Website : www.asthafoundation.in
Frontiers in Crop Improvement
Vol 10 (1) : 85-93 (January-2022) Print ISSN : 2393-8234 Online ISSN : 2454-6011
Astha Foundation, Meerut (U.P.) India

Heterosis of Maize Inbred Lines for Grain Yield and Components in Southern Aravalli Hilly Ranges of Rajasthan

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Abstarct

The 45 hybrids of maize were developed through Line x Tester mating design using 15 female lines and 3 testers. These 45 hybrids along with their 18 parents and two commercial checks, *viz.,* PHM-3 and PM-9 were evaluated at three environments *viz.,* E1 (*Kharif*-2019, Instructional Farm, RCA, Udaipur), E2 (*Kharif*-2019, ARSS Vallabhnagar) and E3 (*Rabi*-2019, Instructional Farm, RCA, Udaipur)to identify suitable hybrid combinations. The data were recorded on grain yield and its components including ear length, ear girth, grain rows per ear and 100-grain weight to assess the magnitude of heterosis. The presence of highly significant differences among all the genotypes was observed for all the traits in all theindividual as well as over the environments indicating presence of significant genetic difference among them. The sum of squares due parents vs crosses were found significant for all the traits under study except starch content on pooled basisindicating the choice of exploitation of heterosis for all the characters under study. Similarly, the variance due to crosses were also found significant for all the traits under study in all the environments as well as on pooled basis indicating hybrids were differ for yield and components traits. The hybrids EI-2525-2 x EI-03, EI-2448 x EI-102, EI-2642 x EI-670, EI-2505 x EI-102 and EI-2653 x EI-03 recorded highest magnitude of significant and positive heterobeltiosis as well as mid parent heterosis for the traits grain yield per plant, 100-grain weight, grain rows per ear, ear girth and ear length, respectively. For economic heterosis, 3 hybrids EI-2525-2 x EI-03 (15.03 %), EI-2176-3 x EI-03 (11.64 %) and EI-2159 x EI-670 (7.19 %) exhibited positive and significant heterotic effect over the best check PHM-3 on pooled basis.Therefore, these F1 hybrids could be reliably recommended for cultivation in the tested locations and their use in the future breeding programmes for developing high yielding maize genotypes.

Key words : *Heterosis, inbred lines, maize, grain yield components.*

Introduction

Maize (*Zea mays* L.; 2n = 20) is a versatile and multi utility grain crop and model genetic plant (1). It was domesticated from Teosinte (*Zea mays* L. spp. *Parviglumis),* aclosest living relative about 10,000 years ago in the Balsas River Basin of South Western Mexico (2). The cultivated maize was introduced in India by the Portuguese during the 17th century (3). It is diclinous, allogamous, protandrous species, belongs to the monocot family Poaceae, Genus *Zea* and Species *mays* (4). It is grown in both irrigated and rainfed regions, of the word and positions third after two major cereal crops wheat and rice (5). It is a staple food for 4.5 billion people of the word (6). It is used extensively as animal feed, particularly for poultry and pigs. Globally, it is grown in 196.76 M ha area across 165 countries, with a total production of 1162.38 MMT, and average productivity of 5.91 metric t/ha (7). In India, it is grown in 9.20 M ha with a total production of 28.00 MMT, and average productivity of 3.04 metric t/ha (7). In Rajasthan, it occupied an area of 9.34 lakh ha with production of 17.64 lakh tonnes and productivity of 1889 kg/ha (8). The demand for maize is expected to double by 2050 and in Indian context the projected demand is expected to be 42 million tonnes by the year 2025 (9, 33). Thus, improving maize productivity is urgent and challenging also due to limited crop land and a growing population. Furthermore, global crop yields were stagnant across 24-39 per cent of the main growing areas. The climate change is projected to reduce maize production globally by 3-10 per cent by 2050 (10, 34). The term 'heterosis' (11) was coined by which means the increase in vigor, size, speed of development, fruitfulness, resistance to biotic and abiotic stresses of the F_1 hybrids than their parental inbred lines. Heterosis is of great importance for agricultural production and one of the most successful examples in crops is from maize (12). Development of hybrid cultivars has accelerated the increase in productivity of maize across the world. Hybrids play a crucial role in increased maize production and food security especially single cross hybrids (13). It is estimated that the use of hybrids and heterosis increases yield by nearly 15 per cent per annum in maize (14). Information on the heterotic patterns among maize germplasm is essential in maximizing the effectiveness of hybrid development. Therefore, it is meaningful for maize

Received : December-2021; Revised : December-2021; Accepted : December-2021

Table-1 : The mean sum of squares due to various source of variations for different traits in maize on pooled basis.

Sources	d.f.	Mean sum of squares						
		DT 50 %	DS 50 %	DBH 75 %	PH (cm)	EH (cm)	EL (cm)	EG (cm)
Replication	2	8.29	5.66	3.82	132.73	54.31	2.04	1.16
Rep. x Env.	4	0.24	4.24	1.46	112.6*	35.7	1.41	0.66
Environments	2	206746.12**	222936.14**	242026.46**	8342.03**	1792.61**	189.78**	96.64**
Treatments	62	56.41**	50.97**	50.23**	2432.16**	710.66**	11.5**	8.66**
Parents	17	58.38**	60.3**	43.25**	1329.96**	355.48**	6.28**	5.2**
Lines (L)	14	63.35**	67.07**	35.58**	1164.34**	367.18**	6.88**	5.35**
Testers (T)	2	35.59**	26.7**	116.59**	353.49**	295.88**	4.71**	5.31**
L vs T	1	34.43**	32.8**	3.87	5601.58**	310.88**	0.96	2.93*
Crosses	44	56.28**	47.89**	52.96**	1453.77**	404.23**	11.32**	8.1**
Parents vs Crosses	1	28.93**	27.8**	48.8**	64218.57**	20231.7**	108.16**	92.09**
Error	372	3.12	2.32	2.56	44.67	18.57	1.00	0.66

Sources	d.f.	Mean sum of squares						
		DT 50 %	DS 50 %	DBH 75 %	PH (cm)	EH (cm)	EL (cm)	EG (cm)
Replication	2	3.19	7.83	75.84	1.71	1.94	0.47	0.21
Rep. x Env.	4	0.63	7.69	9.4	3.86	7.11	0.25	0.02
Environments	2	92.25**	339.64**	9214.63**	557.04**	234.75**	10.3**	2.67**
Treatments	62	10.85**	47.32**	1966.45**	113.72**	56.44**	4.59**	1.44**
Parents	17	6.39**	43.5**	637.24**	42.3**	60.76**	3.35**	1.6**
Lines (L)	14	6.73**	33.53**	555.3**	47.97**	55.27**	3.21**	1.7**
Testers (T)	2	7.12**	133.73**	364.83**	7.81	16.03	5.99**	0.98**
L vs T	1	0.01	2.67	2329.18**	31.85**	227.09**	0.03	1.44**
Crosses	44	10.02**	47.63**	1131.89**	80.11**	55.91**	5.12**	1.3**
Parents vs Crosses	1	123.45**	98.34**	61283.65**	2806.83**	6.1	2.63**	4.89**
Error	372	1.08	4.07	25.86	4.46	7.74	0.24	0.07

* and ** represent level of significance at 5 and 1%, respectively.

DT 50 % = Days to 50 per cent tasseling, DS 50% = Days to 50 per cent silking, DBH 75% = Days to 75 per cent brown husk, PH = Plant height, EH = Ear height, EL = Ear length, EG = Ear girth, GRE = Grain row per ear, 100 GW = 100 Grain weight, GYP = Grain yield per plant, HI (%) = Harvest index, SC (%) = Starch content (%), PC (%) = Protein content and OC (%) = Oil content (%)

breeders or researchers to understand the effect in various crosses for selection of good parental lines which are suitable for future breeding programme.

Materials and Methods

The experimental material comprised of 15 inbred lines, 3 testers and their 45 F_1swith two checks *viz.,* PHM-3 and PM-9. These 45 F_1swere obtained by crossing 15 inbred lines and 3 testers in Line x Tester mating design. These 18 parents (15 lines and 3 testers) along with 45 hybrids and two checks were evaluated at three environments *viz.,* E1 (*Kharif*-2019, Instructional Farm, RCA, Udaipur), E2 (*Kharif*-2019, ARSS Vallabhnagar) and E3 (*Rabi*-2019, Instructional Farm, RCA, Udaipur). The Udaipur district is located in the Aravalli Hill Ranges of Southern part of the Rajasthan with latitude 24°35'31.5" longitudes 73°44'18.2" with an altitude of 582.17 m above mean sea level. The Vallabhnagar is a village in Vallabhnagar tehsil of Udaipur district of Rajasthan. The soil of both experimental fields were clay loam, deep, well drained, alluvial in origin and have good moisture holding capacity. The each treatment was sown in single row plot of 4.0 m length with geometry of 60 x 20 cm row to row and plant to plant spacing, respectively. All the recommended package of practices of zone IV-A(Sub-Humid Southern Plains) were used to raise a healthy crop. Ten randomly competitive plants were chosen from each plot in each replication for recording observations on 14 traits including phenological, yield and quality traits. The estimation of quality traits *viz.,* starch content, protein content and oil content were carried using anthrone reagent method, micro kjeldahl'smethod (15) and soxhlet's ether extraction method (16), respectively.The analysis of variance was carried out for randomized block design separately for all the 14 traits under each environment and pooled over the environments as per method described by Panse and Sukhatme (1985) (17). The mid parent, better parent (Heterobeltiosis) and economic heterosis (Standard Heterosis) was calculated in terms of percent increase or decrease of a hybrid against its mid, better and check cultivar using method suggested by (11,18). The magnitude of standard heterosis was estimated against the standard check PHM-3 under the study as method suggested by. The

Table-2 : Estimates of mid parent, better parent and standard heterosis on pooled basis for yield and its components in maize.

S.No.	Hybrids	DT 50 %			DS 50 %			DBH 75 %			PH (cm)			EH (cm)		
		MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
1.	EI-2159 X EI-03	-1.33	-2.22*	1.58	-0.95	-1.62	1.11	0.2	0.2	1.23	3.64	-5.53**	-20.92**	5.67	0.63	-27.05**
2.	EI-2172 X EI-03	3.32**	1.13	3.17	2.16**	0	1.38	1.3*	-0.92	0.1	-3.17	-9.96**	-24.63**	11.81**	7.81*	-21.85**
3.	EI-2176-3 X EI-03	3.16**	1.56	3.61	2.28**	1.09	2.49	3.2**	1.93**	2.98*	21.04**	19.86**	0.33	28.98**	27.44**	-5.37
4.	EI-2178 X EI-03	-1.92*	-2.26*	-0.29	-2.19**	-2.6**	-1.25	0.51	0	1.03	8.88**	5.69**	-11.53**	10.27**	5.2	-23.74**
5.	EI-2188 X EI-03	-5.62**	-7.36**	-5.48**	-4.46**	-6.28**	-4.99**	-2.11**	-2.95**	-1.95	3.96	-4.93*	-20.42**	15.15**	5.06	-23.84**
6.	EI-2188-1 X EI-03	-0.78	-1.12	1.58	-1.02	-1.22	0.56	-0.93	-2.14**	-1.13	11.57**	5.07*	-12.04**	22.03**	16.35**	-7
7.	EI-2403 X EI-03	2.42*	-1.13	0.87	1.2	-2.05*	-0.69	3.68**	1.73*	2.78*	18.06**	11.55**	-6.62*	11.8**	1.58	-9.89*
8.	EI-2448 X EI-03	-5.17**	-5.37**	-3.47	-5.66**	-5.85**	-4.15**	-1.38*	-1.63*	-0.62	4.48*	1.77	-14.81**	31.38**	22.2**	-11.41*
9.	EI-2505 X EI-03	3.86**	-0.99	1.01	2.8**	-2.05*	-0.69	-1.04	-2.95**	-1.95	18.99**	18.12**	0.34	35.6**	34.01**	-2.86
10.	EI-2507 X EI-03	3.93**	2.97**	5.05**	3.38**	2.32**	3.74*	0.71	0.61	1.65	2.71	2.31	-13.69**	21.01**	16.95**	-15.22**
11.	EI-2522 X EI-03	-5.39**	-8.2**	-6.35**	-4.57**	-7.38**	-6.1**	-3.12**	-5.09**	-4.11**	19.37**	6.88**	-10.53**	36.31**	34.99**	-2.14
12.	EI-2525-2 X EI-03	-0.35	-0.71	1.3	-0.48	-0.82	0.56	2.05**	1.43*	2.47*	18.63**	15.61**	-3.23	26.33**	23.14**	-5.99
13.	EI-2639 X EI-03	-4.12**	-6.08**	-4.18*	-4.12**	-6.28**	-4.99**	-2.63**	-3.77**	-2.78*	8.64**	-3.29	-19.05**	23.27**	17.09**	-15.12**
14.	EI-2642 X EI-03	-6.13**	-6.46**	-3.9*	-5.86**	-6.11**	-4.29**	-6.98**	-7.63**	-5.35**	14.71**	13.63**	-4.88	18.1**	10.63**	-8.19
15.	EI-2653 X EI-03	6.4**	2.26*	4.32*	5.2**	0.96	2.36	4.74**	2.34**	3.4**	7.56**	1.4	-15.12**	25.66**	22.22**	-11.4*
16.	EI-2159 X EI-102	2.29*	-0.83	3.03	1.59*	-1.08	1.67	-0.1	-2.85**	-1.85	6.01**	-2.28	-20.19**	4.31	0.48	-28.88**
17.	EI-2172 X EI-102	-1.26	-1.33	-3.61	-0.71	-0.85	-3.47*	3.16**	2.56**	-0.93	11.92**	5.27*	-14.02**	19.39**	16.47**	-17.58**
18.	EI-2176-3 XEI-102	5.51**	4.82**	3.61	5.36**	4.48**	3.47*	4.88**	3.24**	1.75	21.7**	21.41**	-0.36	24.51**	21.58**	-9.72*
19.	EI-2178 X EI-102	-0.15	-1.99	-0.73	0.21	-1.38	-0.82	2**	-0.31	-0.31	21.57**	19.43**	-2.46	29.77**	25.24**	-11.37*
20.	EI-2188 X EI-102	3.17**	2.79*	1.01	3.48**	3.41**	0.84	3.22**	1.24	0.51	17.47**	8.64**	-11.27**	21.08**	11.69**	-20.96**
21.	EI-2188-1 XEI-102	2.02*	-0.56	2.17	2.09**	-0.14	1.66	2.12**	0.52	-0.93	26.05**	20.1**	-1.91	24.76**	17.61**	-5.99
22.	EI-2403 X EI-102	-0.6	-1.92	-4.32*	-1.44	-2.7**	-5.26**	0.8	-0.11	-2.88*	20.61**	15.3**	-5.83	19.51**	7.42**	-4.7
23.	EI-2448 X EI-102	5.65**	3.55**	5.19**	4.17**	1.9*	3.74*	4.67**	2.05**	2.57*	12.17**	10.59**	-9.68**	36.15**	28.07**	-9.36*
24.	EI-2505 X EI-102	6.3**	3.55**	1.01	5.71**	2.7**	0	7.59**	6.67**	3.6**	15.69**	13.46**	-3.62	37.47**	37.46**	-2.71
25.	EI-2507 X EI-102	-3.07**	-4.32**	-4.18*	-3.1**	-4.04**	-4.71**	0.52	-2.14**	-1.33	18.98**	17.09**	-1.22	33.77**	30.8**	-7.43
26.	EI-2522 X EI-102	5.44**	4.59**	2.01	5.46**	4.41**	1.67	6.74**	5.94**	2.68*	16.8**	5.73**	-13.65**	37.36**	37.05**	-2.57
27.	EI-2525-2 X EI-102	-1.16	-2.99**	-1.73	-0.28	-1.93*	-1.25	-0.84	-2.99**	-3.19**	12.32**	10.78**	-9.52**	29.45**	24.72**	-4.79
28.	EI-2639 X EI-102	4.28**	4.13**	1.88	3.42**	3.13**	0.42	5.78**	4.07**	2.68*	9.93**	-1.07	-19.2**	15.84**	11.31**	-21.24**
29.	EI-2642 X EI-102	0.29	-2.25*	0.43	-0.49	-2.72**	-0.84	1.77**	-1.71*	0.72	22.02**	21.68**	-0.06	28.89**	19.4**	-0.9
30.	EI-2653 XEI-102	6.78**	4.88**	2.31	6.1**	3.84**	1.11	5.52**	5.02**	1.23	7.48**	2.5	-16.28**	13.25**	11.45**	-21.12**
31.	EI-2159 X EI-670	-5.12**	-5.97**	-2.31	-4.15**	-5.12**	-2.49	-3.46**	-3.65**	-2.27	13.03**	0.46	-10.99**	3.53	-7.82*	-22.58**
32.	EI-2172 X EI-670	-2.46**	-4.53**	-2.6	-1.4	-3.16**	-2.49	-0.26	-2.64**	-1.24	16.41**	5.48**	-6.54*	18.96**	7.14*	-10.02*
33.	EI-2176-3 X EI-670	-3.02**	-4.53**	-2.6	-2.5**	-3.3**	-2.63	-2.78**	-4.16**	-2.78*	18.1**	13.75**	0.78	29.67**	22.16**	2.59
34.	EI-2178 X EI-670	1.35	0.99	3.03	1.58*	1.51	2.22	-3.78**	-4.46**	-3.08*	14.06**	7.75**	-4.54	10.46**	-1.49	-17.26**
35.	EI-2188 XEI-670	4.18**	2.26*	4.32*	4.54**	2.89**	3.6*	-3.02**	-4.06**	-2.68*	-0.59	-11.36**	-21.46**	15.7**	-0.97	-16.82**
36.	EI-2188-1 X EI-670	-8.39**	-8.71**	-6.21**	-7.25**	-7.76**	-6.1**	-4.53**	-5.88**	-4.53**	7.77**	-1.13	-12.4**	-7.91**	-10.14**	-24.52**
37.	EI-2403 X EI-670	2.86**	-0.71	1.3	2.12**	-0.83	-0.14	1.09	-1.01	0.42	9.32**	0.61	-10.86**	3.24	0.49	-10.84*
38.	EI-2448 X EI-670	-4.32**	-4.53**	-2.6	-3.69**	-4.22**	-2.49	-1.17*	-1.62*	-0.2	12.34**	6.49**	-5.65	29.06**	12.45**	-5.55
39.	EI-2505 X EI-670	0.59	-4.1**	-2.17	1.01	-3.44**	-2.77	0.62	-1.52*	-0.1	13.55**	11.2**	-1.47	28.73**	18.61**	-0.38
40.	EI-2507 X EI-670	-5.92**	-6.79**	-4.91**	-4.85**	-5.5**	-4.84**	-2.64**	-2.94**	-1.55	7.94**	5.36**	-6.65*	11.95**	1.04	-15.13**
41.	EI-2522 X EI-670	3.79**	0.71	2.74	3.25**	0.55	1.25	0.1	-2.13**	-0.72	15.1**	0.54	-10.92**	8.77**	0.42	-15.66**
42.	EI-2525-2 X EI-670	-0.07	-0.42	1.58	-0.28	-0.28	0.42	0.72	-0.1	1.33	21.57**	15.29**	2.15	27.9**	22.08**	2.53
43.	EI-2639 X EI-670	-0.36	-2.4*	-0.43	1.96*	0	1.11	0.46	-0.91	0.52	12.53**	-2.25	-13.39**	18.29**	5.07	-11.75**
44.	EI-2642 X EI-670	-1.34	-1.69	1.01	-1.03	-1.63	0.27	-3.53**	-4.02**	-1.65	17.59**	13.3**	0.38	21.66**	20.94**	1.58
45.	EI-2653 X EI-670	-2.43*	-6.22**	-4.32*	-2*	-5.64**	-4.99**	-0.68	-3.14**	-1.75	2.64	-5.75**	-16.49**	10.3**	0.14	-15.9**

Table-2 : Contd...

Table-2 : Contd...

S.No.	Hybrids	EL (cm)			EG (cm)			GRE			100 GW (g)			GYP		
		MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
1.	EI-2159 X EI-03	-5.93	-6.78	-24.77**	-1.11	-3.63	-13.79**	-1.21	-1.72	-12.9*	-2.79	-7.79*	-6.8	38.84**	38.13**	-12.51**
2.	EI-2172 X EI-03	1.8	-1.59	-20.59**	4.4	-1.04	-11.46*	0.17	-2.13	-9.13	7.84**	-0.28	0.81	27.98**	16.77**	-26.05**
3.	EI-2176-3 X EI-03	5.02	4.6	-14.91**	10.99**	8.83**	-2.62	9.32**	5.16	-6.79	5.99*	-5.45	-4.44	60.41**	47.16**	11.64**
4.	EI-2178 X EI-03	8.95**	4.44	-15.72**	5.95*	-1.31	-11.67*	10.43**	9.81**	-2.68	-20.32**	-24.52**	-23.7**	18.48**	7.91*	-31.66**
5.	EI-2188 X EI-03	10.63**	8.01*	-8.48	11.9**	11.03**	-0.64	5.14	0.43	-10.98	-16.71**	-19.31**	-18.42**	44.94**	38.51**	-12.27**
6.	EI-2188-1 X EI-03	3.11	0.35	-19.03**	-2.58	-5.93*	-15.77**	12.56**	11.45**	-1.24	1.19	-7.28*	-6.28	1.18	-4.25	-32.07**
7.	EI-2403 X EI-03	4.46	-1.05	-10.73*	1.97	-1.29	-5.66	21.46**	14.2**	1.17	3.71	-5.42	-4.4	45.16**	25.25**	-20.67**
8.	EI-2448 X EI-03	2	0.22	-16.22**	-1.01	-1.8	-10.68*	-5.53	-7.36*	-14.62*	6.95*	-4.89	-3.85	28.12**	21.71**	-22.92**
9.	EI-2505 X EI-03	-8.28**	-8.66*	-26.26**	-11.58**	-12.74**	-21.92**	9.77**	6.19	0.69	1.85	-2.1	-1.04	33.16**	31.58**	-14.65**
10.	EI-2507 X EI-03	11.14**	5.1	-4.87	9.16**	5.67*	1.06	5.58	4.56	-5.49	-11.81**	-17.08**	-16.19**	39.42**	32.4**	-16.15**
11.	EI-2522 X EI-03	13.54**	8.44*	-12.48*	6.18*	1.51	-9.12	7.51*	6.63	-5.49	-9.54**	-17.76**	-16.87**	64.29**	48.35**	-6.05
12.	EI-2525-2 X EI-03	12.28**	8.03*	-5.68	6.64**	4.74	-2.83	4.92	3.7	-8.1	-3.01	-14.95**	-14.02**	87.54**	81.63**	15.03**
13.	EI-2639 X EI-03	14.23**	13.75**	-8.23	9.79**	7.49*	-3.82	0.72	-5.44	-4.53	6.08*	1.05	2.14	35.53**	28.66**	-9.33*
14.	EI-2642 X EI-03	-2.13	-4.88	-18.65**	2.98	1.95	-6.93	13.22**	11.27**	-1.37	-21.9**	-23.81**	-22.98**	30.37**	22**	-22.74**
15.	EI-2653 X EI-03	23.22**	22.73**	-0.19	14.72**	14.24**	3.11*	13**	9.83**	3.09	2.28	-2.17	-1.1	50.34**	47.55**	-6.55
16.	EI-2159 X EI-102	5.21	4.86	-16.34**	10.85**	10.73**	-5.94	0.75	-2.75	-8.3	2.65	-5.58	-14.37**	30.91**	18.94**	-8.75*
17.	EI-2172 X EI-102	9.81**	6.75	-14.85**	13.29**	10.23**	-6.58	-10.02**	-10.68**	-15.79**	18.22**	11.54**	-4.24	-14.69**	-28.3**	-44.99**
18.	EI-2176-3 XEI-102	6.51*	5.48	-14.22**	8.89**	8.08**	-7	0.53	-6.07	-11.46	15.17**	12.9**	-10.49	14.34**	13.7**	-12.76**
19.	EI-2178 X EI-102	-2.45	-5.96	-25.02**	-3.26	-7.55*	-21.64**	-0.21	-3.72	-9.27	21.62**	12.03**	1.29	45.86**	22.39**	-6.11
20.	EI-2188 X EI-102	4.13	1.09	-14.35**	9.88**	7.79*	-5.02	18.05**	9.55**	3.23	3.3	-6.84*	-11.72*	22.31**	7.16*	-17.79**
21.	EI-2188-1 XEI-102	11.71**	9.34*	-12.79*	12.28**	11.36**	-5.66	14.44**	9.95**	3.64*	19.72**	14.02**	-4.05	9.69**	5.56	-19.02**
22.	EI-2403 X EI-102	13.29**	6.73*	-3.74	7.12**	1.04	-3.39	2.61	-6.23	-11.6*	23**	17.72**	-1.94	35.27**	8.15*	-17.03**
23.	EI-2448 X EI-102	-5.55	-7.71*	-22.83**	2.01	-1.46	-10.4*	1.1	0	-5.77	32.09**	29.95**	2.27*	26.13**	9.91**	-15.68**
24.	EI-2505 X EI-102	18.52**	18.33**	-5.3	16.79**	15.17**	0.35	0.44	0.16	-5.08	3.42	-6.06	-12.4*	21.85**	12.43**	-13.74**
25.	EI-2507 X EI-102	11.22**	4.6	-5.3	9.56**	3.34	-1.2	-1.36	-3.4	-8.92	8.67**	0.82	-10.26	-2.89	-15.4**	-35.09**
26.	EI-2522 X EI-102	0.16	-3.8	-23.27**	-0.51	-2.34	-17.26**	-10.72**	-14.08**	-19.01**	19.17**	14.44**	-5.34	21.24**	0.95	-22.56**
27.	EI-2525-2 X EI-102	15.5**	10.51**	-3.56	13.8**	8.87**	0.99	12.78**	8.17*	1.99	0.95	0.92	-23.11**	19.92**	6.34	-18.42**
28.	EI-2639 X EI-102	-3.42	-3.58	-22.83**	-5.06	-5.61	-19.09**	11.02**	7.33*	8.37	0.18	-8.22*	-16.02**	22.17**	17.2**	-10.09*
29.	EI-2642 X EI-102	15.42**	11.54**	-4.62	14.19**	10.09**	0.5	19.42**	13.92**	7.41*	-4.76	-14.66**	-17.97**	8.31*	-6.88*	-28.56**
30.	EI-2653 XEI-102	9.03**	7.98*	-12.16*	14.38**	10.89**	0.07	5.88	5.66	-0.41	10.18**	0.54	-7.22	41.85**	27.3**	-2.34
31.	EI-2159 X EI-670	4.97	-0.26	-12.23*	5.49*	-0.39	-4.81	6.56	3.13	-9.54	9.5**	7.73*	-2.3	60.66**	51.51**	7.19*
32.	EI-2172 X EI-670	-1.06	-8.19*	-19.21**	-2.24	-10.12**	-14.07**	10.64**	4.19	-3.23	-0.16	-1.24	-13.34*	36**	18.2**	-16.37**
33.	EI-2176-3 X EI-670	4.34	0.39	-11.67*	3.71	-1.48	-5.8	4.29	4.18	-14.48*	10.02**	4.7	-8.13	35.53**	30.96**	-0.65
34.	EI-2178 X EI-670	5.96	-2.47	-14.16**	5.25	-4.86	-9.05	3.28	0	-12.35*	3.67	2.14	-7.64	19.69**	3.85	-26.52**
35.	EI-2188 XEI-670	12.37**	10.26**	-2.93	11.55**	7.19*	2.48	6.19	5.3	-13.59*	-18.66**	-21.67**	-25.77**	39.7**	26.83**	-10.27*
36.	EI-2188-1 X EI-670	6.55*	-0.49	-12.41*	7.93**	1.02	-3.47	9.44**	6.41	-7.55	-6.39*	-8.31*	-19.52**	6.45*	6.3	-24.59**
37.	EI-2403 X EI-670	5.74*	4.45	-5.8	3.47	3.46	-1.06	13.58**	10.78**	-9.13	5.87	3.17	-9.45	53.39**	26.52**	-10.49*
38.	EI-2448 X EI-670	3.64	1.04	-11.1*	2.68	0.18	-4.24	20**	13.4**	4.53	-4.42	-9.35**	-20.46**	24.53**	12.41**	-20.46**
39.	EI-2505 X EI-670	3.51	-1.18	-13.04*	3.93	-0.66	-5.02	8.15*	0.88	-4.39	-0.56	-3.48	-10	48.6**	42.42**	0.77
40.	EI-2507 X EI-670	9.58**	8.05*	-2.18	8.95**	8.94**	4.17*	25.08**	19.32**	7.82*	11.73**	10.95**	-1.23	25.9**	13.62**	-19.61**
41.	EI-2522 X EI-670	7.03*	-1.82	-13.6**	-1.34	-8.54**	-12.59**	17.08**	13.65**	-0.96	10.18**	7.01*	-6.09	35.9**	16.97**	-17.24**
42.	EI-2525-2 X EI-670	12.94**	12.48**	-1	4.57	3.05	-1.49	9.81**	6.96	-7.41	12.97**	5.52	-7.38	40.3**	28.99**	-8.74*
43.	EI-2639 X EI-670	12.74**	7.62*	-5.3	14.64**	8.74**	3.96	16.58**	5.66	6.73	-0.01	-2.05	-10.39	37.48**	37.22**	-2.92
44.	EI-2642 X EI-670	6.45*	4.94	-7.67	6.93**	4.55	-0.07	29.75**	27.09**	8.72 *	-1.6	-5.89	-9.52	32.87**	18.27**	-16.32**
45.	EI-2653 X EI-670	6.64*	2.6	-9.73	8.26**	5.24	0.57	17.64**	10.24**	3.5	1.41	-1.08	-8.71	47.25**	37.08**	-3.01

Table-2 : Contd...

Table-2 : Contd...

S.No.	Hybrids	HI (%)			SC (%)			PC (%)			OC (%)		
		MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
1.	EI-2159 X EI-03	13.93**	10.54**	-9.18	-2.48	-7.36**	-5.73	2.36	1.68	-22.67**	5.38	3.94	-14.61**
2.	EI-2172 X EI-03	15.41**	10.28**	-9.4	-10.99**	-14.71**	-13.21**	14.4**	11.76**	-12.16**	-0.54	-1.11	-21**
3.	EI-2176-3 X EI-03	29.46**	22.47**	12.79**	-2.39	-4.69*	-3.01	-5.16	-13.72**	-21.03**	-3.62	-3.86	-23.29**
4.	EI-2178 X EI-03	22.25**	15.91**	-4.77	-5.93**	-11.96**	-10.42**	21.8**	18.53**	-6.02	5.49	2.99	-17.81**
5.	EI-2188 X EI-03	42.32**	36.26**	11.95*	-1.02	-7.11**	-5.48	8.62**	0.34	-11.17*	2.45	2.41	-18.26**
6.	EI-2188-1 X EI-03	7.07*	6.99*	-12.12*	-4.12*	-8.22**	-6.61	-1.69	-10.79**	-17.85**	9.82**	3.08	-17.81**
7.	EI-2403 X EI-03	16.34**	15.86**	-4.04	-8.01**	-10.04**	-8.47*	8.03**	7.84*	-18.84**	7.43*	1.25	-8.68
8.	EI-2448 X EI-03	17.53**	16.78**	-2.82	-6.09**	-11.95**	-10.4**	5.89*	0.84	-16.43**	7.49*	4.05	-11.19*
9.	EI-2505 X EI-03	12.05**	7.64*	-4.01	0.97	0.72	2.48*	-3.31	-10.41**	-21.25**	13.99**	1.94	3.2
10.	EI-2507 X EI-03	3.38	1.17	-13.16**	-1.58	-2.3	-0.58	23.16**	23.14**	-7.67	9.45**	2.32	-18.26**
11.	EI-2522 X EI-03	32.64**	23.65**	1.58	-3.05	-6.54**	-4.9	9.52**	8.37*	-16.98**	-10.79**	-19.17**	-20.55**
12.	EI-2525-2 X EI-03	17.72**	16.42**	-2.2	-2.42	-5.27**	-3.61	-6.75*	-10.32**	-27.16**	12.07**	10.6**	-9.36
13.	EI-2639 X EI-03	9.44**	3.66	-4.77	-3.22	-7.18**	-5.56	3.64	-5.87*	-13.58**	0.37	-6.29*	-13.7**
14.	EI-2642 X EI-03	4.35	1.7	-16.44**	-6.67**	-9.76**	-8.17*	24.66**	20.81**	-3.4	1.51	-6.07	-25.11**
15.	EI-2653 X EI-03	20.74**	19.93**	-1.47	-4.67**	-6.52**	-4.87	-9.44**	-17.08**	-25.19**	20.01**	19.05**	-5.02
16.	EI-2159 X EI-102	21.03**	14.01**	-0.34	0.24	-3.45	-4.56	-11.22**	-19.14**	-25.19**	-0.06	-6.77*	-11.64*
17.	EI-2172 X EI-102	7.37*	-0.34	-12.91**	-2.8	-5.55**	-6.64	3.92	-3.88	-11.06*	22.13**	11.9**	6.16
18.	EI-2176-3 XEI-102	13.72**	10.83**	2.06	-2.26	-3.19	-4.31	8.44**	7.87**	-0.22	11.76**	2.7	-2.74
19.	EI-2178 X EI-102	15.85**	6.72*	-6.72	2.09	-3.15	-4.26	6.47*	-1.16	-8.54	16.47**	4.95	-0.46
20.	EI-2188 X EI-102	33.85**	24.47**	8.81	3.56	-1.47	-2.61	-12.59**	-14.5**	-20.92**	-0.52	-8.4**	-13.24**
21.	EI-2188-1 XEI-102	16.19**	12.61**	-1.55	2.01	-0.97	-2.11	-7.3**	-7.54**	-14.46**	2.16	-11.19**	-15.75**
22.	EI-2403 X EI-102	13.07**	10.11**	-3.76	2.07	1.25	0.08	-2.31	-11.42**	-18.07**	-9.48**	-11.67**	-16.21**
23.	EI-2448 X EI-102	13.52**	10.8**	-3.13	4.05*	-1.11	-2.25	6.94**	1.39	-6.24	11.42**	5.84*	0.23
24.	EI-2505 X EI-102	0.31	-0.68	-11.44*	-2.43	-3.59	-2.37	2.39	-0.16	-7.67	-10.84**	-13.68**	-12.56*
25.	EI-2507 X EI-102	-7.56**	-8.4**	-19.94**	0.77	0.06	0.33	12.77**	2.08	-5.59	-6.55*	-19.06**	-23.29**
26.	EI-2522 X EI-102	1.57	-7.95*	-19.54**	0.56	-1.7	-2.83	1.13	-7.56**	-14.46**	3.69	1.86	0.00
27.	EI-2525-2 X EI-102	3.4	1.39	-11.38*	-1.51	-3.02	-4.14	-6.77**	-12.46**	-19.06**	-2.08	-8.7**	-13.47**
28.	EI-2639 X EI-102	3.26	0.75	-7.43	-1.97	-4.66*	-5.75	-12.62**	-12.93**	-19.5**	4.24	2.71	-2.51
29.	EI-2642 X EI-102	-7.54*	-12.52**	-23.52**	-1.21	-3.12	-4.23	-1.74	-8.42**	-15.33**	-4.87	-18.36**	-22.6**
30.	EI-2653 XEI-102	14.61**	10.44**	-3.47	3.21	2.66	1.48	-9.59**	-10.71**	-17.42**	14.51**	4.7	-0.68
31.	EI-2159 X EI-670	27.92**	22.16**	3.73	-8.15**	-11.03**	-13.06**	1.37	-1.57	-20.59**	-0.49	-4.34	-14.84**
32.	EI-2172 X EI-670	21.73**	14.52**	-2.77	-1.67	-3.91	-6.11	-11.06**	-12.2**	-29.13**	16.95**	10.36**	-1.83
33.	EI-2176-3 X EI-670	22.17**	17.41**	8.13	-3.08	-3.45	-5.65	13.38**	6.67*	-2.3	-8.93**	-13.79**	-23.29**
34.	EI-2178 X EI-670	26.97**	18.52**	0.65	1.2	-3.46	-5.67	23.46**	22.36**	-1.2	8.8**	0.91	-10.27*
35.	EI-2188 XEI-670	39.01**	31.03**	11.27*	-5.51**	-9.61**	-11.67**	-17.58**	-21.21**	-30.23**	8.32**	2.74	-8.68
36.	EI-2188-1 X EI-670	12.44**	10.52**	-6.16	-11.84**	-13.94**	-15.92**	-25.04**	-29.66**	-35.27**	-1.13	-11.64**	-21.46**
37.	EI-2403 X EI-670	28.18**	26.61**	7.51	-3.41	-3.63	-5.83	1.46	-1.96	-20.92**	-8.64**	-9.28**	-18.26**
38.	EI-2448 X EI-670	20.56**	19.36**	1.36	-0.81	-5.2*	-7.37*	-1.99	-3.3	-19.82**	10.01**	7.76*	-4.11
39.	EI-2505 X EI-670	9.3**	6.7*	-4.86	-5.23**	-6.88**	-5.72	12.32**	7.71**	-5.26	-3.41	-9.28**	-8.22
40.	EI-2507 X EI-670	8.5**	7.93*	-7.37	-3.13	-4.36*	-4.11	3.21	-0.45	-19.72**	-2.43	-13.14**	-22.83**
41.	EI-2522 X EI-670	22.37**	12.36**	-4.57	-1.73	-3.39	-5.59	4.77	2.11	-17.63**	-12.5**	-16.65**	-18.04**
42.	EI-2525-2 X EI-670	11.52**	10.93**	-5.82	4.94**	3.92	1.55*	5.37*	5.02	-14.68**	-2.11	-5.93	-16.44**
43.	EI-2639 X EI-670	19.35**	14.83**	5.51	3.19	0.93	-1.37	13.69**	6.78*	-1.86	14.83**	12.9**	3.88*
44.	EI-2642 X EI-670	3.52	-0.7	-15.67**	0.65	-0.74	-3	13.31**	12.77**	-8.98*	-5.44	-16.62**	-25.8**
45.	EI-2653 X EI-670	18.78**	16.08**	-1.44	-3.06	-3.1	-5.23	-0.9	-6.14*	-15.33**	4.89	-1.23	-12.1*

* and ** represent level of significance at 5 and 1%, respectively, MPH = Mid ParentHeterosis, BPH = Better Parent Heterosis, SH = Standard Heterosis

DT 50 % = Days to 50 per cent tasseling, DS 50% = Days to 50 per cent silking, DBH 75% = Days to 75 per cent brown husk, PH = Plant height, EH = Ear height, EL = Ear length, EG = Ear girth, GRE = Grain row per ear, 100 GW = 100 Grain weight, GYP = Grain yield per plant, HI (%) = Harvest index, SC (%) = Starch content (%), PC (%) = Protein content and OC (%) = Oil content (%)

statistical significance of all three type of heterosis was determined by using “t” test. The magnitude of negative heterosis was considered desirable for days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent brown husk, plant height and ear height, whereas positive heterosis considered desirable for remaining traits under the study.

Results and Discussion

The highly significant variance were observed due to genotypes and parents (except ear length in E3 environment) for all the traits in individual environments E1, E2 and E3 and as well as over the environments (Table-1) indicating the presence of significant genetic difference in the experimental material. The sum of squares due parentsvs crosses were also found significant for almost all traits in all environments as well as over the environments (Table-1). Similarly, variance due to crosses were also found significant for all the traits under study in all the environments as well as on pooled basis indicating hybrids were differ for yield and components traits. These findingsin maize are in corroboration with (20, 21). The magnitude of components of all three type heterosis for different traits under the study is given in Table-2. Among the 45 hybrids, 14, 9 and 19 number of hybrids had showed negative and significant mid parent, better parent and standard heterosis, respectively on pooled basis for the trait days to 50 per cent tasseling. The range was varied from -8.39% (EI-2188-1 x EI-670) to 6.78% (EI-2653 x EI-102), from -8.71% (EI-2188-1 x EI-670) to 4.88% (EI-2653 x EI-102) and from -6.35% (EI-2522 x EI-03) to (EI-2448 x EI-102) 5.19% for mid parent, better parent and standard heterosis, respectively on pooled basis. The hybrid EI-2188-1 x EI-670 exhibited maximum significant and negative mid parent (-8.39 %) and better parent heterosis (-8.71%) on pooled basis, whereas hybrid EI-2522 x EI-03 (-6.35%) obtained highest magnitude of negative standard heterosis (-6.35%) on pooled basis for days to 50 per cent tasseling. The results are in corroboration with (22, 23). For days to 50 per cent silking, 13 hybrids for mid parent, 20 hybrids for better parent and11 hybrids for standard heterosis exhibited significant heterosis in desirable negative direction. The maximum magnitude of both mid parent (-7.25%) and better parent (-7.76%) heterosis was evident in the hybrid EI-2188-1 x EI-670 on pooled basis. The hybrids EI-2522 x EI-03 (-6.10 %) and EI-2188-1 x EI-670 (-6.10 %) revealed similar and highest magnitude of negative and significant standard heterosis on pooled basis. The magnitude of mid parent, better parent and standard heterosis in days to 50 per cent silking was ranged from -7.25 % (EI-2188-1 x EI-670) to 6.1 % (EI-2653 x EI-102), from -7.76 % (EI-2188-1 x EI-670) to 4.48 % (EI-2176-3 x EI-102) and from -6.10 % (EI-2522 x EI-03, EI-2188-1 x EI-670) to 3.74 % (EI-2507 x EI-03, EI-2448 x EI-102) on pooled basis, respectively for the trait days to 50 per cent silking. Out of the 45 hybrids on pooled basis, 13 number of hybrids for mid parent, 23 number of hybrids for better parent and 9 number of hybrids for standard heterosis exhibited significant and negative values for the trait days to 75 per cent brown husk. The hybrid EI-2642 x EI-03 had showed highest magnitude of significant negative mid parent (-6.98%), better parent (-7.63%) and standard heterosis (-5.35%) on pooled basis. The per cent mid parent, better parent and standard heterosis was ranged from -6.98% (EI-2642 x EI-03) to 7.59% (EI-2505 x EI-102), from -7.63% (EI-2642 x EI-03) to 6.67% (EI-2505 x EI-102) and from -5.35% (EI-2642 x EI-03) to 3.60% (EI-2505 x EI-102) among the 45 hybrids, respectively on pooled basisfor the trait days to 75 per cent brown husk. The 5 and 28 number of hybrids possessed negative and significant magnitude of better parent and standard heterosis, respectively for the trait plant height. None of the hybrid divulged negative and significant values of mid parent heterosis for the trait plant height on pooled basis. Among the 45 hybrids, hybrid EI-2188 x EI-670 (-11.36%) and hybrid EI-2172 x EI-03 (-24.63 %) obtained maximum magnitude of significant and negative better parent and standard heterosis, respectively. The magnitude of per cent significant heterosis was varied from -11.36% (EI-2188 x EI-670) to 21.68% (EI-2642 x EI-102) for better parent heterosis and from -24.63% (EI-2172 x EI-03) to -6.62% (EI-2403 x EI-03) for standard heterosis, on pooled basis for the trait plant height.The only single hybrid EI-2188-1 x EI-670 expressed negative and significant mid parent (-7.91%) and better parent heterosis (-10.44 %) among the 45 hybrids for the trait ear height. The 27 number of hybrids exhibited negative and significant standard heterosis among the 45 hybrids and maximum magnitude was recorded in the hybrid EI-2159 x EI-670 (-28.88%), over the check on pooled basis. The range of significant heterosis was varied from 7.91% (EI-2188-1 x EI-670) to 33.77% (EI-2507 EI-102), from -10.14% (EI-2188-1 x EI-670) to 37.46% (EI-2505 x EI-102) and from -9.36% (EI-2448 x EI-102) to -28.88% (EI-2159 x EI-670) for mid parent, better parent and standard heterosis on pooled basis for the trait ear height.Thus, these hybrids could be suitable for machine purpose harvest. The hybrid EI-2188-1 x EI-670 reported maximum magnitude of significant negative heterobeltiosis as well as mid parent heterosis for days to 50 per cent tasseling, days to 50 per cent silking and ear height, whereas hybrids EI-2642 x EI-03 reported maximum magnitude of negative and significant heterobeltiosis as well as mid parent heterosis for days to 75 per cent brown husk. The hybrid EI-2188 x

EI-670 recorded maximum magnitude of significant and negative heterobeltiosis as well as mid parent heterosis for the trait plant height. Thus these hybrids can be utilized in rainfed conditions to avoid drought stress in maize. The results are in corroboration with (22, 24, 25, 26, 27). The results for the trait ear length showed that among the 45 hybrids, 25 and 15 number of hybrids exhibited positive and significant relative and better parent heterosis on pooled basis, respectively. The hybrid EI-2653 x EI-03 expressed highest positive and significant relative heterosis (23.22 %) and better parent heterosis (22.73%) with a range varied from -8.28 % (EI-2505 x EI-03) to 23.22 % (EI-2653 x EI-03) and from -8.66 % (EI-2505 x EI-03) to 22.73% (EI-2653 x EI-03) on pooled basis. None of the hybrid, among the 45 studied hybrids surpassed the best check cultivar positively and significantly on pooled basis for the trait ear length.The 26 and 16 number of hybrids exhibited positive significant relative and better parent heterosis for the trait ear girth, respectively on pooled basis. The highest magnitude of positive and significant mid parent (16.79%) and better parent (15.17 %) heterosis was exhibited by the same hybrid EI-2505 x EI-102 on pooled basis. The significant magnitude of mid parent and better parent heterosis was varied from -11.58 % (EI-2505 x EI-03) to 16.79 % (EI-2505 x EI-102) and from -12.74 % (EI-2505 x EI-03) to 15.17 % (EI-2505 x EI-102), respectively on pooled basis. The two hybrids EI-2507 x EI-670 and EI-2653 x EI-03 were found superior over the best check cultivar with a significant magnitude of 4.17 % and 3.11 % for the trait ear girth, on pooled basis. For the trait grain rows per earon pooled basis, 24, 16 and 4 hybrids exhibited positive and significant heterotic effect for mid parent, better parent and standard heterosis, respectively**.**The hybrid EI-2642 x EI-670 exhibited highest magnitude for all three type of heterosis *viz.,* mid parent (29.75 %), better parent (27.09%) and standard heterosis (8.72%) on pooled basis. Therange wasvaried from -10.72 (EI-2522 x EI-102) to 29.75 % (EI-2642 x EI-670) for mid parent and from -14.08 % (EI-2522 x EI-102) to 27.09 % (EI-2642 x EI-670) for better parent heterosis, on pooled basis for the trait grain rows per ear.The 18 and 10 number of hybrids recorded positive and significant relative and better parent heterosis and among them hybrid EI-2448 x EI-102 obtained highest values for mid parent (32.09%) and better parent (29.95 %) over the environments for the trait 100-grain weight. The range for mid parent and better parent heterosis was varied from -21.90 % (EI-2642 x EI-03) to 32.09 % (EI-2448 x EI-102) and from -24.52 % EI-2178 x EI-03 to 29.95 % EI-2448 x EI-102, respectively on pooled basis. The only single hybrid EI-2448 x EI-102 (2.27 %)expressed positive and significant standard heterosis over the best check for the trait 100-grain weight on pooled basis.For the trait grain yield per plant, the 42 and 36 hybrids expressed significant and positive mid parent and better parent heterosis over the environments. The hybrid EI-2525-2 x EI-03 expressed highest magnitude of both mid parent (87.54 %) and better parent (81.63%) heterosis on pooled basis. The magnitude of significant mid parent and better parent heterosis among the 45 hybrids was varied from -14.69 (EI-2172 x EI-102) to 87.54 % (EI-2525-2 x EI-03) and from -28.30 % (EI-2172 x EI-102) to 81.63 % (EI-2525-2 x EI-03), respectively on pooled basis. The 3 hybrids EI-2525-2 x EI-03 (15.03 %), EI-2176-3 x EI-03 (11.64 %) and EI-2159 x EI-670 (7.19 %) out yielded the best check (standard heterosis) and proved to be high yielding than best check cultivar on pooled basis for grain yield per plant. The hybrids EI-2525-2 x EI-03, EI-2448 x EI-102, EI-2642 x EI-670, EI-2505 x EI-102 and EI-2653 x EI-03 recorded highest magnitude of significant and positive heterobeltiosis as well as mid parent heterosis for grain yield per plant, 100-grain weight, grain rows per ear, ear girth and ear length, respectively. These findings in maize are in corroboration with the findings reported by (27, 28, 29). The 36 and 34 number of hybrids exhibited positive and significant mid parent and better parent heterosis, respectively on pooled basis for the trait harvest index. The maximum positive and significant mid parent (42.32%) and better parent (36.26%) heterosis was evident in the hybrid EI-2188 x EI-03 over the environments for this trait. The magnitude was varied from -7.56 % (EI-2507 x EI-102) to 42.32 % (EI-2188 x EI-03) and from 12.52 % (EI-2642 x EI-102) to 36.26 % (EI-2188 x EI-03) for mid parent and better parent heterosis, respectively on pooled basis. The3 hybrids EI-2176-3 x EI-03 (12.79 %) followed by EI-2188 x EI-03 (11.95 %) and EI-2188 x EI-670 (11.27 %) out yielded the check cultivar (standard heterosis) on pooled basis for the trait harvest index. The 2 hybrids expressed positive and significant relative heterosis and maximum magnitude was exhibited by hybrid EI-2525-2 x EI-670 (4.94%) on pooled basis for the trait starch content. Among the 45 hybrids, the mid parent heterosis was varied from -11.84 % (EI-2188-1 x EI-670) to 4.94 % (EI-2525-2 x EI-670) on pooled basis. None of the hybrid divulged positive significant heterobeltiosis on pooled basis. The 2 hybrids EI-2505 x EI-03 (2.48 %), EI-2525-2 x EI-670 (1.55 %) were found superior over the best check cultivar for starch content on pooled basis.The maximum positive and significant heterotic effect for mid parent heterosis was exhibited by the hybrid EI-2642 x EI-03 (24.66 %) with the range varied from -25.04 % (EI-2188-1 x EI-670) 24.66 % (EI-2642 x EI-03) on pooled basis for the trait protein content. The 12 hybrids showed positive significant heterobeltiosis and among them hybrid EI-2507 x EI-03 recorded maximum magnitude of 23.14 per cent on pooled basis. The range for heterobeltiosis was varied from -29.66 % (EI-2188-1 x EI-670) to 23.14 % (EI-2507 x EI-03) on pooled basis for the trait protein content. None of the hybrid out yielded the best check cultivar on pooled basis for the trait protein content. The 17 and 7 number of hybrids manifested positive and significant mid parent and better parent heterosis on pooled basis, respectively for the trait oil content. The hybrid EI-2172 x EI-102 (22.13 %) for mid parent, whereas hybrid EI-2653 x EI-03 for better parent (19.05 %) heterosis manifested highest magnitude. The significant mid parent heterosis was ranged from -12.50 % (EI-2522 x EI-670) to 22.13 % (EI-2172 x EI-102), whereas better parent heterosis ranged from -8.66 % (EI-2522 x EI-03) to 19.05 % (EI-2653 x EI-03) on pooled basis for oil content. In case of standard heterosis for oil content, the only hybrid EI-2639 x EI-670 (3.88 %) among the 45 evaluated hybrids, surpassed check cultivar on pooled basis. These findings on above quality traits in maize are in corroboration with the findings reported by (30, 31, 32, 33, 34). In the present investigation, The hybrids EI-2525-2 x EI-03 for grain yield per plant, EI-2448 x EI-102 for 100-grain weight, EI-2642 x EI-670 for grain rows per ear, EI-2505 x EI-102 for ear girth and EI-2653 x EI-03 for ear length recorded highest magnitude of significant positive heterobeltiosis as well as mid parent heterosis. The 3 hybridsEI-2525-2 x EI-03 (15.03 %), EI-2176-3 x EI-03 (11.64 %) and EI-2159 x EI-670 (7.19 %) out yielded the best check PHM-3 on pooled basis. Therefore, the present findings could better help and guide the plant breeders in recommending maize genotypes for some specific areas, and to use the tested breeding material in future breeding program so as to develop high yielding maize cultivars and hybrids.It was also reported that heterotic reaction for yield and component traits expressed only in selected cross combinations which showed that expression of heterosis due to divergence of parental genotypes as well as the variations among the alleles involved in the expression of traits. Further, this shows the predominant role of non-fixable and non-allelic interactions.

Acknowledgments

The author is grateful to the Head, Department of Genetics and Plant Breeding, Rajasthan College of Agriculture, Udaipur and Project Incharge, AICRP on Maize for providing breeding material and other necessary assistance during the course of research work.

References

1. Hake S. and Ross-Ibarra J. (2015). Genetic, evolutionary and plant breeding insights from the domestication of maize. *Journal of Research, ANGRAU,* 70(3): 257-263.
2. Schnable P.S., Ware D., Fulton R.S., Stein J.C., Wei F. and Pasternak S. (2009).The B73 maize genome complexity, diversity, and dynamics. *Science*, 326: 1112–1115.
3. Manglesdorf P.C. (1974). Corn: Its origin, evolution and improvement. *Harvard University Press*, Cambridge, Massachusetts, USA.
4. Piperno D.R. and Flannery K.V. (2001). The earliest archaeological maize (*Zea mays* L.) from highland Mexico: new accelerator mass spectrometry dates and their implications. *Proceedings of National Academy of Sciences,* 98: 2101-2103.
5. Gerpacio V.R. and Pingali P.L. (2007). Tropical and Sub-tropical Maize in Asia: Production System, Constraints and Research Priorities, *CIMMYT*, Mexico, pp. 93.
6. CGIAR (2015). CGIAR Strategy and Results Framework 2016–2030. Available online at http://www.cgiar.org/our-strategy.
7. USDA (2020). Global market analysis.international production assessment division, foreign agriculture services, United States Department of Agriculture, USA.pp. 28.
8. Anonymous (2020-21). Crop-wise first advance estimates of area, production and yield of various principal crops. *Commissionerate of Agriculture, Government of Rajasthan,* Jaipur. pp. 1.
9. Dass S., Singh M., Ashok K. and Aneja D.R. (1987). Stability analysis in maize.*Crop Research*, 14: 185-187.
10. Rosegrant M.R., Ringler C., Sulser T.B., Ewing M., Palazzo A. and Zhu T. (2009). Agriculture and food security under global change: Prospects for 2025/2050. *International Food Policy Research Institute,* Washington, D.C.
11. Shull G.H. (1908). The composition of field maize. *American Seed Trade Association,* Washington, D.C. 4, 296–301.
12. Duvick D.N. (2001). Biotechnology in the 1930s: The development of hybrid maize. *Nature Reviews Genetics*, 2: 69-74.
13. Karim A.N.M.S., Ahmed S., Akhi A.H., Talukder M.Z.A. and Mujahidi T.A. (2018). Combining ability and heterosis study in maize (*Zea mays* L.) hybrids at different environments in Bangladesh. *Bangladesh Journal of Agriculture Research*, 43(1): 125-134.
14. Duvick D.N. and Cassman K.G. (1999). Post–green revolution trends in yield potential of temperate maize in the North-Central United States. *Crop Sciences*, 39: 1622–1630.
15. Lindner R.C. (1944). Rapid analysis methods for some of more common organic substances of plant and soil. *Plant Physiology*, 19(1):76-84.
16. AOAC (1965). Official methods for oil analysis for Association of Official Agricultural Chemists. Washington D.C., 10th Ed.
17. Panse V.G. and Sukhatme P.V. (1985). Statistical methods for agricultural workers. IVth Enlarge Edition, *ICAR Publication,* New Delhi.
18. Fonseca S. and Patterson F.L. (1968). Hybrid vigour in seven-parental diallel crosses in common winter wheat (*Triticum aestvum* L.). *Crop Sciences,* 8: 85-88.

19. Meredith W.R. and Bridge R.R. (1972). Heterosis and gene action in cotton (*Gossypium hirsutam*). *Crop Sciences.,* 12: 304-310.

20. Ahmad S.Q., Khan S., Ghaffar M. and Ahmad F. (2011). Genetic diversity analysis for yield and other parameters in maize (*Zea mays* L.) genotypes. *Asian Journal Agriculture Sciences*, 3(5): 385-388

21. EL-Hosary A.A., EL-Badawy M.E.M., Saafan T.A.E., El Hosary A.A.A. and Hussein I.A.A. (2014). Evaluation of diallel maize crosses for physiological and chemical traits under drought stress. *Minufiya Journal of Agriculture Research*, 24(1): 43-63.

22. Devi T.R. and Prodhan H.S. (2004). Combining ability and heterosis studies in high oil maize (*Zea mays* L.) genotypes. *Indian Journal of Genetics and Plant Breeding*, 64(4): 323-324.

23. Amanullah S., Jehan M., Mansoor A. and Khan M.A. (2011). Heterosis studies in diallel crosses of maize. *Sarhad Journal of Agriculture*, 27(2): 207-211.

25. Saidaiah P., Satyanarayana E. and Kumar S.S. (2008). Heterosis for yield and yield component characters in maize (*Zea mays* L.). *Agricultural Science Digest*, 28: 201-208.

26. AmanJ., Bantte K., Alamerew S. and Tolera B. (2016). Evaluation of Quality Protein Maize (*Zea mays* L) Hybrids at Jimma, Western-Ethiopia. *Journal of Forensic Anthropology*, 1: 101-111.

27. Nagarajan D. and Nallathambi G.(20170. Estimation of heterosis for grain yield components in maize (*Zea mays* L.). *Research in Environmental Life Sciences*, 10(5): 435-339.

28. Singh S.B., Gupta B.B. and Singh A.K. (20100. Heterotic expression and combining abilty for yield and its components in maize (*Zea mays* L.). *Progressive Agriculture*, 10: 275-281.

29. Avinashe H.A., Jaiwar S.S., Girase V.K., Rawool S.A. and Khanorkar S.M. (2013). Assessment of heterosis and combining ability for biochemical components in crosses among high quality protein maize (*Zea mays* L.). *Journal of Soils and Crops,* 23(1): 176–184.

30. Dubey R.B., Joshi V.N. and Verma M. (2009). Heterosis for nutritional quality and yield in conventional and nonconventional hybrids of maize (*Zea mays* L.). *Indian Journal of Genetics*, 69(2): 109-114.

31. Khan R. and Dubey R.B.(2015). Combining ability analysis for nutritional qualityand yield in maize (*Zea Mays* L.). *The Bioscan,*10(2): 785-788.

32. Gurjar N.R., Dadheech A., Kumar S. and Chittora K. (2020). Elucidating the heterosis for yield and quality parameters in maize (*Zea mays* L.). *Current Journal of Applied Science and Technology,* 39(20): 80-85.

33. Vikas Kumar, Subhash Chand, Rajni Jain, Dilip Kumar, Mahendra Singh, Chaudhary K.R. and Chauhan M.S. (2021). Analysis of temporal change in cropping pattern and its reasons in Bulandshahr district of Uttar Pradesh. *Progressive Research : An International Journal*, 16(2): 154-158.

34. Yallappa M. and Mahadeva Swamy (2021). Isolation of potassium solubilizing bacteria from rhizosphere soils of different crops of Yadgiri district. *Progressive Research : An International Journal*, 16(1): 78-80.