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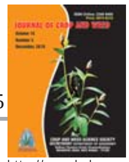

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Breeding for improved leaf yield and studies on combining ability in mulberry

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ABSTRACT

Mulberry is cultivated for its leaves to rear mulberry silkworms and silk productivity determines the profitability in sericulture. In the present study, forty two crosses were generated by crossing six females with seven male parents in Line × test mating design. Segregating hybrid progenies of ten crosses were evaluated for leaf yield and its components for understanding combining ability and gene action in mulberry. The gca and sca effects were highly significant for all the traits studied indicating the importance of additive and non-additive genetic components. The ratio of gca and sca variance was less than unity indicating preponderance of non-additive genetic variance and suggests the good prospects of exploiting variation through heterosis breeding. Bishnupur-10, Kajli OPH, C-776 and CF_1-10 were identified as good general combiners and can be utilized for generating desirable recombinants for further selection. Out of 42 crosses, nineteen exhibited significant positive sca effects for yield and could be used for selection of superior hybrid progenies. Nineteen genotypes recorded significantly higher leaf yield (482-501 g/plant/crop) along with better quality over the check variety S1635 (324 g/plant). These progenies need to be evaluated further following systematic procedures laid down for mulberry for identify promising high yielding varieties.

Keywords: Combining ability, gene action, leaf yield, recombinants, and selection

Sericulture is the important agro-based industry and success of this enterprise depends on successful rearing of silkworms along with mulberry cultivation. Among the four kinds of silks produced in India, mulberry silk occupied a giant's share with a production of 25,344 MT from an area of 2.35 lakh hectares (2018-19). Traditional breeding approaches of hybridization and selection coupled with mutation breeding resulted in development a few high yielding varieties having a leaf yield potential of 55- 60 t ha^{-1} yr^{-1}. Further to enhance the silk production, mulberry leaf productivity has to be improved by developing varieties with higher yield and quality along with wider adaptability. Improvement of mulberry foliage both in quantitative and qualitative aspect is the long term goal of mulberry breeders. The conventional heterosis breeding method follows a very specific procedure from selection of parents to evaluation over space and time (Vijayan 2010). The genetic improvement of mulberry depends on the availability of genetic variability and selection of suitable genotypes from breeding population which requires a thorough knowledge on leaf yield. Mulberry leaf yield is a complex trait contributed by a number of component traits and is highly influenced by environment and management practices. The *per se* leaf yield alone may not be the best criterion for selection and it is therefore, important to understand the genetics and heritability of yield components. Combining ability refers to the ability of a parent to transmit its desirable characters to its progeny in crosses (Sprague, and Tatum, 1942) and a good combining parents are known to produce superior progenies when combined with other parents. Line × Tester analysis is the simplest and efficient method of assessing combining ability in large number of parents. Estimation of GCA helps to select parents with superior combining ability for exploitation of hybrid vigour by development of segregating populations (Vijayan *et al.*, 1997). The purpose of this investigation was to understand the gene action for leaf yield and its component traits and to develop improved mulberry genotypes.

MATERIALS AND METHODS

Study location

An experiment was undertaken at research field of Central Sericultural Research and Training Institute, Berhampore during 2013 to 2016. It is situated at 34° 0′ 28″ North, 71° 34′ 24″ East, at an altitude of 19 m above mean sea level having humid sub-tropical climate.

Mulberry germplasm used in the study

The species and origin of the germplasm used in this study are given in table 1. The male parents used were of species *M. indica*, while the female parents belong to *M. alba, M. multicaulis, M. latifolia* of indigenous and exotic origin.

Development of F_1 hybrids

Six female and seven male parents maintained as high trunk plantation in Germplasm bank of this institute were

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utilized for hybridization during the flowering season between February and April 2013. The plants were pruned at different times for synchronizing flowering and to facilitate generation of enough F_1 hybrid seeds. The butter paper bags covered on the female plant shoots was opened from top and the male catkins were gently tapped over the female catkin. The butter paper cover was again sealed and the details of the male, female parents and date of pollination was noted on the tag attached to the female plant. The seeds from 42 crosses were extracted from harvested hybrid fruits by water soaking method (Table 2). The dried seeds were sown in nursery with a spacing of 10 cm between rows. When seedlings attained sufficient growth of 2-3 weeks, thinning and gap filling was carried out wherever necessary to ensure uniform plant density.

Description of experimental design and evaluation of F_1 Hybrids or segregating families

One year old seedlings of forty two crosses along with parents and check variety S-1635 was transplanted in a row spacing of 60 × 60 cm with a common border under Progeny row trial (PRT). After a period establishment for one year, plants were pruned as per commercial crop schedules of the West Bengal. All the recommended general package practices of cultivation for irrigated condition of this region were followed to raise healthy crop (Roy *et al.*, 1978). Observations were recorded on all the segregating progenies of each cross during July and September 2016 crops for twelve quantitative characters *viz.*, fresh leaf weight (g), leaf area (cm^2), Chlorophyll index by Chlorophyll meter (CCM 200), leaf moisture content (%), specific leaf area ($cm^2 g\ dw^{-1}$), inter-nodal distance (cm), length of longest shoot (cm), primary shoots per plant, total shoots length (cm), harvest index (%), shoot yield (g plant) and leaf yield plant^{-1} (g). The mean data of each cross was analysed for combining ability following the standard method of Kempthorne (1957). Total variance among segregating hybrid families was partitioned into variance due to lines, testers and their interactions. The contribution of lines, testers and interaction of both towards total variability for each of the traits was computed. The genotypes selected from each crosses were further evaluated over five commercial crop seasons under irrigated condition for identifying superior genotypes suitable for of West Bengal. The mean values were subjected to statistical analysis.

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) of the line × tester set revealed highly significant differences in mean sum of squares due to lines, testers and their interaction for all the traits studied indicating both additive and non - additive effects of gene were important in the genetic expression of the character (Table 3). These results are in accordance with those of Vijayan *et al.*, 1997, Banerjee *et al.*, 2004 and Pooja, 2016. Highly significant and positive mean sum of squares for hybrids indicating the diverse performance of different crosses for all the traits studied. The genotypic value of an individual is determined by different types of gene actions such as additive, dominance and interactions of both. The magnitudes of SCA variances were higher than GCA variance for all the traits studied revealed the predominance of non-additive gene action in the expression of these traits (Table 3). The predominance of non-additive genetic variance offers scope for exploitation of heterosis in Mulberry. This kind of results was also reported by Vijayan *et al.*, 1997 and 2008 and Pooja, 2016. The proportional contribution of lines ranged from 7.41% (leaf area) to 54.12% (primary shoots per plant) whereas for testers it ranged from 6.58% (primary shoots plant^{-1}) to 30.15% (length of the longest shoot) (Table 3). However, contribution of their interaction ranged from 39.30% (primary shoots plant^{1}) to 75.31% (shoot yield plant^{-1}) indicating higher contribution of interaction and the importance of combination of specific parents. Similar results were also reported for most of the yield traits by Vijayan *et al.*, 1997 and 2008, Banerjee *et al.*, 2014 and Pooja, 2016.

The plant breeding programme is largely successful depending on the choice of parents for hybridization. Genotypes with high mean performance along with high positive *gca* effects will be useful in generating desirable recombinants in Mulberry. Wide range of gca effects of parents revealed considerable differences among the parents utilized (Table 4). Line Chinese F_1 (10) exhibited highest positive GCA effects for most of the traits studies and is the best combiner for growth and leaf yield. Other parents that are good general combiners for leaf weight, leaf area, leaf moisture and yield were Kajli OPH, *M. multicaulis* and China white for inter-nodal distance along with shoot length. Among the testers, Bishnupur-10 recorded highest *gca* effects in all the traits studied except harvest index and for harvest index, leaf weight and yield was Almora local. Different parents exhibited high magnitude of gca effects for growth and leaf yield traits has been reported in mulberry (Vijayan *et al.*, 1997 and Pooja, 2016). Thus, the estimates of general combining ability (gca) effects of lines and testers showed that Chinese F1 (10) and Bishnupur-10 were more appropriate good general combiner in breeding for improve leaf yield in mulberry.

The specific combining ability effects determine the usefulness of a particular cross for exploitation of heterosis. Specific combining ability is the deviation from the mean value predicted on the basis of general combining ability and crosses with high *gca* effects gave raise to high *sca* effects (Allard, 1956). SCA effects of forty two crosses for twelve traits studied are presented in table 5. For fresh leaf weight and area, 16 crosses exhibited significant positive *sca* effects and for specific leaf area seven crosses showed significant negative *sca*, indicates higher leaf thickness in the hybrids. For the quality characters like leaf chlorophyll index and moisture content, significant positive *sca* effect was recorded in eleven and nine crosses, respectively. Fifteen crosses showed significant positive *sca* effect for total shoots length indicating highest growth in these hybrids. The SCA estimates for leaf moisture, chlorophyll index, growth and yield showed no combination in desirable direction. For leaf yield, among 54 crosses, nineteen recorded significant positive *sca* effects for leaf yield along with higher mean performance. It is observed that among the different crosses, which exhibited high *sca* effects for leaf yield have possessed positive *sca* effects for one or more yield related traits also. Vijayan *et al.*, (1997) also mentioned to include one good general combiner during hybridization to obtain higher heterosis. Grafius (1959) also suggested that there will not be a

Table 1: Species and origin of parents used for hybridization

Name	CSGRC No.	NBPGR No.	Species	Origin
M. indica HP(MHP)	MI - 0099	IC313827	*M. indica*	India
Almora Local	MI - 0015	IC313680	*M. indica*	India
Berhampore-B	MI - 0627	IC405775	*M. indica*	India
Bishnupur-10	MI - 0092	IC313727	*M. indica*	India
China White	ME - 0042	EC493799	*M. alba*	China
Chinese F_1 -10(CF_1 10)			*M. alba*	China
MS-30	MI - 0005	IC313966	*M. alba*	India
Kajli OPH (KOP)			*M. alba*	India
M. multicaulis	ME - 0006	EC493763	*M.multicaulis*	Russia
English Black	ME - 0004	EC493761	*M. latifolia*	France
Kosen	ME - 0066	EC493823	*M.latifolia*	Japan
V - 1	MI-0308	IC-313996	*M. indica*	India
C-776			*M. indica*	India

Table 2: List of mulberry hybrids or crosses generated in L × T mating design

Cross	Name	Cross	Name
1	MHP × V1	22	MS-30 × V1
2	MHP × C-776	23	MS-30 × C-776
3	MHP × Kosen	24	MS-30 × Kosen
4	MHP × Almora Local	25	MS-30 × Almora Local
5	MHP × English Black	26	MS-30 × English Black
6	MHP × Berhampore-B	27	MS-30 × Berhampore-B
7	MHP × Bishnupur-10	28	MS-30 × Bishnupur-10
8	China White × V1	29	*M. multicaulis* x V1
9	China White × C-776	30	*M. multicaulis* × C-776
10	China White × Kosen	31	*M. multicaulis* × Kosen
11	China White × Almora local	32	*M. multicaulis* × Almora local
12	China White × English Black	33	*M. multicaulis* × English Black
13	China White × Berhampore-B	34	*M. multicaulis* × Berhampore-B
14	China White × Bishnupur-10	35	*M. multicaulis* × Bishnupur-10
15	CF_1 (10) × V1	36	KOP × V1
16	CF_1 (10) × C-776	37	KOP × C-776
17	CF_1 (10) × Kosen	38	KOP × Kosen
18	CF_1 (10) × Almora Local	39	KOP × Almora local
19	CF_1 (10) × English Black	40	KOP × English Black
20	CF_1 (10) × Berhampore-B	41	KOP × Berhampore B
21	CF_1 (10) × Bishnupur-10	42	KOP × Bishnupur-10

Table 3: Analysis of variance for combining ability of 13 parents and their 42 F_1 hybrids for different leaf yield traits

Source	DF	FLW	LA	LMC	CCI	SLA	LLS	NPS	TSL	ID	HI	SYP	LYP
		Mean sum of squares											
Season	1	0.30**	922.40**	222.10**	36.80**	3076.80**	2224.50**	3.40**	54729.7**	0.60**	0.01**	11248.4**	11937.2**
Cross	41	0.50**	1393.40**	9.70**	9.30**	777.76**	346.00**	3.30**	34959.8**	0.32**	0.00**	15310.0**	10165.9**
Line (c)	5	0.30**	846.30**	24.40**	28.70**	1881.20**	181.30**	14.50**	25867.0**	0.91**	0.01**	10328.6**	7806.8**
Test (c)	6	0.80**	2111.10**	11.50**	10.30**	602.60**	712.70**	1.50**	39985.8**	0.20**	0.01**	17221.7**	16756.9**
L × T(c)	60	0.50**	1341.00**	206.30**	176.80**	18866.40**	300.00**	1.80**	35470.0 **	0.25**	0.00**	15757.9**	9240.8**
Error	41	0.01	13.10	0.90	0.20	79.80	58.40	0.10	322.70	0.01	0.001	79.80	47.50
CV (%)		3.96	3.31	1.17	2.80	3.28	6.10	3.26	2.57	1.39	1.82	2.76	6.72
		Estimates of variance component											
GCA		-13.39	1.38	0.07	0.09	3.91	1.21	0.04	-13.39	0.002	0.0001	-11.75	24.28
SCA		17573.6	663.98	3.00	2.84	274.54	120.8	0.85	17573.60	0.13	0.001	7839.05	4596.66
GCA/SCA		-0.001	0.002	0.025	0.032	0.014	0.01	0.047	-0.001	0.016	0.143	-0.001	0.005
		Proportional contribution to total variance											
Lines		9.02	7.41	30.7	37.6	29.5	6.39	54.12	9.02	34.28	31.43	23.93	9.37
Testers		16.74	22.17	17.31	16.14	11.34	30.15	6.58	16.74	8.89	16.91	16.46	24.12
L × T		74.24	70.42	51.99	46.26	59.16	63.46	39.30	74.24	56.83	51.66	75.31	66.51

Table 4: Estimates of gca effects of lines and testers for leaf yield and its component traits

SN	Lines &testers	FLW	LA	LMC	CCI	SLA	LLS	NPS	TSL	ID	HI	SYP	LYP
1	M. indica HP	-0.13**	-2.59*	-2.14**	1.07**	-6.34*	-5.15*	1.77**	52.89**	-0.02	-0.02**	8.22**	-21.71**
2	China White	-0.24**	-13.54**	0.01	-0.01	-4.64	1.67	0.70**	50.69**	-0.38**	0.01**	-43.26**	-31.15**
3	Chinese F_1 (10)	0.07**	3.13**	-0.71**	1.08**	-11.5**	4.70*	-0.63**	-39.47**	-0.19**	0.02**	-18.11**	7.61**
4	MS - 30	0.05*	0.27	0.53*	1.18**	-4.37	2.49	-0.62**	1.28	0.12**	-0.03**	27.11**	4.41*
5	M. multicaulis	0.19**	9.63**	0.56*	-0.96**	6.41**	-2.21	-0.64**	-42.03**	0.33**	0.001	-0.18	5.66**
6	Kajli OPH	0.07**	3.10**	1.75**	-2.37**	20.44**	-1.50	-0.58**	-23.35**	0.14**	0.01**	26.21**	35.18**
	SE (i)	0.02	0.96	0.25	0.122	2.38	2.04	0.06	4.80	0.02	0.001	2.38	1.842
1	V - 1	-0.36**	-20.45**	-0.10	-0.32*	-1.15	-9.31**	-0.01	-52.02**	-0.16**	-0.03**	-23.6**	-40.74**
2	C-776	-0.09**	-2.67*	-1.12**	0.35*	-2.62	4.50*	-0.05	25.85**	0.01	0.01**	4.07	11.16**
3	Kosen	-0.17**	-8.56**	0.55*	-0.87**	4.30	-2.53	-0.55**	-62.04**	0.02	0.001	-35.41**	-38.73**
4	Almora Local	0.06*	1.35	0.45	-0.58**	4.96	-4.29	0.22**	-4.41	-0.03	0.01**	5.45*	4.81*
5	English Black	-0.06*	-2.13*	0.92**	-0.07	10.77**	8.20**	-0.28**	5.52	-0.14**	0.02**	-11.58**	1.56
6	Berhampore-B	0.17**	12.79**	-1.54**	-0.41**	-9.06**	-6.98**	0.15*	-23.26**	0.15**	0.001	-18.22**	-8.71**
7	Bishnupur-10	0.45**	19.67**	0.86**	1.91**	-7.21**	10.42**	0.53**	110.36**	0.16**	0.001	79.29**	70.65**
	SE (i)	0.02	1.04	0.20	0.13	2.57	2.21	0.06	5.18	0.02	0.002	2.57	1.98

**, ** Significant at 5 and 1 per cent level respectively*

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FLW: fresh leaf weight (g), LA: leaf area (cm^2), LMC: leaf moisture content (%), SLA: specific leaf area (cm^2g^{-1}), LLS: length of longest shoot (cm), NPS: primary shoots per plant length (cm), ID: inter-nodal distance (cm), HI: harvest index (%), SYP: yield per plant (g) and per plant (g). LYP: leaf yield CCI: Chlorophyll content index, TSL; total shoot

Table 5: Estimates of specific combining ability (sca) effects for leaf yield and its component traits

Cross	FLW	LA	LMC	CCI	SLA	LLS	NPS	TSL	ID	HI	SYP	LYP
1	-0.32**	-19.25**	-0.47	-0.36	-6.40	-8.76	1.67**	138.94**	-0.23**	0.00	8.15	0.43
2	-0.47**	-27.31**	-2.10**	-0.20	10.54	-4.38	-1.45**	-100.71**	-0.43**	0.00	-87.51**	-55.74**
3	0.59**	34.71**	-0.90	0.15	-17.66**	5.32	0.31	82.90**	0.42**	-0.01*	117.59**	59.07**
4	0.54**	35.15**	-0.41	-0.11	-11.45	3.13	0.42*	79.70**	0.76**	0.00	72.37**	53.00**
5	0.59**	28.82**	-0.79	-1.33**	-8.87	3.16	0.04	-9.87	0.08*	0.02**	8.18	20.21**
6	-0.33**	-9.34**	0.64	-2.47**	27.06**	2.57	-0.63**	-86.27**	-0.21**	0.01	-36.64**	-8.41
7	-0.60**	-42.78**	4.02**	4.32**	6.78	-1.04	-0.35*	-104.70**	-0.40**	-0.02**	-82.13**	-68.56**
8	0.20**	16.65**	-1.42*	0.41	9.92	4.23	0.31	-46.08**	0.11**	0.02**	7.83	9.22
9	-0.16**	-9.18**	-1.28	-1.08**	-11.56	8.95	-0.03	-25.98*	0.02	-0.02**	-38.95**	-49.78**
10	-0.03	0.45	-1.19	1.00**	4.85	-3.14	1.17**	111.31**	0.01	-0.01	42.59**	22.81**
11	0.01	6.94**	1.78**	-1.74**	-5.06	-6.86	-0.74**	-85.32**	-0.02	-0.04**	-15.30*	-48.10**
12	0.07	1.07	0.97	0.90**	-8.72	-7.52	-0.31	15.01	-0.04	0.00	23.84**	31.91**
13	0.37**	3.95	2.32**	0.51	1.48	2.12	-0.03	14.77	-0.20**	0.05**	-4.74	44.37**
14	-0.45**	-19.88**	-1.18	0.00	9.09	2.21	-0.38*	16.3	0.12**	0.01	-15.27*	-10.44*
15	0.10	-0.13	1.93**	0.87**	1.81	13.64*	-0.77**	23.91	-0.24**	-0.02**	31.99**	7.79
16	0.34**	21.52**	1.77**	-0.37	10.28	-2.42	-0.05	-12.96	0.40**	-0.01	20.81**	7.94
17	-0.29**	-21.7**	2.07**	0.45	9.64	9.52	-0.68**	-106.78**	-0.36**	-0.02**	-64.46**	-74.04**
18	-0.52**	-37.55**	-3.35**	0.00	-8.90	-13.57*	-0.94**	-173.41**	-0.63**	0.05**	-127.75**	-80.23**
19	0.31**	23.96**	-1.43*	0.87*	-21.64**	2.70	1.11**	104.91**	0.52**	0.00	70.04**	46.06**
20	-0.37**	-14.00	0.03	-0.64	17.67**	-10.70	0.53**	25.04	-0.11**	0.01	-1.31	14.18**
21	0.43**	27.9**	-1.03	-1.17**	-8.87	0.82	0.80**	139.29**	0.41**	0.00	70.68**	78.29**
22	-0.31**	-13.08**	-1.28	1.37**	-9.59	-25.84**	-2.19**	-284.05**	-0.35**	0.02**	-149.84**	-83.00**
23	0.05	0.76	0.62	1.79**	-12.05	20.15**	1.26**	228.05**	-0.09*	0.02**	146.54**	120.5**
24	-0.19**	-8.55**	-0.50	0.88**	4.08	2.26	-0.85**	-106.29**	-0.16**	-0.01	-54.87**	-38.21**
25	-0.60**	-30.52**	1.73*	-0.38	32.28**	-4.58	0.76**	42.28**	-0.05	-0.01	-34.36**	-18.16**
26	0.51**	22.68**	0.84	0.28	0.14	3.97	1.09**	114.9**	0.23**	-0.01*	101.94**	59.15**
27	0.44**	24.42**	-0.38	-0.86*	-3.15	5.12	0.54**	113.57**	0.24**	-0.01	72.7**	29.30**
28	0.10	4.28	-1.02	-3.07**	-11.71	-1.06	-0.62**	-108.45**	0.17**	0.00	-82.11**	-69.58**
29	0.02	2.51	-0.23	-2.70**	-2.77	-6.68	0.12	-27.00*	0.21**	-0.02**	-11.74	-27.71**
30	0.28**	11.56**	2.19**	0.04	18.87**	4.81	0.21	46.35**	-0.08	0.01	28.67**	35.62**
31	0.02	4.43	1.33*	-1.35**	15.93*	3.70	0.42*	105.97**	-0.14**	0.04**	3.76	41.41**
32	0.20**	8.73**	0.75	-0.81*	2.08	1.75	0.17	-5.30	0.03	0.02**	-6.13	17.56**
33	-0.96**	-50.95	-1.83**	0.64	-6.93	-2.00	-1.13**	-128.3**	-0.38**	-0.05**	-68.33**	-88.90**
34	0.54**	26.11**	-0.17	3.32**	-14.42*	8.38	0.43**	98.6**	0.22**	-0.02**	81.38**	47.14**
35	-0.10	-2.39	-2.04**	0.85*	-12.77*	-9.96	-0.22	-90.31**	0.14**	0.02**	-27.62**	-25.13**
36	0.31**	13.30**	1.47*	0.41	7.03	23.41**	0.87**	194.29**	0.49**	0.01	113.60**	93.27**
37	-0.05	2.65	-1.2	-0.17	-16.09*	-27.11**	0.05	-134.76**	0.16**	0.00	-69.57**	-58.55**
38	-0.09	-9.33**	-0.82	-1.13**	-16.85*	-17.66**	-0.37*	-87.1**	0.23**	0.02**	-44.60**	-11.04*
39	0.37**	17.25**	-0.49	3.04**	-8.94	20.13**	0.32*	142.05**	-0.09*	-0.02**	111.18**	75.93**
40	-0.52**	-25.59**	2.24**	-1.35**	46.01**	-0.32	-0.81**	-96.64**	-0.41**	0.04**	-135.67**	-68.44**
41	-0.65**	-31.13**	-2.44**	0.14	-28.64**	-7.49	-0.83**	-165.71**	0.06	-0.05**	-111.39**	-126.58**
42	0.63**	32.85**	1.25	-0.93**	17.49**	9.03	0.76**	147.88**	-0.44**	-0.01	136.46**	95.42**
CD(0.05)	36.11	7.26	1.87	0.92	17.95	15.36	0.44	36.11	0.11	0.01	8.93	13.85

**, **Significant at 5 and 1 per cent level respectively*

FLW: fresh leaf weight (g), LA: leaf area (cm^2), LMC: leaf moisture content (%), SLA: specific leaf area (cm^2g^{-1}), LLS: length of longest shoot (cm), NPS: primary shoots per plant length (cm), ID: inter-nodal distance (cm), HI: harvest index (%), SYP: yield per plant (g) and per plant (g). LYP: leaf yield, CCI: Chlorophyll content index, TSL; total shoot

Table 6: Promising genotypes based on leaf yield performance and its component traits

Sl No	Geno type	Name of the cross	CCI	LMC	SLA	NPS	TSL	ID	HI	LYC	LYA
1	C350	CF_1 (10) x Bishnupur-10	14.10	77.81	223.55	9*	1348*	4.50*	48	512*	2.561*
2	C359	CF_1 (10) x Bishnupur-10	12.54	78.10	237.55	11*	1410*	5.00	54*	512*	2.559*
3	C490	MS-30 x C-776	13.61	76.74	215.03	12*	1845*	5.50	46	508*	2.538*
4	C986	Kajli OPH x Bishnupur-10	11.49	81.83	272.28	12*	1534*	4.00*	46	505*	2.526*
5	C362	CF_1 (10) x Berhampore-B	17.76	76.07	228.10	12*	1366*	3.00*	50*	502*	2.512*
6	C245	China White x English Black	16.42	78.39	246.68	11*	1566*	4.50*	47	501*	2.504*
7	C838	*M. multicaulis* x C-776	30.43*	74.58	185.30*	7	1108	4.50*	49	499*	2.499*
8	C343	CF_1 (10) x Bishnupur-10	15.50	78.68	243.30	9*	1176*	3.50*	49	485*	2.425*
9	C570	MS-30 x English Black	17.34	81.33	270.74	11*	1561*	4.50*	44	482*	2.409*
10	C768	*M.multicaulis* x English Black	12.06	79.85	323.00	10*	1425*	4.50*	44	478*	2.389*
11	C400	CF_1 (10) x English Black	17.34	85.03*	270.00	11*	1760*	4.50*	40	473*	2.367*
12	C936	*M.multicaulis* xAlmora local	11.78	81.44	274.91	11*	1386*	4.50*	46	465*	2.325*
13	C052	*M.indica HP* x Almora Local	17.24	75.57	226.52	8	957	5.00	56*	467*	2.318*
14	C616	MS-30 x Bishnupur-10	16.93	78.73	200.23	11*	1415*	4.00*	43	463*	2.316*
15	C836	*M.multicaulis* xC-776	16.52	88.80*	372.13	9*	1175*	5.00	47	461*	2.306*
16	C413	CF_1 (10) x English Black	15.91	74.11	205.05	8	960	5.20	53*	451*	2.256*
17	C1016	Kajli OPH x Almora local	11.11	82.16	279.14	9*	1145	5.00	49	451*	2.256*
18	C1019	Kajli OPH x Almora local	13.22	78.55	233.35	9*	1234*	5.50	43	436v	2.179*
19	C721	*M.multicaulis* xBishnupur-10	23.75*	76.33	217.93	6	779	7.00	41	421*	2.104*
	S-1635	**OPH of CSRS 1**	**17.10**	**79.23**	**254.40**	**8**	**1018**	**4.80**	**38**	**325**	**1.620**
		LSD (0.05)	**2.10**	**3.15**	**60.10**	**0.5**	**149**	**0.28**	**12**	**45**	**0.345**

*Note : *, Significant at 5 per cent level*
CCI: Chlorophyll content index, LMC: leaf moisture content (%), SLA: specific leaf area (cm^2g^{-1}),
NPS: primary shoots per plant, TSL; total shoot length (cm), ID: inter-nodal distance (cm),
HI: harvest index (%), LYC: leaf yield per crop (g) LYA: leaf yield per annum (kg).

separate gene(s) for *per se* yield and yield being end product of gene interactions among different yield attributes.

The specific combining ability effect clearly revealed that it would not be possible to isolate crosses where all attributes are in the most desirable combinations. The usefulness of a specific cross for exploitation of heterosis is determined by its specific combining ability effects. Seven cross combinations such as MS-30(H) × C-776(H), Kajli OPH(H) × Bishnupur-10(H), Kajli OPH(H) × V1(L), Chinese F_1 10 (H) × Bishnupur-10(H), Kajli OPH(H) × Almora local(H), MS-30(H) × English Black(L), *M. indica* HP(L) × Kosen (L) and *M. indica* HP(L) × Almora Local(H) expressed an appreciable amount(>50%) of the SCA effects. These superior cross combinations involves High × High, High × Low and Low × Low parental gca effects, suggesting the involvement of both additive × additive, additive × dominance, over dominance and epistatic type of genetic interaction action. It is observed from diffent cross combinations, that cross which showed high sca effects for leaf yield had invariable exhibited positive *sca* effects for one or more yield components also. In the present study, any combination among the parents of mulberry may produce hybrid vigour over the parents due to dominant, over dominant or epistatic gene action. The present findings were also similar to Vijayan *et al.*, 1997, Banerjee *et al.*, 2014 and Pooja, 2016.

Different agro-climatic conditions are prevailing in India and it is highly essential to develop mulberry varieties specific to each of these regions for sustainable sericulture and targeted raw silk production. Although a few mulberry varieties are available for commercial cultivation, the full genetic potential of this crop is yet to be harnessed for increasing the leaf productivity. In this direction, around nine hundred and eighty three recombinants were evaluated for leaf yield and its components over five crop seasons under irrigated condition. Wide and significant variation was observed for Chlorophyll index (4.58 - 32.07), specific leaf area (142.4 - 409.3 cm^2g^{-1}), harvest index (42 - 68 %) and leaf yield plant^{-1} (0.06 to 3.41 kg year^{-1}).

Nineteen cross combinations which showed high *sca* effect and mean performance also recorded highly significant differences for leaf yield and its components traits (Table 6). More emphasis was given on leaf yield along with few desired leaf quality parameters in terms of visual thickness, texture and moisture content to identify the high yielding genotypes. Based on annual leaf yield, nineteen superior genotypes were selected from 983 progenies which recorded HIGHER annual leaf yield of range of 2.56 kg (C 350) to 2.10 kg (C 721) along with desirable traits like chlorophyll index (> 10 CCI), leaf moisture (> 70%), Inter-nodal distance (>4 cm) and economical heterosis for leaf yield (>30%). These selected genotypes will be further evaluated under preliminary yield trial (PYT) for leaf productivity and quality is genetic improvement of mulberry.

On the basis of line × tester set analysis, it is concluded that the ratio of ó²GCA/ó²SCA was less than unity for the twelve traits studied indicating involvement of non-additive gene action. The parents Chinese F_1 (10) and Bishnupur-10 were identified as good general combiners and could be further exploiting in mulberry improvement through hybridization breeding. Based on the mean performance and significant *sca* effects, MS-30 x C-776, KOP x Bishnupur-10, KOP x V1, CF_1 (10) x Bishnupur-10, KOP x Almora local, MS-30 x English Black, MHP x Kosen and MHP x Almora local were found to be the most crosses for leaf yield and its components for within family selection. Based on annual performance of progenies under irrigated condition over five seasons, 19 genotypes were identified as high yielding over variety S-1635 which need to be evaluated further following systematic evaluation procedures of mulberry for identify high yielding variety in Mulberry.

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