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 yieldcontributing characters are essential for implementing good breeding program. Significant differences were observed among all parents for general combiningability was noticed.Analysisofgeneralcombiningabilityshowedthehighermagnitudeof SCA variance than GCA variance for most of the characters, which indicates the presence ofnon-additive gene action for most of the traits except for germination percentage, plantheightat 60 DAS and numberof branches. Outofsevenlines*M. cathyana*isthebestgeneral combineras itshows significantpositive GCA for seedling height at 60, 90, 120 DAS, number of leaves per plant, averageleaf weight, leaf area and significant negative GCA for internodal distance which is indesirable direction. Also MI-47 is best general combiner as it shows significant positiveGCA for seedling height at 90, 120 DAS, number of leaves per plant, leaf area (cm^2),numberofbranches. Among the testers V1 was the best general combiner for germination percentage,leaf area (cm^2).

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

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 (*Bombyxmori* L.) to biosynthesize proteinaceousfibre and spin in the form of cocoon. Mulberry is an enduring tree belongs to family Moraceae andoriginated in the lower inclines of the Himalayas (Sarkar, 1990).It can develop underdifferent climatic conditions extending from mild to tropical.In India mulberry developsduring the time because of positive climatic conditions, making sericulture a full timeoccupation. Since mulberry leaf production alone expenses more than 60 percent out ofthe all cost, the financial return in sericulture is generally dictated by the measure of good qualitymulberryleaves deliveredfromaunitregion (DasandKrishnaswami,1964).

If mulberry leaf productionincreased,sericulture productivityincreases.Leafyield in

mulberry is a complex trait which is mainly influenced by environment andmanagement practices and donated by a number of component traits. For selection ofplants average leaf yield alone may not be the good criterion, so it is vital to understandthe heritability and genetics of yield components. Capacity of a parent to pass on itspleasing characters to its progeny in crosses is known as combining ability (Tatum andSprague, 1942) and developing new varieties with high leaf yield and good adaptabilityhelps to achieve this goal. Parents with good combining ability were known to producegreater progenies when united with other parents. The easiest and efficient method toevaluate combining ability in large number of parents is Line × Tester analysis. Parentswith superior combining ability can be selected based on GCA for exploitation of hybridvigourby development ofsegregating populations (Vijayan*et al.,* 1997).

Keeping in vision, the significance of mulberry regarding its foliage esteem, cropimprovement research on this yield should be reinforced. Considering all these viewpoints,the current studywasheld to assessgeneralcombiningabilityofparentsandspecificcombiningabilityofcrossesforseedling traitsin 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 KrishiVignana 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).

Table1:List oflinesand testersusedinL×T study

Sl.No.	Parents
Femaleparents(Lines)	
1.	*M.laevigata*
2.	*M.multicaulis*
3.	MI-47
4.	BC-259
5.	*M.cathyana*
6.	MI-494
7.	*M.indica*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 writtenon 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 × 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) Numberofleaves perplant
d) Averageleafweight (g)
e) Internodaldistance(cm)
f) Singleleafarea(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 using WINDOSTAT Software 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 SCAeffects

which is as follows
Where,
$Xij = \mu + gi + gj + Sij + eijk$

μ = population mean
gi = GCA effect of ith female parent
gj = GCAeffect of jth male parent
Sij =SCAeffectof ijthcombination
e_{ijk}=Errorassociated withthe observationX_{ijk}
i=Number offemaleparents
j=Number of male parents
k=Numberofreplications
Theindividualeffectswereestimatedasindicated below

Genetic combining ability effects (GCA**)**

$$\text{a)Lines:} \quad gl = \frac{Xi..}{tr} - \frac{X\ldots}{ltr}$$

$$\text{b)Testers:} \quad gt = \frac{Xj..}{lr} - \frac{X\ldots}{ltr}$$

Where,

Xi.. = Total of i^{th} line over all testers and replications

Xj..=Totalofj^{th}testeroverallllinesandreplications

Criticaldifference(CD)

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

RESULTS AND DISCUSSION:

Generalcombiningabilityeffects(GCA) :
The estimates of GCA effects of parents help in identifying superior parents to beutilized for production of superior genotypes in segregating populations by concentrationof desirable genes with additive effect. The present study supported to identify lines andtesters with high GCA effect for more number of characters. TheGCA effects represent thebreedingvalueofparentsinvolvedandagoodgeneralcombinerpossessesbetterbreedingvalue. The result pertaining to GCA effects of seven female lines (parents) and three

maleparents(testers)arepresented below.

Table2:Estimates ofgeneralcombiningabilityeffects ofparentsfordifferentgrowthparam.ters atseedlingstageinmulberry

Parents	Germination percentage	Plantheight (cm)at			Number of leavesperplant	Averageleafweight(g)	Singleleaf area(cm^2)	Number ofbranchesperplant	Internodal distance(cm)
		60DAS	90DAS	120DAS					
Lines									
M.laevigata	18.77**	0.13	-5.94**	-10.08**	-3.79	-0.58	-9.17**	-0.01	0.03
M.multicaulis	-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
M.cathyana	-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
M.indica	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
CDat5%	5.17	2.17	3.50	6.70	4.84	1.59	3.72	0.80	0.40
CDat1%	6.92	2.90	4.69	8.96	6.48	2.13	4.98	1.07	0.53
Testers									
V_1	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
CDat5%	3.39	1.42	2.29	4.38	3.17	1.04	2.44	0.52	0.26
CDat1%	4.53	1.90	3.07	5.17	4.24	1.39	3.26	0.70	0.35

Germinationpercent

ThemagnitudeofGCAeffectsinthelinesforgerminationpercentrangedfrom- 7.00 (MI-47) to 18.77 (*M. laevigata*). Among the lines *M. laevigata* showed significantpositive GCAeffect, and three lines *viz.*, MI-47 (-7.00), *M. cathyana* (-5.33), MI-494(-5.33) exhibited significant negative GCAeffects. The GCAeffect in testers for germinationper 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 significantnegativeGCAeffect. Results indicate that*M. laevigata* in lines and V1in testers are good generalcombinersfor thegermination percentage.

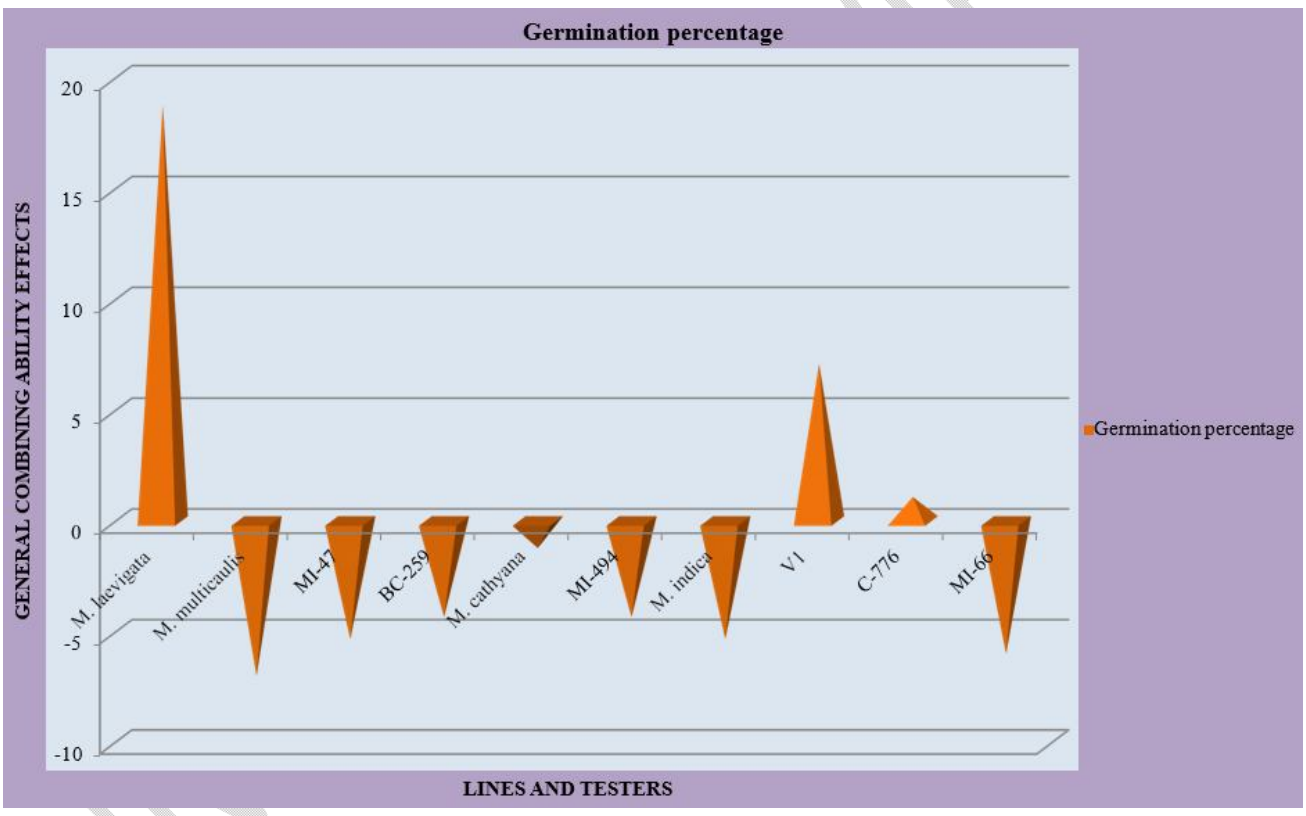

Fig.1:Generalcombiningabilityeffectsoflinesandtestersforgerminationpercentagein mulberry

Plantheight (cm)at60, 90and 120thDAS

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 GCAAt 120 DAS two lines *viz.*, MI-47(7.63),*M.cathyana*(13.57)recordedsignificantpositiveGCAtwolines*viz.*,*M.laevigata*(-10.08),MI-494(-10.75),exhibited significantnegativeGCAFor these character males (testers) recorded GCAranges -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.(Table 2, Fig.2).These results are similar to the findings of Rita Banerjee *et al*., (2007), Ghosh *et al*., (2009) and PerisNderitu*et al* (2014) and Bhuvana*et al. (*2020).

Fig.2:Generalcombining ability effectsoflines and testers forplant height at60, 90and 120DAS inmulberry

Out of all parents *M. cathyana* is best general combiner for higher plant height,whichexpressedpositivesignificantvaluesforseedlingheightat60,90,120DAS.Followed by MI-57 registered significant positive values at 90, 120 DAS. MI-494 is goodgeneralcombiner for

shorterplant 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. (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*. (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) andBhuvana*et al. (*2020).

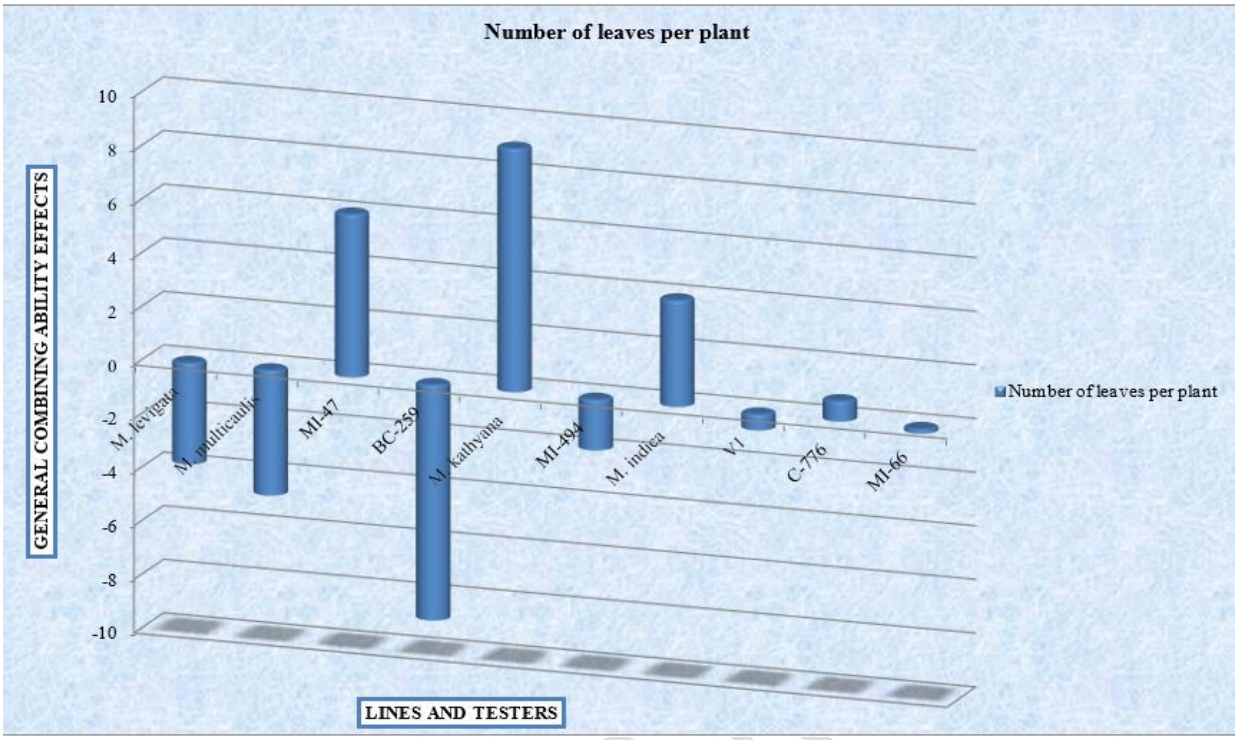

Fig. 3: General combining ability effects of lines and testers for number of leaves per plant in mulberry

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 significantGCA 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 GCAeffect for the trait. In the study of Nazaria *et al*. (2016) in tobacco, parents showedsignificant positive GCAeffect and were found to be good general combiners for fresh leafweightand provedas anusefulindex for combining ability.These results are similar to the findings of Rita Banerjee *et al*., (2007), Ghosh *et al*., (2009) and PerisNderitu*et al* (2014) and Bhuvana*et al. (*2020).

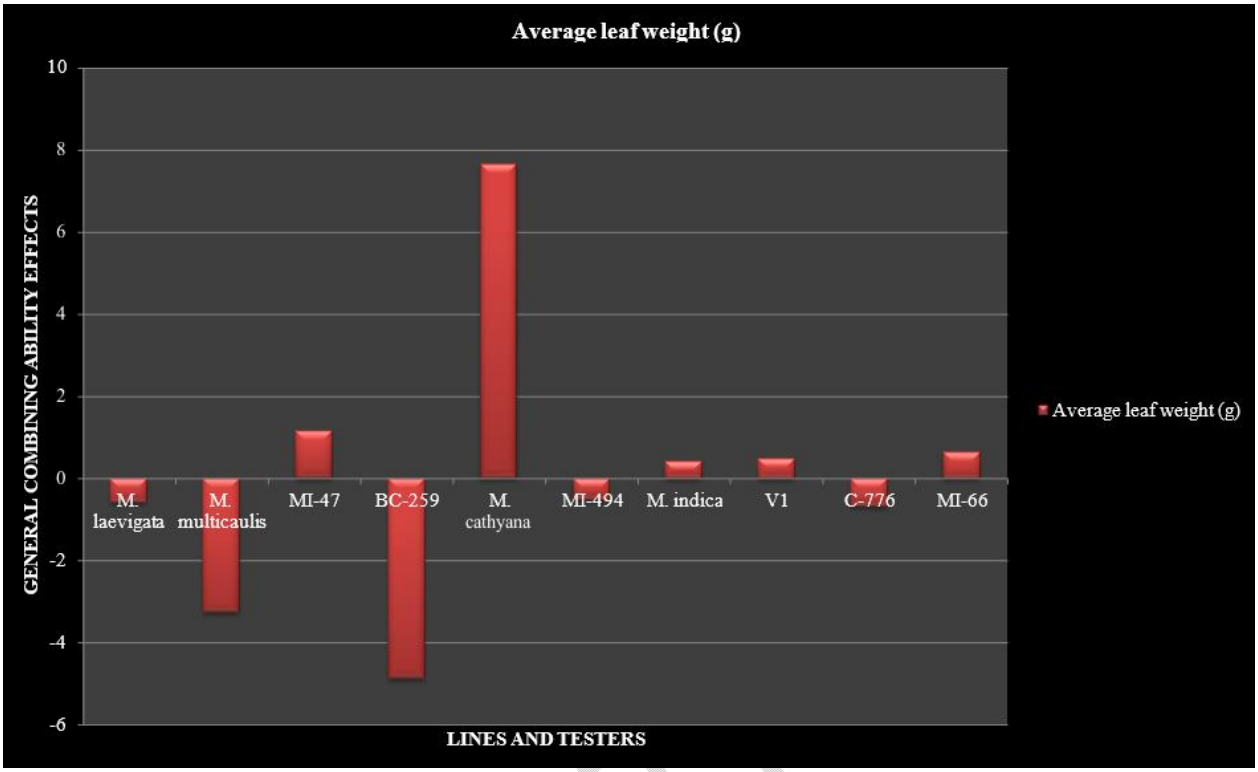

Fig. 4: General combining ability effects of lines and testers for average leaf weight (g) in mulberry

Singleleaf area(cm^2)

The *gca*effects variation for this character in lines ranged from -17.97(MI-494) to13.51(BC-259).Fourlines*viz.*,BC-259(13.51),*M.multicaulis*(6.58),MI-47(4.85),*M. cathyana* (5.95) was registered significant positiveGCAeffect. GCA effect in testersranged from -6.15(MI-66) to 6.17 (V1). Among testers V1 (6.17) showed significantpositiveGCAeffect.MI-66(6.15) showedsignificantnegativeGCA effect (Table 2, Fig.5).ThelineBC-259registeredhighlysignificantpositiveGCAforleaf,itisconsidered as best general combiner for leaf area. *M. multicaulis*, MI-47, *M. cathyana* arealso good general combiners for leaf area, since they registered significant positive GCAvalues. In testersV1 is good generalcombiner.These results are similar to the findings of Rita Banerjee *et al*., (2007), Ghosh *et al*., (2009) and PerisNderitu*et al* (2014) and Bhuvana*et al. (*2020).

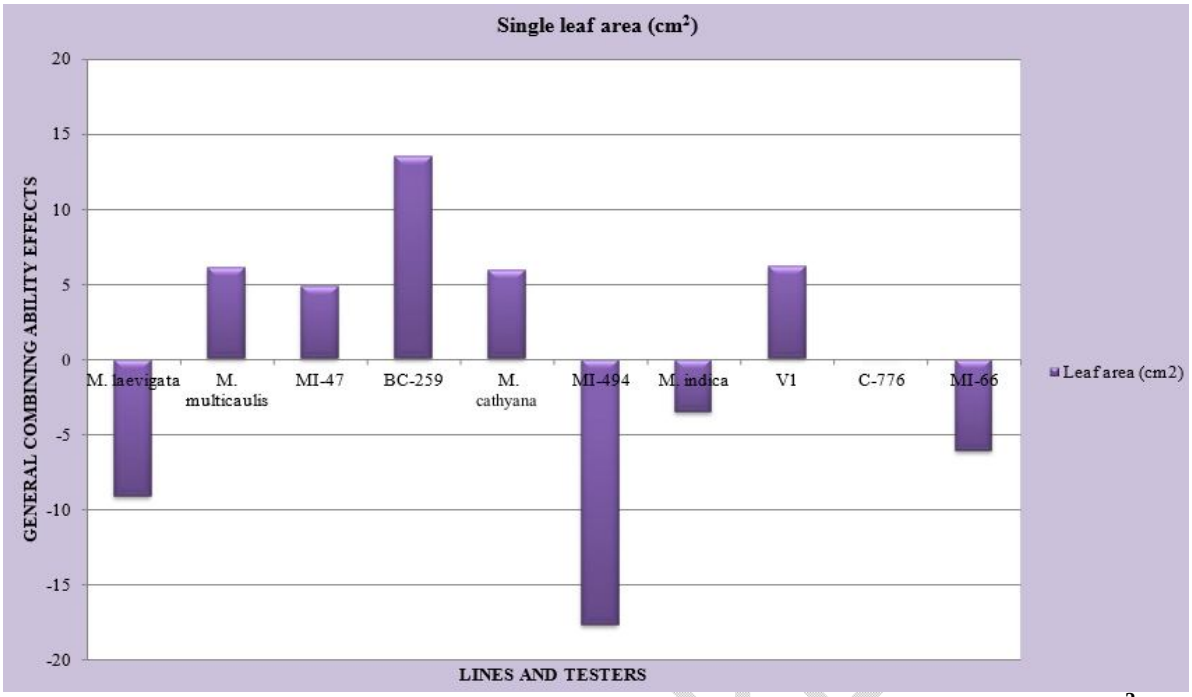

Fig. 5: General combining ability effects of lines and testers for single leaf area (cm^2) in mulberry

Numberof branches perplant:

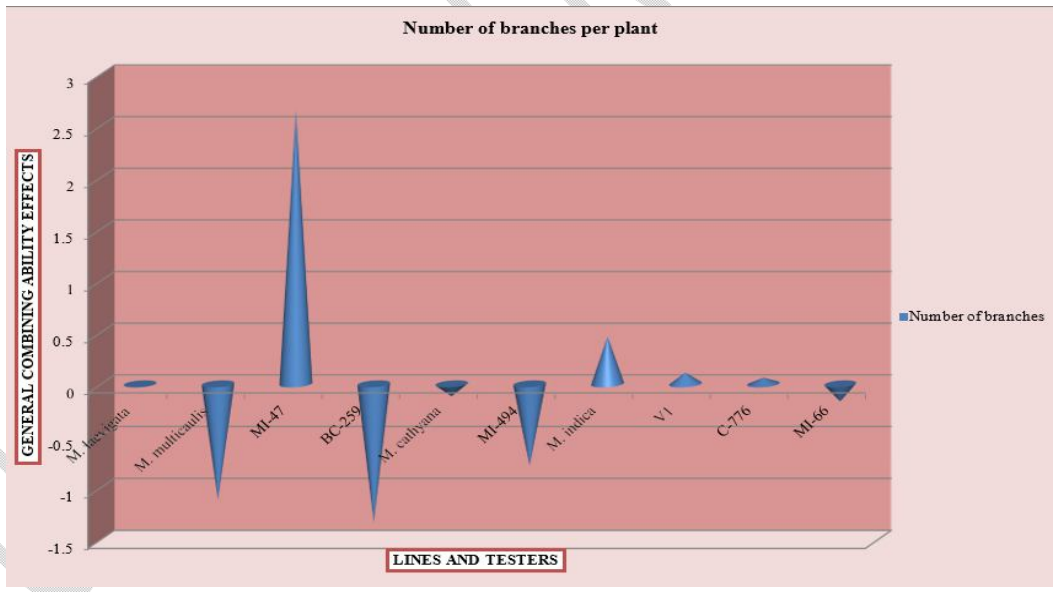

Fig. 6: General combining ability effects of lines and testers for number of branches per plant in mulberry

In lines GCA ranged from -1.34(BC-259) to 2.65(MI-47). Only one line showedsignificantpositiveGCAeffect*i.e.*MI-47(2.65).TwolinesshowedsignificantnegativeGCAeffect*i.e.*BC-259(-1.34)and*M.multicaulis*(-

1.12).In testersGCAeffectrangedfrom - 0.17(MI-66) to0.11(V1). Howeverno tester showed significant GCAeffect(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 significantnegative GCA values. Two parents exhibited significant positive GCA effects for number ofbranchesinastudy conducted by Vijayan*etal.* (1997) and Bhuvana et al. (2020)

Internodaldistance(cm)

GCA effect for this trait in lines ranges from -0.42 (*M. cathyana*) to 0.51(*M.indica*). One line showed significant positive GCAeffect *i.e. M. indica* (0.51). *M. cathyana*(-0.42)registeredsignificantnegativeGCAeffectindesirableway.Intestersitisranged from -0.31(MI-66) to 0.28(C-776). Tester *i.e.* C-776 registered significant positive GCAeffect and MI-66 registered significant negative GCAvalue. (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 negativeGCAvalues. In the study of Vijayan *et al.* (1997) and Banerjee *et al.* (2014), Bhuvana*et al.* (2020) in mulberry reported that parents used in their studies expressed significant negative GCAeffects which indicated that they could be good combiner.

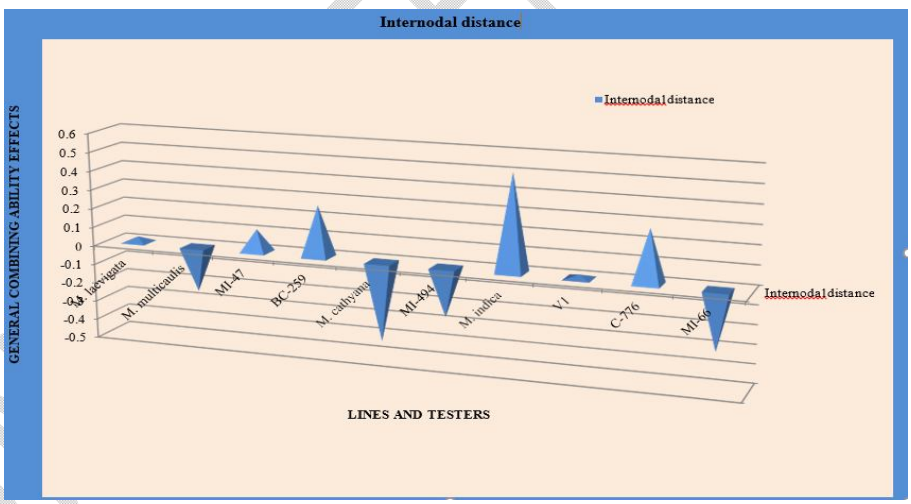

Fig. 7: General combining ability effects of lines and testers for internodal distance (cm) in mulberry

Conclusion:

Significant differences were observed among all parents for general combiningability.Analysisofgeneralcombiningabilityshowedthehighermagnitudeof SCA variance than GCA variance for most of the characters, which indicates the presence ofnon-additive gene action for most of the traits except for germination percentage, plantheightat 60 DAS and numberof branches.Outofsevenlines*M. cathyana*isthebestgeneral combineras itshows significantpositive GCA for seedling height at 60, 90, 120 days after sowing(DAS), number of leaves per plant, averageleaf weight, leaf area and significant negative GCA for internodal distance which is indesirable direction. Also MI-47 is best general combiner as it shows significant positiveGCAfor seedling height at 90, 120 DAS, number of leaves per plant, leaf area (cm^2),numberofbranches.Among the testers V1 was the best general combiner for germination percentage,leaf area (cm^2). Further, this study is proposed to evaluate the crosses of mulberry for yield andrelated traits in large scale multilocation trials to identify promising progeny for theirstabilityoverseasons 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.

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