Original Research Article

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

ABSTRACT:

This study evaluates 56 crosses generated through the Line × Tester mating design, using seeds collected during the kharif season of 2022 from the Post Graduate Research Farm at Lovely Professional University (LPU), Punjab. Alongside the hybrids, 15 parent lines and 1 check were cultivated, and the entire experiment followed a Randomized Block Design (RBD) with three replications during the kharif season of 2023. Analysis of the mean squares for 11 traits revealed significant differences among the entries. The hybrid BPPT1 x BML20 exhibited the highest standard heterosis across all crosses, with BML6 x BML3 ranking second in terms of grain yield per plant. Importantly, these crosses demonstrated significant and desirable standard heterosis not only for grain yield but also for other traits, indicating their potential for enhanced overall performance. The application of heterosis in maize has the potential to produce superior cross combinations, addressing the growing demand for maize driven by its bioactive properties. 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

Maize (*Zea mays* L.) is the third most important cereal crop in India next to rice and wheat. It is gaining significant importance on account of its growing demand for diversified uses, especially feed and industrial uses. Maize owes its importance and its high cultivation area to its adaptation ability to a wide variety of climatic conditions. That is why it is recognized as the main crop of temperate, hot-temperate, sub-tropical and humid zones. Heterosis, or hybrid vigor, is the better performance of a hybrid relative to the parents and is the outcome of the genetic and phenotypic variation. Most traits of economic importance are qualitative and controlled by several too many major genes. Generally, heterosis can be divided into two broad categories, true heterosis and pseudo heterosis. In the case of true heterosis, there is an increase in general vigor, yield, and adaptation. In the case of pseudo heterosis, the F_1 hybrid exhibits an increase in vegetative growth only. It refers to the superiority of F_1 over the standard commercial check variety. So, it is also called economic heterosis or superiority over checks. At present, almost the whole maize

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cultivation area is devoted to hybrids varieties. Therefore, it seems that one of the ways to increase yield in most agronomic and horticultural plants, to produce food for the ever-increasing world's population, is the use of the heterosis phenomenon and ~~introducing~~ introduction of hybrid varieties [1].
The exploitation of hybrid vigour in maize has gained much significance ~~in view of~~ because of its tremendous yield increase. There is a continuous need to evolve new hybrids, which should exceed the existing hybrids in yield and quality. The present work aims to evaluate the expression of heterosis in crosses of fifteen inbreds, following the line x tester mating scheme [2].

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2. MATERIAL AND METHODS

In this research study, a total of 56 crosses were created using the Line × Tester mating design. The cross seeds were acquired during the *kharif* season of 2023 from the Post Graduate Research Farm, School of Agriculture, Lovely Professional University (LPU), Punjab. These 56 different crosses, comprising 8 females and 7 males and 1 check were used and assessed using a Randomized Block Design (RBD) with three replications during the *kharif* season of 2023. To ensure the accuracy of results, special precautions were taken during pollination to prevent any chances of contamination. Hand-emasculation and pollination were performed during autumn 2022, while the seeds of F_1 hybrids and their parent lines were sown during spring 2023. The field planting involved placing seedlings at a spacing of 45 cm between rows and 15 cm between plants in a Randomized Block Design with three replications. Each treatment consisted of 20 plants in a two row, and data were recorded for five competitive plants.

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The study encompassed the recording of ten observations: Days to 50% Tasseling, Days to 50% Silking, Days to Maturity, Plant Height(cm), Ear Height (cm), Ear Length (cm), Ear Girth (cm), Number of Kernel Rows per Ear, Number of Kernels per Row, 100-Kernel Weight(g), Grain Yield Per Plant(g). Throughout the research, the developmental stages, yield parameters, and pest infestation were monitored to gain insights into the growth and productivity of the experimental plants.

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

2.1 STATISTICAL ANALYSIS

Estimation of heterobeltiosis and standard heterosis

Heterobeltiosis

It was calculated as the deviation of F_1 from the better parent and was expressed as percent 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

$\overline{BP}$ = Mean value of better parent of respective cross combination.

Standard heterosis

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

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

Where;

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

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

The significance of estimates of heterobeltiosis and standard heterosis were tested with the help of the following formulae.

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

The significance of heterosis was tested using t-test:

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

Calculated t values were compared with the table value at the error degree of freedom for significance.

3. RESULTS AND DISCUSSION

In this research study, the investigation focused on estimating heterosis for fifteen important traits in maize hybrids. Heterosis, also known as hybrid vigor, refers to the phenomenon where the progeny of two different parent lines exhibits superior performance compared to their ~~individual~~ parents. The three types of heterosis analyzed were relative heterosis (F_1 value over mid-parental value), heterobeltiosis (F_1 value over better parental value), and standard heterosis (F_1 value over the standard check DHM117). These parameters were assessed for the following traits:

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For Days to 50 % Tasseling, the number of days taken from the date of sowing to the date of 50 percent plant with shedding pollen was recorded. Out of the 56 crosses, 25 showed negative heterosis over heterobeltiosis, indicating that these crosses exhibited desirable earliness in flowering. Moreover, 34 crosses displayed negative heterosis over standard heterosis, suggesting their early flowering tendencies. The highest desirable heterobeltiosis was observed in cross L7 x T3 (-18.38%), while L5 x T6 showed the highest standard heterosis (-19.35%). Consistent findings have been documented by previous researchers, including [5, 6, 7].

The Days to 50% silking, the number of days taken from the date of sowing to the date of 50 percent of plants with silk emergence was recorded. Out of 56 crosses, 17 showed negative heterosis over heterobeltiosis, indicating that these crosses exhibited desirable earliness in flowering. Moreover, 33 crosses displayed negative heterosis over standard heterosis, suggesting their flowering tendencies. The highest desirable heterobeltiosis was observed in cross L6 x T1 (-13.09%), while L6 x T1 shows the highest standard heterosis (-19.81%). Earlier investigators, such as [8, 9, 10], have reported comparable outcomes. Studies on maize heterosis have made a substantial contribution to increased crop productivity. In comparison to their inbred parents, hybrid maize types produce more and have better grain quality and greater nutrient absorption. These advancements are essential to boosting food security and satisfying the world's expanding population demands.

Next Days to maturitytrait measured the number of days taken from the date of sowing to the date of 75% of plants with silk emergence was recorded. Among the 56 crosses, 23 exhibited negative heterosis over heterobeltiosis, indicating desirable early maturing in these crosses. Additionally, 45 crosses showed negative heterosis over standard heterosis, further confirming their early maturing nature. The highest desirable heterobeltiosis was recorded in cross L8 x T7 (-11.14%), while L8 x T7 exhibited the highest standard heterosis (-18.25%) for this trait.

For plant height (cm), the plant height was recorded from base to the plant to tip of the tassel in centimeters of five healthy selected plants, and the mean value was expressed in centimeters. Among the 56 crosses, 11 exhibited negative heterosis over heterobeltiosis, indicating less height in these crosses. Additionally, 29 crosses showed negative heterosis over standard heterosis, further conforming less height of the plant. The desirable heterobeltiosis was recorded in cross L4 x T1 (-18.87%), while L4 x T2 exhibited the highest standard heterosis (-26.22%) for the trait. The results demonstrate that the magnitude of heterosis varied significantly across different crosses and traits. Some crosses exhibited desirable heterosis, indicating potential for improved performance, while others showed negative heterosis, signifying a decrease in the expression of certain traits. The findings provide valuable insights into the genetic potential and performance of maize hybrids, contributing to the development of high-yielding and resilient varieties in maize breeding programs. Earlier researchers, including [11, 12, 13], have documented analogous findings.

For Ear height (cm) the measurement was taken from the base to the plant to node of the attachment of the uppermost ear in centimeters. Among 56 crosses 30 exhibited positive heterosis over heterobeltiosis indicating more height in these crosses. Additionally, 6 showed positive heterosis over standard heterosis, indicating their superior performance in terms of ear height. Cross L8XT3 exhibited the highest desirable heterobeltiosis (53.52%), while L5 x T1 showed the highest standard heterosis (25.64%), for ear height.

For Ear Length (cm), the length of five randomly selected fruits from each tagged plant was measured during the picking period, and the mean value was expressed in centimeters. Moreover, 34 crosses showed positive heterosis over heterobeltiosis, indicating more length in these crosses. Additionally, 29 crosses showed positive heterosis over standard heterosis. Cross L2 x T7 exhibited the highest desirable heterobeltiosis (66.67%), while L4 x T7 showed the highest standard heterosis (25.88%), for ear length. The research also investigated Ear grith (cm) 9 crosses showed positive heterosis over heterobeltiosis, suggesting a desirable increase in ear grith compared to the average of the parents. Moreover, 34 crosses showed positive heterosis over standard heterosis, indicating their superior performance in terms of ear grith. Cross L7 xT1 exhibited the highest desirable heterobeltiosis (66.16%), while L1xT4 showed the highest standard heterosis (38.28%) for ear grith. Similar results were reported by earlier workers like [14,15,16].

For the number of Kernel Rows per Ear, the number of seed rows per ear was recorded by counting the number of rows per ear at the middle of the ear. Among 56 crosses 36 exhibited positive heterosis over heterobeltiosis, indicating more kernel rows in these crosses. Additionally, 11 crosses showed positive heterosis over standard heterosis, indicating their superior performance in terms of a number of kernel rows per ear. Cross L6 x T1 exhibited the highest desirable heterobeltiosis (46.02%), while L8 x T7 showed the highest standard heterosis (15.74%) for number of kernel rows per ear. The research also investigated the number of Kernels per row 36 crosses showed positive heterosis over heterobeltiosis, suggesting a desirable increase in ~~a number of~~ kernels per row compared to the average of the parents. Moreover, 16 crosses showed positive heterosis over standard heterosis, indicating their superior performance in terms of number of kernels per row. Cross L6 x T1 exhibited the highest desirable heterobeltiosis (56.13%), while L6 xT1 showed the highest standard heterosis (27.20%) for number of kernels per row.

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The other traits, including 100 kernel weight (gm) Among 56 crosses 19 exhibited positive heterosis over heterobeltiosis, indicating more weight in these crosses. Additionally, 17 crosses showed positive heterosis over standard heterosis, indicating their superior performance in terms of 100 kernel weight. In Grain yield per plant, among 56 crosses 44 exhibited positive heterosis over heterobeltiosis, indicating high yield in these crosses. Additionally, 19 crosses showed positive heterosis over standard heterosis, indicating their superior performance in terms of grain yield per plant. were also evaluated for heterosis levels, providing valuable insights into the performance and productivity of the experimental crosses. The hybrid BPPT1 x BML20 ranked first by expressing the highest standard heterosis followed by BML6 x BML3 for grain yield per plant (Table 1). All these crosses show significant and desirable heterosis for ~~other~~ one or more traits. Earlier investigators, such as [17, 18, 19], have reported parallel outcomes.

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Significant heterosis in both directions *i.e.* positive and negative heterosis was observed for all the growth, earliness, and yield attributes. It is inferred that the magnitude of economic or standard heterosis was higher for most of the growth and earliness characters and the estimates of standard heterosis were found to be highly variable in direction and magnitude among crosses for all the characters under study. The manifestation of negative heterosis recorded in crosses for different traits may be due to the combination of the unfavorable genes of the parents. Hence, negative heterosis is desirable for earliness and plant height while positive heterosis is desirable for yield of the crop. Maize exhibited heterosis for both yield and its attributing traits. However, the magnitude of heterosis varies among hybrids for each trait. To increase yield through selection, yield components should be taken into consideration.

L1 x T2 is the only cross ~~which can~~ be used for earliness in days to 50 % tasseling as well as grain yield per plant as it performs better over standard check 'DHM117' for both *viz.*, days to

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50 % tasseling and grain yield per plant. It concluded that the best positive heterotic cross over better parent (Heterobeltiosis) and standard check for grain yield per plant was L1 x T2 and L2 x T5. While negatively heterotic cross for days to 50% tasseling was L7 x T3 and L5 x T2, L5 x T5, L6 x T4 were revealed negative heterosis over better parent and standard check respectively that are important to exploit the earliness traits in maize. The F_1 hybrid L1 x T2, which has a high potential for yield can be evaluated further for early kharif season in Punjab. Breeders can take advantage of heterosis and improve the performance of the resulting hybrid by combining two distinct inbred lines. The main goals of heterosis research are to assess the performance of the hybrid and determine the optimal combinations of inbred lines to optimize yield and other desired characteristics. In this research, characteristics of the hybrid, like yield, disease resistance, and stress tolerance, are compared to those of its parents.

In this study, L7 x T3 followed by L5 x T5, L5 x T6, L6 x T4 exhibited high negative heterosis for days to 50% tasseling over better parent and standard check respectively indicating their potential for exploiting heterosis for earliness in maize. For yield attributes *viz.* grain yield per plant crosses L1 x T2 and L7 x T2 exhibited highly positive heterosis effect over better parent and standard check. These crosses were identified as promising as the standard check (Nishant) and could be further tested for commercial cultivation during early *kharif* in Punjab. Parallel findings were reported by earlier researchers, as indicated by [20]. Because inbreed lines exhibit predictable features and are genetically stable, they are frequently employed in breeding operations to create hybrids. However, inbreeding depression frequently affects inbreed lines, resulting in decreased vigor and output.

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 as gene dosage, epigenetic changes, and interactions between many genes.

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.

Table 2. Heterobeltiosis and Standard heterosis for grain yield ~~and its~~ 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
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 ~~and its~~ attributing traits in Maize

Comment [Mu15]: Remove please

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**
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.

4. CONCLUSION

In conclusion, the hybrid BML14 X HKI1332 and BML14 X HKI295 exhibited significant positive heterosis for grain yield per plant. However, further investigations are essential to assess its stability for yield and other parameters before widespread adoption. Overall, this hybrid presents a valuable opportunity to enhance crop productivity and pest resistance, making it a viable option for sustainable and efficient food production.

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