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COMBINING ABILITY AND HETEROSIS STUDYIN MAIZE INBREDS THROUGHOUT DIALLEL MATING DESIGN

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Abstract

Combining ability effects were estimated for grain yield and some other important agronomic traits of maize in a 7×7 diallel analysis excluding reciprocals. The variances for general combining ability (GCA) were found significant for yield, days to pollen shedding, days to silking and ear height while it was found non-significant for plant height and number of kernels/ear. Non-significant general combining ability (GCA) variance for plant height and number of kernels/ear indicates that these two traits were predominantly controlled by non- additive type of gene action. Specific combining ability (SCA) was significant for all the characters except yield and days to silking. Non-significant specific combining ability (SCA) variance for yield and days to silking suggests that these two traits were predominantly controlled by additive type of gene action. Both GCA and SCA variances were found significant only in days to pollen shedding and ear height indicated the presence of additive as well as non additive gene effects for controlling the traits. However, relative magnitude of these variances indicated that additive gene effects were more prominent for all the characters studied except days to silking. Parent BIL95 was the best general combiner for both high yield and number of kernels/ear and parent BML4 for dwarf plant type. Two crosses (BML4× BML36 and BIL114× BIL31) exhibited significant and positive SCA effects for grain yield involved low × average and average × average general combining parents. The range of heterosis expressed by different crosses for grain yield and days to silking was from -65.83 to 21.26 percent and -17.85 to 8.22 percent, respectively.. The better performing three crosses (BIL114×BIL31, BIL138×BIL95 and BIL31×BIL95) can be utilized for developing high yielding hybrid varieties as well as for exploiting hybrid vigour.

Keywords: Combining ability,heterosis, maize, GCA, SCA

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Introduction

Maize is one of the oldest and key cereal crops in the world. It is the highest yielding grain crop having multiple uses. A great combination of high market demand with comparatively low production cost, ready market and high yield has generated great interest among the farmers in maize cultivation. Day by day it is gaining popularity in the country due to vast demand, particularly for poultry industry. In Bangladesh it is the third most important crop after rice and wheat and it accounts for 4.8% of the total cropped land area and 3.5% of the value of agricultural output (Ahmad *et al.*, 2011). In 2014-15, maize was cultivated in 3.25 lac hectares of land and yielded 22.72 lac tons (BBS, 2016).

The effects of General Combining Abilities (GCA) and Specific Combining Abilities (SCA) are important indicators of potential value for inbred lines in hybrid combinations. Differences in GCA effects have been attributed to additive, the interaction of additive x additive, and the higher-order interactions of additive genetic effects in the base population, while differences in SCA effects have been attributed to non-additive genetic variance (Falconer, 1981). The concept of GCA and SCA has become increasingly important to plant breeders because of the widespread use of hybrid cultivars in many crops (Wilson *et al.,* 1978). The evaluation of crosses among inbred lines is an important step towards the development of hybrid varieties in maize (Hallauer, 1990). This process ideally should be through the evaluation of all possible crosses (diallel crosses), where the merits of each inbred line can be determined. A diallel analysis provides good information on the genetic identity of genotypes especially on dominance-recessive relations and some other genetic interactions. Diallel crosses have been used in genetic research to determinate the inheritance of a trait among a set of genotypes and to identify superior parents for hybrid or cultivar development (Yan and Manjit, 2003). The present study involving a 7×7 diallel analysis designed to find out the better general combining parents and for isolating good cross combinations in maize for developing suitable hybrid(s) locally.

Materials and Methods

Seven inbred lines of maize viz. P_1(BML4), P_2(BML36), P_3(BIL106), P_4(BIL114), P_5(BIL138), P_6(BIL31) and P_7(BIL95) collected from CIMMYT-Mexico, CIMMYT-ARMP, and locally developed were crossed in all possible combinations (excluding reciprocals) in the *rabi* season of 2012-2013 at Joydebpur. During *rabi* 2013-2014, crossed 21 F_1's and along with three commercial hybrids were grown following Randomized Complete Block Design (RCBD) with three replications were sown on 24 November 2013. Each plot involved of 2 rows 5.0 m long. The unit plot size was 5.0 m x 0.75 m. Spacing adopted was 75 cm × 20 cm between rows and hills, respectively. One healthy seedling per hill was kept after proper thinning. Fertilizers were applied @ 250, 55, 110, 40, 5 and 1.5 kg/ha of N, P, K, S, Zn, B, respectively. Standard agronomic practices were followed and plant protection measures were taken when required. Data on days to 50% pollen shedding and silking were recorded on whole plot basis. Ten randomly selected plants were used for recording observations on plant height and ear height. All the plants in 2 rows were considered for plot yield which was later converted to t/ha. The combining ability analysis was carried out following Model I (fixed effects) and Method IV (one set of F_1's but neither parents nor reciprocal F_1's is included) described by Griffing (1956) using a software 'diallel analysis' by Mark D. Burrow and James G. Coors, version 1.1.

Results and Discussion

Analysis of variances for combining ability (Table1) revealed that variances for general combining ability (GCA) were significant for yield, days to pollen shedding, days to silking and ear height while it was found non-significant for plant height and number of kernels/ear. Non-significant general combining ability (GCA) variance for plant height and number of kernels/ear suggested that these two traits were predominantly controlled by non- additive type of gene action. Specific combining ability (SCA) was significant for all the characters except yield and days to silking. Non-significant specific combining ability (SCA) variance for yield and days to silking suggested that these two traits were predominantly controlled by additive type of gene action.Both GCA and SCA variances were found significant in days to pollen shedding and ear height indicated the presence of additive as well as non additive gene effects for controlling the traits. Importance of both GCA and SCA variances for yield and yield contributing traits in maize was reported by Ahmed *et al.* (2008), Gurung *et al.* (2008) and Abdel-Moneam *et al.* (2009). However, in the present study variances due to GCA were much higher in magnitude than SCA for all the characters except days to silking indicating 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-kernel weight and grain yield. Predominance of additive gene action for various quantitative traits in maize was reported by Muraya *et al.* (2006), Ahmed *et al.* (2008), Alam *et al.* (2008) and Amiruzzaman (2010). The current result was in contrast with Abdel-Moneam *et al.* (2009) who observed GCA/SCA ratio was less than unity for kernels/row, 100-kernels weight and ear yield/plant, indicating non additive gene action were controlling the traits. Kadir (2010) in his study showed that the non-additive effects (SCA) were more important than additive effects (GCA) for plant height, ear height, days to pollen shedding, days to silking, seeds/row, 100-seed weight and grain yield/plant.

Table 1. Analysis of variance for combining ability of seven characters of maize in a 7×7 diallel cross

Source of variation	df	Yield (t/ha)	Pollen shedding (Days)	Silking (Days)	Plant Height (cm)	Ear height (cm)	No. of kernels/ ear	1000-kernel wt.(g)
GCA	6	30.70**	50.86**	47.86*	4869.71	2422.31*	18406.89	6314.28
SCA	14	7.38	6.38**	68.10	2529.84**	804.60**	7937.64**	2744.44**
Error	40	4.17	1.73	56.11	412.00	145.03	2664.03	880.39
GCA/SCA	-	4.16	7.97	0.70	1.92	3.01	2.32	2.30

**P=0.01,*P=0.05

General combining ability (GCA) effects

The GCA effects are shown in Table 2. None of the parents were found to be a good general combiner for all the characters under consideration. A wide range of variability of GCA effects was observed among the parents. In the present study, for days to pollen shedding, silking, plant height and ear height the inbred lines with significant and negative GCA effects were considered as good general combiners. Significant and negative GCA for days to pollen shedding and use of these parents might be useful in developing early hybrid variety(s). On the other hand, for yield and other yield components those with significant and positive GCA effects were considered as good general combiners.

For grain yield, parent BIL95 showed significant and positive GCA effect. In addition to grain yield, parent BIL95 was also good general combiner for days to pollen shedding and no. of kernels/ear. Sharma *et al.* (1982) reported that parents with good general combiners for grain yield generally shows good performance for various yield components. Similar views have been given by Malik *et al.* (2004), Uddin *et al.*(2006), Ahmed *et al.* (2008) and Abdel-Moneam *et al.* (2009). So, parent BIL95 could be used extensively in hybrid breeding program with a view to increase the yield level. Parent BML4, BML36 andBIL95 showed significant and negative GCA for days to pollen shedding though they did not posses significant for days to silking but they showed negative values. So, these parents might be useful in developing early hybrid variety(s). Parent BML4 exhibited significant and negative GCA effect both for plant and ear height. Uddin *et al.* (2006) and Ahmed *et al.* (2008) also found inbred line(s) as good general combiner for short plant type in their study. Significant and negative GCA for ear height was observed by Roy *et al.*(1998), Malik *et al.* (2004), Alam *et al.* (2008) and Amiruzzaman (2010) in their study.

Regarding number of kernels/ear, two parents viz. BIL138 and BIL95showed significant and positive GCA effect for this trait. These two parents are expected to produce more number of grains per ear. Similar observation was also noticed by Alam *et al.* (2008) and Amiruzzaman (2010).

For 1000-kernel weight, the gca effect was found significant for the parents BML36 and BIL31. These two parents are anticipated to contribute towards increasing the kernel size. Highly significant and positive gca effects for 1000-kernel weight was observed by Uddin *et al.*(2006), Alam *et al.* (2008) and Abdel-Moneam *et al*. (2009).

Table 2. Estimates of general combining ability effects (GCA) of the parents for different characters in maize

Parents	Yield (t/ha)	Pollen shedding (Days)	Silking (Days)	Plant ht (cm)	Ear ht (cm)	No. of kernels/ ear	1000-kernel wt.(g)
BML4 (P1)	-2.74**	-1.24**	-0.40	-34.98**	-25.61**	-47.01*	-18.76*
BML36 (P2)	0.73	-1.70**	-0.73	-1.57	-2.31	0.06	21.24*
BIL106 (P3)	-0.35	-0.70	0.60	5.74	4.45	7.06	-2.10
BIL114 (P4)	-0.65	3.43**	0.27	-3.18	0.75	-38.88*	-21.43*
BIL138 (P5)	0.88	1.63**	2.80	16.70*	12.07**	34.32*	-10.10
BIL31 (P6)	0.50	-0.64	0.60	-2.55	-1.19	-4.48	33.90**
BIL95 (P7)	1.63*	-0.77*	-3.13	19.83**	11.85**	48.92**	-2.76
SE (gi)	0.49	0.31	1.79	4.85	2.88	12.34	7.09
LSD(5%)	1.20	0.76	4.38	11.87	7.05	30.20	17.34
LSD(1%)	1.82	1.15	6.63	17.97	10.68	45.74	26.28

*P=0.05, **P=0.01

Specific combining ability effects (SCA)

Generally the crosses showing significant and positive SCA effects also possessed high mean performance and significant negative sca effects possessed low mean performance (Table 3 and 5). This reflected that high *per se* value of the crosses indicated their potentiality.

For grain yield two crosses (BML4×BML36and BIL114×BIL31) exhibited significant and positive SCA effects for grain yield. These crosses involved low x average and average × average general combining parents. Although the cross BML4 × BML36involved low × average general combiners, exhibited the highest significant and positive SCA effect but produced low grain yield. The cross BIL114×BIL31 involved average x average general combining parents but showed the second highest SCA effects and possessed third highest mean value (Table 3 and 5).Two crosses (BIL138×BIL95and BIL31×BIL95) both involved average × high general combiners, exhibited non significant SCA effects but showed high mean performance and high heterosis. Ivy and Hawlader (2000) also reported that good general combining parents do not always show high SCA effects in their hybrid combinations. On the contrary, Paul and Duara (1991) reported that the parents with high GCA always produce hybrids with high estimates of SCA. Thus the SCA effect of the crosses was not reflected through the GCA effects of the parents. Roy *et al.*(1998) and Ivy and Hawlader (2000) also found the similar result.

Table 3. Specific combining ability effects (SCA) of the crosses for different characters in maize

Crosses	Yield (t/ha)	Pollen shedding (Days)	Silking (Days)	Plant ht. (cm)	Ear ht. (cm)	No. of kernels/ ear	1000-kernel wt.(g)
P_1XP_2	2.57*	1.24	0.80	36.22**	20.58**	54.44*	9.11
P_1XP_3	0.52	-1.42*	-2.87	20.58*	11.16	44.78	12.44
P_1XP_4	-2.63*	-1.89**	1.13	-59.44**	-38.42**	-90.62**	-64.89**
P_1XP_5	1.04	-0.76	-2.40	7.95	4.53	13.18	30.44*
P_1XP_6	-2.12*	1.51*	0.13	-14.13	-2.74	-26.69	6.44
P_1XP_7	0.61	1.31	3.20	8.82	4.89	4.91	6.44
P_2XP_3	-0.52	1.71*	-0.20	-21.50*	-6.14	-36.62	-34.22*
P_2XP_4	0.24	0.24	2.80	22.42*	10.22	35.98	1.78
P_2XP_5	0.06	-1.96**	-3.40	-24.66*	-3.56	18.11	3.78
P_2XP_6	-1.12	-0.36	-1.87	-8.54	-9.90	2.58	19.78
P_2XP_7	-1.24	-0.89	1.87	-3.93	-11.20	-74.49**	-0.22
P_3XP_4	0.21	1.24	4.47	26.44*	20.13**	-29.02	58.44**
P_3XP_5	0.30	-0.29	-1.40	-23.77*	-20.52**	7.11	7.11
P_3XP_6	0.69	-0.69	-1.87	7.02	0.54	12.58	-33.56*
P_3XP_7	-1.20	-0.56	1.87	-8.77	-5.16	1.18	-10.22
P_4XP_5	-0.57	2.24**	4.60	-15.18	-4.76	5.04	-6.89
P_4XP_6	2.49*	-1.49	0.80	19.07	6.44	69.84*	2.44
P_4XP_7	0.26	-0.36	-13.80**	6.68	6.40	8.78	9.11
P_5XP_6	-1.16	0.64	-0.73	27.52*	12.45*	-80.69**	-12.22
P_5XP_7	0.34	0.11	3.33	28.14	11.88	37.24	-22.22
P_6XP_7	1.23	0.38	3.53	-30.94**	-6.79	22.38	17.11
SE (ij)	0.96	0.63	3.53	9.56	5.68	24.33	13.99
LSD(5%)	2.06	1.35	7.57	20.51	12.18	52.19	30.01
LSD(1%)	2.86	1.88	10.51	28.46	16.91	72.43	41.65

*P=0.05, **P=0.01

P1=BML4, P2=BML36, P3=BIL106, P4=BIL114, P5=BIL138, P6=BIL31 and P7=BIL95

Significant and negative SCA effects for days to pollen shedding and silking are desirable for selection of early maturing hybrids. Three crosses ($P_1 \times P_3$, $P_1 \times P_4$and $P_2\times P_5$) exhibited significant and negative sca effects for days to pollen shedding and one cross ($P_4 \times P_7$) for days to silking. These crosses mostly involved high × average, high × low and average × average general combining parents. These findings are consistent with the results of Ahmed *et al.(*2008).

Five crosses exhibited significant and negative SCA effects for plant height and two crosses for ear height indicating short statured plant. These two crosses ($P_1 \times P_4$, $P_3 \times P_5$) exhibited significant and negative SCA effects both for plant and ear height and are desirable for exploiting non additive gene. These crosses involved high × average, average × average, average × low general combining parents (Table 2 and 3). In this study, the cross BML4 × BIL114 showed significant and negative SCA effect both for plant and ear height and also possessed the lowest mean value. Although the cross BIL106 × BIL138 showed significant and high negative SCA effect both for plant and ear height but possessed high mean value (Table 3 and 5).

In case of number of kernels ear^{-1}, two crosses expressed significant and positive SCA effect involving average × low general combining parents. Two crosses (BIL36 × BIL95,BIL138 × BIL31) involved high × average combiners and exhibited significant and negative SCA effects but possessed high mean value. On the other hand, cross (BML4 × BIL114) involved low × low general combiners and simultaneously possessed the lowest significant and negative sca effects and the lowest number of kernels/ear (Tables 3 and 5).

For 1000-kernel weight, two crosses showed significant and positive SCA effects involved low × average combining parents. The SCA values for this character ranged from -64.89 (for BML4×BIL114)to 58.44 (for BIL106×BIL114).

Heterosis

The standard/economic heterosis expressed by the F_1 hybrids over the commercial check variety NK 40 for yield and yield related traits are shown in Table 4. All the traits showed significant heterosis in different crosses.

For grain yield/plant only three crosses showed significant and positive heterosis over the standard check variety NK-40 which was found in the range of -65.83 to 21.26 % (Table 4). It appears that among the 21 F_1s, only three crosses exhibited significant and positive heterosis and the others showed significant and negative heterosis for this trait. Amiruzzaman (2010) and Kadir (2010) foundstandard heterosis for karnel yield were -17.60 to 9.71 % and -15.21 to 27.97 % , respectively.

Significant and negative heterosis was exhibited by six crosses for days to pollen shedding and four crosses for days to silking indicating earliness (Table 4). Malik *et al.* (2004) also observed crosses with significant and negative heterosis in their study. None of the crosses showed significant and positive heterosis for grain yield coupled with significant and negative heterosis for days to silking. Ahmed *et al.* (2008) reported significant and negative heterosis for days to silking in maize.

Table 4.Heterosis of the crosses over NK-40 for different characters in maize

Cross	Yield (t/ha)	Pollen shedding (Days)	Silking (Days)	Plant ht (cm)	Ear ht (cm)	No. of kernels/ear	1000-kernel wt.(g)
P_1X P_2	-4.64	-0.74	-0.35	18.89**	13.66**	29.62**	-10.83**
P_1X P_3	-33.80**	-2.58**	-2.85**	13.52**	10.20*	28.84**	-15.83**
P_1X P_4	-65.83**	1.47**	1.07*	-43.73**	-58.86**	-19.07**	-40.00**
P_1X P_5	-17.55**	0.73	0.00	12.45**	11.50**	27.74**	-13.33**
P_1X P_6	-50.42**	0.73	0.36	-14.16**	-15.12**	6.92**	-8.33**
P_1X P_7	-14.58**	0.36	-0.35	15.03**	11.67**	29.41**	-17.50**
P_2X P_3	-11.14**	0.36	-0.35	7.94*	17.98**	19.79**	-17.50**
P_2X P_4	-6.87	3.31**	2.51*	30.48**	34.40**	26.88**	-13.33**
P_2X P_5	5.57	-1.10*	-1.43	12.97**	31.20**	41.50**	-10.00**
P_2X P_6	-8.82*	-1.84**	-2.14*	10.94**	5.79	27.13**	5.00*
P_2XP_7	0.46	-2.58	-2.14*	28.33**	21.00**	20.85**	-9.17**
P_3XP_4	-17.27**	5.51**	5.72**	37.77**	56.00**	11.46**	-5.00*
P_3X P_5	-2.23	1.83**	2.14*	18.25**	17.98**	40.46**	-15.00**
P_3X P_6	-2.14	-1.10*	-0.71	25.67**	28.09**	31.58**	-14.17**
P_3X P_7	-9.19*	-1.10*	-0.71	29.92**	37.59**	42.70**	-17.50**
P_4X P_5	-13.00**	9.19**	8.22**	18.03**	33.63**	27.76**	-23.33**
P_4X P_6	11.79**	2.57**	1.79	27.68**	30.94**	34.61**	-10.00**
P_4X P_7	1.58	3.67**	-17.85**	34.12**	47.80**	32.54**	-17.50**
P_5X P_6	-7.80*	2.93**	2.86**	45.93**	53.41**	14.18**	-10.83**
P_5X P_7	16.53**	2.21**	3.21**	60.74**	69.58**	59.48**	-22.50**
P_6X P_7	21.26**	0.00	1.07	10.30**	28.18**	45.28**	-1.67
Mean	15.36	2.19	2.75	24.61	30.22	29.42	12.54
LSD(5%)	7.46	0.95	1.81	6.33	8.24	5.57	4.82
LSD(1%)	10.18	1.29	2.47	8.64	11.24	7.60	6.58

*P=0.05, **P=0.01

P1=BML4, P2=BML36, P3=BIL106, P4=BIL114, P5=BIL138, P6=BIL31 and P7=BIL95

Negative heterosis is desirable for plant height which helps to develop short stature plant leading to tolerant to lodging. Heterosis for different crosses ranged from -43.73 to 60.74 percent and -58.86 to 69.58 percent, respectively, for plant and ear height. Two crosses exhibited significant and negative heterosis both for plant and ear height and except one cross (BML36 x BIL31) in respect to ear height, rest of the crosses showed significant and positive heterosis. Significant and negative heterosis for both these traits were reported by Uddin*et al.* (2006), Alam *et al.* (2008) and Amiruzzaman (2010).

Except one cross (BML4 × BIL114), rest of the crosses showed significant and positive heterosis for number of kernels ear^{-1}. The value of heterosis ranged from -19.07 to 59.48 % in the cross BML4 × BIL114and BIL138× BIL95, respectively.

Out of 21 F_1's, only one cross (BML36 × BIL31) expressed significant and positive heterosis for 1000-kernel wt. (Table 4). This finding was similar with Shewangizaw (1983) and Nigussie and Zelleke (2001) who observed heterosis only in few crosses.

Table 5. Mean performance of the single crosses evaluated at Joydebpur during *rabi* 2013-2014.

Genotypes	Yield/ plant (g)	Pollen shedding (Days)	Silking (Days)	Plant ht (cm)	Ear ht (cm)	Number of kernels/ ear	1000-kernel wt.(g)
P_1X P_2	10.27	90	93	185	88	490	357
P_1X P_3	7.13	88	91	176	85	487	337
P_1X P_4	3.68	92	94	87	31	306	240
P_1X P_5	8.88	91	93	175	86	483	347
P_1X P_6	5.34	91	94	133	65	404	367
P_1X P_7	9.20	91	93	179	86	489	330
P_2X P_3	9.57	91	93	168	91	453	330
P_2X P_4	10.03	94	96	203	104	479	347
P_2X P_5	11.37	90	92	175	101	535	360
P_2X P_6	9.82	89	91	172	82	480	420
P_2XP_7	10.82	88	91	199	93	457	363
P_3XP_4	8.91	96	99	214	120	421	380
P_3X P_5	10.53	92	95	184	91	531	340
P_3X P_6	10.54	90	93	195	99	497	343
P_3X P_7	9.78	90	93	202	106	539	330
P_4X P_5	9.37	99	101	183	103	483	307
P_4X P_6	12.04	93	95	198	101	509	360
P_4X P_7	10.94	94	77	208	114	501	330
P_5X P_6	9.93	93	96	227	118	431	357
P_5X P_7	12.55	93	96	250	131	603	310
P_6X P_7	13.06	91	94	171	99	549.	393
NK40	10.77	91	93	155	77	378	400
Pioneer	10.46	91	95	193	84	439	347
BHM9	10.69	91	934	215	116	484	327
Mean	9.82	91	93	185	94.66	476	346
LSD(5%)	0.87	1.02	1.79	13.46	8.57	25.77	14.92
LSD(1%)	1.18	1.38	2.43	18.26	11.62	34.98	20.25
F-test	**	**	ns	**	**	**	**
CV	19.82	1.66	7.55	10.48	12.34	10.82	8.72

*P=0.05, **P=0.01, ns= non significant

Conclusion

Parents with good positive gca for yield (BIL95), number of kernels/ear(BIL138and BIL95) and 1000- kernel wt. (BML36andBIL31) and negative gca for days to pollen shedding (BIL95), plant height and ear height (BML4) may be extensively used in hybridization program as a donor. The better performing three crosses (BIL114 × BIL31, BIL138 × BIL95 and BIL31 × BIL95) can be utilized for developing high yielding hybrid varieties as well as for exploiting hybrid vigour.

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