



Effect of General Combining Ability for Different Seedling Traits in Mulberry (*Morus spp.*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Information regarding the nature of gene action controlling the yield and yield contributing characters are essential for implementing good breeding program. Significant differences were observed among all parents for general combining ability was noticed. Analysis of general combining ability showed the higher magnitude of SCA variance than GCA variance for most of the characters, which indicates the presence of non-additive gene action for most of the traits except for germination percentage, plant height at 60 DAS and number of branches. Out of seven lines *M. cathyana* is the best general combiner as it shows significant positive GCA for seedling height at 60, 90, 120 DAS, number of leaves per plant, average leaf weight, leaf area and significant negative GCA for internodal distance which is in desirable direction. Also MI-47 is best general combiner as it shows significant positive GCA for seedling height at 90, 120 DAS, number of leaves per plant, leaf area (cm²), number of branches. Among the testers V1 was the best general combiner for germination percentage, leaf area (cm²).

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Keywords: General combining ability; mulberry; seedling traits; leaf yield; germplasm.

1. INTRODUCTION

An important component of sericulture industry for the production of raw silk is mulberry foliage that serves as an exclusive source of nutrients for the silkworms (*Bombyx mori* L.) to biosynthesize proteinaceous fibre and spin in the form of cocoon. Mulberry is an enduring tree belongs to family Moraceae and originated in the lower inclines of the Himalayas [1]. It can develop under different climatic conditions extending from mild to tropical. In India mulberry develops during the time because of positive climatic conditions, making sericulture a full time occupation. Since mulberry leaf production alone expenses more than 60 percent out of the all cost, the financial return in sericulture is generally dictated by the measure of good quality mulberry leaves delivered from a unit region [2].

If mulberry leaf production increased, sericulture productivity increases. Leaf yield in mulberry is a complex trait which is mainly influenced by environment and management practices and donated by a number of component traits. For selection of plants average leaf yield alone may not be the good criterion, so it is vital to understand the heritability and genetics of yield components. Capacity of a parent to pass on its pleasing characters to its progeny in crosses is known as combining ability [3]. and developing new varieties with high leaf yield and good adaptability helps to achieve this goal. Parents with good combining ability were known to produce greater progenies when united with other parents. The easiest and efficient method to evaluate combining ability in large number of parents is Line \times Tester analysis. Parents with superior combining ability can be selected based on GCA for exploitation of hybrid vigour by development of segregating populations [4].

Keeping in vision, the significance of mulberry regarding its foliage esteem, crop improvement research on this yield should be reinforced. Considering all these view points, the current study was held to assess general combining ability of parents and specific combining ability of crosses for seedling traits in mulberry.

2. MATERIALS AND METHODS

Studies on "Combining ability for seedling traits in mulberry (*Morus* spp.)" were conducted at the Department of Sericulture, University of

Agricultural sciences, Gandhi Krishi Vignana Kendra Bengaluru - 65. The experimental plot is situated at an elevation of 931 m above mean sea level and has latitude of 12°58' N and longitude of 77°37' E. In this chapter the material details, the practices adopted in the conduct and statistical analysis of the experiment followed are explained.

2.1 Selection of Parents

For the current investigation seven lines and three testers are used (Table 1), which were selected from the field germplasm existed at the Department of sericulture, UAS, GKVK, Bangalore-65. With all the recommended package of practices viz., fertilizer application and weeding for rainfed mulberry, these parental materials are maintained [5].

Table 1. List of lines and testers used in L \times T study

Sl. No.	Parents
Female parents (Lines)	
1.	<i>M. laevigata</i>
2.	<i>M. multicaulis</i>
3.	MI-47
4.	BC- 259
5.	<i>M. cathyana</i>
6.	MI-494
7.	<i>M. indica</i> E-05
Male parents (Testers)	
8	V1
9	MI-66
10	C-776

2.2 Hybridization Programme

Using staggered pruning technique lines and testers flower synchronization is done. At the time of green color stage of inflorescence bagging is done, using butter paper bags of size 45 x 20 cm catkins are covered. For aeration minute holes are made to butter paper bags. For pollination pollen was collected from the testers after three days after bagging using Camlin hair brush. And transferred to the catkins in the morning hours between 8:00 to 10:00 AM, and catkins are covered immediately. For 4-5 days same process of pollination was continued [6,2]. Data pertaining to number of catkins pollinated, cross combination, dates of pollination, etc., were written on the tag.

2.3 Harvesting of Crossed Fruits and Seed Extraction

After full maturity, fruits were harvested cross wise. For seeds extraction they were soaked overnight and then squeezed to separate pulp and seeds. Floating seeds and pulp were removed and the good seeds settled at bottom were collected. Obtained seeds from fruits were washed several times to remove debris from seeds. Then they were sundried and used for sowing.

2.4 Evaluation of F1'S

Twenty-one F1 hybrids derive from seven lines and three testers, were the experimental material which were crossed according to line x tester mating design. All the crosses were assessed using randomized complete block design (RCBD) with three replications and 10 plants per treatment per replications were maintained.

2.5 Experimental Crop

Seeds extracted from the fruits were sown in the small pots at 10 seeds per pot. After 30 days seedlings were transferred into polythene bags. After 90 days they were transplanted into field. Regular fertilizer application and watering, plant protection measures were followed. Then observations were recorded at 60, 90 and 120 days after sowing for plant height (cm). Observations on average leaf weight (g), number of leaves per plant, single leaf area (cm²), internodal distance (cm), leaf shape, phyllotaxy, leaf colour, leaf margin (serration) were recorded at 120 days after sowing.

2.6 Observations on Seedling Traits

- a) Germination percentage
- b) Seedling height at different intervals - 60, 90, 120 days after sowing (DAS)
- c) Number of leaves per plant
- d) Average leaf weight (g)
- e) Internodal distance (cm)
- f) Single leaf area (cm)

2.7 Statistical Analysis

2.7.1 Combining ability analysis

General combining ability (GCA) variance of parents and specific combining ability (SCA) variance of different cross combinations were worked out using WINDOSTAT Software based on the procedures developed by Kempthorne

(1957) using means of each replication for the characters recorded for twenty one crosses.

2.8 Estimation of Combining Ability Effects

Linear model given by Kempthorne, 1957 was used to estimate GCA and SCA effects which is as follows

Where,

$$X_{ijk} = \mu + g_i + g_j + S_{ij} + e_{ijk}$$

μ = population mean
 g_i = GCA effect of i^{th} female parent
 g_j = GCA effect of j^{th} male parent
 S_{ij} = SCA effect of ij^{th} combination
 e_{ijk} = Error associated with the observation X_{ijk}
 i = Number of female parents
 j = Number of male parents
 k = Number of replications

The individual effects were estimated as indicated below:

2.9 Genetic Combining Ability Effects (GCA)

- a) Lines: $g_l = X_{i..} / tr - X_{...} / ltr$
- b) Testers: $g_t = X_{.j.} / lr - X_{...} / ltr$

Where,

$X_{i..}$ = Total of i^{th} line over all testers and replications
 $X_{.j.}$ = Total of j^{th} tester over all lines and replications

2.10 Critical Difference (CD)

The critical difference values in each case were computed by multiplying their corresponding SE values with table 't' value at error degrees of freedom at 5 and 1 percent level of significance.

3. RESULTS AND DISCUSSION

3.1 General Combining Ability Effects (GCA)

The estimates of GCA effects of parents help in identifying superior parents to be utilized for production of superior genotypes in segregating populations by concentration of desirable genes with additive effect. The present study supported to identify lines and testers with high GCA effect for more number of characters. The GCA effects represent the breeding value of parents involved and a good general combiner possesses better breeding value. The result pertaining to GCA effects of seven female lines (parents)

and three male parents (testers) are presented below.

3.2 Germination Per Cent

The magnitude of GCA effects in the lines for germination per cent ranged from -7.00 (MI-47) to 18.77 (*M. laevigata*). Among the lines *M. laevigata* showed significant positive GCA effect, and three lines viz., MI-47 (-7.00), *M. cathyana* (-5.33), MI-494(-5.33) exhibited significant negative GCA effects. The GCA effect in testers for germination per cent was -6.00(MI-66) to 7.09(V1). The tester V1 showed highly significant positive *gca* effect. (Table 2, Fig.1). Whereas MI-66 showed highly significant negative GCA effect. Results indicate that *M. laevigata* in lines and V1 in testers are good general combiners for the germination percentage.

3.3 Plant height (cm) at 60, 90 and 120th DAS

In females *gca* effects for plant height ranged from -3.5(MI-494) to 3.00(*M. cathyana*), -9.32

(MI-494) to 7.77 (*M. cathyana*), -10.75 (MI-494) to 13.57 (*M. cathyana*) at 60, 90 and 120 DAS respectively. Among the lines *M. cathyana* (3.00) exhibited significant positive GCA, MI-494 (-3.5) expressed significant negative GCA for plant height at 60DAS. At 90 DAS three lines viz., MI-47(6.69), BC-259 (5.03), *M. cathyana* (0.77) expressed significant positive GCA, whereas *M. laevigata* (-5.94), MI-494(-9.32), *M. indica* (-3.85) recorded significant negative GCA At 120 DAS two lines viz., MI-47(7.63), *M. cathyana* (13.57) recorded significant positive GCA two lines viz., *M. laevigata* (-10.08), MI-494(-10.75), exhibited significant negative GCA For these character males (testers) recorded GCA ranges -1.12 (MI-66) to 0.65 (C-776), -1.58 (MI-66) to 0.87 (V1), -2.38 (MI-66) to 0.89 (V1) at 60, 90, 120 DAS respectively. No tester recorded significant positive GCA effect for plant height. (Table 2, Fig. 2). These results are similar to the findings of Rita Banerjee et al., [7] Ghosh et al., [8] and Peris Nderitu et al [9] and Bhuvana et al. [10].

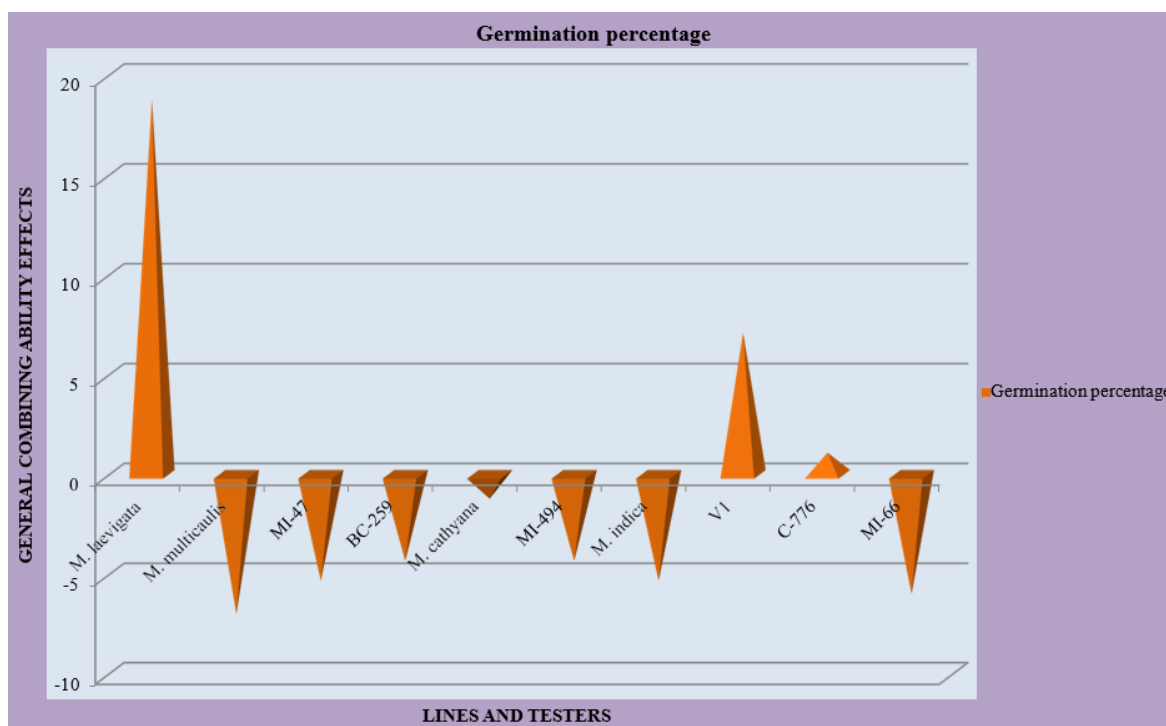


Fig. 1. General combining ability effects of lines and testers for germination percentage in mulberry

Table 2. Estimates of general combining ability effects of parents for different growth parameters at seedling stage in mulberry

Parents	Germination percentage	Plant height (cm) at			Number of leaves per plant	Average leaf weight(g)	Single leaf area(cm ²)	Number of branches per plant	Internodal distance (cm)
		60 DAS	90 DAS	120 DAS					
Lines									
<i>M. laevigata</i>	18.77**	0.13	-5.94**	-10.08**	-3.79	-0.58	-9.17**	-0.01	0.03
<i>M. multicaulis</i>	-1.22	-1.11	-0.37	1.13	-4.68	-3.27**	6.08**	-1.12**	-0.24
MI-47	-7.00**	0.81	6.69**	7.63*	6.09*	1.18	4.85*	2.65**	0.12
BC-259	-4.33	-0.55	5.03**	5.13	-8.79**	-4.88**	13.51**	-1.34**	0.27
<i>M. cathyana</i>	-5.33*	3.00**	7.77**	13.57**	9.09**	7.65**	5.95**	-0.12	-0.42*
MI-494	-5.33*	-3.50**	-9.32**	-10.75**	-1.90	-0.52	-17.67**	-0.79	-0.26
<i>M. indica</i>	4.44	1.22	-3.85*	-6.64	3.98	0.42	-3.55	0.76	0.51*
SEm±	2.56	1.07	1.73	3.31	2.39	0.788	1.84	0.39	0.19
CD at 5%	5.17	2.17	3.50	6.70	4.84	1.59	3.72	0.80	0.40
CD at 1%	6.92	2.90	4.69	8.96	6.48	2.13	4.98	1.07	0.53
Testers									
V1	7.09**	0.47	0.87	1.89	-0.60	0.50	6.17**	0.11	0.02
C-776	1.09	0.65	0.71	0.49	0.77	-0.69	-0.018	0.06	0.28*
MI-66	-6.00**	-1.12	-1.58	-2.38	-0.17	0.64	-6.15**	-0.17	-0.31*
SEm±	1.67	0.70	1.13	2.17	1.56	0.51	1.20	0.26	0.13
CD at 5%	3.39	1.42	2.29	4.38	3.17	1.04	2.44	0.52	0.26
CD at 1%	4.53	1.90	3.07	5.17	4.24	1.39	3.26	0.70	0.35

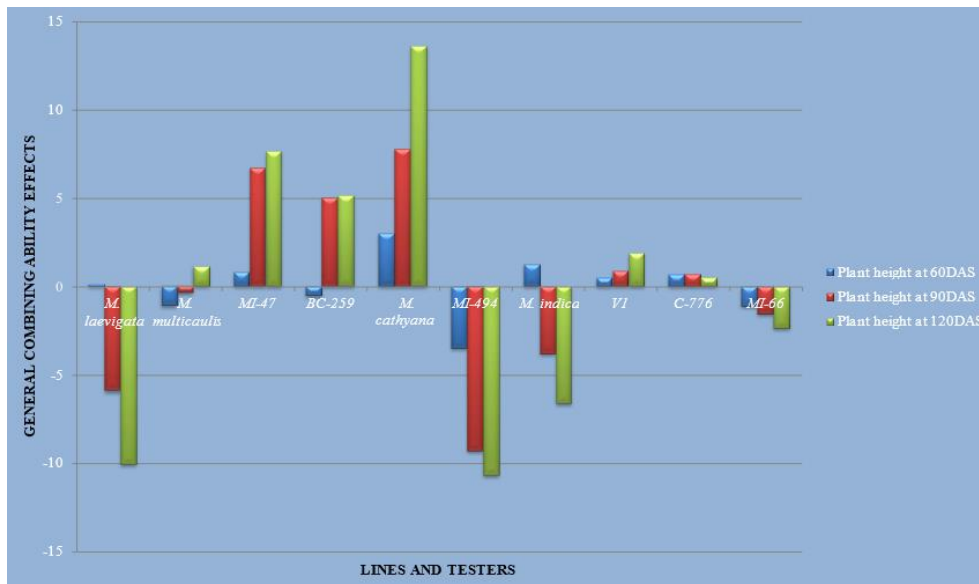


Fig. 2. General combining ability effects of lines and testers for plant height at 60, 90 and 120

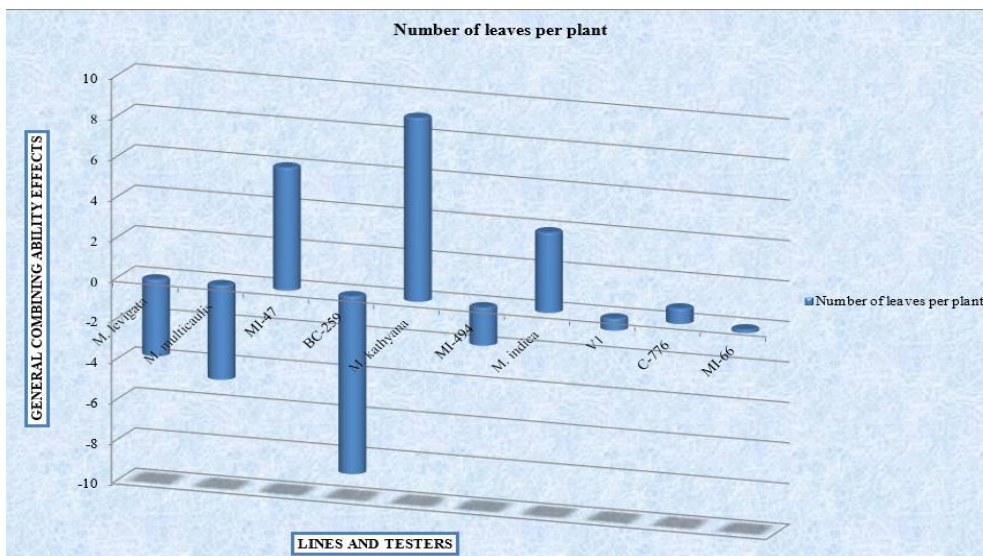


Fig. 3. General combining ability effects of lines and testers for number of leaves per plant in mulberry

3.4 DAS in Mulberry

Out of all parents *M. cathyana* is best general combiner for higher plant height, which expressed positive significant values for seedling height at 60, 90, 120DAS. Followed by MI-57 registered significant positive values at 90, 120 DAS. MI-494 is good general combiner for shorter plant height, followed by *M. laevigata*. In the study of Vijayan et al. [4] parents with highly significant and positive GCA effects were good combiners for tall plants in mulberry. ME-18 registered positive GCA effect at seedling stage

even when studied by Pooja et al. [11]. In the studies conducted by Ahmad et al. [12] and Amiruzzaman et al. [13] concluded that short plants in maize can be obtained from parents which are having highly significant negative GCA effect for that trait.

3.5 Number of Leaves Per Plant

With respect to number of leaves per plant, magnitude of GCA ranged from -8.79 (BC-259) to 9.09 (*M. cathyana*). Among the lines MI-47(6.09), *M. cathyana* (9.09) showed highly

significant positive GCA, and the BC-259 (-8.79) recorded significant negative GCA. The GCA effects ranged between -0.60 (V1) to 0.77 (MI-66) among the testers and no tester expressed significant GCA effect. (Table 2, Fig.3). In this study *M. cathyana* is best general combiner for number of leaves per plant, as it shows highly significant positive GCA value, followed by MI-47 which showed significant positive GCA value. Similar results, that is significant positive GCA effect was recorded in parent MI- 139 when Pooja et al. [11] conducted combining ability studies on mulberry seedling. This was supported by Marani and Sachs [14] where in parents registered significant positive GCA for number of leaves and in the study by Nazaria et al. [15] and Bhuvana et al. [10].

3.6 Average Leaf Weight (g)

With regard to leaf weight magnitude of GCA effects of lines ranged from - 4.88(BC-259) to 7.65 (*M. cathyana*). Among the lines *M. cathyana* (7.65) recorded highly significant positive GCA, BC-259(-4.88), *M. multicaulis* (-3.27), recorded significant negative GCA. In lines GCA ranges from -0.69 to 0.64, but all testers exhibited non significant GCA values. (Table 2, Fig.4). Among parents, a line *M. cathyana* was found to be potential good combiner for the trait which is expressing significant positive GCA effect. No

tester exhibited significant GCA effect for the trait. In the study of Nazaria et al. [15] in tobacco, parents showed significant positive GCA effect and were found to be good general combiners for fresh leaf weight and proved as an useful index for combining ability. These results are similar to the findings of Rita Banerjee et al., [7] Ghosh et al., [8] and Peris Nderitu et al [9] and Bhuvana et al. [10].

3.7 Single Leaf Area (cm²)

The *gca* effects variation for this character in lines ranged from -17.97(MI-494) to 13.51(BC-259). Four lines viz., BC-259(13.51), *M. multicaulis* (6.58), MI-47(4.85), *M. cathyana* (5.95) was registered significant positive GCA effect. GCA effect in testers ranged from - 6.15(MI-66) to 6.17 (V1). Among testers V1 (6.17) showed significant positive GCA effect. MI-66(6.15) showed significant negative GCA effect (Table 2, Fig.5). The line BC-259 registered highly significant positive GCA for leaf, it is considered as best general combiner for leaf area. *M. multicaulis*, MI-47, *M. cathyana* are also good general combiners for leaf area, since they registered significant positive GCA values. In testers V1 is good general combiner. These results are similar to the findings of Rita Banerjee et al., [7] Ghosh et al., [8] and Peris Nderitu et al [9] and Bhuvana et al. [10].

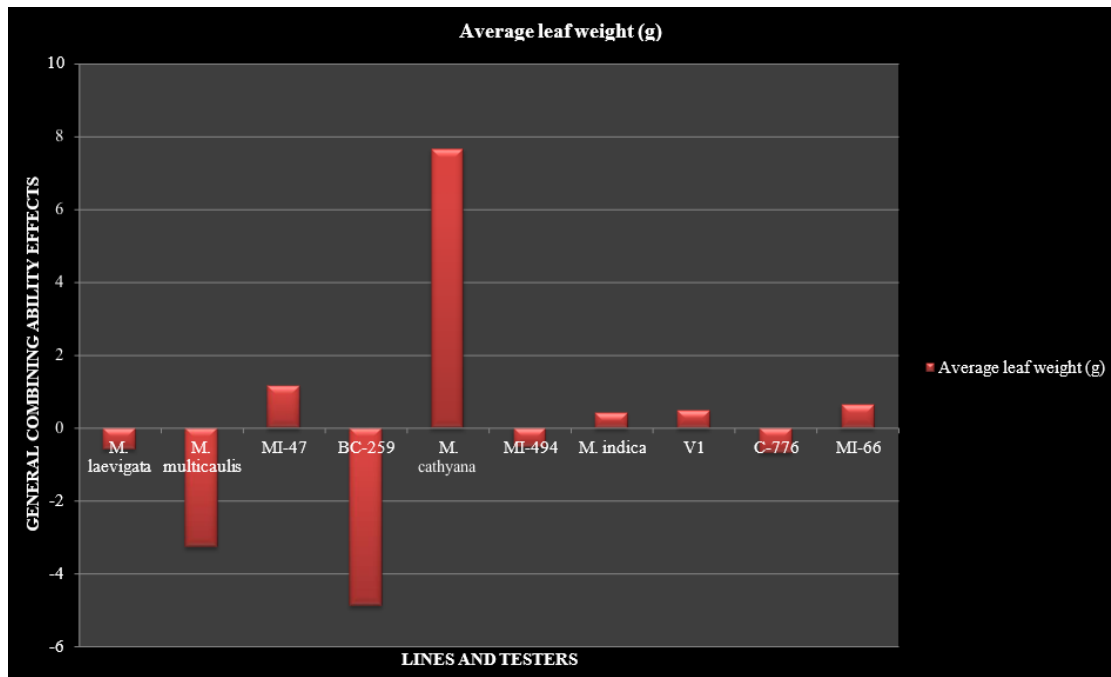


Fig. 4. General combining ability effects of lines and testers for average leaf weight (g) in mulberry

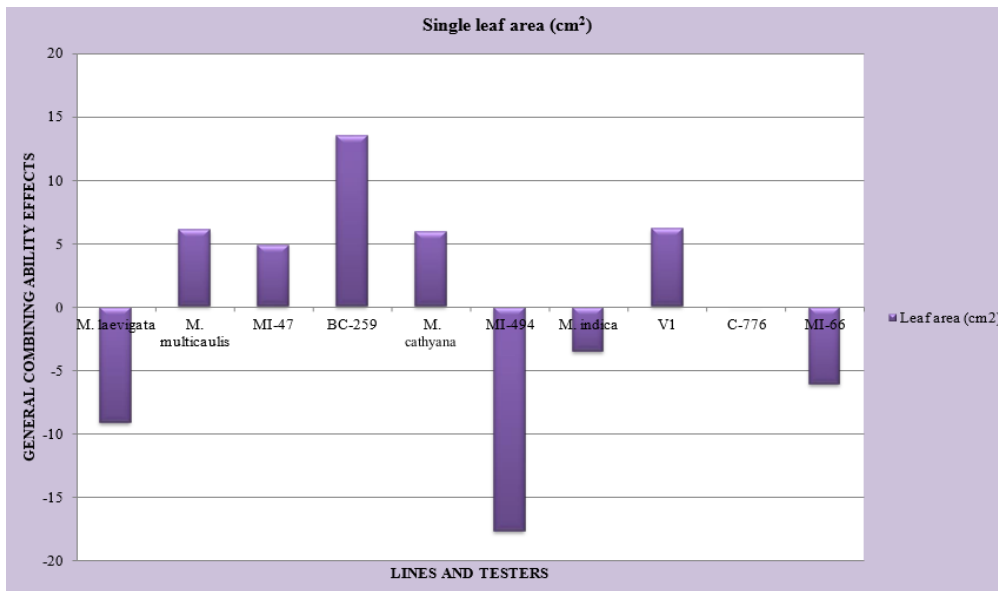


Fig. 5. General combining ability effects of lines and testers for single leaf area (cm²) in mulberry

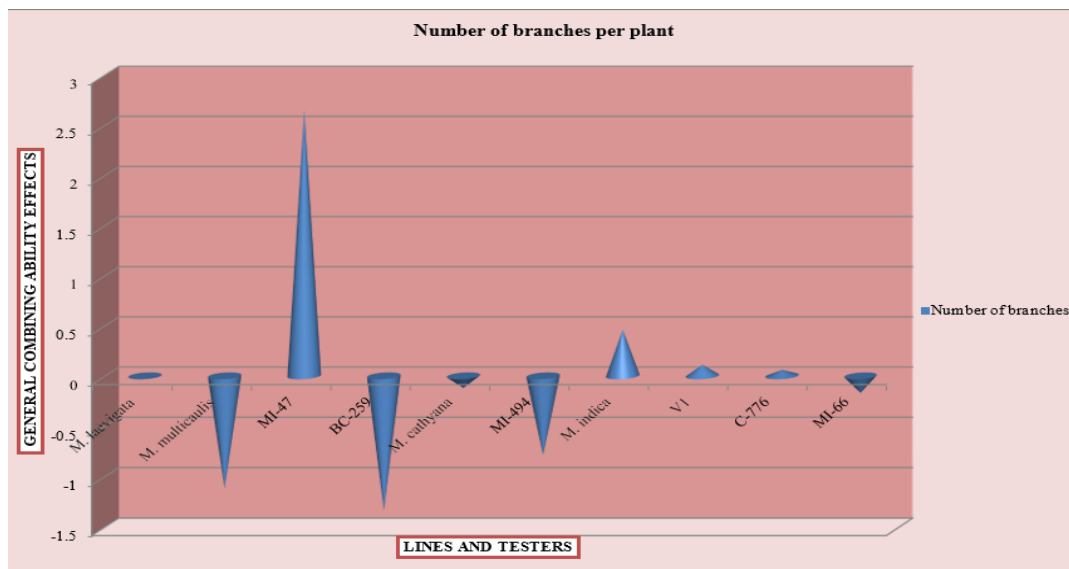


Fig. 6. General combining ability effects of lines and testers for number of branches per plant in mulberry

3.8 Number of Branches Per Plant

In lines GCA ranged from -1.34(BC-259) to 2.65(MI-47). Only one line showed significant positive GCA effect *i.e.* MI-47(2.65). Two lines showed significant negative GCA effect *i.e.* BC-259(-1.34) and *M. multicaulis* (-1.12). In testers GCA effect ranged from - 0.17(MI-66) to 0.11(V1). However no tester showed significant GCA effect (Table 2, Fig. 6). In lines MI-47 is good general combiner for number of branches.

BC-259 and *M. multicaulis* are poor combiners for number of branches since they showed significant negative GCA values. Two parents exhibited significant positive GCA effects for number of branches in a study conducted by Vijayan et al. [4] and Bhuvana et al. [10].

3.9 Internodal Distance (cm)

GCA effect for this trait in lines ranges from -0.42 (*M. cathyana*) to 0.51(*M. indica*). One line

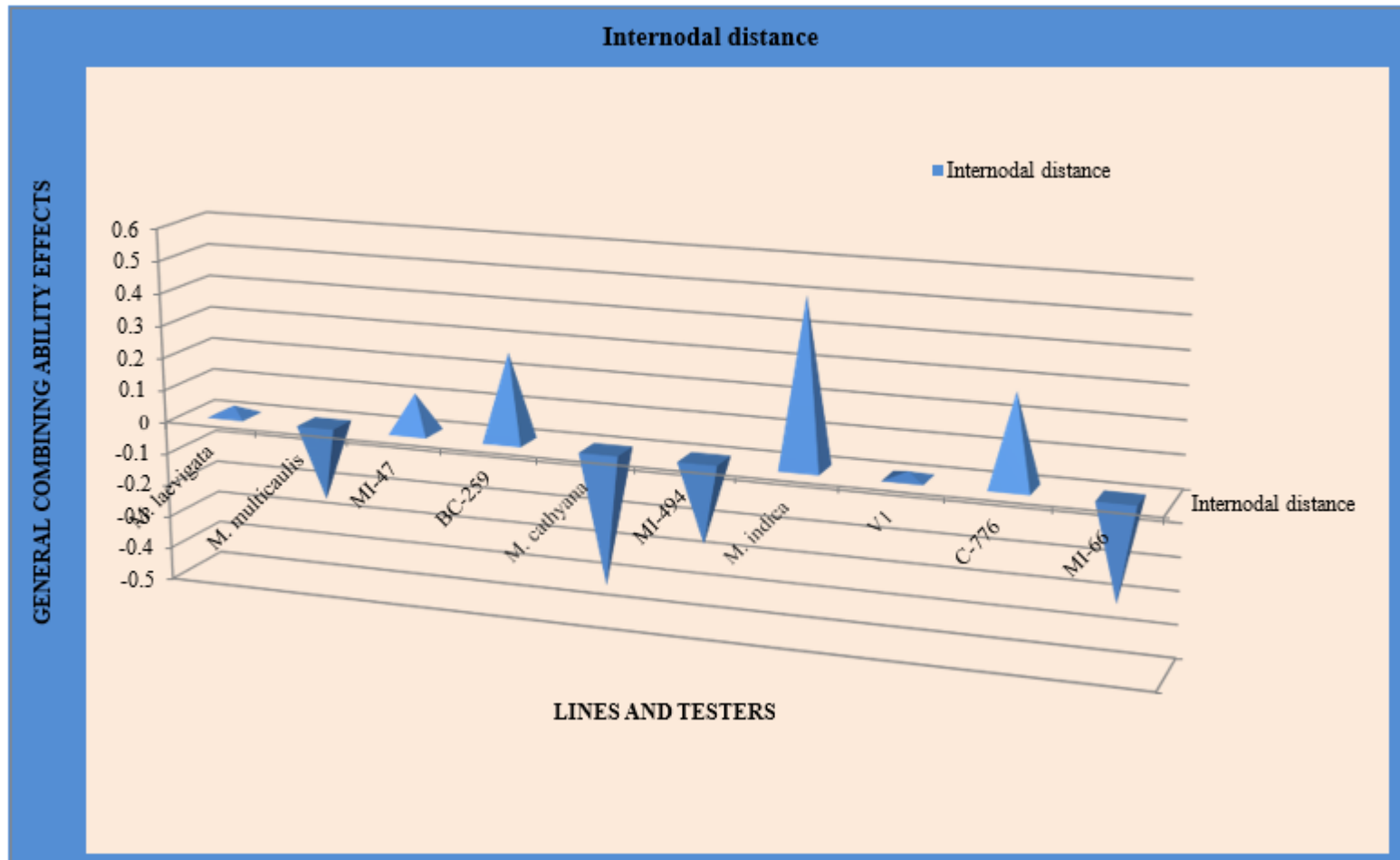


Fig. 7. General combining ability effects of lines and testers for internodal distance (cm) in mulberry

showed significant positive GCA effect *i.e.* *M. indica* (0.51). *M. cathyana* (-0.42) registered significant negative GCA effect in desirable way. In testers it is ranged from -0.31(MI-66) to 0.28(C-776). Tester *i.e.* C-776 registered significant positive GCA effect and MI-66 registered significant negative GCA value. (Table 2, Fig.7). With respect to intermodal distance two parents *viz.*, *M. cathyana* and MI-66 are best general combiners, since they registered significant negative GCA values. In the study of Vijayan et al. [4,16-18] and Banerjee et al. [19-20] Bhuvana et al. [10,21,22] in mulberry reported that parents used in their studies expressed significant negative GCA effects which indicated that they could be good combiner.

4. CONCLUSION

Significant differences were observed among all parents for general combining ability. Analysis of general combining ability showed the higher magnitude of SCA variance than GCA variance for most of the characters, which indicates the presence of non-additive gene action for most of the traits except for germination percentage, plant height at 60 DAS and number of branches. Out of seven lines *M. cathyana* is the best general combiner as it shows significant positive GCA for seedling height at 60, 90, 120 days after sowing (DAS), number of leaves per plant, average leaf weight, leaf area and significant negative GCA for internodal distance which is in desirable direction. Also MI-47 is best general combiner as it shows significant positive GCA for seedling height at 90, 120 DAS, number of leaves per plant, leaf area (cm²), number of branches. Among the testers V1 was the best general combiner for germination percentage, leaf area (cm²). Further, this study is proposed to evaluate the crosses of mulberry for yield and related traits in large scale multilocation trials to identify promising progeny for their stability over seasons and locations.

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 the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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