

Original Research Article

Effect of General Combining Ability for different seedling traits in mulberry (*Morus* spp.)

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 undesirable 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).

Key words: General Combining Ability, Mulberry, Seedling traits, Leaf Yield, Germplasm

Introduction:

Mulberry is a key harvest for the sericulture business as it is the selective wellspring of feed for silkworm. It is an enduring tree belongs to family Moraceae and originated in the lower inclines of the Himalayas (Sarkar, 1990). 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 (Das and Krishnaswami, 1964).

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 (Tatum and Sprague, 1942) 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 (Vijayan *et al.*, 1997).

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

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.

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 (Dandin and Giridar, 2010).

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

Sl.No.	Parents
--------	---------

Femaleparents(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
Maleparents(Testers)	
8.	V1
9.	MI-66
10.	C-776

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 (Mukherjee 1965; Das and Krishnaswamy, 1964). Data pertaining to number of catkins pollinated, cross combination, dates of pollination, etc., were written on the tag.

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.

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 \times 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.

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.

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)

STATISTICAL ANALYSIS

Combining ability analysis

General combining ability (GCA) variance of parents and specific combining ability (SCA) variance of different cross combinations were worked out based on the procedures developed by Kempthorne (1957) using means of each replication for the characters recorded for twentyone crosses.

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

Genetic combining ability effects (gca)

$$\text{a) Lines: } g_l = \frac{X_{i..} - X_{...}}{t - ltr}$$

$$\text{b) Testers: } g_t = \frac{X_{j..} - X_{...}}{l - ltr}$$

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

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.

RESULTS AND DISCUSSION:

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 represented below.

Germination percent

The magnitude of *gca* effects in the lines for germination percent 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 percent was -6.00 (MI-66) to 7.09 (V1). The tester V1 showed highly significant positive *gca* effect. (Table 1, 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.

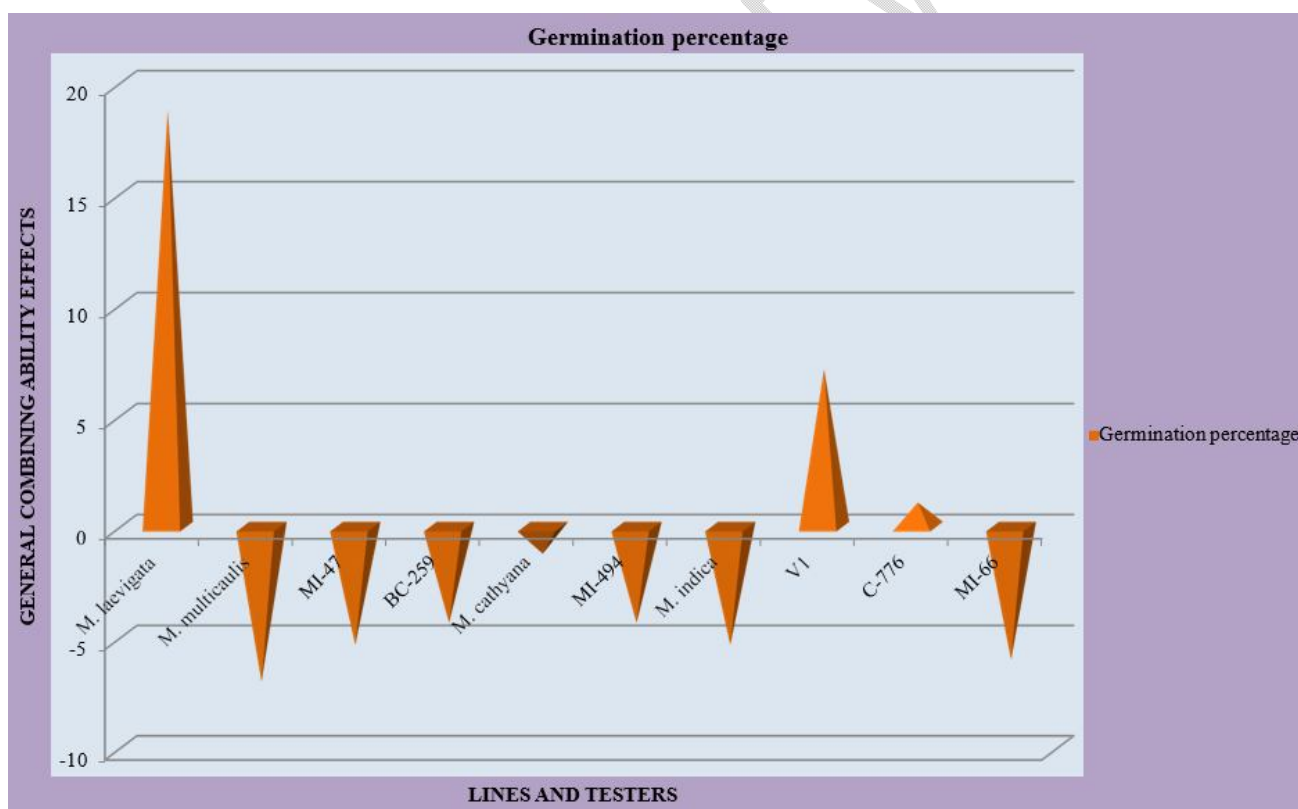


Fig.1: General combining ability effects of lines and testers for germination percentage in mulberry

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

Infemalesgca effectsfor plantheightrangedfrom-3.5(MI-494) to3.00(*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) exhibitedsignificant positive gca, MI-494 (-3.5) expressed significant negative gca for plant heightat 60DAS. At 90 DAS three lines viz., MI-47(6.69), BC-259 (5.03), *M. cathyana* (0.77)expressedsignificantpositivegca,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)recordedsignificantpositivegca,twolinesviz.,*M.laevigata*(-10.08),MI-494(-10.75),exhibited significantnegativegca. For these character males (testers) recorded gca ranges -1.12 (MI-66) to 0.65 (C-776),-1.58(MI-66)to0.87(V1),-2.38(MI-66)to0.89(V1)at60,90,120DAS respectively.Notesterrecordedsignificantpositivegcaeffectforplantheight.(Fig.2).



Fig.2:General combining ability effects of lines and testers for plant height at 60, 90 and 120 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, 120 DAS. Followed by MI-47 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.* (1997) 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.* (2016). In the studies conducted by Ahmad *et al.* (2010) and Amiruzzaman *et al.* (2013) concluded that short plants in maize can be obtained from parents which are having highly significant negative gca effect for that trait.

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. (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.* (2016), conducted combining ability studies on mulberry seedling. This was supported by Marani and Sachs (1966), where in parents registered significant positive GCA for number of leaves and in the study by Nazaria *et al.* (2016).

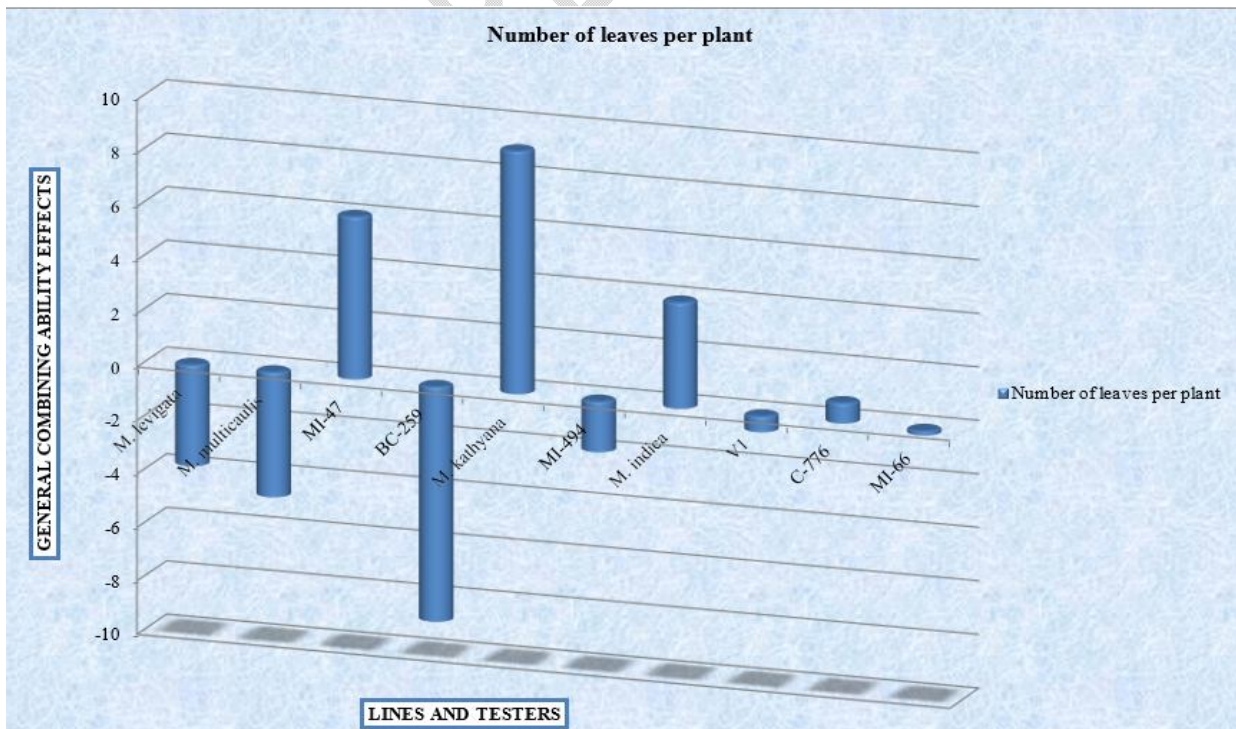


Fig. 3: General combining ability effects of lines and testers for number of leaves per plant in mulberry

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. (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.* (2016) in tobacco, parents showed significant positive gca effect and were found to be good general combiners for fresh leaf weight and proved as a useful index for combining ability.

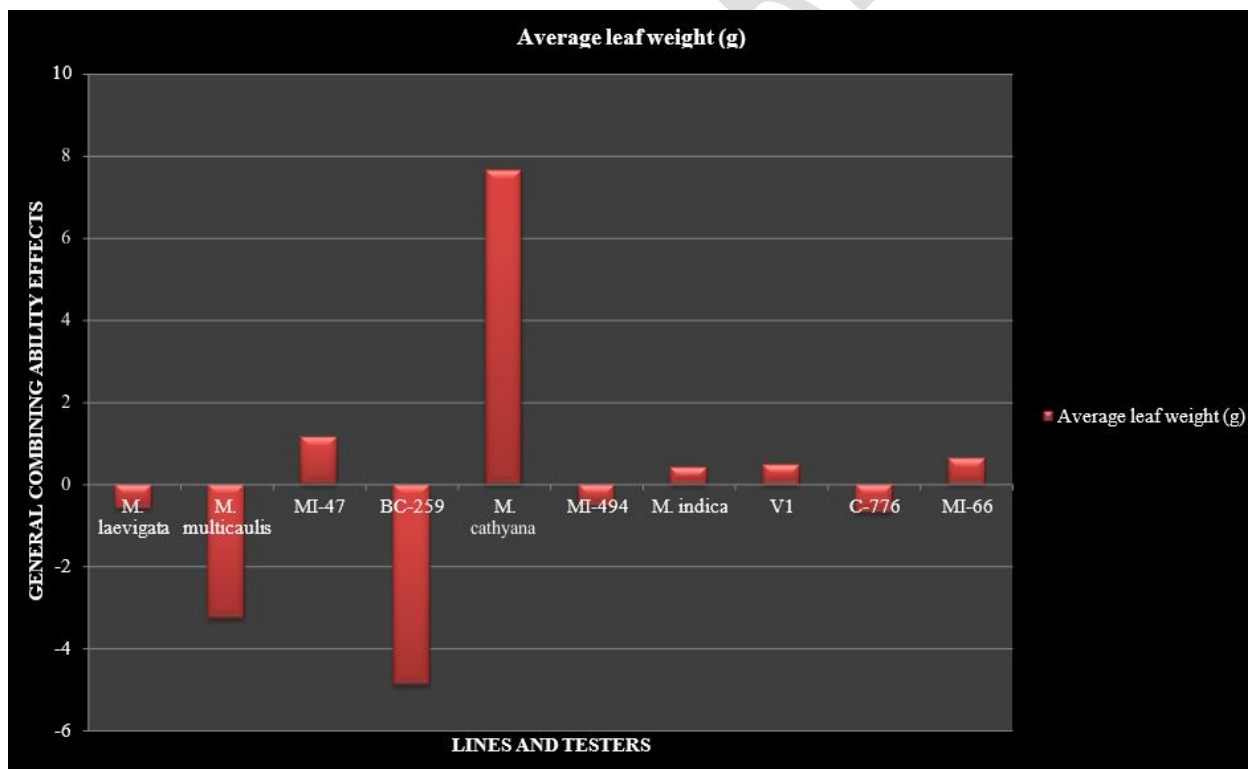


Fig. 4: General combining ability effects of lines and testers for average leaf weight (g) in mulberry

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. (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.

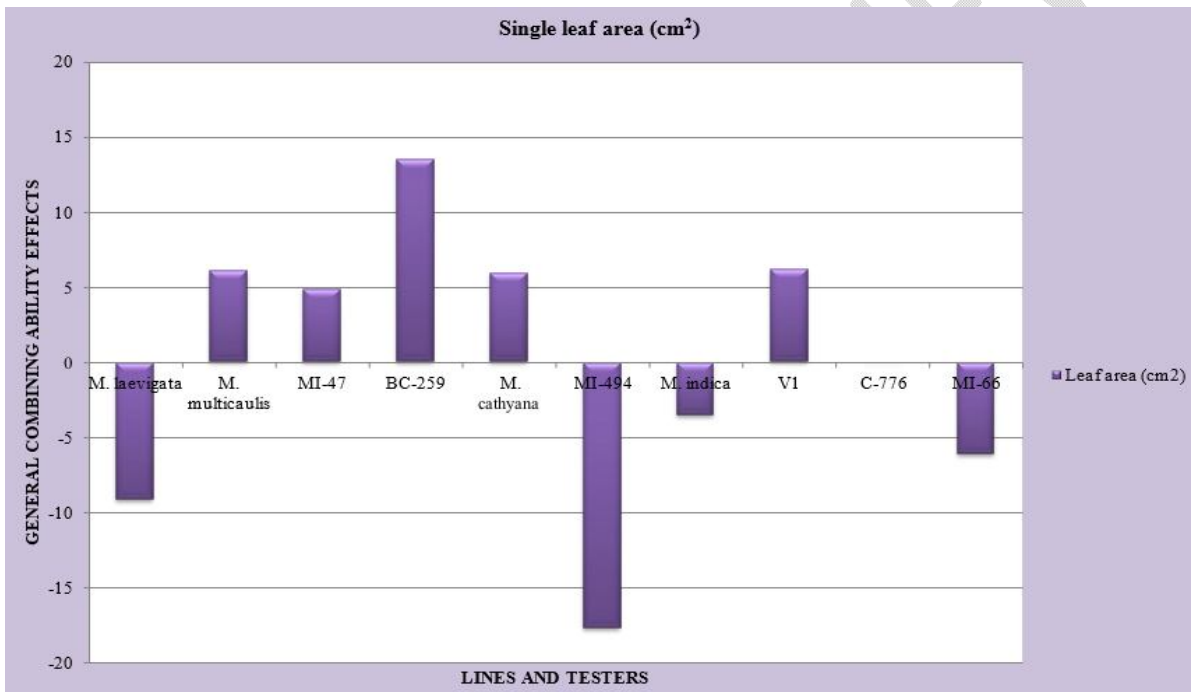


Fig. 5: General combining ability effects of lines and testers for single leaf area (cm²) in mulberry

Number of branches per plant:

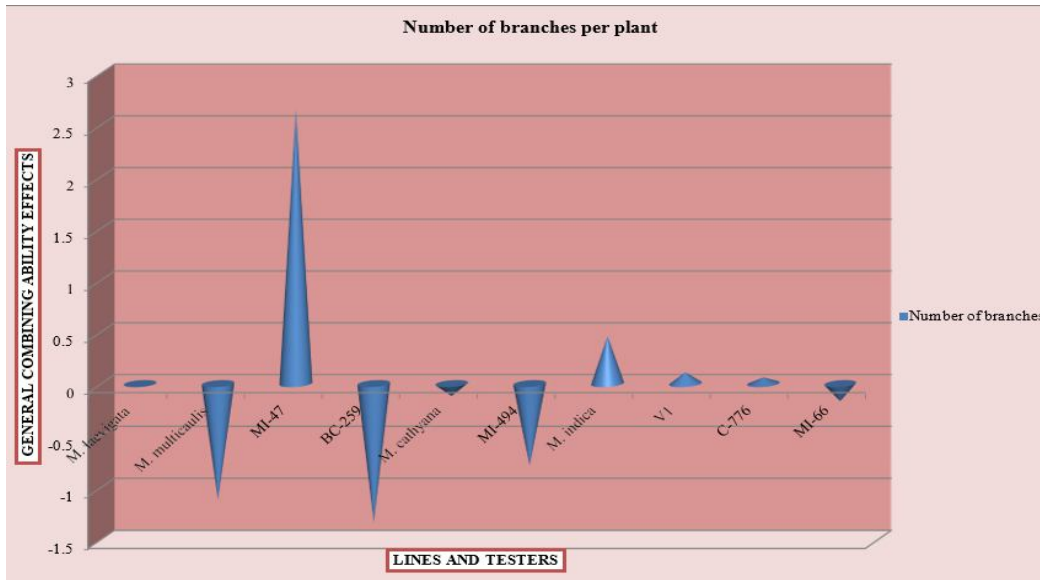


Fig. 6: General combining ability effects of lines and testers for number of branches per plant in mulberry

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 (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.* (1997).

Internodal distance (cm)

GCA effect for this trait in lines ranges from -0.42 (*M. cathyana*) to 0.51 (*M. indica*). One line showed significant positive *gca* effect *i.e.* *M. indica* (0.51). *M. cathyana* (-0.42) registered significant negative *gca* effect in undesirable 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. (Fig.7). With respect to internodal 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.* (1997) and Banerjee *et al.* (2014) in mulberry reported that parents used in their studies expressed significant negative *gca* effects which indicated that they could be good combiner.

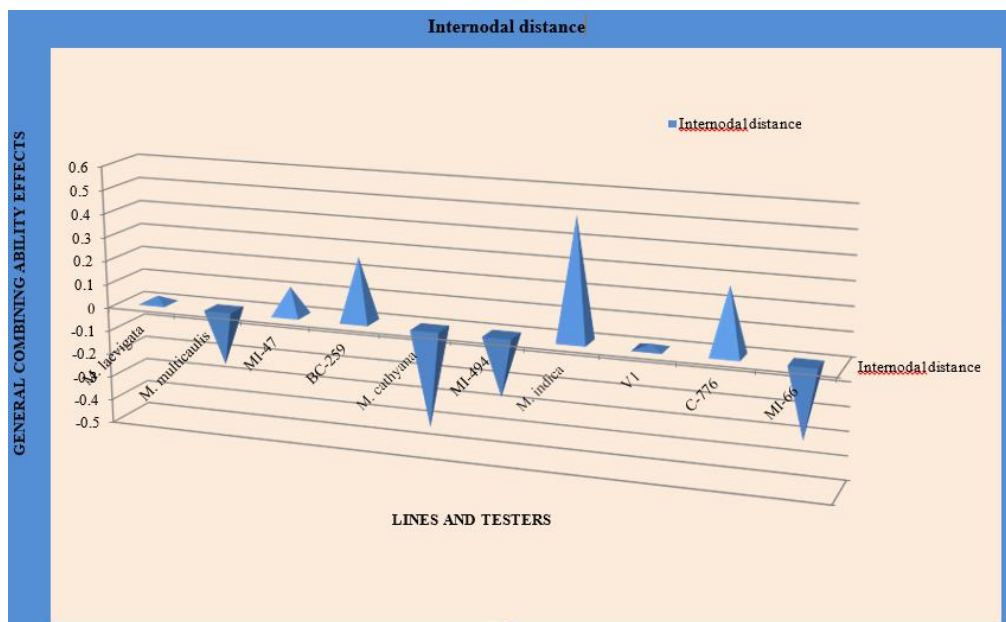


Fig. 7: General combining ability effects of lines and testers for internodal distance (cm) in mulberry

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. cathayana* 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 undesirable 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).

References:

1. Amiruzzaman M, Islam MA, Hassan L, Kadir M. and Rohman MM, Heterosis and combining ability in a diallel among elite inbred lines of maize (*Zea mays* L.). *Emir. J. Food Agric.*, 2013; **25** (2):132-137.

2. Ahmad AEE, Eltahir SA, Silvestro KM and AbuElhassan SI, Combining ability and heterosis in single crosses derived from some local maize (*Zea mays* L.) inbred lines. *Gezira J. Agric. Sci.*, 2010; **8**(1):87 –104.
3. Banerjee R, Chattopadhyay S, Das, NK, Doss SG, Saha, AK. and Nirmal Kumar S, Combining ability analysis for bacterial leafspot resistance, leaf yield and agronomic traits in mulberry clones. *J. Crop. Imp.*, 2014; **28**: 305-323.
4. Dandin SB and Giridhar K, *Handbook of sericulture technologies*, CSB publications, 2010; p:67-73.
5. Das BC, Mulberry varieties, exploitations and pathology. *Sericologia*, 1984; **24**: 369- 372.
6. Das BC and Krishnaswami S, Effects of colchicine on germinating seeds of mulberry. *Indian J. Seric.*, 1964; **3**(2): 5-6.
7. Gardner CO, Estimation of genetic parameters in cross-pollinated plants and their implications in plant breeding, Statistical genetics and plant breeding. *NAS-NRS Washington D. C. Publ.*, 1963; **982**: 228.
8. Kempthorne O, *An Introduction to Genetic Statistics*. John Wiley and Sons Inc., New York; Chapman and Hall, London, 1957.
9. Marani A and Sachs Y, Heterosis and combining ability in a diallel cross among nine varieties of oriental tobacco. *Crop Sci.*, 1966; **6**: 19-22.
10. Mukherjee SK, On some morphological evidence in floral structure towards the development of unisexuality in mulberry. 1965; *Indian J. Seric.*, **4**: 1-7.
11. Nazari RS, Ghadimzadeh M, Darvishzadeh R and Alavi SR, Gene action in oriental tobacco genotypes under *Orobanchae aegyptiana*. *Pers. Infestation. Indian J. Fund. Applied Life Sci.*, 2016; **6**(1):1-9.
12. Pooja GN, Chikkalingaiah, Bhaskar RN and Malashree Mankani, Combining ability for growth parameters at seedling stage in mulberry (*Morus* spp.). *Adv. life Sci.*, 2016; **5**(20): 2278-384.
13. Ramachandra RK, Nagappa BH. and Anjenaya Reddy B, Heterosis studies on yield and quality parameters in bidi tobacco (*Nicotiana tabacum* L.). *J. Bio. Innov.*, 2015; **4**(4): 126-134.
14. Sarkar A, Towards understanding the problem of breeding in mulberry, the factors involved in biometrical studies. *Workshop in biometrical genetics*, CSRTI, Mysore, 1990; pp. 1–4.
15. Sprague GF and Tatum LA, General Vs Specific combining ability crosses of corn. *J.*

Amer.Soc. Agron., 1942; **34**:932-942.

16. Suresh K, Jalaja KS, Chakravarty D and Sivaprasad V, Breeding for improved leaf yield and studies on combining ability in mulberry. *J.Crop. Weed.*, 2019; **15**(3): 65-71.
17. Vijayan K, Chauhan S, Das NK, Chakraborti SP and Roy BN, Leaf yield combining abilities in mulberry (*Morus* spp.). *Euphytica*, 1997; **98**:47-52.
18. Vijayan K, Srivastava PP, Raju PJ and Saratchandra B, Breeding for higher productivity in mulberry. *Genet. Plant Breed.*, 2012; **48**(4): 147-156.

UNDER PEER REVIEW