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Heterosis Exploration in Single-Cross Inbred Line Combinations of Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study evaluates 56 crosses generated through the Line × Tester mating pattern using seeds collected during the kharif season of 2022 from the Post Graduation research Farm at Lovely Professional University (LPU), Punjab's Post Graduate Research Farm during the 2022 kharif season. In addition to the hybrids, fifteen parent lines and one check were grown. The experiment was conducted using a Randomized Block Design (RBD) with three replications in the 2023 kharif season. Significant disparities between the entries were found by analyzing the mean squares for 11 attributes. Out of all the crosses, the hybrid BPPT1 x BML20 showed the greatest standard heterosis; BML6 x BML3 ranked second in terms of grain yield per plant. Crucially, these hybrids showed noteworthy and desired standard heterosis for other characteristics as well as grain production, suggesting that they might lead to improved overall performance. Using heterosis in maize might result in better cross combinations, meeting the increasing demand for the grain due to its bioactive qualities. The results of this study can help breeders create robust and high yielding varieties of maize, promoting sustainable agriculture and guaranteeing food security in the face of

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changing environmental issues. The findings of this research can guide breeders in developing high yielding and resilient maize varieties, contributing to sustainable agriculture, and ensuring food security in the face of evolving environmental challenges.

Keywords: Maize; inbreds; L x T; hybrid vigour; heterobeltiosis; standard heterosis.

1. INTRODUCTION

After rice and wheat, maize (*Zea mays* L.) is India's third-most significant cereal crop. It is becoming increasingly important because to the increased need for a variety of purposes, particularly in feed and industry. Because of its capacity to adapt to a wide range of climatic conditions, maize is an important crop with a significant cultivated area. For this reason, it is acknowledged as the principal crop in humid, subtropical, hot-temperate, and temperate zones. The result of genetic and phenotypic variety is heterosis, also known as hybrid vigor, which is the superior performance of a hybrid in comparison to its parents. The majority of important economic qualities are qualitative in nature and governed by an excessive number of main genes. True heterosis and pseudo heterosis are the two main categories into which heterosis can be broadly classified. There is a rise in overall vigor, yield, and adaptability when there is real heterosis. Only vegetative growth is increased in the F1 hybrid in the pseudo heterosis scenario. It refers to the superiority of F1's over the standard commercial check type. Thus, it is also known as mastery over checks or economic heterosis. At the moment, hybrid varieties occupy nearly the whole area used for maize farming. Thus, it appears that using the heterosis phenomenon and introducing hybrid varieties is one strategy to boost yield in most horticultural and agronomic plants in order to provide food for the growing global population [1].

Due to its remarkable yield increase, the application of hybrid vigor in maize has garnered significant attention. New hybrids must constantly adapt to outperform current hybrids in terms of yield and quality. The goal of the current study is to assess the expression of heterosis in fifteen inbred crosses using the line x tester mating technique [2].

2. MATERIALS AND METHODS

Using the Line × Tester mating design, 56 crosses were produced for this research investigation. The cross seeds were obtained from the Lovely Professional University (LPU), Punjab, Post Graduate Research Farm, School of Agriculture. During the 2023 kharif season, these 56 distinct crosses eight females, seven males, and one check were employed and evaluated utilizing a Randomized Block Design (RBD) with three replications. Special measures were taken during pollination to exclude any possibility of contamination to guarantee the correctness of the results. In fall 2022, manual emasculation and pollination were carried out, and in spring 2023, the seeds of the F1 hybrids and their parent lines were sowed. In a Randomized Block Design with three replications, seedlings were positioned in the field with a 45 cm gap between rows and 15 cm between plants. Data were gathered for five competing plants in each treatment, which comprised 20 plants arranged in two rows.

Eleven observations were recorded for the study, including Days to 50% Tasseling, Days to 50% Silking, Days to Maturity, Grain Yield Per Plant (g), Number of Kernel Rows per Ear, Number of Kernels per Row, 100-Kernel Weight (g), Plant Height (cm), Ear Height (cm), Ear Length (cm), and Ear Girth (cm). To learn more about the growth and productivity of the experimental plants, the study team observed the developmental phases, yield characteristics, and insect infestation.

2.1 Statistical Analysis

2.1.1 Estimation of heterobeltiosis and standard heterosis

2.1.1.1 Heterobeltiosis

It was calculated as the deviation of F_1 from the better parent and was expressed as per cent basis by the following formula [3].

$$\text{Heterobeltiosis}(\%) = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where,

$\overline{F_1}$ = Mean performance of F_1

$\overline{SC}$ = Mean performance of the standard hybrid (DHM117)

Table 1. List of genotypes and check used in crossing programme

Genotypes	Notation	Source
	Males	
BML 22	M1	CIMMYT, Hyderabad
BML 20	M2	CIMMYT, Hyderabad
BML 15	M3	CIMMYT, Hyderabad
BML 14	M4	CIMMYT, Hyderabad
BML 8	M5	CIMMYT, Hyderabad
BML 3	M6	CIMMYT, Hyderabad
HKI 335	M7	CIMMYT, Hyderabad
	Females	
BPPTI 34	F1	CIMMYT, Hyderabad
BPPT 135	F2	CIMMYT, Hyderabad
BPPT144	F3	CIMMYT, Hyderabad
HKI 1332	F4	CIMMYT, Hyderabad
BML 6	F5	CIMMYT, Hyderabad
HKI 586	F6	CIMMYT, Hyderabad
HKI 295	F7	CIMMYT, Hyderabad
HKI 323-8	F8	CIMMYT, Hyderabad
DHM 117	**Check**	ANGRAU, Hyderabad

2.2 Standard Heterosis

Standard heterosis referred to as the superiority of F_1 over standard hybrid and was estimated as per the formula given byMeredith et *al*. [4].

$$\text{StandardHeterosis}(\%) = \frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$$

Where;

$\overline{F_1}$ = Mean performance of F_1
$\overline{SC}$ = Mean performance of the standard hybrid (DHM117)

The following formulas were used to assess the significance of estimations of heterobeltiosis and standard heterosis.

S.E. of difference for heterobeltiosis and standard heterosis = (2Me/r)

Where;

Me = Error mean square
R = number of replications

C.D. = S.E. (d) x table value of ‘t’ at error d.f at P = 0.05 and 0.01 levels of significance Significance of heterosis was tested using t test:

$$t = \frac{\overline{F_1} - \overline{BP} \text{ or SC}}{\text{S.E. of heterosis over BP or SC}}$$

To determine significance, calculated "t" values were compared to table values at the error degree of freedom

3. RESULTS AND DISCUSSION

The estimation of heterosis for fifteen significant features in maize hybrids was the focus of this work. Heterosis, also referred to as hybrid vigor, is the occurrence in which offspring from two distinct parent lines perform better than their parents. Relative heterosis (F1 value over mid-parental value), heterobeltiosis (F1 value over greater parental value), and standard heterosis (F1 value over the standard check DHM117) were the three forms of heterosis that were examined. The following characteristics were evaluated for these parameters:

Days to 50% Tasseling: The duration in days between the date of seeding and the date at which 50% of the plants had begun to shed pollen was noted. Of the 56 crosses, 25 displayed heterosis above heterobeltiosis in a negative way, meaning that these crosses flowered at a desirable early stage. Additionally, 34 crossings showed negative heterosis as opposed to conventional heterosis, indicating an early tendency toward blooming. L5 x T6 displayed the greatest standard heterosis (-19.35%), whereas cross L7 x T3 displayed the most ideal heterobeltiosis (-18.38%). A few earlier researchers have found consistent findings, including [5-7].

The number of days from the date of planting to the date at which 50% of the plants had emerged with silk was measured and recorded as the "Days to 50% Silking." Of the 56 crosses, 17 displayed heterosis above heterobeltiosis in a negative way, meaning that these crosses flowered at a desired early stage. Additionally, 33 crossings showed negative heterosis relative to typical heterosis, indicating a tendency toward blooming. Cross L6 x T1 had the greatest standard heterosis (-19.81%), whereas L6 x T1 displayed the most acceptable heterobeltiosis (-13.09%). Previous researchers, including [8-10], have documented similar results. The productivity of crops has grown significantly because of research on maize heterosis. Hybrid varieties of maize yield more, have higher grain quality, and absorb more nutrients than their inbred counterparts. Compared to their inbred counterparts, hybrid varieties of maize yield more, have higher-quality grains, and absorb more nutrients.

Next, Days to maturity characteristic counted the number of days that elapsed between the date of planting and the date that 75% of cob husk turns brown after silk emergence. 23 of the 56 crosses showed negative heterosis above heterobeltiosis, indicating that these crosses will mature more quickly than desired. Furthermore, 45 crosses had negative heterosis as opposed to ordinary heterosis, which supports the idea that they mature early. Cross L8 x T7 had the greatest standard heterosis (-18.25%) for this feature, whereas L8 x T7 had the most ideal heterobeltiosis (-11.14%).

For measuring plant height (cm), the base to the tip of the tassel on five healthy chosen plants was measured in centimeters, and the mean value was reported in centimeters. Of the 56 crossings, 11 showed a decrease in height due to negative heterosis over heterobeltiosis. Furthermore, 29 crosses had negative heterosis as opposed to conventional heterosis, further confirming the plant's reduced height. L4 x T2 showed the maximum standard heterosis (-26.22%) for the trait, but cross L4 x T1 showed the desired heterobeltiosis (-18.87%). The findings show that for various crossings and features, the degree of heterosis varied considerably. While some crossings showed negative heterosis, which denotes a decline in the expression of features, others showed favorable heterosis, which suggested the possibility of increased performance. The results offer insightful information on the genetic potential and performance of hybridized maize, which helps breeding programs create durable and high-yielding cultivars. Previous investigators [11-13] have reported similar results.

The measurement of ear height (cm) was obtained by measuring the distance in centimeters from the base of the plant to the node where the uppermost ear is attached. Thirty of the fifty-six crosses showed positive heterosis above heterobeltiosis, suggesting that these crosses were taller. Furthermore, six displayed positive heterosis as opposed to conventional heterosis, demonstrating their greater ear height performance. For ear height, cross L8XT3 had the greatest standard heterosis (25.64%), whereas cross L5 x T1 displayed the most desired heterobeltiosis (53.52%).

Five randomly chosen fruits from each tagged plant were measured for ear length (cm) during the picking period, and the mean value was given in centimeters. Additionally, 34 crossings had positive heterosis above heterobeltiosis, suggesting that these crossovers were longer. 29 hybrids also displayed positive heterosis as opposed to ordinary heterosis. For ear length, cross L2 x T7 had the greatest standard heterosis (25.88%) and the highest desired heterobeltiosis (66.67%). The study also looked at ear grith (in centimeters). Nine crosses revealed positive heterosis above heterobeltiosis, indicating a desired increase in ear grith over the parents' average. Additionally, 34 crosses outperformed normal heterosis in terms of ear grith, as evidenced by positive heterosis. The cross L7 xT1 had the greatest standard heterosis (38.28%) for ear grith, whereas L1xT4 displayed the most acceptable heterobeltiosis (66.16%). Previous researchers like [14-16] obtained outcomes that were comparable.

For the number of Kernel Rows per Ear, each ear was counted to determine the number of kernel rows per ear, or seed rows per ear. 36 of the 56 crosses showed positive heterosis above heterobeltiosis, meaning that these crosses had more kernel rows. Furthermore, 11 crosses outperformed ordinary heterosis in terms of the number of kernel rows per ear, as evidenced by positive heterosis. In terms of the number of kernel rows per ear, cross L6 x T1 had the greatest standard heterosis (15.74%), whereas cross L8 x T7 displayed the most desired heterobeltiosis (46.02%). The study also looked at how many kernels there are in a row. A desirable increase in the number of kernels per row in comparison to the average of the parents was suggested by the 36 crossings that exhibited positive heterosis over heterobeltiosis. Additionally, 16 crosses outperformed the typical heterosis in terms of the number of kernels per row, demonstrating positive heterosis. In terms of the number of kernels per row, cross L6 x T1 had the greatest standard heterosis (27.20%), whereas cross L6 x T1 displayed the highest desired heterobeltiosis (56.13%).

The other traits, such as the 100-kernel weight (gm) Nineteen out of the fifty-six crosses showed positive heterosis above heterobeltiosis, suggesting that these crosses were heavier. Furthermore, 17 crosses outperformed the typical heterosis in terms of 100 kernel weight, as evidenced by positive heterosis. Out of the 56 crossings, 44 showed positive heterosis above heterobeltiosis in grain production per plant, indicating good yield in these crosses. were also assessed for heterosis levels, offering important insights into the productivity and performance of the experimental crosses. Furthermore, 19 crosses demonstrated positive heterosis over normal heterosis, suggesting their higher performance in terms of grain output per plant. In terms of grain yield per plant, the hybrid BPPT1 x BML20 came in top by expressing the greatest standard heterosis, followed by BML6 x BML3 (Table 2). Significant and desired heterosis for one or more characteristics is seen in all these crosses. Previous researchers [17-19] have documented similar results.

For every character under study, there was significant heterosis in both directions (i.e., positive, and negative heterosis) for all growth, earliness, and yield attributes. The magnitude of economic or standard heterosis was higher for most growth and earliness characters, and the estimates of standard heterosis were found to be highly variable in both direction and magnitude among crosses. The manifestation of negative heterosis observed in crosses for various traits could be attributed to the combination of the unfavorable genes of the parents. As a result, positive heterosis is desirable for crop yield, and negative heterosis is desirable for earliness and plant height. Maize showed heterosis for both yield and its attributing traits. For every attribute, hybrids differ in the degree of heterosis. Yield components should be considered to boost yield through selection.

Because L1 x T2 outperforms standard check 'DHM117' in terms of both days to 50% tasseling and grain yield per plant, it is the only cross that may be employed for both earliness in these parameters. It was determined that L1 x T2 and L2 x T5 were the best positive heterotic cross over superior parent (Heterobeltiosis) and standard check for grain production per plant. L7 x T3 and L5 x T2, L5 x T5, and L6 x T4 were found to be negatively heterotic crosses for days to 50% tasseling, respectively, indicating negative heterosis over better parent and standard check, which is crucial to capitalize on the early characteristics in maize. It is possible to assess the F1 hybrid L1 x T2, which has a high yield potential, further for Punjab's early kharif season. By fusing two different inbred lines, breeders can take advantage of heterosis and enhance the performance of the resulting hybrid. The primary objectives of heterosis research are to evaluate the hybrid's performance and identify the best combinations of inbred lines to maximize yield and other desirable traits. This study compares the hybrid's traits with those of its parents, including yield, disease resistance, and stress tolerance.

The research findings indicate that L7 x T3, L5 x T5, L5 x T6, and L6 x T4 can exploit heterosis for early maturity in maize. These genotypes also showed substantial negative heterosis for days to 50% tasseling over better parent and standard check, respectively. Grain yield per plant crossings L1 x T2 and L7 x T2 showed a substantially favorable heterosis impact over superior parent and standard check for yield qualities. These crosses showed promise as compared to the conventional check (DHM117), and they may be investigated further for commercial planting in Punjab in the early kharif. Previous researchers reported similar results, as [20] indicates. Inbred lines are commonly used in breeding operations to develop hybrids because they are genetically stable and display predictable traits. But inbreed lines are often affected by inbreeding depression, which leads to reduced productivity and vigor.

Furthermore, understanding the genetic basis of heterosis has been greatly aided by studies on heterosis. While the underlying mechanisms remain incompletely understood, the consensus is that hybrids perform better because of their heterozygosity, which is the outcome of combining different alleles from both parents. To determine the genetic cause of heterosis, scientists have been examining elements such gene dosage, epigenetic changes, and interactions between many genes.

Table 2. Heterobeltiosis and standard heterosis for grain yield and its attributing traits in maize

Cross No.	Genotypes	Days to 50 % Tasseling		Days to 50% silking		Days to maturity		Plant height (cm)		Ear Height (cm)		Ear Length (cm)	
		BPH	SH	BPH	SH	BPH	SH	BPH	SH	BPH	SH	BPH	SH
C1	L1 x T1	7.02**	-1.61	6.81*	-1.45	3.59	-2.75	9.36*	0.09	2.77	-23.02**	-10.42*	-16.34**
C2	L1 x T2	9.71**	3.23	3.05	-1.93	1.29	-4.93**	18.01**	-6.34	17.35**	-19.35**	-11.13*	-8.37
C3	L1 x T3	-10.86**	-16.13**	6.09*	0.97	3.45	-5.25**	2.83	-8.71*	49.37**	-5.05	-6.98	-4.09
C4	L1 x T4	6.86**	0.54	1.02	-3.86	5.87**	-4.71*	-5.48	-13.49**	8.68	-28.51**	30.89**	-2.72
C5	L1 x T5	4.00	-2.15	2.54	-2.42	2.17	-6.19**	14.08**	-3.36	9.15*	-16.25**	1.85	7.00
C6	L1 x T6	4.57*	-1.61	5.10	-0.48	-3.34	-2.86	20.86**	-2.51	26.61**	-15.75**	15.87**	-10.51*
C7	L1 x T7	-5.14*	-10.75**	-7.11**	-11.59**	-1.41	-4.49*	10.32*	-12.75**	8.10	-25.71**	39.36**	1.95
C8	L2 x T1	-6.51**	-15.05**	-4.79	-13.53**	5.67**	4.73*	10.81*	-9.75*	31.46**	-1.53	15.21**	7.59
C9	L2 x T2	-8.28**	-16.67**	-6.38*	-14.98**	-1.85	5.44**	16.40**	-7.62*	45.66**	0.11	8.68	12.06**
C10	L2 x T3	-8.28**	-16.67**	-7.45**	-15.94**	1.35	3.38	8.31	-11.78**	51.75**	4.29	8.49	11.87*
C11	L2 x T4	-5.92**	-14.52**	-4.26	-13.04**	5.93**	5.47**	-1.86	-20.07**	51.27**	3.96	47.38**	9.53*
C12	L2 x T5	-9.47**	-17.74**	-7.98**	-16.43**	2.13	6.47**	-7.18	-24.40**	35.17**	3.71	7.59	13.04**
C13	L3 x T6	-8.28**	-16.67**	-6.38*	-14.98**	-3.93*	6.63**	9.94*	-11.31**	46.19**	0.47	49.62**	15.56**
C14	L2x T7	-5.92**	-14.52**	-4.79	-13.53**	3.54	-11.14**	10.53*	-12.59**	54.76**	6.36	66.67**	21.60**
C15	L3x T1	10.53**	1.61	9.42**	0.97	4.45*	-2.75	-10.82*	-20.02**	-15.15**	-36.44**	26.04**	17.70**
C16	L3x T2	-1.68	-5.38*	-1.99	-4.83	-2.23	-4.93**	13.30**	-10.08**	-22.16**	-45.09**	7.36	10.70*
C17	L3 x T3	-13.81**	-16.13**	-4.98	-7.73**	-4.30*	-5.25**	10.66*	-1.75	0.00	-29.45**	4.72	7.98
C18	L3 x T4	-3.37**	-7.53**	-6.03*	-9.66**	-5.55**	-4.71*	23.35**	10.62**	-4.12	-32.36**	61.56**	21.01**
C19	L3 x T5	-4.97**	-7.53**	-4.98	-7.73**	-3.97*	-6.19**	-10.31*	-24.02**	-23.60**	-41.38**	7.78	13.23**
C20	L3 x T6	-0.56	-5.38*	1.53	-3.86	1.20	-2.86	27.37**	2.74	-16.55**	-41.13**	40.05**	8.17
C21	L3 x T7	-6.63**	-9.14**	-5.97*	-8.70**	-2.73	-4.49*	39.35**	10.20**	-6.19	-33.82**	54.81**	15.95**
C22	L4 x T1	0.58	-7.53**	-0.52	-8.21**	-0.86	4.73*	-18.87**	-25.75**	32.33**	-0.87	15.83**	8.17
C23	L4 x T2	-1.68	-5.38*	-2.00	-5.31*	-5.30**	5.44**	-7.04	-26.22**	39.31**	-4.25	3.40	6.61
C24	L4 x T3	0.00	-3.23	0.50	-2.90	-4.18*	3.38	-16.28**	-25.67**	48.12**	0.18	-6.79	-3.89
C25	L4 x T4	1.12	-3.23	-3.52	-7.25**	-4.55*	5.47**	-17.68**	-24.66**	43.82**	-2.73	55.30**	19.65**
C26	L4 x T5	-3.33	-6.45**	-2.00	-5.31*	-5.07**	6.47**	-9.58*	-23.40**	34.36**	3.09	3.89	9.14*
C27	L4 x T6	-7.91**	-12.37**	-6.63*	-11.59**	-4.31*	6.63**	-6.25	-24.37**	42.74**	-3.45	52.90**	18.09**
C28	L4 x T7	5.00*	1.61	5.00	1.45	-5.02**	-11.14**	-4.10	-24.16**	56.67**	7.67*	63.38**	25.88**
C29	L5 x T1	-7.02**	-14.52**	8.90**	0.48	5.63**	-2.75	26.41**	8.38*	37.65**	25.64**	31.04**	22.37**
C30	L5 x T2	-14.53**	-17.74**	1.00	-1.93	0.59	-4.93**	50.12**	19.14**	29.32**	18.04**	-2.45	0.58
C31	L5 x T3	-16.13**	-16.13**	-4.39	-5.31*	-2.58	-5.25**	41.35**	21.18**	5.46	-3.75	2.64	5.84

Cross No.	Genotypes	Days to 50 % Tasseling		Days to 50% silking		Days to maturity		Plant height (cm)		Ear Height (cm)		Ear Length (cm)	
		BPH	**SH**	**BPH**	**SH**	**BPH**	**SH**	**BPH**	**SH**	**BPH**	**SH**	**BPH**	**SH**
C32	L5 x T4	12.92**	-16.67**	-8.04**	-11.59**	-5.08**	-4.71*	20.23**	3.08	2.55	-6.40	21.92**	-3.70
C33	L5 x T5	-17.74**	-17.74**	-9.76**	-10.63**	-5.92**	-6.19**	58.49**	34.26**	28.13**	16.95**	-2.22	2.72
C34	L5 x T6	-15.25**	-19.35**	-1.02	-6.28*	-3.34	-2.86	43.74**	15.95**	25.22**	14.29**	43.60**	13.42**
C35	L5 x T7	-13.26**	-15.59**	-6.47*	-9.18**	-3.97*	-4.49*	56.28**	23.59**	21.95**	11.31**	48.03**	16.93**
C36	L6 x T1	2.34	-5.91**	-13.09**	-19.81**	1.50	4.73*	43.13**	28.87**	16.35**	1.96	13.75**	6.23
C37	L6 x T2	-6.15**	-9.68**	-7.46**	-10.14**	-4.09*	5.44**	44.60**	14.77**	8.88*	-4.58	9.62*	13.04**
C38	L6 x T3	-10.75**	-10.75**	-7.80**	-8.70**	-4.91**	3.38	36.22**	20.94**	-13.07**	-23.82**	7.36	10.70*
C39	L6 x T4	-14.04**	-17.74**	-6.53*	-10.14**	-3.96*	5.47**	32.85**	19.62**	-11.24**	-22.22**	44.24**	7.20
C40	L6 x T5	-11.29**	-11.29**	-9.71**	-10.14**	-6.21**	6.47**	-8.97*	-22.88**	17.30**	2.80	-3.33	1.56
C41	L6 x T6	3.39	-1.61	4.08	-1.45	2.39	6.63**	24.64**	0.54	-22.45**	-32.04**	49.62**	15.56**
C42	L6 x T7	-1.1	-3.76	-1.49	-4.35	-0.81	-11.14**	13.70**	-10.08**	-9.21*	-20.44**	24.34**	-8.56
C43	L7 x T1	1.17	-6.99**	-2.62	-10.14**	-2.75	-10.01**	30.81**	16.85**	-27.93**	-41.82**	26.25**	17.90**
C44	L7 x T2	2.79	-1.08	-1.49	-4.35	-4.93**	-9.12**	47.11**	16.75**	-13.51**	-30.18**	10.00*	13.42**
C45	L7 x T3	-18.38**	-18.82**	-7.32**	-8.21**	-5.25**	-8.56**	26.01**	11.88**	-14.41**	-30.91**	4.72	7.98
C46	L7 x T4	5.06*	0.54	0.00	-3.86	-4.71*	-9.51**	32.82**	18.65**	0.95	-18.51**	38.92**	4.86
C47	L7 x T5	0.54	0.00	-3.88	-4.35	-6.19**	-8.80**	54.89**	31.21**	14.01**	-7.96*	15.19**	21.01**
C48	L7 x T6	1.69	-3.23	-2.04	-7.25**	-2.86	-8.56**	51.01**	21.82**	-1.17	-20.22**	48.36**	14.59**
C49	L7 x T7	1.1	-1.61	-2.99	-5.80*	-4.49*	-8.71**	51.08**	19.47**	-0.63	-19.78**	46.39**	10.51*
C50	L8 x T1	10.65**	0.54	8.47**	-0.97	4.73*	-3.64*	-15.41**	-23.36**	29.66**	-2.87	16.25**	8.56
C51	L8 x T2	7.69**	-2.15	8.99**	-0.48	5.44**	-2.99	-3.79	-23.64**	38.68**	-4.69	7.74	11.09*
C52	L8 x T3	7.10**	-2.69	5.82*	-3.38	3.38	-4.89**	-14.26**	-23.88**	53.52**	-6.44	-4.53	-1.56
C53	L8 x T4	5.92*	-3.76	1.06	-7.73**	5.47**	-2.96	-16.22**	-24.09**	0.61	-33.82**	45.81**	8.37
C54	L8 x T5	10.65**	0.54	10.58**	0.97	6.47**	-2.04	-9.11*	-23.00**	-12.80**	-33.09**	7.78	13.23**
C55	L8 x T6	10.65**	0.54	11.11**	1.45	6.63**	-1.90	-7.33	-25.25**	-0.55	-33.82**	49.12**	15.18**
C56	L8 x T7	-5.92*	-14.52**	-4.76	-13.04**	-11.14**	-18.25**	-3.44	-23.64**	-1.59	-32.36**	49.60**	9.14*

**, ** denotes significance at 5% and 1% respectively*

Table 2. (Cont.…) Heterobeltiosis and Standard heterosis for yield and its attributing traits in Maize

Cross No.	Genotypes	Ear Grith (cm)		Number of Kernel Rows per Ear		Number of Kernels Per Row		100 Kernel Weight (gm)		Grain Yield per Plant	
		BPH	SH	BPH	SH	BPH	SH	BPH	SH	BPH	SH
C1	L1 x T1	64.52**	33.47**	6.74	4.03	8.71	-11.08*	-4.24	-2.29	30.69**	1.84
C2	L1 x T2	9.02	29.45**	14.82*	11.90*	15.43**	2.64	-24.19**	-22.65**	61.30**	25.69**
C3	L1 x T3	1.77	31.86**	13.87*	10.97	-9.51*	-7.12	-1.00	1.02	53.12**	19.32**
C4	L1 x T4	4.79	38.28**	9.60	6.80	4.69	-2.77	-5.90*	-2.54	7.91	-15.70**
C5	L1 x T5	4.68	32.66**	12.45*	9.58	3.26	0.40	-16.46**	-14.76**	8.18	-15.70**
C6	L1 x T6	5.11	35.07**	14.35*	11.43*	7.23	7.65	-17.96**	-16.28**	1.95	-13.86*
C7	L1 x T7	10.64	33.47**	11.50*	8.66	15.56**	-3.96	-4.24	-2.29	-1.55	-8.28
C8	L2 x T1	43.16**	14.99*	7.96	-14.03*	41.85**	21.64**	13.95**	12.21**	17.26*	-11.63
C9	L2 x T2	11.72*	32.66**	14.94*	-8.47	31.75**	17.15**	15.50**	13.74**	33.30**	3.88
C10	L2 x T3	-29.85**	-9.10	12.91	-10.09	13.88**	16.89**	17.57**	15.78**	52.09**	17.02**
C11	L2 x T4	-25.64**	-1.88	36.09**	11.20*	30.82**	21.50**	17.69**	21.88**	18.00*	-7.82
C12	L2 x T5	-20.67**	0.53	10.29	-12.18*	17.37**	14.12**	14.21**	12.47**	15.31*	-10.45
C13	L3 x T6	-2.39	25.43**	0.99	-19.58**	16.82**	17.28**	23.26**	21.37**	26.90**	7.23
C14	L2x T7	-3.34	16.60*	1.12	-7.78	32.15**	13.32**	21.19**	19.34**	2.75	-4.27
C15	L3x T1	53.16**	23.02**	12.43	-11.25*	2.62	-12.14*	-11.99**	-6.62*	26.34**	6.83
C16	L3x T2	4.96	24.63**	13.57	-10.09	-0.15	-11.21*	-7.43*	-1.78	16.86*	-1.18
C17	L3 x T3	-3.81	24.63**	14.78*	-9.40	-11.31*	-8.97	-6.95*	-1.27	20.43**	1.84
C18	L3 x T4	-26.86**	-3.48	10.03	-10.09	11.93*	3.96	-15.11**	-9.92**	-8.47	-22.60**
C19	L3 x T5	-1.03	25.43**	10.38	-12.87*	6.38	3.43	-11.75**	-6.36*	10.88	-6.24
C20	L3 x T6	2.61	31.86**	15.66*	-8.70	-1.84	-1.45	-6.95*	-1.27	34.89**	14.06*
C21	L3 x T7	3.99	25.43**	-1.68	-10.33	27.58**	9.23	14.63**	21.63**	-0.85	-7.62
C22	L4 x T1	28.16**	2.94	9.85	-13.80*	25.81**	2.90	-0.52	-2.54	21.38**	4.07
C23	L4 x T2	-21.42**	-6.70	16.49*	-7.78	8.46	-3.56	9.97**	1.02	16.09*	-0.46
C24	L4 x T3	-34.19**	-14.73*	4.54	-17.96**	0.39	3.03	-2.84	-4.33	38.85**	19.05**
C25	L4 x T4	-12.25*	15.79*	39.21**	13.75*	15.20**	6.99	-5.65	-2.29	26.36**	8.34
C26	L4 x T5	-27.65**	-8.30	24.31**	-2.45	10.04*	6.99	7.20*	-1.53	19.08**	2.10
C27	L4 x T6	-2.39	25.43**	30.21**	2.17	14.32**	14.78**	4.99	-3.56	31.34**	12.61*
C28	L4 x T7	9.31	31.86**	15.33*	5.18	30.63**	8.58	14.96**	5.60	31.38**	22.40**
C29	L5 x T1	36.16**	9.37	33.25**	1.48	29.35**	5.80	8.67**	18.07**	37.76**	16.49**
C30	L5 x T2	6.99	27.04**	28.19**	1.48	18.99**	5.80	7.49**	16.79**	40.01**	18.40**
C31	L5 x T3	-10.01	16.60*	15.13*	-11.25*	0.64	3.30	11.94**	21.63**	20.44**	1.84
C32	L5 x T4	-9.82	19.01**	-2.72	-20.51**	7.95	0.26	6.79*	16.03**	41.65**	19.78**

Cross No.	Genotypes	Ear Grith (cm)		Number of Kernel Rows per Ear		Number of Kernels Per Row		100 Kernel Weight (gm)		Grain Yield per Plant	
		BPH	**SH**	**BPH**	**SH**	**BPH**	**SH**	**BPH**	**SH**	**BPH**	**SH**
C33	L5 x T5	-28.28**	-9.10	12.36	-12.87*	5.02	2.11	9.84**	19.34**	20.44**	1.84
C34	L5 x T6	-6.76	19.81**	29.11**	1.02	5.78	6.20	8.20**	17.56**	42.11**	20.17**
C35	L5 x T7	-11.99*	6.16	17.36**	7.04	29.84**	7.92	22.25**	32.82**	27.22**	18.53**
C36	L6 x T1	46.16**	17.40*	46.02**	11.20*	56.13**	27.70**	-14.42**	-7.89*	14.83	-8.41
C37	L6 x T2	-2.48	15.79*	40.76**	11.43*	31.01**	16.49**	-22.93**	-17.05**	16.47*	-7.10
C38	L6 x T3	-9.39	17.40*	45.46**	12.13*	20.57**	23.75**	-9.46**	-2.54	26.44**	0.85
C39	L6 x T4	-18.34**	7.76	38.64**	13.29*	23.30**	14.51**	-16.08**	-9.67**	25.29**	-0.07
C40	L6 x T5	-27.01**	-7.50	41.61**	9.81	27.68**	24.14***	-21.04**	-15.01**	27.68**	1.84
C41	L6 x T6	-20.51**	2.14	42.13**	11.20*	25.62**	26.12**	-22.22**	-16.28**	24.88**	5.52
C42	L6 x T7	-29.31**	-14.73*	17.87**	7.50	42.86**	18.73**	11.58**	20.10**	6.49	-0.79
C43	L7 x T1	66.16**	33.47**	39.77**	12.59*	22.39**	9.63	-11.69**	-13.49**	49.24**	16.10**
C44	L7 x T2	6.31	26.24**	15.06*	-7.32	15.61**	3.56	-12.97**	-18.07**	56.49**	21.94**
C45	L7 x T3	-2.57	26.24**	13.04	-8.94	0.13	2.77	-13.44**	-14.76**	38.26**	7.56
C46	L7 x T4	-20.77**	4.55	15.13*	-5.93	12.07*	4.09	-5.65	-2.29	20.86**	-5.59
C47	L7 x T5	-1.66	24.63**	36.90**	10.28	11.94*	8.84	-0.54	-6.36*	53.12**	19.12**
C48	L7 x T6	-1.14	27.04**	25.40**	1.02	20.37**	20.84**	6.49*	0.25	35.22**	14.26*
C49	L7 x T7	-10.66	7.76	4.16	-5.00	12.96*	1.19	2.97	-3.05	-1.83	-8.54
C50	L8 x T1	42.16**	14.19*	20.23**	-3.15	20.52**	4.62	-7.64**	1.53	53.75**	18.59**
C51	L8 x T2	-9.36	7.63	18.39**	-4.63	14.39*	1.72	-25.93**	-18.58**	52.95**	19.19**
C52	L8 x T3	-33.05**	-13.25	-2.01	-21.06**	-2.83	-0.26	-25.69**	-18.32**	58.26**	22.08**
C53	L8 x T4	-22.70**	2.01	35.41**	10.65	10.94*	3.03	-21.06**	-13.23**	35.41**	5.78
C54	L8 x T5	-3.67	22.09**	16.95*	-5.79	9.91	6.86	-22.45**	-14.76**	31.98**	2.50
C55	L8 x T6	-12.49*	12.45	0.29	-19.21**	2.23	2.64	-15.74**	-7.38*	22.08**	3.15
C56	L8 x T7	-28.28**	-9.10	12.36	-12.87*	20.52**	4.62	6.02*	16.54**	7.90	0.53

**, ** denotes significance at 5% and 1% respectively*

Overall, maize single cross heterosis research has aided in the creation of improved maize hybrids and offered insightful information on the possible advantages of hybrid breeding. Research in this area will help us better understand the genetic pathways behind heterosis and make valuable contributions.

4. CONCLUSION

In conclusion, the hybrid BML14 X HKI1332 and BML14 X HKI295 exhibited significant positive heterosis for grain yield par plant. Before it is widely adopted, more research is necessary to evaluate its stability for yield and other criteria. All things considered, this hybrid offers a great chance to increase crop yield and resistance to pests, which makes it a good choice for effective and sustainable food production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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