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Studies on heterosis and heterobeltiosis effects on growth, quality and yield traits of improved mulberry hybrids (*Morus* spp.)

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Abstract
The major concern of the plant breeder is the genetic improvement of both the qualitative and quantitative characters of a crop. The genetic improvement can be enhanced at a faster rate if the genetic architecture of different growth parameters are correctly deciphered. Heterosis studies in 21 F_1 hybrids including two checks was assessed based on some morphological and yield contributing traits. The experiment was carried out in an randomized complete block design at University of Agricultural Sciences, GKVK, Bangalore, during 2020-21. Hybrids were found to be highly significant for all the characters studied, suggesting that these traits are under the control of additive genes. *M. cathyana* × V1 showed significant positive heterosis over standard check for plant height and total shoot length. Number of branches per plant and leaf yield/ plant showed significant negative heterosis over standard check in MI-494 × C-776 hybrid. M. indica × V1 showed significant positive heterosis over mid parent, better parent and standard check for internodal distance. *M. multicaulis* × C-776 and BC-259 × V1 showed significant negative heterosis over mid parent, better parent and standard check, indicating their superiority as promising hybrids for single leaf area and number of leaves per plant respectively. It has further been observed that among the twenty one F_1 hybrids, *M. cathyana* × V1 and *M. multicaulis* × C-776 were found highly promising for future utilization.

Keywords: Heterosis, F1 hybrid, better parent, mid parent, standard parent

Introduction
Mulberry is the principal host of the silkworm (*Bombyx mori* L.), which belongs to the family Moraceae and is commercially exploited (Sarkar *et al*, 1996) [10]. Mulberry is responsible for more than 60% of the entire cost of cocoon production in commercial sericulture. Mulberry leaf output can be increased by generating new varieties with higher leaf yield and adaptability, which boosts sericulture productivity. The long-term goal of a breeder is to boost up the quality and quantity of leaf in mulberry through hybridization, selection, and mutation breeding. It is necessary to have sufficient knowledge of mulberry genetics in order to change the genetic constitution of plant. (Vijayan *et al*, 2012) [12].
Improvement in the production of silk involves first and foremost improvement in yielding ability of mulberry the host plant of silkworm, *Bombyx mori* L. The major concern of the plant breeder is the genetic improvement of both the qualitative and quantitative characters of a crop. The genetic improvement can be enhanced at a faster rate if the genetic architecture of different growth parameters are correctly deciphered.
The potentiality of a parent to create superior progenies when combined with another parent is referred to as good combining ability. The genetic variation between the parents and their selection is vital for producing F1 progeny with superior performance. Parents with high GCA are usually considered for population progress and for beginning of pedigree breeding as it is heritable and can be fixed. GCA consists of additive effects and additive × additive type of interactions. High heterosis can be produced by parents with high GCA/SCA (Specific combining ability) consists of dominant effects and non-additive effects, other interactions. Specific combining ability is not heritable and therefore it cannot be utilised in pure line breeding. To exploit hybrids commercially they should possess high SCA (Ravindra Singh *et al*, 2003) [7].
Heterosis in mulberry has been studied for leaf yield and its component characters by several workers. (Vijayan *et al*, 1998) [11] reported that heterosis breeding in mulberry is quite possible, though the plant is known to be highly heterozygous. It has further been observed that a hybrid Berhampore-1× Kajli is highly promising for future utilization.

(Sahu *et al*, 1995 [9], Bari *et al*, 1989 [1]) found negative heterosis for internodal distance which is desirable as this would enhance the number of leaves per unit length of the stem, thereby increasing the leaf yield per unit area. To produce high yielding hybrids, the commercially feasible level of heterosis must be expressed in contrast to the parents' combining ability.

Materials and Methods

For the current investigation, parents including seven lines and three testers were selected from the field germplasm existed at the Department of Sericulture, UAS, GKVK, Bangalore and crossed according to line × tester mating design. Twenty one F_1 crosses was developed and planted during 2019. All the crosses were assessed using randomized complete block design (RCBD) with three replications and 10 plants per treatment per replications were maintained. The studies on heterosis on different growth and yield attributing characters were studied in these mulberry crosses in the year 2020-21 and the crosses were evaluated at 60^{th} day after pruning for growth and yield parameters in two seasons *viz.,* winter and summer with all the recommended package of practices *viz.,* fertilizer application and weeding for mulberry crosses was given under rainfed conditions (Dandin and Giridar, 2010) [3].

Heterosis study

Heterosis value of each hybrid was worked out for all the growth and yield parameters. Relative heterosis was calculated as the per cent deviation of the F_1 hybrids from its mid parental value. Heterobeltiosis in each hybrid combination was expressed for each character as per cent increase or decrease of F_1 value over corresponding better parent value and the standard heterosis was calculated over the standard check variety to show the superiority of hybrid over the recommended variety M5. Three types of heterosis were estimated using the following formulae (Chaudhury, 1996) [2].

Relative Heterosis = di = $(F_1 / MP - 1) \times 100$
Heterobeltiosis = dii = $(F_1/ BP - 1) \times 100$
Standard Heterosis = diii = $(F_1 / SC - 1) \times 100$

Where, F_1 = Mean of hybrid
MP = Mean of two parents involved in the hybrid combination
BP = Mean of better parent of the hybrid combination
SC = Mean of standard check
Significance for combining ability and heterosis was tested by using LSD value at 1 and 5 per cent levels of significance.

Results and Discussion

Heterosis and heterobeltiosis effect are presented in the table 1, 2 and 3.

Plant height (cm)

Only one hybrid, MI-47 × C-776 showed significant positive heterosis of 31.76 % over mid parent and 28.84 % over better parent and hybrid *M. cathyana* × V1 showed significant positive heterosis of 51.26 % over standard check for plant height indicating their superiority as promising hybrids. The present findings were also similar with results reported by Ghosh *et al*, 2009) [4].

Total shoot length (cm)

The hybridization between *M. multicaulis* and C-776, showed significant positive heterosis of 92.70 % over mid parent and 78.33 % over better parent and hybrid *M. cathyana* × V1 showed significant positive heterosis of 120.74 % over standard check for total shoot length. The present findings were also similar with results of earlier work (Ghosh *et al*, 2009) [4].

Number of branches per plant

Number of branches per plant in *M. cathyana* × V1 showed significant negative heterosis of -87.18 % over mid parent and -89.78 % over better parent and hybrid MI-494 × C-776 showed significant negative heterosis of -66.68 % over standard check for number of branches per plant indicating their superiority as promising hybrids.

Number of leaves per plant

Only one hybrid, BC-259 × V1 showed significant negative heterosis of -84.78 % over mid parent and -86.27 % over better parent and -85.36 % over standard check for number of leaves per plant indicated as promising hybrids. The present findings were also similar with results of earlier work (Ghosh *et al*, 2009) [4].

Internodal distance (cm)

The F1 hybrid, *M. indica* × V1 showed significant positive heterosis of 81.09 % over mid parent and 59.86 % over better parent and of 63.62 % over standard check for intermodal distance indicating their superiority as promising hybrids. The present findings were also similar with results of earlier work (Ghosh *et al*, 2009) [4].

Single leaf area (cm^2)

Only one hybrid, *M. multicaulis* × C-776 showed significant negative heterosis of -69.74 % over mid parent, better parent and standard check for single leaf area for indicating their superiority as promising hybrids.

Leaf yield/ plant (g/plant)

Leaf yield/ plant for BC-259 × V1 showed significant negative heterosis of -94.81 % over mid parent and -96.13 % over better parent and hybrid MI-494 × C-776 showed significant negative heterosis of -94.71 % over standard check for leaf yield/ plant indicating their superiority as promising hybrids. Results revealed the predominant role of non additive gene action for leaf yield/ plant reported by Premalatha and Kalamani, 2010 [6]. The ratio of additive to dominance variance was lower than unity for all traits, indicating higher non additive variance than additive variance was reported by Reddy *et al*, 2016 [8]. The present findings were also similar with results of earlier work. (Ghosh *et al*, 2009) [4].

Table 1: Estimates of heterosis over mid parent, better parent and standard parent for plant height (cm) and total shoot length (cm) in mulberry hybrids

Crosses	Plant height (cm)			Total shoot length (cm)		
	Mid parent	Better parent	Standard check	Mid parent	Better parent	Standard check
M. laevigata × V1	5.85	3.42	31.14 **	27.59 **	22.30 *	90.35 **
M .laevigata × C-776	14.61 **	0.29	21.34 **	41.79 **	11.58	59.28 **
M .laevigata × MI-66	-8.51 *	-13.93 **	18.13 **	3.68	-6.77	66.66 **
M. multicaulis × V1	-2.93	-16.65 **	5.68	8.17	-12.62	36.01 *
M. multicaulis × C-776	19.23 **	19.11 **	8.32	92.70 **	78.73 **	71.26 **
M. multicaulis × MI-66	-4.45	-20.57 **	9.02	13.27	-13.01	55.51 **
MI-47 × V1	20.65 **	1.59	28.82 **	39.40 **	16.48	81.30 **
MI-47 × C-776	31.76 **	28.84 **	16.94 **	71.35 **	52.86 **	59.69 **
MI-47 × MI-66	-5.02	-22.49 **	6.37	6.07	-15.97	50.22 **
BC-259 × V1	-4.58	-14.43 **	8.51	0.63	-15.57	31.41 *
BC-259 × C-776	15.89 **	10.20	10.90	63.55 **	45.26 **	53.29 **
BC-259 × MI-66	7.24	-7.06	27.55 **	26.17 **	0.33	79.34 **
M. cathyana × V1	20.07 **	19.29 **	51.26 **	43.50 **	41.82 **	120.74 **
M. cathyana × C-776	10.82 *	-4.41	19.64 **	40.46 **	8.08	64.29 **
M. cathyana × MI-66	0.24	-4.17	31.52 **	16.53 *	7.81	92.73 **
MI-494 × V1	14.15 **	4.27	32.21 **	41.55 **	19.62	86.17 **
MI-494 × C-776	20.53 **	12.43 *	17.88 **	78.86 **	57.65 **	69.31 **
MI-494 × MI-66	-5.68	-16.81 **	14.17 *	20.47 *	-3.57	72.37 **
M. indica × V1	6.36	-7.78	16.94 **	20.45	-2.32	52.03 **
M. indica × C-776	29.19 **	27.58 **	18.76 **	73.87 **	60.51 **	55.37 **
M. indica × MI-66	-21.94 **	-34.50 **	-10.10	-9.18	-30.00 **	25.13

Table 2: Estimates of heterosis over mid parent, better parent and standard parent for number of branches per plant, number of leaves per plant and internodal distance (cm) in mulberry hybrids

Crosses	Number of branches per plant			Number of leaves per plant			Internodal distance (cm)		
	Mid parent	Better parent	Standard check	Mid parent	Better parent	Standard check	Mid parent	Better parent	Standard check
M. laevigata × V1	-84.43 **	-87.24 **	-57.18 **	-62.75 **	-74.11 **	-72.39 **	31.34 **	24.01 *	42.88 **
M .laevigata × C-776	-76.36 **	-83.34 **	-44.07 **	-47.09 **	-52.23 **	-75.34 **	3.16	-1.98	12.93
M .laevigata × MI-66	-79.66 **	-83.34 **	-44.07 **	-36.05 **	-53.63 **	-57.16 **	19.43 *	11.04	27.94 *
M. multicaulis × V1	-80.32 **	-82.78 **	-63.11 **	-65.50 **	-76.02 **	-74.43 **	11.72	9.78	16.39
M. multicaulis × C-776	-57.72 **	-60.78 **	-36.96 **	-21.84 *	-29.44 **	-63.57 **	7.62	6.46	12.86
M. multicaulis × MI-66	-60.65 **	-65.57 **	-26.21 *	-34.84 **	-52.75 **	-56.35 **	29.24 **	24.98 *	32.50 **
MI-47 × V1	-68.49 **	-73.35 **	-42.89 **	-57.46 **	-67.95 **	-65.82 **	9.39	6.39	15.21
MI-47 × C-776	-53.35 **	-55.04 **	-33.36 **	-32.47 **	-33.99 **	-64.31 **	-2.22	-4.28	3.67
MI-47 × MI-66	-59.96 **	-66.13 **	-27.43 **	-43.71 **	-55.39 **	-58.79 **	13.34	8.49	17.50
BC-259 × V1	-84.79 **	-85.58 **	-65.50 **	-84.78 **	-86.27 **	-85.36 **	-0.47	-6.94	9.47
BC-259 × C-776	-77.90 **	-82.60 **	-58.36 **	-64.03 **	-71.19 **	-75.29 **	0.97	-5.00	11.76
BC-259 × MI-66	-69.57 **	-71.16 **	-31.00 **	-49.04 **	-50.86 **	-54.61 **	6.35	-2.06	15.21
M. cathyana × V1	-87.18 **	-89.78 **	-63.14 **	-65.89 **	-77.13 **	-75.61 **	19.70 *	18.95	23.31 *
M. cathyana × C-776	-75.17 **	-82.85 **	-38.14 **	-32.73 **	-42.70 **	-70.41 **	13.30	13.27	17.50
M. cathyana × MI-66	-84.27 **	-87.47 **	-54.79 **	-64.01 **	-74.93 **	-76.84 **	34.08 **	31.09 **	35.89 **
MI-494 × V1	-81.24 **	-83.35 **	-64.32 **	-72.23 **	-81.38 **	-80.14 **	7.19	4.28	12.86
MI-494 × C-776	-78.05 **	-79.94 **	-66.68 **	-58.83 **	-64.90 **	-81.88 **	5.45	3.26	11.76
MI-494 × MI-66	-76.24 **	-78.92 **	-54.82 **	-59.64 **	-71.87 **	-74.01 **	-5.51	-9.52	-2.07
M. indica × V1	-84.00 **	-85.04 **	-63.14 **	-83.32 **	-84.99 **	-83.99 **	81.09 **	59.86 **	63.62 **
M. indica × C-776	-74.60 **	-80.22 **	-51.25 **	-63.61 **	-70.79 **	-75.08 **	46.75 **	28.80 *	33.61 **
M. indica × MI-66	-77.78 **	-79.23 **	-48.82 **	-72.79 **	-73.83 **	-75.82 **	-11.66	-20.88	-21.65

Table 3: Estimates of heterosis over mid parent, better parent and standard parent for single leaf area (cm^2) and leaf yield/plant (g/plant) in mulberry hybrids.

Crosses	Single leaf area (cm2)			Leaf yield/plant (g/plant)		
	Mid parent	Better parent	Standard check	Mid parent	Better parent	Standard check
M. laevigata × V1	-43.87 **	-43.87 **	-43.87 **	-80.28 **	-88.01 **	-82.68 **
M .laevigata × C-776	-60.36 **	-60.36 **	-60.36 **	-73.72 **	-77.31 **	-90.28 **
M .laevigata × MI-66	-58.32 **	-58.32 **	-58.32 **	-56.68 **	-71.89 **	-70.59 **
M. multicaulis × V1	-64.18 **	-64.18 **	-64.18 **	-89.03 **	-93.38 **	-90.43 **
M. multicaulis × C-776	-69.74 **	-69.74 **	-69.74 **	-63.63 **	-69.06 **	-86.76 **
M. multicaulis × MI-66	-63.17 **	-63.17 **	-63.17 **	-78.17 **	-85.95 **	-85.30 **
MI-47 × V1	-61.52 **	-61.52 **	-61.52 **	-81.95 **	-88.11 **	-82.82 **
MI-47 × C-776	-59.93 **	-59.93 **	-59.93 **	-74.56 **	-75.41 **	-88.72 **

MI-47 × MI-66	-61.79 **	-61.79 **	-61.79 **	-80.95 **	-86.30 **	-85.66 **
BC-259 × V1	-56.91 **	-56.91 **	-56.91 **	-94.81 **	-96.13 **	-94.40 **
BC-259 × C-776	-60.37 **	-60.37 **	-60.37 **	-85.29 **	-88.24 **	-91.60 **
BC-259 × MI-66	-59.97 **	-59.97 **	-59.97 **	-72.72 **	-77.05 **	-75.99 **
M. cathyana × V1	-39.93 **	-39.93 **	-39.93 **	-88.80 **	-93.51 **	-90.62 **
M. cathyana × C-776	-50.05 **	-50.05 **	-50.05 **	-60.45 **	-69.59 **	-86.98 **
M. cathyana × MI-66	-53.03 **	-53.03 **	-53.03 **	-79.75 **	-87.65 **	-87.08 **
MI-494 × V1	-57.32 **	-57.32 **	-57.32 **	-93.25 **	-96.07 **	-94.33 **
MI-494 × C-776	-59.32 **	-59.32 **	-59.32 **	-84.06 **	-87.63 **	-94.71 **
MI-494 × MI-66	-66.71 **	-66.71 **	-66.71 **	-88.85 **	-93.16 **	-92.85 **
M. indica × V1	-61.52 **	-61.52 **	-61.52 **	-92.24 **	-94.07 **	-91.43 **
M. indica × C-776	-63.86 **	-63.86 **	-63.86 **	-83.27 **	-86.95 **	-90.03 **
M. indica × MI-66	-56.26 **	-56.26 **	-56.26 **	-93.22 **	-94.13 **	-93.86 **

Conclusion

Hybrids were found to be highly significant for all the characters studied, suggesting that these traits are under the control of additive genes. The significant difference noticed for leaf yield and its attributing characters between means of parents as a group and those of hybrids suggests that heterosis resulted from dominant genes and its interactions or from complementary gene interactions, as reported in rice (Gravois and Mc New, 1993) [5]. From this investigation it can be concluded that heterosis breeding in mulberry is quite possible, though mulberry is known to be a highly heterozygous and heterogeneous plant. It has further been observed that among the twenty one F_1 hybrids, *M. cathyana* × V1 and *M. multicaulis* × C-776 were found highly promising for future utilization.

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