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Heterosis and Inbreeding Depression for Yield and Yield Attributing Traits of Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In present Investigation 45 single cross hybrids were evaluated along with their parental lines and checks heterosis and inbreeding depression. The standard heterosis, the hybrid combinations DI- 123 x DI- 111(91.11), DI- 121 x DI- 117 (80.82), DI- 121 x DI- 111(80.33), DI- 121 x D- 56 (78.33), DI- 123 x DI- 117 (74.10), DI- 122 x D- 52(70.23), DI- 121 x D- 52 (67.04) and DI- 117 x D- 56 (62.24) were identified as best for grain yield per plant (g) and some of the yield contributing traits. Maximum inbreeding depression was obtained from DI- 111 x DI- 118 (61.50) for grain yield per plant (g).

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Keywords: Maize; yield; heterosis; inbreeding depression.

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most versatile crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. Maize is a principal food crop for human consumption as well as animal feed around the world and as a model plant for understanding evolution, domestication, and heterosis [1] it ranks third after wheat and rice [2].The kernel protein of maize is made up of five different fractions, viz., albumin 7%, globulin 5%, non-protein nitrogen 6%, prolamine 52% and glutelin 25% and left over 5% residual nitrogen.

In India its production has been recorded about 33.60mt from 10.00mha area with average productivity of 3.3 tons per ha. [3].

For improving of yield and quality parameters insight knowledge of genetic mechanism involved in the inheritance of various quantitative and quality traits is essential for effective manipulation. Hence, present investigation has been taken up to gather the information on the heterosis and selection of parents for productivity in maize. Diallel mating heterosis and design provides an opportunity to mate the given set of parents in all possible combinations (Griffing, 1956) and thus helps in the selection of desirable parents for utilization in the hybridization programme, as well as in the choice of appropriate breeding procedure for the genetic improvement of traits in maize. Grafius [4] and Kebble and Pellew [5] concluded that the genetic basis of heterosis for a complex trait like yield could be explained by the multiplicative interaction on the phenotype level for component trait.

The information's on heritability and genetic advances are also useful for plant breeder. Genetic advance means improvement in the genotypic value of new population over base population. The systematic exploitation of heterosis for yield per plot and quality can be achieved through heterotic grouping only [6].

2. MATERIALS AND METHODS

The present investigation was carried out during *Rabi* 2022- 23 at Student's instructional farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur(U.P.).

The experimental material for present investigation comprised of 10 parental lines *viz*., DI- 122, DI-121, DI-124, DI-123, DI-109, DI-111, DI-118, DI-117, D-52 and D-56. These parental lines were crossed to develop 45 F_1s and F_2s using half diallel mating design. A total of 100 treatments (10 parents + 45 F_1s + 45 F_2s) were evaluated for the study of genetical analysis for fifteen quantitative characters in maize.

The individual plant data for the following characters were recorded in each treatment of all replications on 10 randomly tagged plants in each parent, F_1s and F_2s for traits *viz.,* Days to 50% tasseling, Days to 50% silking, Plant height (cm), Days to 75 % dry husk, Number of cobs per plants, Cob length (cm), Cob diameter (cm), Cob weight (g), Number of grains per cobs, 100 Kernel weight (g), Shelling percentage, Protein content (%), Lycine content (%), Tryptophan content (%)and Grain yield per plant (g).

Heterosis was estimated as per cent increase or decrease in the mean values of F_1 hybrid over the standard commercial check variety value by formula heterosis (%) = [(FI -CV)/CV] x 100. where, F_1s and CV represented the mean performance of hybrid and standard check variety. The significance test for heterosis was done by using standard error of the value of check variety.

The coefficient of inbreeding depression was calculated by the following formula:

$$\text{Inbreeding depression value (\%)} = \frac{\bar{F}1 - \bar{F}2}{\bar{F}1} \times 100$$

Where,

$\bar{F}$ = Mean of F_1 generation
$\bar{F}_2$ = Mean of F_2 generation

The combining ability analysis was worked out by the procedure suggested by Griffings [7] Method 2. Model I.

3. RESULTS AND DISCUSSION

According to Griffing and Lindstrom [8] the expression of heterosis was due to accumulation of desirable genes in a hybrid plant through the crossing of parents in their genetic makeup and it had very often been related to the magnitude of genetic diversity. Robinson (1960) and Moll et al., (1964)were of the view that heterosis was mostly dependent on genetic diversity present in the parental stock.

Table 1. Heterosis and inbreeding depression for all 15 traits over check D 52 (p9)

S.N	Hybrids	Days to 50% tasseling		Days to 50% silking		Days to 75% dry husk		Plant height (cm)		Number of cobs per plant		Cob length (cm)	
		EH	ID	EH	ID	EH	ID	EH	ID	EH	ID	EH	ID
1	DI-122 × DI- 121	-2.18	2.23	-4.24 *	-1.21	-4.42 *	-1.99	0.94	-0.76	39.85 **	10.75**	14.24 **	-1.56
2	DI-122 × DI- 124	-3.91	0.46	-5.79 **	-0.42	-6.01 **	-4.37	2.28	1.30	35.34 **	-0.17	21.29 **	2.55
3	DI-122 × DI- 123	-4.36 *	4.09	-5.79 **	-2.46	-3.8	-0.66	3.98	1.64	9.77 **	0.01	13.38 **	1.34
4	DI-122 × DI- 109	-3.05	4.92*	-6.56 **	-4.96*	-3.8	-0.99	0.94	2.06	39.85 **	3.23	10.48 **	2.33
5	DI-122 × DI- 111	-6.96 **	-1.40	-4.63 *	-3.25	-2.85	1.62	0.00	2.28	0.00	24.81**	14.50 **	5.99*
6	DI-122 × DI- 118	-5.22 *	2.30	-6.95 **	-2.91	-2.53	-0.32	-1.90	1.74	0.00	5.26	18.85 **	6.43*
7	DI-122 × DI- 117	-3.91	2.71	-5.02 *	-2.04	-2.53	1.31	1.71	2.80	39.85 **	3.23	15.56 **	1.88
8	DI-122 × D- 52	-3.48	1.35	-4.24 *	-1.21	-1.9	-0.33	1.51	0.93	30.08 **	30.64**	21.29 **	11.25**
9	DI-122 × D- 56	-1.75	3.98*	-1.54	0.39	-2.21	2.26	3.22	7.72	24.81 **	0.01	14.50 **	3.45
10	DI-121 × DI-124	-9.13 **	-3.82	-2.32	-0.40	-1.9	1.94	-0.76	2.29	9.77 **	4.11	6.33 **	-0.43
11	DI-121 × DI-123	-8.27 **	0.94	-5.40 **	0.42	-6.65 **	-5.08*	-0.19	1.71	24.81 **	32.53**	14.90 **	4.02
12	DI-121 × DI-109	-6.52 **	0.001	-6.95 **	-1.24	-4.75 *	-5.95*	2.28	3.34	35.34 **	3.89	9.23 **	-1.99
13	DI-121 × DI-111	-9.13 **	-3.34	-8.87 **	-4.65*	-4.42 *	-5.97*	2.28	1.67	45.11 **	31.09**	12.26 **	0.01
14	DI-121 × DI-118	-6.52 **	0.47	-5.79 **	0.001	-3.8	-1.32	2.85	1.66	-5.26 *	-37.30**	15.38 **	2.86
15	DI-121 × DI-117	-7.83 **	-1.42	-5.79 **	0.81	-6.01 **	-2.70	-0.19	0.95	39.85 **	32.26**	18.00 **	4.47
16	DI-121 × D- 52	-8.27 **	-2.84	-5.40 **	-0.81	-4.11	-2.97	0.00	1.33	35.59 **	11.11**	19.12 **	4.26
17	DI-121 × D- 56	-9.13 **	-1.44	-2.7	0.39	-6.96 **	-3.74	3.22	0.001	24.81 **	-8.43*	10.55 **	4.00
18	DI-124 x DI-123	-10.00 **	-4.83*	-3.48	-1.20	-6.01 **	-1.01	0.57	1.13	5.26 *	5.00	13.84 **	-1.91
19	DI-124 x DI-109	-10.88 **	-5.37**	-5.40 **	-0.81	-4.75 *	-2.33	-0.19	0.95	24.81 **	3.61	10.42 **	2.27
20	DI-124 x DI-111	-8.27 **	0.47	-6.56 **	-2.89	-4.42 *	-1.99	1.51	-2.24	35.59 **	18.89**	21.49 **	6.84
21	DI-124 x DI-118	-10.88 **	-8.30**	-3.48	1.20	-5.70 **	-2.36	3.79	0.001	35.34 **	7.78	10.94 **	-2.61
22	DI-124 x DI-117	-6.52 **	-2.32	-4.63 *	-1.63	-4.11	-0.99	3.98	1.64	9.77 **	-23.29**	14.50 **	3.68
23	DI-124 x D- 52	-9.13 **	-3.82	-5.79 **	-2.88	-8.22 **	-4.48*	2.65	-0.19	15.04 **	-17.65**	8.57 **	-5.65*
24	DI-124 x D- 56	-9.13 **	-1.44	-3.48	0.40	-6.65 **	-2.72	3.22	2.76	24.81 **	12.05**	1.32	-8.20**
25	DI- 123 X DI-109	-9.57 **	-0.49	-4.63 *	-2.84	-9.49 **	-6.29**	3.79	0.55	5.26 *	-28.57**	4.81 *	-2.33
26	DI- 123 X DI-111	-10.43 **	-6.31**	-4.24 *	-1.21	-7.60 **	-2.74	4.55 *	1.63	39.85 **	13.98**	4.61	0.88
27	DI- 123 X DI-118	-10.00 **	-6.77**	-5.40 **	0.42	-7.91 **	-3.78	3.98	0.73	35.34 **	18.89**	7.91 **	4.28
28	DI- 123 X DI-117	-9.57 **	-1.44	-5.79 **	0.00	-8.54 **	-3.11	2.08	3.16	24.81 **	-8.43*	8.31 **	3.23
29	DI- 123 X D- 52	-12.61 **	-4.97*	-3.08	-1.20	-8.22 **	-3.79	3.79	0.001	35.34 **	0.00	-0.07	-10.62**
30	DI- 123 X D- 56	-10.43 **	0.001	-5.79 **	-0.42	-6.01 **	-0.33	-1.33	-1.93	24.81 **	19.88**	12.26 **	2.11
31	DI-109 X DI-111	-9.57 **	-2.88	-4.63 *	-1.63	-6.32 **	-2.70	3.22	4.41*	-9.77 **	5.83	4.35	0.63
32	DI-109 X DI-118	-12.18 **	-9.42**	-1.92	2.76	-2.85	1.30	4.36	2.00	39.85 **	10.75**	4.35	0.63
33	DI-109 X DI-117	-9.57 **	-4.33	-6.56 **	-2.48	-3.8	-0.66	-0.76	-4.78*	0.01	0.01	2.83	0.00
34	DI- 109 X D-52	-9.13 **	-1.44	-5.79 **	1.64	-4.75 *	-1.99	2.65	6.65**	0.01	0.01	2.37	-0.64

S.N	Hybrids	Days to 50% tasseling		Days to 50% silking		Days to 75% dry husk		Plant height (cm)		Number of cobs per plant		Cob length (cm)	
		EH	ID	EH	ID	EH	ID	EH	ID	EH	ID	EH	ID
35	DI-109 X D- 56	-10.88 **	-6.83**	-3.48	4.00	-4.75 *	-1.00	0.00	0.76	39.85 **	10.75**	3.03	1.47
36	DI-111 X DI- 118	-9.57 **	-1.93	-6.17 **	-0.41	-5.70 **	-2.69	-1.14	-0.96	35.34 **	26.11**	5.47 *	3.13
37	DI-111 X DI- 117	-12.18 **	-4.96*	-5.79 **	-2.46	-4.75 *	-1.66	-1.71	0.78	20.30 **	-8.12*	6.59 **	5.81*
38	DI-111 X D- 52	-10.00 **	-3.99	-4.63 *	2.43	-5.70 **	-1.35	1.71	3.92	9.77 **	-9.59**	1.98	0.45
39	DI-111 X D- 56	-10.88 **	-6.35**	-6.17 **	-1.23	-3.8	0.33	2.85	-0.37	5.26 *	5.00	8.57 **	5.10
40	DI-118 X DI- 117	-10.88 **	-4.39	-5.40 **	1.22	-2.85	-0.65	1.14	-2.81	35.34 **	11.11**	10.55 **	0.42
41	DI-118 X D- 52	-9.57 **	-2.88	-5.79 **	-2.46	-2.85	-2.61	3.42	4.03	39.85 **	6.99*	13.84 **	1.39
42	DI-118 X D- 56	-10.43 **	-1.46	-6.56 **	-4.13	-1.58	-0.64	3.98	5.83*	35.59 **	18.89**	14.70 **	5.75*
43	DI-117 X D-52	-7.83 **	-7.08**	-2.32	0.001	-3.47	-0.32	2.85	0.001	35.34 **	11.11**	17.53 **	2.58
44	DI-117 X D-56	-6.96 **	-4.68*	-3.08	-1.98	-3.47	0.001	4.55 *	1.27	39.85 **	3.23	16.48 **	2.49
45	D-52 X D -56	-10.00 **	-6.77**	-5.40 **	-4.08	-0.63	-1.59	4.36	0.55	39.85 **	10.75**	23.07 **	10.18**
	SE ±		**1.24**		**0.99**		**1.55**		**2.19**		**0.11**		**0.45**
	CD at 5%		**2.46**		**1.96**		**3.08**		**4.34**		**0.22**		**0.89**
	CD at 1%		**3.03**		**2.42**		**3.79**		**5.35**		**0.27**		**1.10**

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S.N	Hybrids	Cob diameter		Cob weight (g)		Number of grains per cobs		100 kernel weight (g)		Shelling (%)		Lycine content (%)	
		EH	ID	EH	ID	EH	ID	EH	ID	EH	ID	EH	ID
1	DI-122 × DI- 121	70.66 **	28.07**	-13.70 **	5.06*	-29.68 **	10.12**	7.43 **	2.56	5.39 *	3.80	10.33 **	4.68*
2	DI-122 × DI- 124	74.55 **	14.24**	-18.93 **	-44.47**	-28.82 **	18.90**	8.39 **	1.65	4.34	1.33	31.00 **	12.96**
3	DI-122 × DI- 123	46.71 **	10.82**	12.03 **	25.88**	9.26 **	10.63**	12.40 **	4.59*	6.97 **	3.02	11.44 **	5.96*
4	DI-122 × DI- 109	52.69 **	19.61**	-10.70 **	-18.66**	-33.83 **	10.45**	6.95 **	5.73*	2.90	0.89	21.03 **	5.49*
5	DI-122 × DI- 111	36.83 **	12.69**	-18.10 **	20.94**	-29.57 **	6.22*	4.20	1.25	8.71 **	5.29*	7.75 **	7.88**
6	DI-122 × DI- 118	29.94 **	2.53	-2.21	11.35**	9.77 **	12.70**	6.46 *	3.49	4.34	1.78	12.92 **	2.61
7	DI-122 × DI- 117	42.81 **	6.29*	2.36	13.10**	-28.29 **	1.84	4.05	5.29*	6.14 **	1.75	1.11	6.57*
8	DI-122 × D- 52	55.69 **	1.92	38.23 **	26.42**	2.75	19.44**	13.84 **	9.87**	10.65 **	1.25	11.81 **	3.96
9	DI-122 × D- 56	9.88 **	11.44**	13.73 **	9.35**	-25.36 **	0.35	13.99 **	4.91*	8.57 **	0.84	8.86 **	3.73
10	DI-121 × DI-124	34.73 **	8.89**	42.15 **	6.83*	21.65 **	2.15	2.75	4.37*	4.48	0.89	17.71 **	8.78**
11	DI-121 × DI-123	17.07 **	12.28**	48.25 **	12.86**	19.82 **	22.75**	6.46 *	1.54	5.59 *	1.75	4.06	2.13
12	DI-121 × DI-109	27.84 **	2.81	34.50 **	6.67*	21.82 **	12.82**	5.16 *	5.37*	2.90	0.01	11.07 **	2.33
13	DI-121 × DI-111	41.62 **	6.13*	58.31 **	14.22**	33.98 **	28.52**	5.64 *	3.20	4.98 *	0.01	14.76 **	4.82*
14	DI-121 × DI-118	37.72 **	6.96*	51.48 **	2.62	50.70 **	22.15**	3.71	3.58	4.42	0.01	14.02 **	2.27
15	DI-121 × DI-117	54.79 **	19.92**	53.44 **	9.53**	31.04 **	1.35	5.64 *	1.37	7.60 **	2.99	16.97 **	5.99*
16	DI-121 × D- 52	44.61 **	20.50**	65.66 **	9.98**	2.36	3.70	9.99 **	6.45*	5.81 *	0.01	18.82 **	11.18**

S.N	Hybrids	Cob diameter		Cob weight (g)		Number of grains per cobs		100 kernel weight (g)		Shelling (%)		Lycine content (%)	
		EH	**ID**	**EH**	**ID**	**EH**	**ID**	**EH**	**ID**	**EH**	**ID**	**EH**	**ID**
17	DI-121 × D- 56	24.85 **	5.28*	74.11 **	10.90**	8.60 **	24.97**	11.29 **	1.60	7.66 **	0.01	16.97 **	8.20**
18	DI-124 x DI-123	46.71 **	22.86**	22.17 **	11.29**	-1.00	16.63**	6.95 **	3.61	10.09 **	3.34	16.24 **	9.84**
19	DI-124 x DI-109	48.80 **	16.10**	14.98 **	14.99**	-32.61 **	10.83**	5.16 *	3.21	5.45 *	0.01	14.02 **	-1.94
20	DI-124 x DI-111	36.23 **	4.40	19.42 **	9.66**	-22.51 **	1.08	4.68	4.01	5.94 *	0.01	27.31 **	20.58**
21	DI-124 x DI-118	19.76 **	-10.00**	5.93 *	10.11**	-19.59 **	4.85	5.16 *	2.43	7.19 **	3.43	16.61 **	8.23**
22	DI-124 x DI-117	34.73 **	11.56**	20.73 **	14.82**	-24.03 **	7.32*	9.99 **	7.02**	11.25 **	1.24	0.37	-11.76**
23	DI-124 x D- 52	27.84 **	2.34	31.18 **	8.56**	-20.60 **	8.04*	12.25 **	5.59*	8.85 **	0.01	14.76 **	2.89
24	DI-124 x D- 56	51.20 **	27.13**	21.43 **	10.94**	-38.92 **	4.90	12.25 **	3.44	9.40 **	1.68	13.65 **	6.17*
25	DI- 123 X DI-109	47.60 **	11.36**	37.23 **	11.52**	20.66 **	26.59**	7.57 **	2.11	2.77	0.01	22.88 **	6.31*
26	DI- 123 X DI-111	55.09 **	14.48**	84.55 **	35.95**	6.74 **	14.61**	14.18 **	7.18**	4.29	0.01	36.53 **	21.89**
27	DI- 123 X DI-118	58.68 **	22.64**	28.17 **	11.31**	14.68 **	10.96**	11.58 **	6.05*	2.21	0.01	13.28 **	6.19*
28	DI- 123 X DI-117	42.81 **	13.42**	54.21 **	16.88**	20.33 **	26.70**	17.08 **	10.71**	3.73	0.01	22.51 **	9.04**
29	DI- 123 X D- 52	31.74 **	6.82*	37.53 **	9.36**	-21.13 **	2.30	10.47 **	6.42*	3.87	0.01	15.13 **	6.41**
30	DI- 123 X D- 56	27.25 **	4.24	41.41 **	11.39**	26.13 **	37.48**	15.63 **	6.01*	10.65 **	4.16	-18.08 **	-31.08**
31	DI-109 X DI-111	23.65 **	8.72**	40.06 **	20.70**	23.89 **	10.21**	16.11 **	5.15	5.03 *	3.08	19.56 **	4.63
32	DI-109 X DI-118	40.72 **	7.87*	54.87 **	17.73**	-23.58 **	9.40**	10.32 **	3.67	4.01	2.21	3.69	-0.36
33	DI-109 X DI-117	27.84 **	2.11	-5.08	-3.03	-3.42	12.99**	10.81 **	9.58**	11.12 **	8.01**	14.76 **	4.18
34	DI- 109 X D-52	30.84 **	10.76**	24.31 **	-11.06**	-4.63 *	-7.43*	6.27 *	5.13*	5.59 *	2.62	7.38 **	3.09
35	DI-109 X D- 56	62.57 **	26.89**	71.41 **	6.55*	-10.09 **	2.06	7.91 **	3.13	2.77	0.01	23.62 **	11.04**
36	DI-111 X DI- 118	33.83 **	5.37*	-11.93 **	12.35**	-41.21 **	10.79**	10.81 **	5.22*	5.03 *	1.76	16.61 **	4.43
37	DI-111 X DI- 117	37.82 **	6.52*	-34.39 **	18.12**	-33.79 **	25.83**	8.06 **	8.04**	10.51 **	7.83**	4.43	2.83
38	DI-111 X D- 52	24.25 **	16.87**	-41.48 **	30.07**	-51.32 **	10.07**	4.82	3.68	7.19 **	1.75	14.76 **	8.04**
39	DI-111 X D- 56	41.62 **	18.60**	-34.91 **	18.72**	-34.50 **	18.11**	9.65 **	5.98*	8.85 **	1.27	12.55 **	6.89*
40	DI-118 X DI- 117	51.80 **	16.57**	65.32 **	56.31**	-5.40 *	34.61**	15.15 **	10.77**	4.48	0.01	18.82 **	11.18**
41	DI-118 X D- 52	55.69 **	19.23**	54.26 **	30.37**	-14.26 **	13.16**	6.27 *	3.63	7.33 **	2.58	4.80	4.58
42	DI-118 X D- 56	31.74 **	12.95**	57.52 **	47.84**	-10.15 **	42.03**	9.50 **	5.73*	7.66 **	3.52	15.13 **	6.09*
43	DI-117 X D-52	51.80 **	17.16**	35.16 **	8.34**	38.12 **	27.22**	7.91 **	2.24	9.59 **	1.69	19.56 **	10.19**
44	DI-117 X D-56	34.73 **	13.56**	40.96 **	9.27**	-3.74	20.87**	14.95 **	8.81**	8.57 **	2.55	13.28 **	4.56
45	D-52 X D -56	44.01 **	5.41*	38.05 **	8.45**	-10.46 **	11.54**	17.22 **	6.17*	10.65 **	3.32	4.06	4.96
	SE ±		**0.11**		**2.70**		**4.84**		**0.55**		**1.51**		**0.09**
	CD at 5%		**0.22**		**5.36**		**9.60**		**1.09**		**3.00**		**0.18**
	CD at 1%		**0.27**		**6.60**		**11.83**		**1.34**		**3.69**		**0.22**

Continue…

SN	Hybrids	Tryptophan content (%)		Protein content (%)		Grain yield/plant (g)	
		EH	ID	EH	ID	EH	ID
1	DI-122 × DI- 121	-8.02 **	11.76**	7.78 **	5.73*	-15.90 **	17.11**
2	DI-122 × DI- 124	35.14 **	4.00	7.04 **	4.61	-17.37 **	18.11**
3	DI-122 × DI- 123	16.22 **	6.98*	6.17 **	0.81	-0.31	9.74*
4	DI-122 × DI- 109	29.73 **	4.17	5.80 **	10.15**	-12.73 **	14.14**
5	DI-122 × DI- 111	13.51 **	7.14**	4.57 *	8.62**	-34.91 **	33.04**
6	DI-122 × DI- 118	10.81 **	7.32**	5.80 **	6.65*	-4.68 *	6.61
7	DI-122 × DI- 117	5.41 *	7.69**	4.07	5.93*	12.81 **	13.36**
8	DI-122 × D- 52	16.22 **	4.65*	4.94 *	0.82	70.23 **	59.94**
9	DI-122 × D- 56	13.51 **	4.76*	3.70	2.38	20.69 **	14.42**
10	DI-121 × DI-124	24.32 **	0.00	3.33	0.48	58.96 **	32.13**
11	DI-121 × DI-123	8.11 **	7.50**	3.33	8.36**	40.75 **	26.92**
12	DI-121 × DI-109	16.22 **	6.98**	4.07	1.30	2.53	-27.79**
13	DI-121 × DI-111	21.62 **	8.89**	3.70	6.79*	80.33 **	44.63**
14	DI-121 × DI-118	18.92 **	9.09**	4.57 *	0.59	59.50 **	20.55**
15	DI-121 × DI-117	10.81 **	14.63**	4.07	0.59	80.82 **	30.30**
16	DI-121 × D- 52	24.32 **	13.04**	2.47	0.36	67.04 **	7.27*
17	DI-121 × D- 56	27.03 **	12.77**	4.07	2.49	78.33 **	17.39**
18	DI-124 x DI-123	-13.51 **	6.25*	3.70	2.74	46.28 **	28.04**
19	DI-124 x DI-109	18.92 **	4.55	3.33	2.63	17.29 **	1.87
20	DI-124 x DI-111	32.43 **	14.29**	4.57 *	1.65	12.57 **	6.21
21	DI-124 x DI-118	10.81 **	17.07**	2.84	1.56	17.29 **	20.56**
22	DI-124 x DI-117	5.41 *	17.95**	3.33	2.87	5.69 **	5.88
23	DI-124 x D- 52	18.92 **	11.36**	4.07	1.19	1.28	10.35**
24	DI-124 x D- 56	2.70	18.42**	3.70	1.55	9.61 **	10.46**
25	DI- 123 X DI-109	5.41 *	23.08**	4.07	0.95	27.18 **	16.85**
26	DI- 123 X DI-111	10.81 **	14.63**	5.80 **	0.70	94.11 **	38.61**
27	DI- 123 X DI-118	18.92 **	6.82**	2.84	1.32	41.86 **	12.81**
28	DI- 123 X DI-117	27.03 **	8.51**	2.84	8.40**	74.10 **	32.70**
29	DI- 123 X D- 52	21.62 **	13.33**	1.60	0.73	38.89 **	11.03**
30	DI- 123 X D- 56	-13.51 **	18.75**	5.31 *	9.73**	49.67 **	42.03**
31	DI-109 X DI-111	24.41 **	4.35	6.17 **	0.35	29.43 **	39.07**
32	DI-109 X DI-118	8.11 **	5.00	3.33	1.67	14.80 **	18.26**
33	DI-109 X DI-117	18.92 **	4.55	4.94 *	0.82	-28.38 **	5.22
34	DI- 109 X D-52	13.60 **	9.52**	3.70	2.26	12.16 **	9.65*
35	DI-109 X D- 56	2.70	7.89**	4.20 *	1.66	44.52 **	6.92

SN	Hybrids	Tryptophan content (%)		Protein content (%)		Grain yield/plant (g)	
		EH	**ID**	**EH**	**ID**	**EH**	**ID**
36	DI-111 X DI- 118	13.51 **	11.90**	4.07	2.14	0.56	61.50**
37	DI-111 X DI- 117	8.11 **	22.50**	3.83	2.26	-29.58 **	25.93**
38	DI-111 X D- 52	18.92 **	9.09**	3.70	1.55	-41.27 **	8.77*
39	DI-111 X D- 56	18.92 **	13.64**	4.94 *	1.18	-32.91 **	12.59**
40	DI-118 X DI- 117	21.62 **	11.11**	4.32 *	0.59	32.22 **	51.24**
41	DI-118 X D- 52	10.81 **	9.76**	4.69 *	3.30	6.40 **	7.65
42	DI-118 X D- 56	21.62 **	8.89**	3.95	0.24	23.97 **	57.30**
43	DI-117 X D-52	10.81 **	12.20**	4.94 *	0.82	44.80 **	16.36**
44	DI-117 X D-56	18.92 **	11.36**	6.17 **	0.81	62.24 **	19.28**
45	D-52 X D -56	13.51 **	11.90**	4.57 *	4.01	24.84 **	14.69**
	SE ±		**0.0110**		**0.084**		**2.44**
	CD at 5%		**0.0218**		**0.17**		**4.84**
	CD at 1%		**0.0269**		**0.21**		**5.97**

EH= Economic Heterosis, ID= Inbreeding Depression

Heterosis unless it is economical, is of no use. In the present investigation heterosis in F_1's over commercial variety (D- 52) and inbreeding depression were estimated and presented in Table 1.

It is evident from the result DI- 123 x D- 52 (-12.61), DI- 109 x DI- 118 (-12.18), DI- 109 x D- 56 (-10.88), DI- 111 x D- 56 (-10.88) and DI- 118 x DI- 117 (-10.88)the crosses combinations showed significant negative heterosis over economic parent for days to 50% tasseling in desirable direction out of which DI- 123 x D- 52 (-12.61) showed maximum while minimum in DI- 122 x D- 56 (-1.75).Significant negative heterosis over economic parent for days to 50% silking was ranged from-8.87 (DI- 121 x DI- 111) to -1.54(DI- 122 x D- 56), and maximum from DI- 121 x DI- 111 (-8.87) followed by DI- 121 x DI- 118 (-6.95), DI- 122 x DI- 109 (-6.95) and DI- 122 x DI- 109 (-6.56). Cross combinations *viz.*, DI- 123 x DI- 109 (-9.49), DI- 123 x DI- 117 (-8.54), DI- 123 x D- 52 (-8.22) and DI- 124 x D- 52 (-8.22) revealed significant negative heterosis over economic parent for days to 75% dry husk.These hybrids may be commercialized as early maturing maize hybrids after confirmation of their suitability for commercial cultivation.

Significant positive heterosis over economic parent was revealed by two cross combinations for plant height (cm), four for number of cobs per plant and cob diameter (cm), five for cob weight (g),six for cob length (cm),number of grains per cob and100- kernel weight (g), seven for shelling (%),tryptophan content (%) and protein content (%), eight for lycine content (%).Cross combinations *viz.,* DI- 123 x DI- 111(91.11), DI- 121 x DI- 117 (80.82), DI- 121 x DI- 111(80.33), DI- 121 x D- 56 (78.33), DI- 123 x DI- 117 (74.10), DI- 122 x D- 52(70.23), DI- 121 x D- 52 (67.04) and DI- 117 x D- 56 (62.24) revealed significant positive heterosis over economic parent for grain yield per plant (g). Similar results were obtained by Singh et al., [9], Kiani et al., [10], Annor and Badu [11], Chandan et al., [12], Abdulla et al., [13], Chaurasia, et al., [14], Lone et al., [15], Mekasha et al., [16,17] Subba et al., [18] and Lal et al., [19],These hybrids may be commercialized as high yielding, bold seeded and quality rich maize hybrids after confirmation of their suitability for commercial cultivation.

One of the characteristics of heterosis is that the increase in vigour is confined to F_1 generation. There is considerable depression from F_1 to $F_2$and later generation. Shull (1914) reported that high inbreeding depression (positive) is the reflection of higher heterosis especially in cross-pollinated crop like maize. It may be seen from the present study that hybrid combinations that showed higher estimates of heterosis in general found to show substantial inbreeding depression (Table 1). In maize, inbreeding is accompanied by a reduction in the mean phenotypic value of most of the traits of economic importance simply because of reduction in fitness.

Maximum inbreeding depression for days to 50% tasseling were observed from DI- 122 x DI- 109 (4.92), DI- 109 X D- 56 (4.00)for days to 50% silking, DI 122 x D- 56 (2.26)for days to 75% dry husk, DI- 109 x DI- 117 (-4.78)for plant height, DI- 121 x DI- 118 (-37.30) for number of cobs per plant, DI- 123 x D- 52 (-10.62)for cob length (cm),DI- 124 x DI- 118 (-10.00)for cob diameter (cm), DI- 122 x DI- 124 (-44.47)for cob weight (g), DI- 124 x D- 56 (4.90)for number of grains per cob, DI- 124 x DI- 111 (4.01)for 100- kernel weight (g), DI- 123 x DI- 109 (23.08) for shelling (%), DI- 111 x DI- 118 (4.43) for lycine content (%), DI- 123 x DI- 109 (23.08) for tryptophan content (%), DI- 122 x DI- 109 (10.15) for protein content (%), and DI- 111 x DI- 118 (61.50) for grain yield per plant (g).

These findings were reported earlier by Talukder et al., [20], Ilyas et al*.,* [21], Raj et al., [22] and Lone et al*.,* [15,23,24,25].

4. CONCLUSION

Among 45 crosses which generated from all possible combinations, eight revealed significant positive heterosis over economic parent for grain yield per plant (g)*viz.,* DI- 123 x DI- 111(91.11), DI- 121 x DI- 117 (80.82), DI- 121 x DI- 111(80.33), DI- 121 x D- 56 (78.33), DI- 123 x DI- 117 (74.10), DI- 122 x D- 52(70.23), DI- 121 x D- 52 (67.04) and DI- 117 x D- 56 (62.24). These crosses may be further used in maize improvement programme for the development of superior inbred lines.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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