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EXPLOITATION OF HETEROSIS FOR GROWTH AND YIELD ATTRIBUTES IN MULBERRY (*MORUS* SPP.) USING LINE × TESTER ANALYSIS

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ABSTRACT

The present study was conducted to evaluate the heterotic potential of mulberry (*Morus* spp.) hybrids following Line × Tester analysis using six female (lines) and four male(testers) parental accessions. Twenty-four F_1 hybrids were derived and assessed for key growth and yield parameters. Significant levels of heterosis was observed for most of the traits over both mid-parent and better parent values, indicating the presence of hybrid vigour. Notably, hybrids such as, ME-18 × MI-0079, ME-06 × MI-0423 and MI-0025 × MI-0079 recorded highly positive heterosis for seedling height, number of leaves and fresh leaf weight, while ME-0008 × MI-0308 showed desirable negative heterosis for internodal distance. The study concludes that several hybrids possess superior growth attributes and are promising candidates for future selection to be used as parents and large-scale cultivation in sericulture programs, aiming to enhance leaf yield and quality for silkworm rearing.
***Keywords*:** Heterosis; mulberry; F_1 hybrids; Mid parent; better parent

Introduction

Mulberry is a cross pollinated heterozygous perennial plant of the family Moraceae. Mulberry exhibits high plasticity and acclimatizes itself to various climatic conditions (Ashiru, 2002). The foliage of mulberry serves as a sole source of food for monophagous silkworm, *Bombyx mori* L. and 60 per cent of total cost of cocoon production goes towards mulberry production alone. Hence, the productive quality leaves is utmost important for sustainability and profitability of sericulture industry. Therefore, development of new mulberry hybrids with novel and desirable traits boost sericultural economy. Pre-requisites for any breeding programme are: selection of compatible parents and appropriate breeding techniques. Selection of parental genotypes should be selected based on their phenotypic performance and intrinsic genetic values for formulating successful breeding programs (Bhalodiya *et al.*, 2019). Among the various selection approaches, line × tester analysis (Kempthorne ,1957) and diallel analysis are fruitful for identification of best combining parental genotypes as they provide the information of general combining ability (GCA) of parents and specific combining ability (SCA) of the F_1 progenies (Sprague and Tatum, 1942; Harika *et al.*, 2025). So, estimation of GCA helps to select parents with superior combining ability for exploitation of hybrid vigour (heterosis). Hybrid vigour, the manifest effect of heterosis has been one of the most interesting topics in the science of genetics and plant breeding. Study on hybrid vigour in the beginning were mainly of academic interest. Various hypotheses have been advanced to explain the phenomenon. Theory of heterozygosity (Shull, 1911; East, 1908), theory of dominance (Davenport, 1908; Bruce, 1910; Keeble and Pellow, 1910) theory of intra-allelic interaction (East, 1936; Labroo *et al.*, 2021) the super dominance or over dominance hypotheses (Hull, 1945) and physiological hypotheses (Ashby, 1937) are some among the several hypotheses put forth. Consensus is that one or several of these phenomena act alone or in combination in any given situation of heterotic effect. Heterosis refers to the phenomenon in which progeny of diverse varieties of a species, or crosses between species, display greater biomass, faster development and higher fertility than their parents in tropical countries, mulberry is generally propagated through vegetative means. Hence, the traits like leaf yield and quality can be perpetuated in successive clonal generations without much alterations. Exploitation of heterosis is considered to be one of the outstanding achievements of plant breeding and the scope of its exploitation depends upon the direction and magnitude of interactions of the genes involved. In general, heterosis for a trait could always be attributed to a significant level of heterosis in at least one of its components (Vijayan *et al.*, 1998; Sarkar *et al.*, 2023). Present study was designed to assess the combining ability for mulberry and to identify the suitable crosses through Line x Tester mating design.

Material and Methods

For the present study, parental materials comprising six lines and four testers were chosen from the field germplasm available at the Department of Sericulture, UAS, GKVK, Bengaluru. The experimental site is located at an altitude of 931 m above sea level, with a latitude of 13.077492° N and longitude of 77.575778° E. The six lines and four testers were mated using a line × tester breeding design (Table 1). Successful crossing was achieved through several initial procedures including pruning, bagging and pollination. After one week, fully ripened fruits were collected from the lines and seeds were extracted by soaking the fruits in water overnight. Floating seeds were discarded, while the submerged seeds were selected for sowing after being shade-dried (Mbora *et al.,* 2008). A completely randomized design (CRD) with three replications was employed for planting the twenty-four F_1 progenies. Seeds were sown in polybags filled with a mixture of soil, sand and farmyard manure in a 1:1:1 ratio (Dandin *et al.*, 2003; Ranjitha *et al.*, 2023). Observations related to growth parameters of mulberry were recorded on the 30, 60 and 90 days after sowing (DAS).

Table 1: List of lines and testers involved in study

Sl. No.	Scientific name	Accession number
LINES		
1.	*M. nigra*	ME-0008
2.	*M. latifolia*	ME-0185
3.	*M. cathayana*	ME-03
4.	*M. multicaulis*	ME-06
5.	*M. bombycis*	ME-18
6.	*M. sinensis*	MI-0025
TESTERS		
1.	*M. laevigata*	MI-0079
2.	*M. indica*	MI-0173
3.	*M. indica*	MI-0308
4.	*M. alba*	MI-0423

Estimation of heterosis

The overall mean for each parent or hybrid from the three replications for each character was considered for the estimation of heterosis. The magnitude of heterosis over mid parent (MP) and better parent (BP) was calculated using INDOSTAT software. The percentage increase or decrease in the mean of the F1 over their respective mid parent and better parent mean value was calculated by using the following formulae;

$$1.\ \text{Heterosis over mid parent (Relative hetrosis)} = \frac{\overline{\text{F1}} - \overline{\text{MP}}}{\overline{\text{MP}}} \times 100$$

$$\text{where, Mid parent} = \frac{\text{P1} + \text{P2}}{2}$$

$$2.\ \text{Heterosis over better parent (Heterobeltiosis)} = \frac{\overline{\text{F1}} - \overline{\text{BP}}}{\overline{\text{BP}}} \times 100$$

where,

$\overline{\text{F1}}$= Mean performance of the F_1

P1 = Mean performance of the parent one

P2 = Mean performance of the parent two

$\overline{\text{BP}}$= Mean performance of the better parent

For better parent value (BP) for each character, superior value between the parents in each cross was taken.

Significance of estimates of heterosis

The estimates of relative heterosis and heterobeltiosis effects were tested for their statistical significance as follows:

SE (MP) = $\sqrt{(3Me/2r)}$

SE (BP) = $\sqrt{(2Me/r)}$

where,

Me= Error mean sum of squares in ANOVA table of Line x Tester analysis

r = number of replications

Overall status of the parents and crosses with respect to heterosis

Since yield and its component characters are correlated either positively or negatively, it is common to find heterosis for a particular parent and hybrid respectively, in the desirable direction for some characters and in the undesirable direction for some characters.

Results and Discussion

Germination percentage

Among the twenty-four hybrids fifteen hybrids registered significant positive heterosis ranging from 1.83 to 19.85 per cent over mid-parent. ME-06 × MI-0308 (19.85 %) recorded exhibited significant high positive heterosis over mid-parent, followed by ME-18 × MI-0308 (17.66 %) and ME-03 × MI-0308 (16.29 %) hybrids (Table 2).

For better parent, six hybrids exhibited significant positive heterosis ranging from 6.80 to 15.36 per cent heterosis. ME-18 × MI-0308 (15.36 %) exhibited significant high positive heterosis over better parent, followed by ME-06 × MI-0423 (9.96 %) and ME-06 × MI-0308 (7.79 %) hybrids (Table 2).

Table 2: Estimation of per cent heterosis over mid-parent and better-parent for germination percentage

Crosses	Heterosis over	
	Mid parent	Better parent
ME-0008×MI-0079	-16.06**	-30.69 **
ME-0008×MI-0173	-6.13 **	-12.04 **
ME-0008×MI-0308	5.73**	-2.44 **
ME-0008×MI-0423	-5.68 **	-21.00 **
ME-0185×MI-0079	-11.19**	-22.96**
ME-0185×MI-0173	1.83 *	1.12
ME-0185×MI-0308	11.79 **	9.21**
ME-0185×MI-0423	0.25	-11.69 **
ME-03×MI-0079	-0.22 **	-4.18**
ME-03×MI-0173	8.27 **	-2.04 **
ME-03×MI-0308	16.29**	6.80**
ME-03×MI-0423	3.65 **	1.30
ME-06×MI-0079	2.87 **	1.05
ME-06×MI-0173	-7.69 **	-18.18 **
ME-06×MI-0308	19.85**	7.79**
ME-06×MI-0423	9.96 **	9.96 **
ME-18×MI-0079	-0.58 **	-10.44 **
ME-18×MI-0173	-4.72 **	-8.07 **
ME-18×MI-0308	17.66**	15.36 **
ME-18×MI-0423	0.95	-7.58 **
MI-0025×MI-0079	-10.73 **	-23.59**
MI-0025×MI-0173	0.29	-1.96 *
MI-0025×MI-0308	11.55 **	7.32**
MI-0025×MI-0423	2.86 **	-10.61 **
SE m±	0.4684	0.5408
CD at 5 %	0.9428	1.0886
CD at 1 %	1.2585	1.0886

*Significant at p = 0.05 and ** significant at p = 0.01

Seedling height (cm)

At 30 DAS

Among the twenty-four hybrids thirteen hybrids registered significant positive heterosis for seedling height at 30 DAS, ranging from 11.30 to 64.93 per cent over mid-parent. ME-18 × MI-0423 (64.93 %) exhibited significant high positive heterosis over mid-parent, followed by MI-0025 × MI-0079 (58.54 %) and MI-0025 × MI-0423 (30.48 %) hybrids (Table 3).

For better parent, six hybrids exhibited significant positive heterosis ranging from 20.00 to 64.15 per cent heterosis. ME-18 × MI-0423 (64.15 %) recorded significant high positive heterosis over better parent, followed by ME-06 × MI-0423 (9.96 %) and ME-06 × MI-0308 (7.79 %) hybrids (Table 3).

At 60 DAS

Among the twenty-four hybrids ten hybrids recorded significant positive heterosis for seedling height at 60 DAS, ranging from 10.26 to 47.90 per cent over mid-parent. ME-18 × MI-0308 (47.90 %) exhibited significant high positive heterosis over mid-parent, followed by ME-03 × MI-0423 (40.92 %) hybrids (Table 3).

For better parent, six hybrids exhibited significant positive heterosis ranging from 4.55 to 41.05 per cent heterosis. ME-18 × MI-0308 (41.05 %) exhibited significant high positive heterosis over better parent followed by MI-0025 × MI-0079 (17.49 %) hybrids (Table 3).

At 90 DAS

Among the twenty-four hybrids eight hybrids registered significant positive heterosis for seedling height at 90 DAS, ranging from 4.81 to 36.62 per cent over mid-parent. ME-03 × MI-0079 (36.62 %) exhibited significant high positive heterosis over mid-parent, followed by ME-18 × MI-0079 (36.40 %) hybrids (Table 3).

For better parent, four hybrids exhibited significant positive heterosis ranging from 6.95 to 14.05 per cent heterosis. ME-18 × MI-0079 (14.05 %) exhibited significant high positive heterosis over better parent followed by ME-0185 × MI-0079 (10.47 %) hybrids (Table 3).

The present findings are in line with those of Ghosh *et al.* (2009), who reported that the hybrid S-1908 exhibited a significant positive heterosis of 39.72 per cent over the better parent for plant height, indicating its potential as a promising hybrid. Similar findings were also reported by Sapna and Chikkalingaiah (2022).

Table 3: Estimation of per cent heterosis over mid-parent and better-parent for seedling height at 30, 60 and 90 DAS

Crosses	Seedling height at 30 DAS		Seedling height at 60 DAS		Seedling height at 90 DAS	
	MPH (%)	BPH (%)	MPH (%)	BPH (%)	MPH (%)	BPH (%)
ME-0008×MI-0079	8.51	-4.67	-5.21	-12.66 **	-2.56	-3.32
ME-0008×MI-0173	-0.48	-2.80	15.08 **	11.71 **	1.50	-12.01**
ME-0008×MI-0308	-35.56 **	-41.67 **	-28.82 **	-43.21 **	-26.96**	-46.11**
ME-0008×MI-0423	-2.83	-3.74	-6.35 *	-14.22 **	-3.88	-22.34**
ME-0185×MI-0079	16.20 **	6.12	-14.60 **	-25.96 **	17.56**	10.47**
ME-0185×MI-0173	14.00 *	11.76	-11.80 **	-26.92 **	-8.56**	-16.72**
ME-0185×MI-0308	11.30 *	-3.03	-11.32 **	-12.96 **	-36.13**	-51.05**
ME-0185×MI-0423	4.43	0.95	-23.53 **	-33.33 **	-13.06**	-26.57**
ME-03×MI-0079	21.27 **	-4.29	29.68 **	4.55 *	36.62**	-0.51
ME-03×MI-0173	8.26	-6.43	2.25	-20.86 **	-41.92**	-52.62**
ME-03×MI-0308	23.53 **	20.00 **	-20.34 **	-25.67 **	-11.06**	-12.21**
ME-03×MI-0423	17.55 **	2.86	40.92 **	14.17 **	7.43**	-5.85**
ME-06×MI-0079	4.35	-14.29 **	-15.48 **	-27.50 **	-7.66**	-28.83**
ME-06×MI-0173	17.54 **	6.35	22.67 **	0.62	-13.21**	-24.09**
ME-06×MI-0308	-38.76 **	-40.15 **	-9.63 **	-10.19 **	-0.56	-7.26**
ME-06×MI-0423	-7.36	-15.08 **	-3.26	-16.56 **	-3.98*	-9.12**
ME-18×MI-0079	12.30 *	-0.94	-2.49	-13.27 **	36.40**	14.05**
ME-18×MI-0173	32.69 **	30.19 **	22.24 **	3.74	10.80**	6.95**

ME-18×MI-0308	38.66 **	25.00 **	47.90 **	41.05 **	27.67**	8.32**
ME-18×MI-0423	64.93 **	64.15 **	18.63 **	6.12 *	-1.72	-6.54**
MI-0025×MI-0079	59.51 **	58.54 **	25.61 **	17.49 **	23.08**	0.00
MI-0025×MI-0173	11.96 *	0.98	10.26 **	-1.90	3.61	-3.37
MI-0025×MI-0308	0.00	-18.94 **	14.14 **	3.40	4.81**	-8.32**
MI-0025×MI-0423	46.52 **	30.48 **	2.63	-3.42	-0.55	-2.04
SE m±	0.1783	0.2059	0.2201	0.2541	0.4754	0.5489
CD at 5 %	0.3589	0.4144	0.4430	0.5115	0.9568	1.1048
CD at 1 %	0.4791	0.5532	0.5914	0.6828	1.2773	1.4749

MPH- Mid parent heterosis, BPH-Better parent heterosis
*Significant at p = 0.05 and ** significant at p = 0.01

Number of leaves per plant

Among the twenty-four hybrids assessed for leaf count, seven out of twenty-four hybrids registered significant positive heterosis ranging from 3.39 to 31.00 per cent over mid-parent. MI-0025 × MI-0423 (31.00 %) exhibited significant high positive heterosis over mid-parent, followed by ME-06 × MI-0423 (25.87 %) hybrids (Table 4). Subsequently, three hybrids exhibited significant positive heterosis ranging from 4.72 to 18.98 per cent over better parent. ME-06 × MI-0423, MI-0025 × MI-0423 and MI-0025 × MI-0173 demonstrated superior better parent heterosis percentages of 18.98, 9.49 and 4.72, respectively (Table 4).

For the number of leaves per plant in mulberry seedlings, high positive heterosis over the better parent indicates that the hybrid seedlings have a significantly greater leaf count compared to the best-performing parent. This increased number of leaves enhances the plants overall photosynthetic capacity and biomass production. High positive heterosis in this trait suggests that the hybrids can outperform the best parent, leading to improved leaf yield and potentially greater productivity. In breeding programs, selecting hybrids with high positive heterosis for the number of leaves per plant can result in higher leaf production, which is beneficial for silkworm nutrition and overall crop yield.

The present findings corroborate those of Ravi (1991), who reported that six hybrids exhibited positive better-parent heterosis, indicating greater leaf production potential than the superior parent. Furthermore, the current results are in agreement with the studies of Ghosh *et al.* (2008) and Lohithashwa *et al.* (2024), reinforcing the consistency and reliability of observed trends in leaf yield potential across different hybrids and experimental conditions.

Internodal distance (cm)

Nine out of twenty-four hybrids registered significant negative heterosis ranging from -6.10 to -24.56 per cent over mid-parent. MI-0008 × MI-0173 (-24.56 %) exhibited significant negative heterosis over mid-parent, followed by ME-06 × MI-0423 (-17.46%) hybrids (Table 4).

For the better parent, fifteen hybrids exhibited significant negative heterosis ranging from -2.94 to -37.50 per cent heterosis. ME-0008 × MI-0308 (-37.50 %) recorded significant negative heterosis over better parent, followed by ME-0008 × MI-0173 (-21.87 %) (Table 4).

The findings are in agreement with those of Bari *et al.* (1989) and Sahu *et al.* (1995), who reported that negative heterosis for internodal length is generally desirable, as it increases the number of leaves per unit stem length, thereby improving leaf yield per unit area. The present results are also supported by the findings of Ghosh *et al.* (2008), who reported significant negative better-parent heterosis for internodal distance in the C-2041 hybrid (−16.25%). These observations are further substantiated by the study of Lohithashwa *et al.* (2024).

In summary, negative heterosis for internodal distance is advantageous as it allows for a greater number of leaves per unit stem length, ultimately leading to higher leaf yield per unit area. Six hybrids exhibited positive mid-parent heterosis ranging from 20.64 to 69.32 per cent, showing a significant difference from the parent lines. In terms of heterosis over the better parent, five hybrids registered positive heterosis ranging from 20.35 to 30.54 per cent, remaining hybrids exhibited negative heterosis over better parent (Table 4).

Table 4: Estimation of per cent heterosis over mid-parent and better-parent for number of leaves per plant and internodal distance (cm)

Crosses	Number of leaves per plant		Internodal distance (cm)	
	Mid parent	Better parent	Mid parent	Better parent
ME-0008×MI-0079	-11.89 **	-22.48 **	-6.10 **	-21.87 **
ME-0008×MI-0173	-0.98	-4.72 **	-24.56 **	-32.81 **
ME-0008×MI-0308	-22.58 **	-40.33 **	-15.79 **	-37.50 **
ME-0008×MI-0423	-13.19 **	-25.55 **	-13.88 **	-29.69 **
ME-0185×MI-0079	-2.56 *	-11.63 **	-10.70 **	-26.15 **
ME-0185×MI-0173	-11.85 **	-12.26 **	-10.43 **	-20.77 **
ME-0185×MI-0308	-13.99 **	-32.04 **	-11.46 **	-34.62 **
ME-0185×MI-0423	-4.13 **	-15.33 **	-11.85 **	-28.46 **
ME-03×MI-0079	4.56 **	-4.49 **	2.17	-5.05 *
ME-03×MI-0173	0.00	-16.03 **	6.53 **	6.00 **
ME-03×MI-0308	-5.04 **	-11.60 **	77.64 **	44.44 **
ME-03×MI-0423	-20.82 **	-25.64 **	71.11 **	55.56 **
ME-06×MI-0079	-10.76 **	-13.18 **	3.63 *	-7.41 **
ME-06×MI-0173	-15.79 **	-21.31 **	52.88 **	47.22 **
ME-06×MI-0308	-3.63 **	-19.34 **	-2.35	-23.15 **
ME-06×MI-0423	25.87 **	18.98 **	-17.46 **	-27.78 **
ME-18×MI-0079	-24.56 **	-33.33 **	32.35 **	13.45 **
ME-18×MI-0173	3.41 *	0.00	15.07 **	5.88 **
ME-18×MI-0308	-18.57 **	-37.02 **	35.91 **	3.36 *
ME-18×MI-0423	3.39 **	-10.95 **	11.00 **	-6.72 **
MI-0025×MI-0079	18.55 **	1.55	19.46 **	-2.94 *
MI-0025×MI-0173	12.12 **	4.72 **	19.49 **	3.68 *
MI-0025×MI-0308	-7.69 **	-30.39 **	39.39 **	1.47
MI-0025×MI-0423	31.00 **	9.49 **	17.05 **	-6.62 **
SE m±	0.0883	0.1020	0.0282	0.0325
CD at 5 %	0.1778	0.2053	0.0567	0.0655
CD at 1 %	0.2373	0.2740	0.0757	0.0874

*Significant at p = 0.05 and ** significant at p = 0.01

Single leaf area (cm^2)

The hybrid ME-03 × MI-0308 exhibited significant positive heterosis over the mid-parent (69.32 %) and better parent (30.54 %), suggesting their potential for further breeding efforts aimed at increasing leaf area (Table 5). These findings align with the results reported by Lohithashwa *et al.* (2024), who found that single leaf area exhibited significant positive heterosis over better parent ranged from 15.64 to 53.11 per cent, highlighting the variability in leaf size among different hybrids and their potential for selection and improvement.

Fresh leaf weight per plant (g)

The fresh weight of the leaves exhibited the significant positive heterosis, ranging from 5.64 to 42.64 per cent for mid-parent heterosis across all five hybrids. The greatest positive heterosis over mid-parent was observed in MI-0025 × MI-0423, which recorded a heterosis of 42.64 % followed by MI-0025 × MI-0079 (41.96 %) mentioned in Table 5.

Positive heterosis over the better parent was noted in three hybrids out of twenty-four hybrids, namely MI-0025 × MI-0079 (26.72 %), MI-0025 × MI-0423 (9.05 %) and ME-03 × MI-0423 (5.20 %), suggesting that these hybrids exhibited a greater fresh weight of leaves compared to the better parent (Table 5).

The present findings are in agreement with earlier studies of Ravi (1991), Ghosh *et al.*, 2009 and Sapna and Chikkalingaiah (2022), who noticed that the fresh leaf weight was an important character for the leaf yield.

Table 5: Estimation of per cent heterosis over mid-parent and better-parent for single leaf area (cm^2) and fresh leaf weight per plant (g).

Crosses	Single leaf area (cm^2)		Fresh leaf weight per plant (g)	
	Mid parent	**Better parent**	**Mid parent**	**Better parent**
ME-0008×MI-0079	28.15 **	20.35 **	-1.50	-8.07 **
ME-0008×MI-0173	-28.14 **	-52.67 **	-30.37 **	-31.14 **
ME-0008×MI-0308	-30.74 **	-45.22 **	-44.57 **	-62.50 **
ME-0008×MI-0423	-62.77**	-76.52 **	-34.66 **	-48.25 **
ME-0185×MI-0079	-27.37 **	-39.99 **	-11.78 **	-19.46 **
ME-0185×MI-0173	-38.59 **	-52.30 **	-20.45 **	-21.47 **
ME-0185×MI-0308	-49.41 **	-49.80 **	-48.00 **	-65.25 **
ME-0185×MI-0423	-59.55 **	-70.56 **	-23.60 **	-40.55 **
ME-03×MI-0079	-24.97 **	-49.02 **	-7.60 **	-18.22 **
ME-03×MI-0173	-51.59 **	-51.73 **	18.37 **	-2.19
ME-03×MI-0308	69.32 **	30.54 **	5.64 **	-19.22 **
ME-03×MI-0423	-2.78	-11.14**	12.22 **	5.20 **
ME-06×MI-0079	-13.85 **	-43.12 **	-6.92 **	-25.71 **
ME-06×MI-0173	-31.11 **	-34.97 **	-32.79 **	-49.41 **
ME-06×MI-0308	-51.10 **	-63.72 **	-8.58 **	-23.05 **
ME-06×MI-0423	-36.17 **	-38.48**	-12.78 **	-17.77 **
ME-18×MI-0079	42.76 **	26.77 **	-15.31 **	-21.79 **
ME-18×MI-0173	-39.08 **	-55.37 **	-3.68 **	-17.27 **
ME-18×MI-0308	39.34 **	29.16 **	-14.70 **	-36.83 **
ME-18×MI-0423	-7.01 **	-35.69**	-26.46 **	-33.98 **
MI-0025×MI-0079	20.64 **	5.91	41.96 **	26.72 **
MI-0025×MI-0173	-46.44 **	-60.43 **	-2.60	-6.18 **
MI-0025×MI-0308	23.03 **	15.44 **	-19.39 **	-46.80 **
MI-0025×MI-0423	-45.31 **	-61.89 **	42.64 **	9.05 **
SE m±	0.9386	1.0838	0.0640	0.0739
CD at 5 %	1.8893	2.1816	0.1289	0.1488
CD at 1 %	2.5221	2.9122	0.1721	0.1987

*Significant at p = 0.05 and ** significant at p = 0.01

Conclusion

Among the hybrid combinations, most of the selected hybrids recorded significantly positive heterosis for the majority of the growth and yield attributes when compared to the mid-parent and better parent, indicating the hybrids exhibit enhanced vigour and performance over their parental lines. Out of the twenty-four hybrids estimated for heterosis, ME-18 × MI-0308 hybrid recorded significant high positive heterosis for gemination percentage and seedling height at 60 DAS, ME-18 × MI-0423 hybrid for seedling height at 30 DAS, ME-18 × MI-0079 hybrid for seedling height at 90 DAS, ME-06 × MI-0423 hybrid for number of leaves per plant, ME-03 × MI-0308 hybrid for single leaf area and MI-0025 × MI-0079 for fresh leaf weight per plant over better parent. ME-0008 × MI-0308 hybrid displayed significant negative heterosis over better parent for internodal distance. Based on this, these hybrids are consider as most promising hybrids, equally superior to conventional hybrids for many economic and yield contributing traits.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of manuscripts.

Competing Interests

Authors have declared that no competing interests exist.

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