

## STUDY ON COMBINING ABILITY AND HETEROSIS OF MAIZE INBRED LINES THROUGH LINE $\times$ TESTER METHOD

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### Abstract

Eleven inbred lines were crossed with two testers in a Line  $\times$  Tester mating design and the resulting twenty-two crosses along with the lines, testers and two checks BARI Hybrid Maize-9 (BHM-9) and 981 were evaluated during rabi season, 2013-14 in an alpha lattice design with two replications, for grain yield and its components to estimate the general combining ability (GCA) and specific combining ability (SCA) effects and heterosis. The analysis of variance (ANOVA) was found significant for most of the characters studied among the genotypes indicating greater diversity in the parental lines of the traits. Parents with good GCA for yield, E21 and BIL51(1), for 1000 grain weight, line E21 and for grains/ear, BIL72 and BIL51(1) could be used in hybridization program as donor. Heterosis was noticed - 44.92 to 13.02% among the cross combinations. However, three crosses BIL51(1)  $\times$  BIL28, E21  $\times$  BIL95 and E04  $\times$  BIL95 were found promising considering SCA effect and could be utilized for enhancing hybrid production.

Keywords: Maize (*Zea mays* L.), line  $\times$  tester, GCA (general combining ability), SCA (specific combining ability).

### Introduction

Maize (*Zea mays* L) is now cultivated worldwide, although it is grown mainly in wet and hot climates, that it is an extremely versatile crop (Fernandez, 2011). In 2020-21, maize was cultivated in 11.86 lac acre of land and production was 41.16 lac mtons (BBS, 2022) in Bangladesh. Due to its diversified use, increasing demand for poultry industry, higher nutritive value and also higher per acre yield, maize cultivation is increasing day by day in the country and it continues to increase speedily at an average rate of 20% per year (CIMMYT, 2008). Combining ability is an excellent tool which helps discern the goal and direction in a breeding programme (Manonmani and Khan, 2003). Exploitation of hybrid vigor and selection of parents based on combining ability has been used as an important breeding approach in crop improvement. In this context, Line  $\times$  Tester (L  $\times$  T)

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analysis (Kempthorne, 1957) has widely been used for evaluation of inbred lines by crossing them with testers. Breeder's objectives are to select hybrids on the basis of expected level of heterosis as well as specific combining ability. A combining ability is prerequisite for developing a good hybrid maize variety. It is one of the powerful tools in identifying the best combiner that may be used in crosses either to exploit heterosis or accumulate fixable genes. The present study involving a line  $\times$  tester analysis aimed to determine the general combining ability (GCA) and specific combining ability (SCA) of crosses for different traits mostly on yield and evolving suitable hybrids locally.

### **Materials and Methods**

Eleven inbred lines (as female parents) and two testers (as male parents) having good GCA were selected and crossed in line  $\times$  tester fashion to generate 22 crosses were obtained from locally developed inbred lines in rabi 2012-13 at BARI, Gazipur. Seeds of all the parents and their F<sub>1</sub> hybrids were sown in Alpha lattice design with two replications in November 2013. Each entry was sown in 2 rows 5m long plot. Spacing was adopted 75 cm  $\times$  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 and B, respectively. Standard agronomic practices were followed (Quayyum, 1993). Two border rows were used at each end of the replication for minimize the border effect. Data on days to 50% pollen shedding and silking were recorded on whole plot basis. All the plants in 2 rows were considered for plot yield which was later converted to t/ha. Ten randomly selected plants were used for recording observations on plant ear height and grain yield (t/ha). Estimates of combining ability and their variance were made as suggested by Kempthorne (1957). Data were analyzed using R software (2017).

### **Results and Discussion**

In the analysis of variance for combining ability (Table 1), the mean squares due to the parents, parents vs. crosses, crosses, lines, testers and lines  $\times$  testers were found significant for several characters. It indicated the presence of genetic variability among the genotypes for those characters. Similar genotypic difference for ear length, grain weight, grain yield and other characters were reported by Sofi and Rathor (2006) and Narro *et al.* (2003). Significant variance was present in parents in respect of days to pollen shedding, days to silking and grains/ear. The variances for line were found significant only for days to silking and yield and the rest of the characters exhibited non-significant variances. Similarly, variances due to testers were found significant for grains/ear and yield and other traits were showed non-significant variances. Non-significant variances due to lines and testers for different traits suggested that these traits were predominantly controlled by non-additive type of gene action. Variances due to lines  $\times$  testers were found

**Table 1. Analysis of variance for grain yield and its component traits in line × tester analysis of Maize**

Source of variation	DF	DP	DS	PH	EH	GR/EAR	TGW	YLD
Parents	12	79.73**	87.79**	550.21	242.92	10803.59**	1379.48	2.57
Parents vs. Crosses	1	247.95**	322.51**	50387.66**	18317.80**	850570.58**	89459.66**	758.62**
Crosses	21	6.02**	4.08	254.84	226.00	7708.46*	1679.22*	5.47**
Lines (L)	10	6.50	6.15*	323.54	231.26	6817.95	2316.36	8.96**
Testers (T)	1	4.45	1.11	10.02	87.36	35001.84*	81.81	0.10**
L×T	10	5.70**	2.31	210.62	234.61	5869.64	1201.88	2.52
Error	34	1.77	2.29	391.15	214.10	3106.97	814.70	1.62
Total	169							

\*P=0.05, \*\*P=0.01.

DP=Days to pollen shedding, DS = Days to silking, PH = Plant height (cm), EH = Ear height (cm).

GR/EAR= Grains per ear, TGW=1000- grain weight (g), YLD= Grain yield (t/ha).

**Table 2. Proportional contribution of lines, testers and their interactions to total variance in maize**

Source	DP	DS	PH	EH	GR/EAR	TGW	YLD
Due to line	51.41	71.72	60.45	48.72	42.11	65.68	77.98
Due to tester	3.52	1.29	0.18	1.84	21.62	0.23	0.09
Due to L x T	45.07	26.98	39.35	49.32	36.26	34.08	21.92

DP=Days to pollen shedding, DS=Days to silking, PH =Plant height (cm), EH =Ear height (cm).

GR/EAR= Grains per ear, TGW=1000- grain weight (g), YLD= Grain yield (t/ha).

significant only in days to pollen shedding suggesting the presence of non-additive type of gene action in controlling the traits. In parents vs. crosses all the characters showed significant variances. Except ear height, all the traits mean sum of squares due to line were of a large magnitude than those due to line  $\times$  tester. The variance due to GCA (line) being higher than the variance due to SCA (lines  $\times$  testers) indicating preponderance of additive gene effects. Further it also revealed that the genetic advance for these characters could be made by simple breeding procedures involving selection based on progeny performance. The mean square due to testers were lower than lines  $\times$  testers for all the characters studied suggested preponderance of non-additive gene effects.

The contribution of lines, testers and interactions to total variance are presented in Table 2. The proportional contribution of lines and interactions to the total variances was much higher than tester in all the traits. However, the contribution of lines was higher than the interactions to total variance for all the characters. This suggested female parent contributed the maximum to total variance in maize, which was followed by interaction and the estimate of variance due to general combining ability. Testers contributed the lowest to variance, which was in conformity with Rissi *et al.* (1991).

### **General combining ability**

The GCA effects is shown in Table 3. Negative GCA value is desirable for days to pollen shedding, days to silking, plant height and ear height for short and earliness. None of the parents exhibited significant and negative GCA effects for days to pollen shedding, days to silking, plant height and ear height although some lines (E19, E05, E04, E34, E36, BIL72, E21, Lmly08 etc) showed negative values. Two parents BIL72 and BIL51(1) showed significant and positive GCA effects for these characters and expected to produce a greater number of grains/ear. For 1000-kernel weight, the GCA effect was found significant for two parents BIL51(1) and E21 and suppose to contribute for 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). For grain yield, three parents showed significant and positive GCA effect. Significant and positive GCA for yield in maize was also reported by Paul and Duara (1991) and Ivy and Hawlader (2000). Parent BIL51(1) was also a good general combiner for grains/ear besides grain yield.

### **Specific combining ability effects (SCA)**

None of the crosses showed significant and positive sca effect for yield. Five crosses (BIL19  $\times$  BIL28, E04  $\times$  BIL 95, BIL51(1)  $\times$  BIL28, BIL51(1)  $\times$  BIL95 and E21  $\times$  BIL95) involved average  $\times$  average, high  $\times$  average and low  $\times$  average general combiners but exhibited non-significant SCA effects with high mean performance. Ivy and Hawlader (2000) reported that good general combining

Table 3. GCA effects and mean performance of parents for different yield contributing traits in Maize

Tester	DP	DS	PH	EH	GR/EAR	TGW	YLD
1. BIL 28	0.32 (105)	0.16 (105)	-0.48 (134)	-1.41 (56.5)	-28.20 (404)	-1.36 (250)	0.05 (3.82)
2. BIL 95	-0.32 (104)	-0.16 (105)	0.48 (147.5)	1.41 (68)	28.20 (230)	1.36 (255)	-0.05 (2.00)
SE ± (gi)	0.284	0.323	4.217	3.120	11.884	6.085	0.272
<b>Line</b>							
1. BIL72	0.82 (88)	0.75 (91)	-1.55 (91)	2.89 (31.5)	63.00* (284.5)	-45.91** (250)	-0.99 (3.02)
2. E19	-0.43 (90)	0.25 (94)	5.20 (116.5)	3.64 (42.5)	-0.25 (246)	14.09 (325)	0.25 (3.28)
3. E05	-1.43 (89)	-1.25 (91)	-2.30 (107)	-0.61 (43)	-9.75 (264)	4.09 (270)	-0.45 (2.39)
4. BIL51(2)	1.82* (88)	2.00* (90)	-8.30 (87.5)	-7.11 (34)	-13.50 (163)	6.59 (300)	-0.10 (1.92)
5. Lmly08	2.32* (94)	2.00* (97)	-10.05 (113)	-12.11 (45)	25.75 (263)	-28.41* (285)	0.36 (2.69)
6. E04	-1.43 (88)	-1.25 (91)	-11.80 (124)	-9.86 (55)	-0.25 (371)	16.59 (325)	1.26* (4.71)
7. BIL51(1)	0.57 (97)	0.75 (101)	15.95 (94)	8.64 (27)	47.75* (157.5)	26.59* (275)	2.23** (1.43)
8. BIL50(1)	0.32 (90)	-1.00 (92)	7.70 (112)	7.64 (42.5)	17.50 (306)	-25.91* (300)	-1.02 (3.48)
9. E34	-0.93 (86)	-1.00 (89)	2.95 (112)	6.89 (40.5)	-43.50* (175.5)	9.09 (285)	-0.47 (1.38)
10. E36	-0.68 (88)	-0.25 (92)	-7.70 (115)	-6.36 (39)	-87.50** (246)	-5.91 (295)	-3.05** (1.91)
11. E21	-0.93 (88)	-1.00 (91)	9.45 (112.5)	6.39 (39.5)	0.75 (232)	29.09* (315)	1.98** (3.34)
SE ± (gi)	0.667	0.758	9.998	7.316	27.870	14.272	0.637

DP=Days to pollen shedding, DS=Days to silking, PH =Plant height (cm), EH =Ear height (cm).  
GR/EAR= Grains per ear, TGW=1000- grain weight (g), YLD= Grain yield (t/ha).

Table 4. SCA effects and mean performance of F<sub>1</sub> hybrids for yield and yield contributing traits in maize

Crosses	DP	DS	PH	EH	GR/EAR	TGW	YLD
1. BIL72 × BIL28	1.18 (90)	0.84 (92)	-14.27 (152)	-15.34 (63)	9.45 (529)	11.36 (325)	0.34 (8.86)
2. BIL72 × BIL95	-1.18 (87)	-0.84 (90)	14.27 (181.5)	15.34 (96.5)	-9.45 (567)	-11.36 (305)	-0.34 (8.07)
3. E19 × BIL28	0.43 (88)	0.34 (91)	3.98 (177)	6.41 (85.5)	-18.80 (438)	-13.64 (360)	1.43 (11.19)
4. E19 × BIL95	-0.43 (87)	-0.34 (90)	-3.98 (170)	-6.41 (75.5)	18.80 (532)	13.64 (390)	-1.43 (8.22)
5. E05 × BIL28	-0.57 (86)	-0.66 (89)	3.48 (169)	3.16 (78)	46.70 (494)	-13.64 (350)	1.14 (10.19)
6. E05 × BIL95	0.57 (87)	0.66 (90)	-3.48 (163)	-3.16 (74.5)	-46.70 (457)	13.64 (380)	-1.14 (7.81)
7. BIL51(2) × BIL28	-0.82 (89)	-0.41 (92)	-5.52 (154)	-3.84 (64.5)	1.45 (445)	13.86 (380)	0.04 (9.45)
8. BIL51(2) × BIL95	0.82 (90)	0.41 (93)	5.52 (166)	3.84 (75)	-1.45 (499)	-13.86 (355)	-0.04 (9.27)
9. Lmly08 × BIL28	-1.82* (89)	-1.41 (91)	3.73 (161.5)	-0.34 (63)	44.20 (527)	33.86 (365)	-0.52 (9.35)
10. Lmly08 × BIL95	1.82* (92)	1.41 (94)	-3.73 (155)	0.34 (66.5)	-44.20 (495)	-33.86 (300)	0.52 (10.29)
11. E04 × BIL28	0.43 (87)	0.84 (90)	7.98 (164)	5.91 (71.5)	-51.80* (405)	-11.14 (365)	-1.19 (9.58)
12. E04 × BIL95	-0.43 (86)	-0.84 (88)	-7.98 (149)	-5.91 (62.5)	51.80* (565)	11.14 (390)	1.19 (11.86)

Crosses	DP	DS	PH	EH	GR/EAR	TGW	YLD
13. BIL51(1) × BIL28	0.93 (90)	0.84 (92)	-0.77 (183)	2.41 (86.5)	8.20 (513)	13.86 (400)	0.23 (11.97)
14. BIL51(1) × BIL95	-0.93 (87)	-0.84 (90)	0.77 (185.5)	-2.41 (84.5)	-8.20 (553)	-13.86 (375)	-0.23 (11.40)
15. BIL50(1) × BIL28	1.68* (90)	0.09 (90)	1.98 (177.5)	6.41 (89.5)	-77.55** (397)	-13.64 (320)	-0.55 (7.94)
16. BIL50(1) × BIL95	-1.68* (86)	-0.09 (89)	-1.98 (174.5)	-6.41 (79.5)	77.55** (609)	13.64 (350)	0.55 (8.94)
17. E34 × BIL28	-0.57 (87)	-0.41 (89)	10.23 (181)	8.66 (91)	27.45 (441)	11.36 (380)	0.26 (9.29)
18. E34 × BIL95	0.57 (86)	0.41 (90)	-10.23 (161.5)	-8.66 (76.5)	-27.45 (443)	-11.36 (360)	-0.26 (8.68)
19. E36 × BIL28	-1.82* (89)	-0.66 (90)	-8.52 (152)	-11.09 (58)	21.45 (391)	-18.64 (335)	-0.62 (5.83)
20. E36 × BIL95	1.82* (88)	0.66 (91)	8.52 (170)	11.09 (83)	-21.45 (405)	18.64 (375)	0.62 (6.98)
21. E21 × BIL28	0.93 (86)	0.59 (90)	-2.27 (175)	-2.34 (79.5)	-10.80 (447)	-13.64 (375)	-0.57 (10.91)
22. E21 × BIL95	-0.93 (86)	-0.59 (89)	2.27 (180.5)	2.34 (87)	10.80 (525)	13.64 (405)	0.57 (11.95)
SE± (sij)	0.94	1.07	13.99	10.35	39.41	20.18	0.90

DP=Days to pollen shedding, DS=Days to silking, PH =Plant height (cm), EH =Ear height (cm).

GR/EAR= Grains per ear, TGW=1000- grain weight (g), YLD= Grain yield (t/ha).

**Table 5. Heterosis over check variety (BHM-9) for different characters of F<sub>1</sub> crosses**

SL	Crosses	DP	DS	PH(cm)	EH(cm)	Grains/ear	TGW(g)	Yield (t/ha)
1	BIL72×BIL28	-4.23**	-4.15**	-28.13**	-39.42**	9.18**	20.37**	-16.34**
2	BIL72×BIL95	-7.41**	-6.22**	-14.18**	-7.21**	16.91**	12.96**	-23.79**
3	E19×BIL28	-6.35**	-5.18**	-16.31**	-17.79**	-9.69**	33.33**	5.65*
4	E19×BIL95	-7.94**	-6.22**	-19.62**	-27.40**	9.69**	44.44**	-22.37**
5	E05×BIL28	-8.47**	-7.77**	-20.09**	-25.00**	1.86	29.63**	-3.75
6	E05×BIL95	-7.94**	-6.74**	-22.93**	-28.37**	-5.77**	40.74**	-26.24**
7	BIL51(2)×BIL28	-5.29**	-4.15**	-27.19**	-37.98**	-8.25**	40.74**	-10.77**
8	BIL51(2)×BIL95	-4.23**	-3.63**	-21.51**	-27.88**	2.78	31.48**	-12.50**
9	Lmly08×BIL28	-5.82**	-5.18**	-23.64**	-39.42**	8.66**	35.19**	-11.68**
10	lmly08×BIL95	-2.65**	-2.59**	-26.71**	-36.06**	2.06	11.11**	-2.85**
11	E04×BIL28	-7.41**	-6.22**	-22.46**	-31.25**	-16.49**	35.19**	-9.55**
12	E04×BIL95	-8.99**	-8.29**	-29.55**	-39.90**	16.49**	44.44**	11.97**
13	BIL51(1)×BIL28	-4.76**	-4.15**	-13.48**	-16.83**	5.77**	48.15**	13.02**
14	BIL51(1)×BIL95	-7.41**	-6.22**	-12.29**	-18.75**	14.02**	38.89**	7.68**
15	BIL50(1)×BIL28	-4.23**	-6.74**	-16.08**	-13.94**	-18.14**	18.52**	-25.04**
16	BIL50(1)×BIL95	-8.47**	-7.25**	-17.49**	-23.56**	25.46**	29.63**	-15.54**
17	E34×BIL28	-7.94**	-7.25**	-14.42**	-12.50**	-9.07**	40.74**	-12.25**
18	E34×BIL95	-7.41**	-6.74**	-23.64**	-26.44**	-8.76**	33.33**	-18.03**
19	E36×BIL28	-8.99**	-6.74**	-28.13**	-44.23**	-19.38**	24.07**	-44.92**
20	E36×BIL95	-5.82**	-5.70**	-19.62**	-20.19**	-16.60**	38.89**	-34.08**
21	E21×BIL28	-6.35**	-6.22**	-17.26**	-23.56**	-7.84**	38.89**	3.05
22	E21×BIL95	-8.99**	-7.77**	-14.66**	-16.35**	8.25**	50.00**	12.88**
	Mean	6.69	5.96	20.43	26.09	10.96	33.67	15.63
	Min	-8.88	-8.29	-29.55	-44.23	-19.38	11.11	-44.92
	Max	-2.65	-2.59	-12.29	-7.21	25.46	50.00	13.02
	SD ±	1.84	1.48	5.34	10.22	6.16	10.73	10.39
	CD (5%)	0.81	0.66	2.37	4.53	2.73	4.76	4.61
	CD (1%)	1.12	0.91	3.21	6.22	3.91	6.56	6.61

DP= Days to pollen shedding, DS= Days to silking, PH = Plant height (cm), EH = Ear height (cm),  
 GR/EAR = Grains per ear, TGW = 1000- grain weight (g), YLD= Grain yield (t/ha).

parents did not show high SCA effects in their hybrid combinations. On the contrary, Paul and Duara (1991) reported that the parents with high GCA always produced 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. Significant and negative SCA effects for days to pollen shedding and silking are desirable for selection of early maturing hybrids. Three crosses showed significant and negative SCA effects for pollen shedding. None of the crosses exhibited significant and negative SCA effects for days to silking. Although only three crosses (Lmly08 × BIL28, BIL50(1) × BIL95 and E36 × BIL28) in days to pollen shedding and none of the crosses in days to silking exhibited significant and negative SCA effects but all the crosses showed significant and negative heterosis. Negative SCA effects for plant and ear height indicating short stature plant. None of the parents showed significant and negative SCA effects but exhibited significant and negative heterosis for all the crosses. In case of number of grains per ear, two crosses (E04 × BIL95 and BIL50(1) × BIL95) expressed significant and positive SCA effect. A positive SCA effect is desirable for 1000- grain weight. No significant and positive SCA was observed among the crosses but all the crosses showed significant and positive heterosis for this character.

### Heterosis

Percent heterosis over BHM-9 was calculated for grain yield and other six different yield contributing characters are presented in Table 5. The degree of heterosis varied from cross to cross and from character to character. Negative heterosis is desirable for days to pollen shedding, days to silking, plant height and ear height. All the crosses in respect to days to pollen shedding, days to silking, plant height and ear height exhibited significant and negative heterosis. Positive heterosis is desirable for grains/ear, 1000- grains weight and yield. Regarding grains/ear, nine crosses showed significant and positive heterosis. All the crosses in respect of 1000- grains wt showed significant and positive which is desirable. For grain yield, five crosses showed significant and positive heterosis in the range - 44.92 to 13.02% although none of the crosses exhibited significant and positive SCA effect (Table 4). Karim *et al.* (2021) and Talukder *et al.* (2016) reported -23.39 to 4.6% and -51.39 to 12.53% heterosis for grain yield in their study, respectively.

### Conclusion

Good general combining ability effects for yield and important yield contributing characters were observed in the lines E21 and BIL51(1) for yield, E21 and BIL51(1) for 1000 - grain weight and BIL72 and BIL51(1) for grains /ear could be used in hybridization program as donor. These parents could result in the production of superior single crosses. Better performing three crosses BIL51(1) × BIL28, E21 × BIL95 and E04 × BIL95 could be used for commercial variety development after verifying the performance across locations.

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