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Heterosis Analysis in Single cross Maize (*Zea mays* L.) Hybrids

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ABSTRACT

The present investigation consisted of 53 entries including 36 hybrids along with 12 parents, 3 testers and 2 checks viz., PHM-3 and Pratap Raj Hybrid Maize 1095 were evaluated in three different environments during *Kharif* 2023. The estimates of standard heterosis for grain yield and its attributing traits along with quality traits showed that hybrid L4×T3 exhibited maximum estimates of significant positive standard heterosis for grain yield per plant E1 (9.80%), in E3 (9.31%) and on pooled basis (13.67%). This hybrid also possessed maximum significant estimates of economic heterosis for ear girth (7.92%) in E1 and protein content in E1 (7.88%) while negative economic heterosis for ear height (-17.20%) in E1 environment. For other agro-morphological traits, hybrid L9×T1 for 100-grain weight (6.50%), L1×T1 for ear height (-18.44%) and L8×T3 for number of grain rows per ear in E3 (8.21%) and L8×T1 (6.90%) for harvest index showed maximum economic heterosis across the environment. L4×T3 exhibited maximum estimates of significant positive standard heterosis suggesting that hybrid may be exploited before commercial release for confirmation of its superiority.

Key words : *Heterosis, Maize*

Introduction

Maize (*Zea mays* L.; 2n = 20) is one of versatile and multi utility as well as a foundational model for genetics and genomics (Hake and Ross-Ibarra, 2015). It was domesticated around 10,000 years ago from Teosinte (*Zea mays* L. spp. *Parviglumis*) in South Western Mexico's Balsas River Basin (Schnable *et al.*, 2009). Teosinte is the closest living relative, according to morphology, crossability, chromosome morphology, and molecular genetic studies (Dhillon *et al.,* 2005). The Portuguese introduced cultivated maize to India in the seventeenth century (Mukherjee *et al.*, 1971; Mangelsdorf, 1974).

Globally, maize is cultivated on 204.63 million hectares across 165 countries, producing a total of 1,214.29 MMT with an average productivity of 5.93 metric tons per hectare (USDA, 2023). It ranks among the top three most widely grown cereal crops worldwide as of 2022, and a 5.08 percent increase in production is projected for 2023 (USDA, 2023). In Asia, eight major maize-producing countries China, India, Indonesia, Nepal, Pakistan, Philippines, Thailand, and Vietnam account for 98% of the continent's maize production and 28% globally (Prasanna, 2014).

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In India, it is grown in 10.0 M ha with a total production of 34.30 MMT, and average productivity of 3.43 metric t/ha (USDA, 2023). It is grown both in *kharif* and *rabi* seasons with a share of 85 per cent and 15 percent, respectively. About 25 per cent of maize produced is used for human consumption (Kaul, 2009). Among all the states, percent share of production in Karnataka (13.83%) was found to be maximum followed by Madhya Pradesh (13.65%), Tamil Nadu (8.21%), Maharashtra (7.82%), Andhra Pradesh (7.61%), Bihar (7.02%), Uttar Pradesh (6.22%), West Bengal (5.73%) and Rajasthan (4.22%) (Patel *et al*., 2022). In Rajasthan, it occupied an area of 9.57 lakh ha with production of 21.79 lakh tonnes and productivity of 2277 kg/ha (Anonymous, 2022-23).

Heterosis plays a crucial role in agricultural production, particularly exemplified by maize, which has achieved significant yield potential through hybrid development. Maize breeding programs prioritize the complexity of this trait, aiming to enhance productivity worldwide. Hybrid cultivars, especially single cross hybrids, have significantly boosted maize production and food security (Karim *et al.*, 2018). The annual yield increases of approximately 15 percent attributed to hybrids and heterosis underscores their importance (Duvick and Cassman, 1999). Therefore, comprehending the genetic basis of heterosis and general combining ability (GCA) in key agronomic traits is crucial for maize breeders and researchers (Flint-Garcia *et al.*, 2009; Thiemann *et al.*, 2014).

Materials and Mmethod

The Rajasthan College of Agriculture, Udaipur is located in the Aravalli Hill Ranges in the Southern part of the Rajasthan. Geographically it is located between 24°35'31.5" latitude 73°44'18.2" longitudes with an altitude of 582.17 m above mean sea level. The experimental material comprised of 12 inbred lines, 3 testers, their 36 F_1s and two checks *viz.*, PHM-3 and Pratap Raj Hybrid Maize 1095. These 36 F_1s were obtained by crossing 12 inbred lines and 3 testers in Line X Tester mating design. These 15 parents (12 lines and 3 testers) along with 36 hybrids and two checks were evaluated at three environments viz; Udaipur (E1), Chittorgarh (E2) and Banswara (E3) during *Kharif*-2023. 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.

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's method by Lindner R.C. (1944) and soxhlet's ether extraction method by AOAC (1965), 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). 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 Shull (1908) and Fonseca and Patterson (1968).

Results and Discussion

Partitioning of genotypic variance into parents, hybrids and parents v/s hybrids revealed that in all the three environments there were significant differences except mean square due to parents for days to 50 per cent silking in E2, ear height in E3, harvest index in E2, grain starch content in E3, while days to 50 per cent tasseling and plant height in all the three environments. The mean squares due to hybrids were also significant for all the characters in all the environments except for ear length in E2, plant height in E3 and days to 50 per cent tasseling in all the three environments while mean square of parents v/s hybrids were non-significant for days to 50 per cent tasseling in E1 and E3, days to 50 per cent silking in E1 and E2, days to 75 per cent brown husk in E2, plant height in E1 and E2 and starch content in E1 environments.

The estimates of standard heterosis for grain yield and its attributing traits along with quality traits showed that hybrid L4×T3 exhibited maximum estimates of significant positive standard heterosis for grain yield per plant E1 (9.80%), in E3 (9.31%) and on pooled basis (13.67%). This hybrid also possessed maximum significant estimates of economic heterosis for ear girth (7.92%) in E1 and protein content in E1 (7.88%) while negative economic heterosis for ear height (-17.20%) in E1 environment. In case of maturity traits, hybrid L6×T3 expressed significant negative economic heterosis for days to 50 percent tasseling on pooled basis (-5.95%), in E1(- 5.00%), 50 percent tasseling in E3 (-6.21%) and hybrid L5×T3 (-5.06%) for days to 75 per cent brown husk on pooled basis.

For other agro-morphological traits, hybrid L9×T1 for 100-grain weight (6.50%), L1×T1 for ear height (-18.44%) and L8×T3 for number of grain rows per ear in E3 (8.21%) and L8×T1 (6.90%) for harvest index showed maximum economic heterosis across the environment. Among the quality traits, for protein content hybrid L12×T2 (4.72%), for starch content, hybrid L6×T1 (4.55%) and for oil content hybrid L8×T3 (9.18%) on pooled basis depicted the maximum significant positive economic heterosis.

Conclusion

The estimates of standard heterosis for grain yield and its attributing traits along with quality traits showed that hybrid L4×T3 exhibited maximum estimates of significant positive standard heterosis for grain yield per plant E1 (9.80%), in E2 (9.31%) and on pooled basis (13.67%). This hybrid also possessed maximum significant estimates of economic hetero-

Table 1. Extent of heterosis for 100- Grain Weight (g)

Sl.	Crosses	Heterosis				Heterobeltiosis				Economic Heterosis			
No.		E1	E2	E3	Pool	E1	E2	E3	Pool	E1	E2	E3	Pool
1.	L1 x T1	-12.21**	-5.06	-10.46**	-9.35**	-	-	-	-	-	-	-	-
2.	L2 x T1	-8.68**	19.78**	7.28*	5.75	-	6.31	-	-	-	-	-	-
3.	L3 x T1	3.75	22.76**	9.20**	11.64**	-	12.81**	-	1.74	-	-	-	-
4.	L4 x T1	-4.49	21.91**	7.45*	7.89*	-	6.44	-	-	-	-	-	-
5.	L5 x T1	-2.00	11.35**	3.05	3.92	-	-	-	-	-	-	-	-
6.	L6 x T1	7.71*	38.91**	4.68	16.53**	-	19.64**	-	0.38	-	-	-	-
7.	L7 x T1	-17.16**	13.26**	22.18**	5.91	-	-	7.89*	-	-	-	1.14	-
8.	L8 x T1	-10.78**	5.30	3.98	-0.75	-	-	-	-	-	-	-	-
9.	L9 x T1	20.36**	56.20**	31.54**	35.42**	7.68*	38.74**	16.55**	20.49**	3.79	6.45*	9.26**	6.50*
10.	L10 x T1	0.47	39.89**	18.60**	19.03**	-	27.30**	8.31*	8.56*	-	-	1.54	-
11.	L11 x T1	-12.42**	28.81**	7.74*	7.20*	-	18.58**	-	-	-	-	-	-
12.	L12 x T1	-11.61**	22.92**	6.77*	5.21	-	17.18**	2.92	2.55	-	-	-	-
13.	L1 x T2	-32.49**	-15.13**	-4.86	-17.73**	-	-	-	-	-	-	-	-
14.	L2 x T2	9.11**	33.86**	15.04**	19.02**	-	17.70**	3.30	5.42	-	-	-	-
15.	L3 x T2	-6.87*	17.23**	6.83*	5.45	-	6.67	-	-	-	-	-	-
16.	L4 x T2	3.83	33.17**	22.63**	19.49**	-	15.20**	7.84*	4.25	-	-	-	-
17.	L5 x T2	8.30**	32.22**	19.50**	19.67**	-	14.45**	4.80	4.48	-	-	-	-
18.	L6 x T2	6.40*	34.85**	14.43**	18.17**	-	15.09**	-	1.73	-	-	-	-
19.	L7 x T2	26.61**	66.07**	18.04**	36.23**	8.98**	42.41**	5.11	18.47**	5.30	11.67**	-	4.86
20.	L8 x T2	6.06*	26.59**	10.67**	14.17**	-	15.91**	1.03	4.81	-	-	-	-
21.	L9 x T2	19.91**	47.84**	29.12**	31.88**	7.16*	30.08**	15.37**	17.27**	3.54	2.00	6.10*	3.80
22.	L10 x T2	16.41**	51.72**	12.69**	26.41**	6.13	36.73**	3.81	15.22**	2.55	7.21*	-	1.98
23.	L11 x T2	-4.90	29.37**	11.45**	11.33**	-	17.92**	3.07	3.44	-	-	-	-
24.	L12 x T2	-3.48	29.67**	8.14**	10.72**	-	22.35**	5.21	7.85*	-	-	-	-
25.	L1 x T3	-13.81**	13.23**	8.19**	2.17	-	1.50	-	-	-	-	-	-
26.	L2 x T3	-7.30*	17.49**	2.62	3.89	-	2.66	-	-	-	-	-	-
27.	L3 x T3	4.89	24.78**	3.53	10.74**	-	12.80**	-	-	-	-	-	-
28.	L4 x T3	8.71**	37.15**	15.44**	19.94**	-	17.91**	-	2.80	-	-	-	-
29.	L5 x T3	6.92*	37.26**	15.44**	19.34**	-	18.08**	-	2.36	-	-	-	-
30.	L6 x T3	4.61	27.50**	20.33**	17.15**	-	8.16*	1.63	-	-	-	0.21	-
31.	L7 x T3	4.63	29.72**	-6.21*	8.74**	-	10.56**	-	-	-	-	-	-
32.	L8 x T3	-13.47**	21.79**	1.15	2.59	-	10.78**	-	-	-	-	-	-
33.	L9 x T3	3.43	36.05**	14.31**	17.35**	-	18.96**	-	2.46	-	-	-	-
34.	L10 x T3	8.39**	35.40**	-7.99**	11.29**	-	21.22**	-	-	-	-	-	-
35.	L11 x T3	-5.69*	21.62**	5.09	6.43*	-	10.13**	-	-	-	-	-	-
36.	L12 x T3	-15.34**	17.78**	3.55	1.20	-	10.37**	-	-	-	-	-	-

*,** Significant at 5% and 1% respectively

Table 2. Extent of heterosis for Grain Yield Per Plant (g)

Sl. No.	Crosses	Heterosis				Heterobeltiosis				Economic Heterosis			
		E1	E2	E3	Pool	E1	E2	E3	Pool	E1	E2	E3	Pool
1.	L1 x T1	37.61**	44.81**	32.44**	37.90**	34.60**	44.22**	26.89**	34.91**	-	-	-	-
2.	L2 x T1	45.94**	58.16**	44.57**	48.99**	32.31**	42.78**	29.21**	34.21**	-	-	-	-
3.	L3 x T1	61.97**	85.41**	65.95**	70.28**	54.14**	75.62**	62.31**	63.40**	-	-	-	-
4.	L4 x T1	70.92**	70.79**	62.04**	67.73**	58.92**	62.75**	45.98**	55.31**	-	-	-	-
5.	L5 x T1	38.28**	42.22**	40.45**	40.19**	33.22**	33.19**	31.17**	32.46**	-	-	-	-
6.	L6 x T1	47.16**	71.31**	35.97**	50.22**	35.77**	58.50**	22.16**	37.38**	-	-	-	-
7.	L7 x T1	41.80**	70.60**	52.57**	54.01**	37.72**	63.33**	45.14**	47.84**	-	-	-	-
8.	L8 x T1	-0.44	11.97**	-3.30	2.24	-	-	-	-	-	-	-	-
9.	L9 x T1	75.29**	109.72**	69.92**	83.37**	72.35**	106.27**	69.79**	81.36**	4.34	4.17	-	1.70
10.	L10 x T1	21.32**	32.82**	15.35**	22.54**	14.82**	25.18**	11.43*	16.69**	-	-	-	-
11.	L11 x T1	27.51**	72.96**	26.53**	40.03**	26.55**	64.72**	22.99**	36.30**	-	-	-	-
12.	L12 x T1	35.58**	56.96**	30.05**	39.96**	30.59**	48.54**	29.11**	35.53**	-	-	-	-
13.	L1 x T2	42.16**	44.50**	40.96**	42.42**	39.58**	41.29**	35.76**	40.52**	-	-	-	-
14.	L2 x T2	68.80**	72.84**	67.12**	69.35**	53.57**	58.67**	50.07**	53.73**	-	-	-	-
15.	L3 x T2	25.47**	37.20**	42.78**	35.10**	18.97**	27.72**	38.92**	28.57**	-	-	-	-
16.	L4 x T2	52.50**	74.14**	69.95**	65.10**	42.30**	68.93**	53.84**	54.10**	-	-	-	-
17.	L5 x T2	70.74**	95.82**	74.66**	79.28**	65.10**	86.64**	63.93**	70.79**	-	-	-	-
18.	L6 x T2	58.21**	97.96**	57.23**	69.38**	46.47**	86.35**	41.94**	56.12**	-	-	-	-
19.	L7 x T2	80.06**	93.19**	80.20**	83.86**	75.53**	88.32**	72.30**	77.97**	1.90	-	-	-
20.	L8 x T2	27.26**	57.86**	29.57**	37.13**	13.85**	36.43**	17.92**	22.15**	-	-	-	-
21.	L9 x T2	73.83**	96.87**	73.50**	80.35**	70.26**	90.16**	72.44**	76.87**	3.07	-	-	-
22.	L10 x T2	31.76**	101.40**	37.47**	54.03**	24.25**	86.56**	32.12**	45.48**	-	2.96	-	-
23.	L11 x T2	40.01**	107.89**	38.94**	58.65**	39.50**	101.55**	35.76**	55.73**	-	-	-	-
24.	L12 x T2	45.51**	92.24**	55.09**	62.68**	39.64**	78.79**	53.16**	56.23**	-	-	-	-
25.	L1 x T3	29.23**	40.56**	27.20**	31.91**	19.77**	32.44**	16.77**	22.44**	-	-	-	-
26.	L2 x T3	42.56**	58.20**	49.13**	49.51**	23.02**	35.00**	28.13**	28.39**	-	-	-	-
27.	L3 x T3	46.37**	55.44**	48.88**	49.95**	45.51**	53.95**	45.47**	47.99**	-	-	-	-
28.	L4 x T3	89.59**	108.00**	80.73**	92.01**	67.53**	86.65**	56.46**	69.21**	9.80**	9.31**	-	13.67**
29.	L5 x T3	70.26**	64.51**	67.35**	67.55**	55.56**	45.26**	49.92**	50.50**	1.96	-	-	-
30.	L6 x T3	47.64**	43.82**	55.00**	49.12**	29.51**	25.56**	33.85**	29.90**	-	-	-	-
31.	L7 x T3	30.38**	55.78**	25.42**	36.02**	20.03**	40.41**	14.35**	24.01**	-	-	-	-
32.	L8 x T3	-3.64	21.20**	2.27	5.91	-	12.83**	-	-	-	-	-	-
33.	L9 x T3	55.29**	101.54**	52.79**	68.00**	49.36**	92.18**	46.19**	60.88**	-	6.99**	-	-
34.	L10 x T3	47.56**	47.65**	37.65**	44.05**	47.54**	47.01**	36.19**	43.32**	-	-	-	-
35.	L11 x T3	54.94**	67.79**	44.80**	54.96**	45.58**	50.48**	34.75**	43.15**	-	-	-	-
36.	L12 x T3	44.75**	82.32**	53.16**	58.97**	42.11**	80.75**	47.46**	55.44**	-	0.63	-	-

*,** Significant at 5% and 1% respectively

sis for ear girth (7.92 cm) and protein content in E1. The top five hybrids viz., L7 x T2, L4 x T3, L3 x T1, L9 x T1, L8 x T2 were identified as best performing hybrids on the basis per se performance for grain yield per plant other yield contributing traits. The 34 hybrids showed heterobeltiosis for grain yield per plant on the pooled basis with maximum significant positive heterobeltiosis exhibited by hybrid L9×T1 in E1 (72.35%), in E2 (106.27%) and in E3 (81.36%) environment. A perusal of mid parent heterosis revealed that positive significant mid parent heterosis for this trait was exhibited by 34 hybrids on the pooled basis with maximum positive mid parent heterosis exhibited by hybrid L4×T3 (92.01%) on pooled basis.

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