P_4×P_8	0.00	2.24**	-0.76	-7.76**	2.22*	-15.41**	-9.35**	-24.78**
P_5×P_6	2.25**	3.73**	2.60*	-7.76**	4.44**	-12.31**	-5.57**	-34.24**
P_5×P_7	1.87**	3.73**	0.46	-5.75*	4.44**	-15.54**	-9.35**	-24.29**
P_5×P_8	1.87**	4.10**	-6.88**	-19.83**	2.22*	-15.02**	-15.01**	-40.25**
P_6×P_7	-1.50**	0.37**	-3.98**	-13.51**	8.89**	4.06	2.93	-23.26**
P_6×P_8	0.00	1.49**	-1.83	-10.06**	2.22*	-7.03**	0.09	11.29**
P_7×P_8	0.37	2.24**	-4.74**	-5.17*	2.22*	-12.44**	-3.68*	-38.93**
Mean	1.54	3.27	0.62	-4.48	3.73	-8.39	-6.48	-26.17
SE	0.37	0.35	1.03	2.05	0.90	2.32	1.39	2.30
LSD (5%)	0.75	0.72	2.12	4.20	1.85	4.76	2.86	4.72
LSD (1%)	1.02	0.98	2.87	5.68	2.49	6.42	3.86	6.37

*, ** indicated at 5% and 1% level of significance; DPH (Days to pollen shed), DS (Days to silk), PH (Plant height), EH (Ear height), EL (Ear length), NG/E (No. of grain/ear), TGW (1000 grain weight), Y (Yield).

Conclusion

The results of the study revealed that parents P_3 and P_6 having good combining ability for yield, also P_6 showed desirable value for days to pollen shedding and days to silking. Whereas P_8 showed good combining ability for days to pollen shedding, days to silking number of grain per ear, plant height and ear height. Besides P_2 also having good combining ability for plant height and ear height. These parents could be used as a donor parent for transferring desirable gene in hybrid breeding program. Two cross combinations P3× P5 and P6× P8 were identified as the best on their performance for specific combining ability and heterosis value. So, these promising crosses can be used in maize hybrid development program.

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