

EXPRESSION OF HETEROSIS FOR GRAIN YIELD AND COMPONENT TRAITS IN ELITE MAIZE (*ZEA MAYS* L.) HYBRIDS ACROSS CONTRASTING ENVIRONMENTS

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ABSTRACT

Heterosis is a major breeding strategy for enhancing productivity and associated agronomic traits in maize. The present studies had undertaken to estimate the heterosis for grain yield and its component traits in elite maize inbred lines. The 25 F₁ hybrids were developed using a line × tester mating design involving five lines and five testers, along with two standard checks. The hybrids and their parents were evaluated in a randomized block design with two replications across three environments, namely Kolhapur, Gurugram (NCR) and Jalna. Heterosis was estimated as mid-parent heterosis (MPH), better-parent heterosis (BPH) and standard heterosis over two checks (SH₁ and SH₂) for ten quantitative traits. Pooled analysis revealed substantial cross-specific variation in heterotic expression. For grain yield, MPH ranged from -18.72 to 15.61%, BPH from -23.04 to 4.49%, SH₁ from -16.66 to 7.75% and SH₂ from -16.07 to 8.52%. The cross IC297843 × EC639266 recorded the highest MPH (15.61%) and BPH (4.49%) for grain yield, whereas IC297841 × EC639023 exhibited the highest standard heterosis over Check 1 (7.75%) and Check 2 (8.52%). Considerable heterosis was also observed for yield-contributing traits. IC297841 × EC632062 recorded high heterosis for cob length, while IC298591 × EC632049 showed the highest MPH (16.14%) and BPH (14.29%) for 100-seed weight. For earliness, IC297843 × EC639023 consistently expressed desirable negative heterosis for tasseling and silking. The results demonstrated that heterotic expression was highly dependent on cross combination and trait, highlighting the importance of evaluating multiple heterosis criteria across environments. The identified cross combinations can provide useful material for further maize hybrid breeding and yield improvement.

KEYWORDS: Maize, heterosis, grain yield, F₁ hybrids, line × tester, hybrid breeding.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops globally and is widely utilized for food, feed, fodder and industrial purposes. Its broad adaptation, high yield potential and cross-pollinated reproductive system have made maize particularly amenable to hybrid breeding. The exploitation of heterosis has consequently become one of the major approaches for improving grain productivity and associated agronomic traits (Paril *et al.*, 2024; Wang *et al.*, 2023). Heterosis, or hybrid vigour, refers to the superior performance of an F₁ hybrid relative to one or both of its parents and has been extensively exploited in maize hybrid development (Shull, 1914; Birchler *et al.*, 2010; Paril *et al.*, 2024). The commercial success of hybrid maize represents one of the most important applications of heterosis in crop improvement. However, heterotic expression is not uniform across cross combinations and traits, as it is influenced by parental genetic divergence, the complementarity of favourable alleles, genetic architecture of the target trait and environmental conditions (Li *et al.*, 2021; Liu *et al.*, 2021; Wang *et al.*, 2023). The genetic basis of heterosis has traditionally been explained through dominance, overdominance and epistatic interactions, while recent genomic studies indicate that heterosis can involve complex interactions among multiple loci, allelic combinations and regulatory mechanisms (Birchler *et al.*, 2010; Li *et al.*, 2021; Paril *et al.*, 2024). In maize, genomic analyses have demonstrated that heterotic performance for grain yield and yield-associated traits can be associated with parental genetic differentiation and the accumulation or complementation of favourable alleles (Li *et al.*, 2021; Wang *et al.*, 2023). Furthermore, phenotypic plasticity and genotype × environment interactions can contribute to differences in hybrid performance across environments, emphasizing the importance of multilocation evaluation during hybrid development (Liu *et al.*, 2021). Recent multi-environment research in maize has likewise demonstrated significant variation among environments, genotypes and genotype × environment interactions for grain yield and related agronomic traits (Birchler *et al.*, 2010; Girma *et al.*, 2024). Beyond genetic improvement, modern agricultural research also emphasizes efficient resource management and improved production practices as complementary approaches to enhancing agricultural productivity (Geetanjali & Singh, 2025).

Heterosis is commonly quantified relative to the mid-parent, better parent and a standard commercial check. Mid-parent heterosis (MPH) measures the percentage deviation of an F₁ hybrid from the mean of its two parents, whereas better-parent heterosis (BPH) or heterobeltiosis indicates the superiority or inferiority of the hybrid

relative to the better-performing parent. Standard heterosis compares hybrid performance with an established commercial or breeding check and therefore provides an important measure for assessing the practical value of experimental hybrids (Shull, 1914; Paril *et al.*, 2024). Recent maize studies using line $\times$ tester and related mating approaches have demonstrated substantial variation in heterosis for grain yield and yield-associated traits, highlighting the importance of appropriate parental combinations for hybrid development (Girma *et al.*, 2024; Goud *et al.*, 2025). Grain yield in maize is a complex quantitative trait influenced by several component characters, including cob length, kernel number, kernel-row number, shelling percentage and seed weight. Consequently, heterotic expression in individual yield components can contribute to the overall heterotic response for grain yield. Genetic analyses of maize hybrids have demonstrated that heterosis for yield-related traits can have different genetic architectures, and the magnitude of heterosis may vary considerably among traits and parental combinations (Li *et al.*, 2021; Zhang *et al.*, 2021). Recent genomic studies have further identified heterosis-associated genomic regions for traits such as ear length, kernel-row number, kernels per row and kernel weight, providing evidence that heterosis for yield components can involve trait-specific genetic mechanisms. Despite the extensive utilization of heterosis in maize, identification of cross combinations showing desirable heterotic expression for grain yield together with favourable performance for yield-associated traits across contrasting environments remains an important objective of hybrid breeding. This is particularly relevant because high heterosis for an individual component does not necessarily result in superior grain yield, and the magnitude of heterosis can differ according to the reference parent or check used for its estimation. Therefore, simultaneous evaluation of mid-parent heterosis, better-parent heterosis and standard heterosis provides a more comprehensive assessment of hybrid performance.

MATERIALS AND METHODS

Experimental material and hybrid development

The experimental material comprised of 25 F₁ hybrids developed through a line $\times$ tester (L $\times$ T) mating design, involving five elite inbred lines and five testers, together with two standard checks. The 25 crosses along with parental lines and standard checks (Table 1) were evaluated across three environments: E₁-Kolhapur, E₂-Gurugram (NCR), and E₃-Jalna (Maharashtra).

Experimental evaluation

The hybrids and parental material were evaluated in a randomized block design (RBD) with two replications in each environment. Data were recorded for 10 yield and component traits (Quantitative): days to 50% tasselling, days to 50% silking, days to 75% dry husk, plant height (cm), cob length (cm), shelling percentage, grain yield plant⁻¹ (q/ha), kernel rows cob⁻¹, kernels row⁻¹ and 100-seed weight (g).

Table 1: List of elite lines, testers, and the 25 crosses along with two standard checks of Maize evaluated across three environments

Symbols	Elite Maize Lines, Testers & Checks	The 25 crosses (F ₁) of Maize using Lines x Testers (L x T) design	
L ₁	IC297841	IC297841 $\times$ EC656228	IC298425 $\times$ EC639023
L ₂	IC297843	IC297841 $\times$ EC639266	IC298425 $\times$ EC632062
L ₃	IC298425	IC297841 $\times$ EC639023	IC298425 $\times$ EC632049
L ₄	IC298595	IC297841 $\times$ EC632062	IC298425 $\times$ EC656228
L ₅	IC298591	IC297841 $\times$ EC632049	IC298595 $\times$ EC639266
T ₁	EC656228	IC297843 $\times$ EC656228	IC298595 $\times$ EC639023
T ₂	EC639266	IC297843 $\times$ EC639266	IC298595 $\times$ EC632062
T ₃	EC639023	IC297843 $\times$ EC639023	IC298595 $\times$ EC632049
T ₄	EC632062	IC297843 $\times$ EC632062	IC298591 $\times$ EC656228
T ₅	EC632049	IC297843 $\times$ EC632049	IC298591 $\times$ EC639266
SC ₁	Advanta PAC751	IC298425 $\times$ EC656228	IC298591 $\times$ EC639023
SC ₂	Sangam 33C99	IC298425 $\times$ EC639266	IC298591 $\times$ EC632062
			IC298591 $\times$ EC632049

Estimation of heterosis:

Heterosis was estimated for each F₁ hybrid using pooled mean performance across the three environments. Three measures were calculated:

Mid-parent heterosis (MPH):

$$\text{MPH (\%)} = \frac{F_1 - \text{MP}}{\text{MP}} \times 100 \quad \text{Where, MP} = (P_1 + P_2) / 2$$

Better-parent heterosis (BPH):

$$\text{BPH (\%)} = \frac{F_1 - \text{BP}}{\text{BP}} \times 100 \quad \text{Where, BP represents the better-performing parent}$$

Standard heterosis:

$$\text{SH (\%)} = \frac{F_1 - \text{SC}}{\text{SC}} \times 100 \quad \text{Where, SC represents the respective standard check}$$

Standard heterosis was estimated separately against standard check 1 (SC₁) and standard check 2 (SC₂). The present study estimated heterosis environment-wise in addition to the pooled analysis.

Statistical analysis:

The data were analysed separately for each environment and over the environments using OPSTAT software to assess the variation among genotypes and the magnitude of heterotic expression. For phenotypical traits, negative heterosis was considered desirable, whereas positive heterosis was considered desirable for grain yield and component traits, according to the breeding objective.

Traits considered for heterotic response:

Particular emphasis was given to grain yield plant⁻¹ and its associated traits, while flowering and maturity traits were interpreted in terms of earliness. The magnitude, direction and consistency of MPH, BPH, SC₁ and SC₂ across environments were used to characterize the heterotic response of the 25 F₁ combinations.

RESULTS AND DISCUSSION:**Heterotic expression across environments:**

The pooled analysis of the 25 F₁ hybrids evaluated across Kolhapur, Gurugram (NCR) and Jalna (Maharashtra) revealed substantial variation in the magnitude and direction of heterosis for grain yield and its component traits. Heterotic expression differed markedly according to the reference used, i.e., mid-parent, better parent and standard checks, indicating that the magnitude of hybrid superiority was strongly dependent on the parental combination and the benchmark used for comparison (Annexure I). Such differential heterotic responses are consistent with recent maize studies reporting substantial cross-specific variation for heterosis across yield and associated traits. The contrasting responses observed among the present hybrids are particularly important because a cross showing high mid-parent heterosis did not necessarily show corresponding superiority over commercial checks. This distinction highlights the importance of considering standard heterosis in addition to relative heterosis and heterobeltiosis when assessing the practical value of experimental hybrids.

Days to 50% tasselling showed considerable heterotic variation, with pooled MPH, BPH, SH₁, and SH₂ ranging from -6.77 to 10.16%, -6.19 to 10.86%, -8.46 to 4.83%, and -10.62 to 2.36%, respectively. Since shorter duration indicates earliness, negative heterosis was considered desirable. IC297843 × EC639023 was the most consistent cross (-6.77% MPH, -6.19% BPH, -8.46% SH₁, -10.62% SH₂), followed by IC298591 × EC639266 and IC297841 × EC639266. Days to 50% silking followed a similar pattern, with pooled MPH, BPH, SH₁, and SH₂ ranging from -6.53 to 9.79%, -5.97 to 10.46%, -8.16 to 4.66%, and -10.26 to 2.28%, respectively. IC297843 × EC639023 again showed the most desirable heterosis (-6.53%, -5.97%, -8.16%, and -10.26% over MP, BP, check 1, and check 2), with IC298591 × EC639266 and IC297841 × EC639266 also showing useful negative heterosis.

For days to 75% dry husk, IC297843 × EC639023 recorded the most desirable negative heterosis (-2.79% MPH, -3.13% BPH, -4.79% SH₁, -5.43% SH₂), indicating earlier physiological maturity, followed by IC297843 × EC639266 and IC297841 × EC639266. In contrast, IC298595 × EC656228 showed positive heterosis (5.11% MPH, 4.74% BPH, 2.05% SH₁, 1.36% SH₂), indicating delayed maturity. This wide contrast shows that maturity duration depended strongly on parental combination. Overall, IC297843 × EC639023 showed a consistent tendency toward earliness across flowering and maturity traits. Plant height showed broad heterotic variation, with pooled MPH, BPH, SH₁, and SH₂ ranging from -6.07 to 12.82%, -6.77 to 12.41%, -6.07 to 15.79%, and -5.83 to 16.08%, respectively. IC298595 × EC656228 showed positive heterosis in all four comparisons (12.82%, 12.41%, 15.79%, and 16.08%), while IC298595 × EC639023 and IC298595 × EC632062 also showed substantial positive heterosis.

Negative heterosis for days to tasselling, silking, and maturity is desirable in maize because it indicates earliness. In the present study, the crosses showed reductions relative to both the parents and the standard checks, indicating useful hybrid earliness rather than a consequence of poor parental performance. The consistent response in tasselling and silking suggests that these hybrids expressed earlier reproductive development across flowering traits, in agreement with recent maize heterosis studies (cite). These results also support evaluating multiple phenotypic traits together when selecting early hybrids. For plant height, superiority over the parental and check references indicates strong heterotic expression for vegetative growth. However, increased height should be interpreted alongside crop architecture and lodging risk and not treated as an independent breeding target.

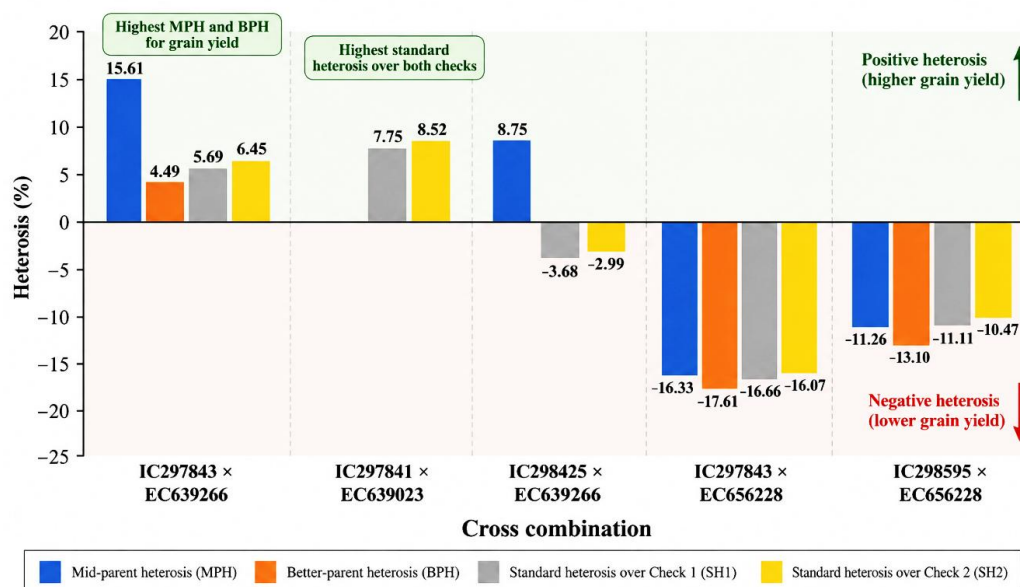


Fig. 1. Pooled heterosis (%) for grain yield in selected maize F₁ hybrids evaluated across three environments [MPH- mid-parent heterosis; BPH- better-parent heterosis (heterobeltiosis); SH₁ and SH₂, standard heterosis over Check 1 and Check 2, respectively. The cross IC297843 × EC639266 showed the highest MPH (15.61%) and BPH (4.49%), while IC297841 × EC639023 recorded the highest standard heterosis over Check 1 (7.75%) and Check 2 (8.52%)].

Cob length showed substantial heterosis. IC297841 × EC632062 recorded 19.51% MPH, 18.07% BPH, 20.99% SH₁, and 15.30% SH₂, followed by IC297841 × EC639266 (17.79%, 17.08%, 18.52%, and 12.95%, respectively). IC298425 × EC632049 recorded 13.73% MPH and 13.46% BPH, with the highest standard heterosis over Check 1 (24.70%) and Check 2 (18.82%). Shelling percentage showed narrower heterosis than cob length, and although several crosses had positive MPH and BPH, standard heterosis was generally lower. IC298425 × EC639266 recorded 2.10% MPH and 2.02% BPH, while IC298425 × EC632049 showed 1.54% MPH, 1.52% BPH, and the highest SH₂ (4.15%), followed by IC298425 × EC639023 (4.06%). For grain yield, the key breeding trait, pooled heterosis ranged from -18.72 to 15.61% (MPH), -23.04 to 4.49% (BPH), -16.66 to 7.75% (SH₁), and -16.07 to 8.52% (SH₂). IC297843 × EC639266 recorded the highest MPH (15.61%) and BPH (4.49%), along with positive standard heterosis of 5.69% over Check 1 and 6.45% over Check 2.

Kernel row number showed limited heterosis, with pooled MPH, BPH, and standard heterosis ranging from -3.92 to 3.92%, -4.47 to 3.37%, and -4.47 to 3.33%, respectively. IC298425 × EC632049 recorded the highest MPH (3.92%) with positive SH₁ and SH₂ (3.33% each), while IC298425 × EC656228 recorded the highest BPH (3.37%). IC297843 × EC632049 also showed positive heterosis over both checks. Kernels per row showed appreciable heterotic variation (MPH: -15.14 to 8.61%; BPH: -18.50 to 5.58%; SH₁: -13.95 to 5.58%; SH₂: -18.50 to 0.00%). IC298425 × EC639023 recorded the highest MPH (8.61%), whereas IC298591 × EC632062 recorded the highest BPH and SH₁ (5.58% each) with no heterosis over Check 2. Hundred-seed weight showed substantial heterosis (MPH: -14.10 to 16.14%; BPH: -18.68 to 14.29%; SH₁: -7.59 to 13.64%; SH₂: -11.61 to 8.70%). IC298591 × EC632049 recorded the highest MPH (16.14%) and BPH (14.29%), with positive SH₁ (9.09%) and SH₂ (4.35%). IC298591 × EC632062 was also consistently positive (MPH 12.49%, BPH 10.75%, SH₁ 9.09%, SH₂ 4.35%). In contrast, IC298425 × EC639266 showed low MPH (4.17%) and no BPH (0%) but the highest standard heterosis (13.64% over Check 1 and 8.70% over Check 2).

Heterosis for grain yield was strongly cross-specific, ranging from positive hybrid vigour to marked depression relative to parental and commercial benchmarks. IC297841 × EC639023 recorded the highest standard heterosis over both checks (7.75% SC₁ and 8.52% SC₂) despite a modest MPH (1.91%) and negative BPH (-5.00%), showing that a hybrid can outperform the checks without markedly exceeding its better parent. Conversely, high MPH did not always translate into high standard heterosis. IC298425 × EC639266 showed 8.75% MPH but -3.68% and -2.99% over Checks 1 and 2, respectively, which shows that heterosis relative to parental performance alone may overestimate the practical value of a hybrid, whereas standard heterosis benchmarks it against established hybrids. At the other extreme, IC297843 × EC656228 recorded -16.33% MPH, -17.61% BPH, -16.66% SC₁, and -16.07% SC₂, and IC298595 × EC656228 was also consistently negative.

Among yield components, cob length showed relatively high heterosis in selected crosses, with some exceeding the checks substantially, suggesting that parental complementation contributed to larger cobs, in line with earlier maize reports (citation). 100-seed weight varied strongly, with IC298595 × EC639266 and IC297843 × EC639266 showing pronounced negative heterosis. This indicates that seed weight contributed substantially to hybrid differentiation and is an important target when selecting combinations for grain size and weight. In contrast, shelling percentage and kernel row number showed small heterosis and a narrow range, indicating that they were less responsive to hybridization than grain yield, cob length, and 100-seed weight. Even so, positive heterosis in selected crosses suggests scope for improving grain recovery through suitable parental combinations.

Since grain yield is a composite trait, it likely responds more strongly when several components are favourably modified together than when a single component changes

CONCLUSION

The study revealed substantial and cross-specific heterotic expression among the 25 maize F₁ hybrids across three environments. IC297843 × EC639266 showed the highest MPH (15.61%) and BPH (4.49%) for grain yield, whereas IC297841 × EC639023 recorded the highest standard heterosis over both checks (7.75% and 8.52%). Other crosses showed desirable heterosis for earliness, cob length, kernel number and 100-seed weight. Overall, the results demonstrate considerable scope for exploiting heterosis in the evaluated maize germplasm, with promising crosses warranting further multilocation evaluation.

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Author contribution

AAM: Conceptualization, Writing - original draft. DKJ: Conceptualization, Writing - original draft. LS, DR & SY: Writing – review and editing. All authors read, revised, and approved the final manuscript.

Conflict of interest:

On behalf of all authors, the corresponding author states that there is no conflict of interest. The corresponding author also confirms that the submitted manuscript is original, has not been published previously, and is not under simultaneous consideration by another journal.

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13. **Annexure I:** Estimates of percentage of mid-parent heterosis (MPH), better-parent heterosis (BPH) and standard heterosis in the 25 F₁ crosses of Maize for yield and component traits over the environments

Sr. No.	Maize hybrids (F ₁)	Days to 50% tasselling				Days to 50% silking				Days to 75% Dry Husk				Plant Height (cm)			
		MPH	BPH	SC ₁	SC ₂	MPH	BPH	SC ₁	SC ₂	MPH	BPH	SC ₁	SC ₂	MPH	BPH	SC ₁	SC ₂
1.	IC297841 × EC656228	-0.62	1.89	-2.42	-4.72	-0.59	1.82	-2.33	-4.56	0.35	-0.17	-1.71	-2.38	-0.25	-0.98	1.25	1.51
2.	IC297841 × EC639266	-3.02	-2.43	-3.02	-5.31	-2.92	-2.35	-2.92	-5.13	-0.87	-1.04	-2.22	-2.89	0.75	0	0.75	1.01
3.	IC297841 × EC639023	-0.91	0	-1.21	-3.54	-0.88	0	-1.17	-3.42	0.26	0.17	-1.37	-2.04	-6.07	-6.77	-6.07	-5.83
4.	IC297841 × EC632062	0	0.61	0	-2.36	0	0.59	0	-2.28	0.61	0.35	-0.68	-1.36	1.46	-0.71	4.51	4.77
5.	IC297841 × EC632049	-2.93	-0.6	0	-2.36	-2.83	-0.58	0	-2.28	-0.26	-1.85	-0.17	-0.85	-0.22	-0.59	0.9	1.16
6.	IC297843 × EC656228	0.94	1.89	-2.42	-4.72	0.9	1.82	-2.33	-4.56	1.49	1.4	-1.03	-1.7	3.3	2.92	6.02	6.28
7.	IC297843 × EC639266	-2.76	-1.86	-4.23	-6.49	-2.66	-1.79	-4.08	-6.27	-1.31	-1.9	-3.08	-3.74	6.32	4.38	7.52	7.79
8.	IC297843 × EC639023	-6.77	-6.19	-8.46	-10.62	-6.53	-5.97	-8.16	-10.26	-2.79	-3.13	-4.79	-5.43	6.57	4.62	7.77	8.04
9.	IC297843 × EC632062	2.76	3.72	1.21	-1.18	2.66	3.58	1.17	-1.14	1.74	1.04	0	-0.68	3.97	2.86	8.27	8.54
10.	IC297843 × EC632049	0.3	4.33	1.81	-0.59	0.29	4.18	1.75	-0.57	0.69	-1.34	0.34	-0.34	8.82	8.03	11.28	11.56
11.	IC298425 × EC656228	0.31	1.89	-2.42	-4.72	0.3	1.82	-2.33	-4.56	-0.17	-0.87	-2.05	-2.72	-5.65	-6.76	-4.66	-4.42
12.	IC298425 × EC639266	0.92	1.22	0	-2.36	0.88	1.18	0	-2.28	1.04	1.04	-0.17	-0.85	-4.83	-5.12	-5.26	-5.03
13.	IC298425 × EC639023	6.12	6.12	4.83	2.36	5.9	5.9	4.66	2.28	3.56	3.29	2.05	1.36	4.98	4.67	4.51	4.77
14.	IC298425 × EC632062	-2.74	-2.45	-3.63	-5.9	-2.65	-2.36	-3.5	-5.7	-0.26	-0.35	-1.37	-2.04	5.08	2.38	7.77	8.04
15.	IC298425 × EC632049	-3.85	-0.61	-1.81	-4.13	-3.71	-0.59	-1.75	-3.99	-1.96	-3.36	-1.71	-2.38	11.28	10.37	12.03	12.31
16.	IC298595 × EC656228	10.16	10.86	4.83	2.36	9.79	10.46	4.66	2.28	5.11	4.74	2.05	1.36	12.82	12.41	15.79	16.08
17.	IC298595 × EC639266	1.25	3.83	-1.81	-4.13	1.2	3.69	-1.75	-3.99	1.75	0.69	-0.51	-1.19	4.68	2.77	5.86	6.13
18.	IC298595 × EC639023	2.19	4.47	-1.21	-3.54	2.11	4.31	-1.17	-3.42	1.14	0.35	-1.37	-2.04	10.78	8.76	12.03	12.31
19.	IC298595 × EC632062	0.62	3.19	-2.42	-4.72	0.6	3.08	-2.33	-4.56	0.09	-1.04	-2.05	-2.72	3.97	2.86	8.27	8.54
20.	IC298595 × EC632049	0	5.75	0	-2.36	0	5.54	0	-2.28	0.09	-2.35	-0.68	-1.36	2.45	1.7	4.76	5.03
21.	IC298591 × EC656228	4.31	6.94	2.42	0	4.15	6.69	2.33	0	3.32	2.96	1.03	0.34	2.86	2.21	4.51	4.77
22.	IC298591 × EC639266	-5.44	-4.86	-5.44	-7.67	-5.25	-4.69	-5.25	-7.41	-0.35	-0.69	-1.88	-2.55	0.65	-0.2	0.75	1.01
23.	IC298591 × EC639023	-3.33	-2.45	-3.63	-5.9	-3.22	-2.36	-3.5	-5.7	0.78	0.7	-1.03	-1.7	-0.85	-1.69	-0.75	-0.5
24.	IC298591 × EC632062	0	0.61	0	-2.36	0	0.59	0	-2.28	0.78	0.35	-0.68	-1.36	1.36	-0.71	4.51	4.77
25.	IC298591 × EC632049	-2.93	-0.6	0	-2.36	-2.83	-0.58	0	-2.28	-0.6	-2.35	-0.68	-1.36	1.02	0.74	2.26	2.51

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Sr. No.	Maize hybrids (F ₁)	Cob Height (cm)				Shelling (%)				Grain yield (q/ha)				Kernel rows cob ⁻¹			
		MPH	BPH	SC ₁	SC ₂	MPH	BPH	SC ₁	SC ₂	MPH	BPH	SC ₁	SC ₂	MPH	BPH	SC ₁	SC ₂
1.	IC297841 × EC656228	5.53	4.89	6.18	1.19	0.68	0.48	-2.09	1.46	-2.01	-2.02	-3.93	-3.24	0	0	-1.13	-1.13
2.	IC297841 × EC639266	17.79	17.08	18.52	12.95	0	-0.28	-4.43	0.48	3.92	-4.74	-6.61	-5.94	1.71	1.13	1.13	1.13
3.	IC297841 × EC639023	-4.35	-4.93	-4.93	-9.4	-1.25	-1.25	-5.15	-1.71	1.91	-5	7.75	8.52	2.2	1.05	2.2	2.2
4.	IC297841 × EC632062	19.51	18.07	20.99	15.3	0.08	-0.09	-4.02	1.32	-6.94	-6.96	-8.79	-8.13	1.13	0	1.13	1.13
5.	IC297841 × EC632049	-9.41	-13.48	-4.93	-9.4	0.24	-0.25	-2.43	1.11	-0.21	-0.96	-2.9	-2.2	-0.57	-1.13	-1.13	-1.13
6.	IC297843 × EC656228	-4.53	-7.05	-6.18	10.58	0	-0.13	-3.6	-0.11	16.33	17.61	16.66	16.07	-0.53	-2.15	0	0
7.	IC297843 × EC639266	-2.92	-3.81	0	-4.7	2.2	2.09	-1.49	3.69	15.61	4.49	5.69	6.45	-1.09	-2.15	0	0
8.	IC297843 × EC639023	3.76	-4.5	4.93	0	1.74	1.48	-3.05	0.47	12.17	16.92	-5.78	-5.1	-2.75	-3.26	-1.13	-1.13
9.	IC297843 × EC632062	-0.6	-1.19	2.47	-2.35	0.2	-0.16	-2.7	0.83	2.57	0.96	2.12	2.85	-1.64	-2.15	0	0
10.	IC297843 × EC632049	1.06	-2.26	7.41	2.35	0.2	-0.16	-3.77	-0.29	0.91	-1.37	-0.24	0.47	2.21	1.11	3.33	3.33
11.	IC298425 × EC656228	3.42	-1.13	8.64	3.53	1.18	1.17	-0.12	3.51	-2.67	-3.96	-5.83	-5.16	3.37	3.37	2.2	2.2
12.	IC298425 × EC639266	7.53	3.35	13.58	8.24	2.1	2.02	-1.51	2.07	8.75	0.91	-3.68	-2.99	1.71	1.13	1.13	1.13
13.	IC298425 × EC639023	0	-4.5	4.93	0	1.13	0.78	0	4.06	-6.65	14.04	-2.51	-1.81	-1.13	-2.24	-1.13	-1.13
14.	IC298425 × EC632062	6.28	3.37	13.58	8.24	1.52	1.48	-3.5	0	-2.57	-3.83	-5.77	-5.09	-1.13	-2.24	-1.13	-1.13
15.	IC298425 × EC632049	13.73	13.46	24.7	18.82	1.54	1.52	-0.17	4.15	-7.38	-7.91	-11.07	10.44	3.92	3.33	3.33	3.33
16.	IC298595 × EC656228	-4.64	-7.95	0	-4.7	1.34	1.3	-2.13	3.81	-11.26	-13.1	-11.11	10.47	1.15	1.15	0	0
17.	IC298595 × EC639266	1.25	1.22	16.04	10.62	1.47	1.36	-0.42	3.28	-0.36	-10.4	-8.34	-7.68	-0.57	-1.13	-1.13	-1.13
18.	IC298595 × EC639023	9.69	9.4	14.93	8.86	0.48	0.42	-0.7	3.36	-8.25	12.74	-1.04	-0.33	1.13	0	1.13	1.13
19.	IC298595 × EC632062	7.39	4.55	13.58	8.24	1.34	1.3	-3.57	0	-7.29	-9.24	-7.16	-6.49	2.2	1.05	2.2	2.2
20.	IC298595 × EC632049	-5.3	-4.55	3.7	-1.18	0.8	0.72	-3.15	0.36	-4.74	-7.41	-5.29	-4.61	-3.92	-4.47	-4.47	-4.47
21.	IC298591 × EC656228	4	1.15	8.64	3.53	0.31	0.25	-3.26	2.12	-5.87	-11.86	-0.96	-0.25	-1.08	-1.08	-2.2	-2.2
22.	IC298591 × EC639266	8.59	6.03	13.58	8.24	-1.8	-2.37	-5.9	-2.54	-8.62	21.09	-11.34	-10.7	-0.57	-1.13	-1.13	-1.13
23.	IC298591 × EC639023	1.77	-4.28	4.93	0	-1.25	-1.25	-5.55	-1.15	18.72	19.09	-8.24	-7.58	1.13	0	1.13	1.13
24.	IC298591 × EC632062	8.06	5.74	13.58	8.24	3.42	3.35	-0.12	3.51	17.78	23.04	13.52	12.91	2.2	1.05	2.2	2.2
25.	IC298591 × EC632049	14.64	13.89	24.7	18.82	2.21	2.15	-1.5	4.43	13.77	19.84	-9.92	-9.28	1.71	1.13	1.13	1.13

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Sr. No.	Maize hybrids (F ₁)	Kernels row ⁻¹				100-seed weight (g)			
		MPH	BPH	SC ₁	SC ₂	MPH	BPH	SC ₁	SC ₂
1.	IC297841 × EC656228	0.96	-5.43	-2.79	-7.93	-1.12	-7.12	-1.5	-5.78
2.	IC297841 × EC639266	-3.34	-10.57	-5.58	-10.57	1.39	-2	11.36	6.52
3.	IC297841 × EC639023	-9.06	-15.86	-11.16	-15.86	-7.04	-8.33	0	-4.35
4.	IC297841 × EC632062	-9.32	-13.95	-13.95	-18.5	2.22	-1.41	4.55	0
5.	IC297841 × EC632049	0	-6.33	-3.71	-8.8	-3.8	-9.99	-4.55	-8.7

6.	IC297843 × EC656228	- 7.74	- 13.5 8	- 11.1 6	- 15.8 6	0	- 6.38	0	- 4.35
7.	IC297843 × EC639266	- 11.9 1	- 18.5	- 13.9 5	- 18.5	- 14.1	- 16.6 8	- 5.32	- 9.43
8.	IC297843 × EC639023	- 7.14	- 14.0 9	- 9.29	- 14.0 9	- 11.5 8	- 12.5	- 4.55	-8.7
9.	IC297843 × EC632062	2.44	- 2.79	- 2.79	- 7.93	6.27	2.13	9.09	4.35
10.	IC297843 × EC632049	3.86	- 2.72	0	- 5.29	4.95	- 2.13	4.55	0
11.	IC298425 × EC656228	- 1.46	- 8.15	- 5.58	- 10.5 7	1.15	- 4.35	0	- 4.35
12.	IC298425 × EC639266	5.74	- 2.64	2.79	- 2.64	4.17	0	13.6 4	8.7
13.	IC298425 × EC639023	8.61	0	5.58	0	- 9.91	- 11.7 9	- 3.77	- 7.96
14.	IC298425 × EC632062	2.96	- 2.79	- 2.79	- 7.93	-1.5	- 4.35	0	- 4.35
15.	IC298425 × EC632049	4.37	- 2.72	0	- 5.29	6.16	0	4.55	0
16.	IC298595 × EC656228	- 6.88	- 8.15	- 5.58	- 10.5 7	1.18	- 2.27	- 2.27	- 6.52
17.	IC298595 × EC639266	- 13.5 8	- 15.8 6	- 11.1 6	- 15.8 6	- 13.4 9	- 18.6 8	- 7.59	- 11.6 1
18.	IC298595 × EC639023	- 10.8 6	- 13.2 2	- 8.37	- 13.2 2	- 10.8 7	- 14.5 8	- 6.82	- 10.8 7
19.	IC298595 × EC632062	- 2.79	- 2.79	- 2.79	- 7.93	- 0.76	-1.5	-1.5	- 5.78
20.	IC298595 × EC632049	- 6.88	- 8.15	- 5.58	- 10.5 7	3.95	0	0	- 4.35
21.	IC298591 × EC656228	- 11.1 6	- 13.5 8	- 11.1 6	- 15.8 6	1.2	0	- 4.55	-8.7
22.	IC298591 × EC639266	- 15.1 4	- 18.5	- 13.9 5	- 18.5	4.35	-4	9.09	4.35
23.	IC298591 × EC639023	- 1.38	- 5.29	0	- 5.29	2.22	- 4.17	4.55	0
24.	IC298591 × EC632062	7.08	5.58	5.58	0	12.4 9	10.7 5	9.09	4.35
25.	IC298591 × EC632049	- 2.79	- 5.43	- 2.79	- 7.93	16.1 4	14.2 9	9.09	4.35