Philippine Journal of Science
137 (1): 29-38, June 2008
ISSN 0031 - 7683

Genetic Diversity of *Morus* Species of Indigenous and Exotic Accessions Evaluated by Important Agronomical Traits

Amalaendu Tikader* and **Chandrakanth Kamble**

Central Sericultural Germplasm Resources Centre
Thally Road, Tamil Nadu, India

The genetic diversity and relationship among 50 mulberry germplasm accessions from India and abroad were evaluated for 8 agronomical important traits at Central Sericultural Germplasm Resources Centre (CSGRC), Hosur, Tamil Nadu, India. Significant variations between indigenous and exotic mulberry accessions were observed in different agronomical traits. There were significant variations in 8 agronomic traits among the tested mulberry accessions. Genetic background and environment are the main factors influencing leaf yield. Correlation matrix of different traits showed that leaf yield is a combination of multiple traits and plays a significant role. Ward's minimum variance cluster analysis based on Mahalanobis distances of 8 agronomic traits grouped the indigenous and exotic accessions into 9 clusters. Maximum accessions were grouped in cluster VI and minimum in cluster VIII. The CIMMYT selection indices were employed to group and select the suitable mulberry accessions. Indian accession MI-0416 performed better followed by MI-0376 and Thailand accession ME-0058 than other test germplasm accessions. Both the Indian and exotic accessions have the potential to select and could be important germplasm resources for enriching the genetic background of Indian mulberry accessions through crop improvement program.

Key Words: *Morus* species, agronomic traits, genetic diversity, indigenous, exotic

INTRODUCTION

The horizontal expansion of sericulture in traditional and non-traditional states has made it necessary to develop mulberry varieties specific to different agro-climatic zones. The importance of research for the progress of sericulture in India was realized in the beginning of the 19th century. Before India's independence, sericulture was mostly practiced in the traditional belt of West Bengal, Jammu & Kashmir, Uttar Pradesh, Assam, and Karnataka. Sericulture gained momentum with the establishment of the Central Silk Board (CSB) in 1949, as a national nodal agency for planning, monitoring, and extension of sericulture development program in the country. Presently, sericulture is widely distributed in different states of India. The different research institutes have been involved in developing improved varieties to cope with increasing demand and, subsequently, more exotic mulberry germplasms were introduced in India and used as parent material for crop improvement. Presently, the improved varieties in use are mostly developed involving exotic accessions as parent (Tikader & Kamble, 2007).

In developing improved mulberry varieties, a large quantity of germplasm is required for testing. Sericulture advanced countries like Japan, China and Italy have evaluated temperate mulberry accessions (Cappellozza et al. 1995, 1996, Katsumata 1972, Machii et al. 2001).

*Corresponding author: atikader_csgrc@yahoo.co.in
drckkamble@yahoo.com

Evaluating and grouping of mulberry germplasm in a certain region is helpful for study of the evolutionary relationship in line with the history of the crop in that region, which also helps crop improvement through crosses between apparently unrelated genotypes.

Moreover, estimates of genetic diversity and relationship between various collections from diverse origin have helped in efficient management and utilization of germplasm (Rabbani et al. 1988). Several authors have highlighted the variability of mulberry germplasm (Thangavelu et al. 2000, Tikader & Rao 2002, Rao et al. 2004,), whereas the association of different agronomical traits have been studied and highlighted (Vijayan et al. 1997, Sarkar et al. 1987, Tikader & Roy 1999). To ensure efficient mulberry leaf production, breeders aimed to produce high yield and quality cultivars. The information on the genetic diversity in Morus species could help breeders to understand and predict which combination would produce the best offspring. Many investigations revealed that there are considerable genetic variations among indigenous and exotic mulberry germplasm accessions, and pointed out to group the accessions and select suitable combinations to meet the specific requirement and genetic manipulation (Fotedar & Dandin 1998, Rajan et al. 1997, Tikader et al. 1999, Vijayan et al. 1999, Tikader & Roy 2002, Tikader et al. 2003). The combination of characters and their performance is determined through selection index and in this study; CIMMYT selection index was employed to select suitable accessions or combination of accessions for breeders. Since the breeders pay more attention to morphological traits, 8 agronomical important traits of 50 mulberry accessions from diverse origins were evaluated in a particular statistical design. The study aimed to investigate the variation, association, and genetic diversity of the selected mulberry germplasm accessions from India and abroad for the 8 agronomical traits.

MATERIALS AND METHODS

Plant materials

The plant materials comprised 50-mulberry germplasm accessions including indigenous and exotic origins. Twenty-five mulberry germplasm accessions from India, four each from Bangladesh, China, and Zimbabwe; two each from France, Thailand and Vietnam; one each from Papua New Guinea, Indonesia, Japan, Georgia, and three unknown exotic origins (Table 1).

Experimental design

The experiment was set up in partial lattice design (PLD) with three replications at the Central Sericultural Germplasm Resources Center, Hosur, Tamil Nadu, India. The center is situated at 12.45° N, 77.51° E and 942 m altitude with tropical dry climate. The average rainfall ranges from 500 – 1000 mm per annum. The soil is red loamy with pH 6.5–7.5. The plantation was maintained as low bush with 90 x 90 cm spacing nine plants per replication with standard cultural practices (Tikader & Rao 2002). The first pruning was done after one year of establishment of the plantation, and four harvests per year were recorded after 90 days of pruning.

Data collection

After 90 days of pruning, seven plants were randomly sampled from each replication for evaluation of eight agronomic traits. The traits were primary branches per plant (NB), length of the longest shoot (LLS), total shoot length (TSL), internodal distance (ID), leaf moisture content (MC), leaf moisture retention capacity (MRC), leaf yield per plant (LYD), and single leaf weight (SLW). The data on agronomical traits were collected four times per year for three years, and completed 13 harvests form 2002–2006. Standard procedure was followed as described by various authors (Thangavelu et al. 2000; Machii et al. 2001). The leaf yield per plant was recorded after 90 days of pruning. Fifty leaves from 5^{th}- 9^{th} position in descending order on a stem from 10 twigs were collected at 9–10 AM in polythene bags in three replications, and moisture loss was recorded after six h at room temperature followed by hot air oven drying at 80°C for 48 h. The leaf moisture content and leaf moisture retention capacity was calculated as described earlier (Vijayan et al. 1996; Tikader & Roy 1999).

$$\text{Moisture content (\%)} = \frac{\text{Fresh leaf wt} - \text{Oven dry leaf wt}}{\text{Fresh leaf weight}} \times 100$$

$$\text{Moisture retencion capacity (\%)} = \frac{\text{Leaf wt after 6 hr dry} - \text{Oven dry leaf wt}}{\text{Fresh leaf wt} - \text{Oven dry leaf wt}} \times 100$$

Data analysis

The data recorded and compiled were statistically analyzed following the standard statistical package. Analysis of variance of the eight agronomic traits were carried out using partial balanced lattice design model, and considered the adjusted values. The mean values for eight agronomic traits were used for correlation matrix and cluster analyses. Pair wise distances between the accessions based on Mahalanobis distances were recorded (Mahalanobis 1936). Ward's minimum variance cluster analysis (Ward 1963) was used to group the tested mulberry germplasm accessions. The CIMMYT selection index was followed to

Table 1. List of mulberry accessions used for the study

S L . NO.	IC/ EC Number	CSGRC No	Accession name	Collection (Country)
1	IC-313977	MI-0029	KOLLEGAL	INDIA (KARNATAKA)
2	IC-313814	MI-0080	BC259	INDIA (WEST BENGAL)
3	IC-313775	MI-0154	UP-14	INDIA (UTTAR PRADESH)
4	IC-313796	MI-0252	KALIMPONG	INDIA (WEST BENGAL)
5	IC-313671	MI-0290	MORUS ALBA	INDIA (KARNATAKA)
6	IC-314005	MI-0296	ACC-16	INDIA (KARNATAKA)
7	IC-314010	MI-0301	ACC-1	INDIA (KARNATAKA)
8	IC-313996	MI-0308	V1	INDIA (KARNATAKA)
9	IC-314155	MI-0310	CHAK MAJRA	INDIA (UTTARAKHAND)
10	IC-314023	MI-0312	GULIKADAWA	INDIA (KERALA)
11	IC-314024	MI-0313	SEEKUPARI	INDIA (TAMIL NADU)
12	IC-313939	MI-0324	ERRC-101	INDIA (KERALA)
13	IC-313941	MI-0326	ERRC-71	INDIA (KERALA)
14	IC-314116	MI-0346	TINGARI LOCAL	INDIA (ASSAM)
15	IC-314119	MI-0349	GAROBADHA	INDIA (MEGHALAYA)
16	IC-314159	MI-0369	RESHAM MAJRI-6	INDIA (UTTARAKHAND)
17	IC-314160	MI-0370	RESHAM MAJRI-7	INDIA (UTTARAKHAND)
18	IC-314166	MI-0376	KUNJAGAO-2	INDIA (UTTARAKHAND)
19	IC-314170	MI-0388	HERBERTPUR	INDIA (UTTARAKHAND)
20	IC-314233	MI-0400	KRISHNASWAMI-2	INDIA (KARNATAKA)
21	IC-314046	MI-0415	GUHANATHAPURAM	INDIA (KERALA)
22	IC-314047	MI-0416	KEERAITHODHU	INDIA (KERALA)
23	IC-314182	MI-0431	SAHARANPUR ROAD	INDIA (UTTARAKHAND)
24	IC-314185	MI-0437	BARAGARH-2	INDIA (UTTARAKHAND)
25	IC-314187	MI-0439	RRSRS, SAHASPUR	INDIA (UTTARAKHAND)
26	EC-493764	ME-0007	SHRIM-2	BANGLADESH
27	EC-493782	ME-0025	SHRIM-8	BANGLADESH
28	EC-493790	ME-0033	THAILAND MALE	THAILAND
29	EC-493799	ME-0041	SHRIM-5	BANGLADESH
30	EC-493809	ME-0052	PAPUA NEW GUINEA	PAPUA NEW GUINEA
31	EC-493815	ME-0058	THILAND	THAILAND
32	EC-493823	ME-0066	KOSEN	JAPAN
33	EC-493841	ME-0084	BOGURA-1	BANGLADESH
34	EC-493856	ME-0129	ZIMBABWE- 3	ZIMBABWE
35	EC-493857	ME-0130	ZIMBABWE- 4	ZIMBABWE
36	EC-493859	ME-0132	ZIMBABWE- 6	ZIMBABWE
37	EC-493861	ME-0134	ZIMBABWE- 8	ZIMBABWE
38	EC-493870	ME-0143	SRDC-1	-----
39	EC-493871	ME-0144	MUKI	FRANCE
40	EC-493883	ME-0156	XUAN-5	CHINA
41	EC-493884	ME-0157	SRDC-3	-----
42	EC-493887	ME-0160	SRDC-2	-----
43	EC-493892	ME-0165	CHINA BLACK -A	CHINA
44	EC-493894	ME-0167	VIETNAM -3	VIETNAM
45	EC-493895	ME-0168	M. MULTICAULIS	INDONESIA
46	EC-493836	ME-0169	GEORGIA	GEORGIA
47	EC-493897	ME-0170	TONKIN	CHINA
48	EC-493900	ME-0173	VIETNAM -2	VIETNAM
49	EC-493901	ME-0174	XUAN - 9	CHINA
50	EC-493906	ME-0179	FURCATA	FRANCE

select the better performing accessions compared to other test accessions. The standardized selected agronomical traits were provided target value and 0 -10 intensity to get desired target.

RESULTS

Comparison of agronomic traits between indigenous and exotic accessions

The mean, standard deviation, coefficients of variation, maximum and minimum of the eight agronomic traits are shown in Table 2. Variance analysis of eight agronomic traits indicated that significant variation exists among the 50 mulberry germplasm accessions. Significant difference ($p<0.01$), was observed between exotic and indigenous accessions in 8 agronomic traits, i.e. number of primary branches per plant, length of the longest shoot, total shoot length, internodal distance, leaf moisture content, leaf moisture retention capacity, leaf yield per plant, and single leaf weight. The indigenous accessions showed higher values in respect of number of primary branches per plant, internodal distance, and leaf moisture content. The exotic accessions showed higher values for length of the longest shoot, total shoot length, leaf moisture retention capacity, leaf yield per plant, and single leaf weight. The interaction between accession x season was significant for all the agronomic characters except the number of primary branches per plant.

Correlation coefficient matrix

The association of different agronomical traits were analysed through Pearson simple correlation matrix. The relationship of different traits indicated that all the traits are associated directly or indirectly with leaf yield. The leaf yield is a complex trait and contributed by other traits. Leaf yield is directly related with the number of primary branches per plant, length of the longest shoot, total shoot length, internodal distance, leaf moisture content, leaf moisture retention capacity, and single leaf weight. Other traits are associated with each other and formed a complex relationship among them.

Clustering of mulberry germplasm accessions

Ward's minimum variance cluster analysis based on Mahalanobis distances grouped 50 mulberry accessions into nine clusters (Table 3 & Figure 1). Cluster I contained eight accessions, which includes accessions from India (6), Bangladesh (1), and

Table 2. Comparison of 8 agronomic characters between indigenous and exotic mulberry accessions

Origin	Item	X1	X2	X3	X4	X5	X6	X7	X8
Indigenous (n=25)	Mean	11.52	151.94	1352.32	5.16	73.27	67.63	778.85	3.82
	Std	1.39	14.58	222.89	0.61	1.52	3.80	138.76	1.39
	C.V.	12.03	2.92	16.48	11.74	2.08	5.61	17.83	39.32
	Max	14.39	176.38	1718.60	6.96	75.79	72.75	1071.08	6.80
	Min	9.30	122.43	891.26	4.19	70.22	61.00	496.68	1.82
Exotic (n=25)	Mean	10.38	164.89	1324.15	5.46	73.62	69.16	781.88	4.80
	Std	1.78	21.51	322.67	0.50	1.08	3.82	155.23	1.33
	C.V.	17.14	13.05	24.37	9.08	1.46	5.52	19.85	27.66
	Max	13.12	206.76	1823.73	6.60	75.18	74.39	1233.21	7.21
	Min	5.69	123.62	549.49	4.55	70.42	60.85	418.81	3.08
Total (N=50)	Mean	10.95	158.42	1338.24	5.31	73.45	68.40	780.15	4.31
	Std	1.68	19.33	274.83	0.57	1.32	3.85	145.73	1.43
	C.V.	15.35	12.20	20.54	10.69	1.79	5.62	18.68	33.25
	Max	14.39	206.76	1823.73	6.96	75.79	74.39	1233.21	7.21
	Min	5.69	122.43	549.49	4.19	70.22	60.85	416.81	1.82
	Accession	**	**	**	**	**	**	**	**
	Season	NS	**	**	**	**	**	**	**
	Acc x Season	NS	**	**	**	**	**	**	**

**, Significant at 1% level, NS = non-significant
X1 = Number of primary branches, X2 = Length of the longest shoot (cm),
X3 = Total shoot length (cm), X4 = Internodal distance (cm),
X5 = Leaf moisture content (%), X6 = Leaf moisture retention capacity (%),
X7 = Leaf yield per plant (g), X8 = Single leaf weight (g)

Thailand (1). Cluster II contained three accessions, included two from Bangladesh and one from China. Cluster III contained 4 from India, and one each from Zimbabwe and Vietnam. Cluster IV grouped 4 accessions from India, and two from unknown exotic origin. Cluster V contained seven accessions, two from India and one each from China, Japan, France, Georgia, and Zimbabwe. Cluster VI contained maximum nine accessions, which includes six from India and one each from Bangladesh, Papua New Guinea, and unknown exotic origin. Cluster VII contained six accessions, two from India, and one each from China, Indonesia, Vietnam, and Zimbabwe. Cluster VIII includes only one accession from Georgia. Cluster IX has one accession each from India, Thailand, and Zimbabwe. The cluster mean values are shown in Table 4. Cluster I showed higher mean values for number of primary branches per plant, length of the longest shoot length, and total shoot length. Cluster III indicates low value internodal distance. Cluster V showed higher values for leaf moisture retention capacity. Cluster VIII having only one accession had higher values for leaf yield and single leaf weight. Cluster IX showed higher values for leaf moisture content.

The intra and inter cluster distances are presented in Table 5. Maximum and minimum inter-cluster distance was recorded between clusters III and clusters VIII (6.37), and between clusters VI and VII (2.73) indicates that the accessions grouped in these clusters are genetically divergent and similar. Intra-cluster distance was recorded higher in cluster V (3.90) and minimum in cluster VIII (0.00). The accessions are distributed equally in different clusters except cluster VIII.

Table 3. Distribution mulberry germplasm in different clusters

Cluster	No. of mulberry accessions	Distributions of mulberry germplasm accessions
I	8	MI- 0029 (Kollegal), MI- 0296 (Acc.16), MI- 0290 (*Morus alba*), MI-0313 (Seekupari), MI-0346 (Tingari local), MI-0154 (UP-14) - **Indigenous** ME -0084 – Bogura–1 (Bangladesh), ME-0058- Thailand (Thailand) - **Exotic**
II	4	ME- 0156- Xuan-5 (China), ME-0025 – Shrim-8 (Bangladesh), ME- 0041 Shrim-5 (Bangladesh), ME-0174- Xuan-9 (China) - **Exotic**
III	6	MI- 0312 (Gulikadava), MI-0349 (Garobadha-2), MI-0415 (Guhanathapuram), MI- 0370 (Resham Majri-7) - **Indigenous** ME- 0134 – Zimbabwe-8 (Zimbabwe), ME-0167 –Vietnam –3 (Vietnam) - **Exotic**
IV	6	MI- 0388 (Herbertpur), MI-0400 (Krishnaswami-2), MI-0301 (Acc.1), MI- 0439 (RSRS, Sahaspur) - **Indigenous** ME- 0157 – SRDC-3 (Unknown), ME-0160- SRDC-2 (Unknown) - **Exotic**
V	7	MI- 0080 (BC259), MI-0252 (Kalimpong) - **Indigenous** ME- 0066 – Kosen (Japan), ME-0165–China Black- A (China), ME-0179–Furcata(France),ME-0132–Zimbabwe – (Zimbabwe) ME- 0144- Muki (France) - **Exotic**
VI	9	MI-0310 (Chak Majra), MI-0437 (Baragarh –2), MI-0308 (V1), MI-0369 (Resham Majri-6), MI-0431 (Saharanpur Road), MI-0416 (Keeraithodu) - **Indigenous** ME-0007 – Shrim –2 (Bangladesh), ME-0052 – Papua New Guinea (Papua New Guinea), ME-0143 – SRDC-1 (Unknown) - **Exotic**
VII	6	MI- 0324 (ERRC-101), MI-0326 (ERRC-71) -- **Indigenous** ME-0130- Zimbabwe-4 (Zimbabwe), ME-0168- *M.multicaulis* (Indonesia) ME-0170 - Tonkin (China), ME-0173 – Vietnam-2 (Vietnam) - **Exotic**
VIII	1	ME-0169 – Georgia (Georgia) - **Exotic**
IX	3	MI-0376 (Kunjagao-2) **- Indigenous** ME-003 – Thailand male (Thailand), ME-0129 Zimbabwe-3 (Zimbabwe) - **Exotic**

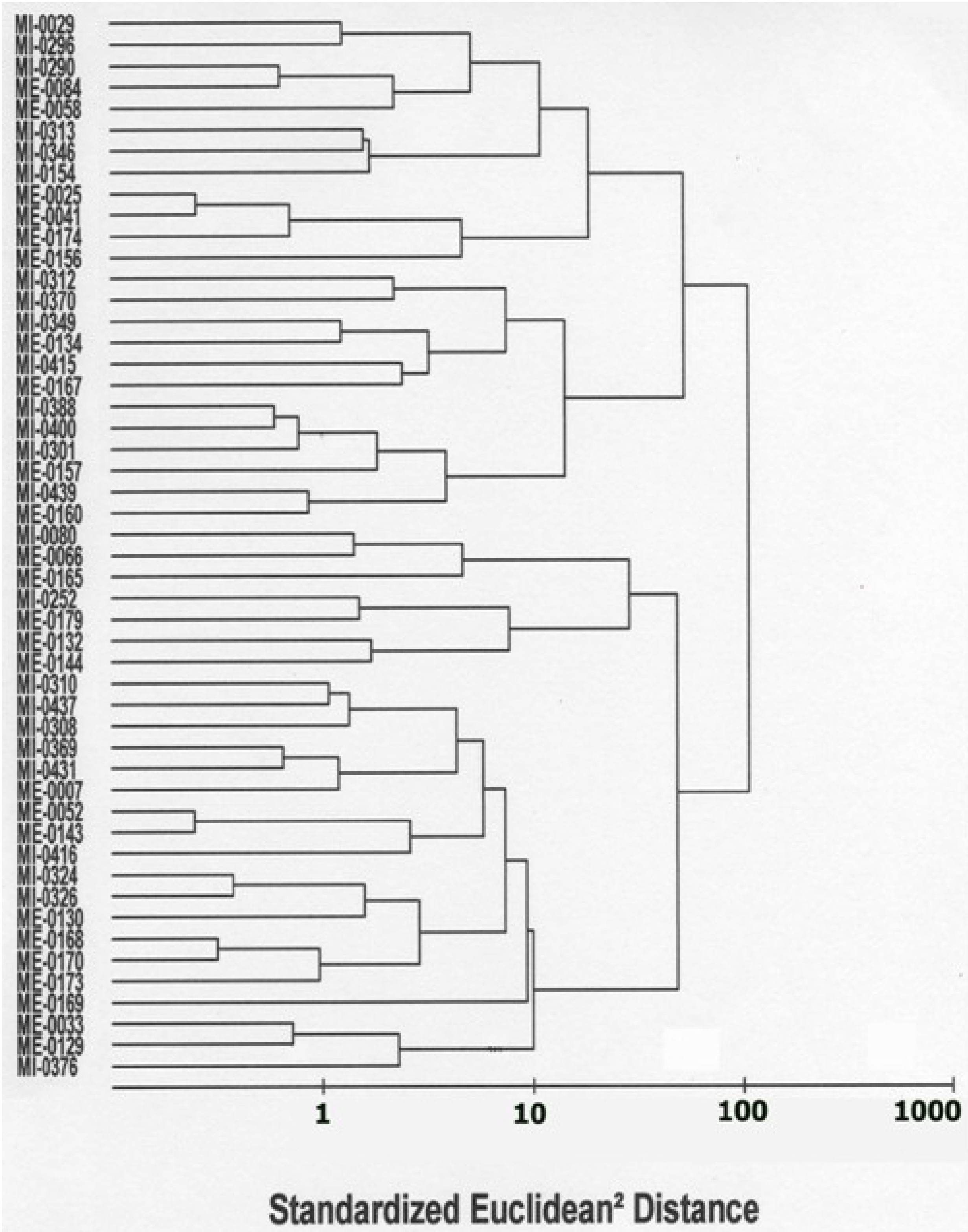

Figure 1. Dendrogram produced using Ward's Minimum Variance cluster analysis based on D² matrix demonstrating the association among 50 mulberry accessions.

Table 4. Cluster mean values for agronomic traits

Traits	Clusters								
	I	II	III	IV	V	VI	VII	VIII	IX
X1	13.05	11.39	10.73	10.28	8.29	11.08	10.63	11.72	12.77
X2	163.07	200.23	150.56	143.61	150.59	158.02	154.19	160.69	161.85
X3	1634.72	1739.70	1232.19	1143.33	951.42	1355.86	1259.21	1475.18	1576.32
X4	4.89	5.61	4.85	5.05	5.83	5.16	5.71	5.98	5.73
X5	72.54	72.46	71.73	73.95	74.43	74.06	73.70	73.63	74.92
X6	63.24	63.94	65.68	68.57	72.58	70.81	71.37	72.50	68.52
X7	806.13	767.73	617.18	692.98	652.79	923.37	808.42	1233.21	887.62
X8	2.52	3.47	2.83	3.98	6.13	4.95	5.54	7.21	4.19

X1 = Number of primary branches, X2 = Length of the longest shoot (cm),
X3 = Total shoot length (cm), X4 = Internodal distance (cm),
X5= Leaf moisture content (%), X6 = Leaf moisture retention capacity (%),
X7 = Leaf yield per plant (g), X8 = Single leaf weight (g)

Table 5. Mean intra and inter-cluster D^2 values of 9 clusters among mulberry germplasm

Clusters	I	II	III	IV	V	VI	VII	VIII	IX
I	**2.59**	3.63	3.56	3.99	6.50	4.04	4.46	5.78	3.65
II		**1.93**	4.23	4.53	6.13	4.19	4.26	5.45	3.67
III			**2.58**	2.97	5.31	4.11	3.98	6.37	4.53
IV				**1.78**	3.91	2.82	2.56	5.19	3.42
V					**3.90**	4.39	3.54	5.61	5.06
VI						**2.08**	2.23	3.42	2.57
VII							**1.56**	3.52	2.76
VIII								**0.00**	3.70
IX									**1.74**

Bold value for intra-cluster distance and normal value for inter-cluster distance

Selection index (CIMMYT)

Overall performance of mulberry accessions was assessed through CIMMYT selection index (Table 6). MI-0416 from India performed better than other test accessions followed by ME-0058 from Thailand, and MI-0376 and MI-0308 from India. Likewise 25 entries were selected from 50-mulberry accession tested. The result indicates that the lower the index value, the accessions showed better cumulative performance compared to other accessions. Out of 25 selected accessions, there were 11 from India, four from Bangladesh, two each from China, Thailand, and Zimbabwe, and one each from Georgia, Indonesia, Papua New Guinea, and unknown exotic origin. A total of 14 accessions collected from other countries (exotic) qualified among 25 selected accessions. The diverse mulberry accessions that qualified coming from different geographical origins have equal chances for selection.

DISCUSSION

The experiment was conducted in partial lattice design with 50 diverse mulberry accessions against eight agronomical important traits. The accessions were collected from 11 countries including India. Significant differences were observed in all the traits i.e. number of primary branches per plant, length of the longest shoot, total shoot length, internodal distance, leaf moisture content, leaf moisture retention capacity, leaf yield per plant, and single leaf weight for 50 accessions (Tikader & Rao 2002). The indigenous materials (Indian origin) locally adopted and mostly grown in tropical condition are capable to adjust to local environment. Whereas, the exotic accession that were either from sub-tropical to temperate climate origins took more time to adjust to local conditions, although the exotic accessions performed well in tropical dry condition at Hosur.

The relationship of different agronomic traits was worked out. All the traits showed association with leaf yield. Several authors have reported similar findings

Table 6. Listing of selected mulberry germplasm accessions (CIMMYT selection index)

Sl no.	Acc. no	Index	X1	X2	X3	X4	X5	X6	X7	X8
1	MI-0416	17	11.60	174.45	1552.23	4.92	73.37	70.66	1071.08	5.28
2	ME-0058	19	13.12	174.75	1790.07	5.05	74.39	64.58	940.28	3.44
3	MI-0376	19	13.10	176.38	1715.08	6.06	75.24	70.80	902.59	4.12
4	MI-0308	19	11.31	165.99	1434.08	5.18	74.96	72.36	906.56	4.44
5	ME-0169	20	11.72	160.69	1475.18	5.98	73.63	72.50	1233.21	7.21
6	MI-0437	21	10.74	145.81	1244.30	5.03	75.79	72.75	950.21	5.59
7	ME-0033	21	13.08	152.52	1540.66	5.46	74.92	67.04	891.23	3.68
8	ME-0129	21	12.12	156.65	1473.23	5.67	74.60	68.71	869.03	4.28
9	MI-0310	21	11.21	150.40	1338.80	5.57	74.56	72.32	993.35	5.45
10	ME-0174	21	11.70	206.76	1819.26	5.60	72.95	65.06	823.56	3.52
11	ME-0052	21	10.04	169.63	1294.50	5.07	73.50	70.40	872.80	5.37
12	ME-0143	22	9.56	177.47	1276.96	5.19	73.24	71.30	902.63	5.73
13	ME-0007	22	12.26	149.39	1435.28	5.22	72.83	67.93	891.89	4.33
14	MI-0431	22	10.86	150.07	1278.90	5.15	74.13	69.69	860.20	4.61
15	ME-0025	22	11.16	198.41	1635.95	5.46	73.48	65.19	711.69	3.38
16	MI-0369	22	12.13	139.00	1347.68	5.14	74.19	69.91	861.65	3.80
17	MI-0029	23	14.39	154.62	1718.60	5.08	73.53	63.50	818.42	2.22
18	ME-0041	23	10.90	204.64	1679.87	5.67	73.01	64.65	744.49	3.61
19	ME-0168	23	9.85	159.84	1230.40	5.65	73.94	70.29	856.09	6.44
20	ME-0084	23	11.65	180.92	1637.23	5.39	73.98	62.66	722.28	3.03
21	MI-0326	23	11.65	153.07	1297.08	5.59	73.66	70.08	746.93	4.86
22	MI-0290	23	12.61	170.88	1605.33	5.35	73.28	63.12	796.38	2.59
23	MI-0324	23	11.81	152.00	1365.14	5.96	73.75	70.21	820.70	4.80
24	ME-0130	23	10.55	162.12	1291.65	6.03	73.98	74.37	783.13	5.35
25	ME-0170	23	9.72	157.22	1213.41	5.56	73.58	72.83	849.66	6.08

X1 = Number of primary branches, X2 = Length of the longest shoot (cm),
X3 = Total shoot length (cm), X4 = Internodal distance (cm),
X5 = Leaf moisture content (%), X6 = Leaf moisture retention capacity (%),
X7 = Leaf yield per plant (g), X8 = Single leaf weight (g)

(Sarkar et al. 1987, Vijayan et al. 1997; Tikader & Roy 1999). The highly correlated traits with leaf yield i.e., number of branches, length of the longest shoot, and total shoot length, etc. should be taken into consideration during selection of accessions. In case of cluster analysis, the eight agronomic traits of indigenous and exotic accessions were grouped into nine clusters irrespective of geographic origin. The entire cluster group have both exotic and indigenous accessions except clusters II and VIII where only exotic accession was grouped. Earlier reports on clustering in mulberry by various authors also indicated that the exotic and indigenous accessions could be grouped in same cluster (Rajan et al. 1997, Fotedar & Dandin 1998; Tikader & Roy 2002; Tikader et al. 2003). The present study also supports the earlier findings. The clustering pattern clearly indicates that genetic diversity and geographical distribution possess no relation, and the mulberry accessions collected from different sources grouped as per their performance based on agronomical traits. Only exotic accessions grouped in cluster II and VIII. In other clusters, the combination of accessions joined with each other based on close affinity and genetic value. The breeders have the opportunity to select a suitable group of germplasm for further utilization. In India, most of the improved variety developed by involving exotic accession as one of the parents is where lies the importance of using exotic germplasm (Tikader & Kamble 2007).

The mulberry accessions were considered for overall performance and assessed through CIMMYT selection indices. The combined analysis indicates that Indian accessions and exotic accessions performed well among selected accessions. The exotic accessions adjusted to the local environment, established and performed better. The adaptive changes of a population to a habitat may occur very rapidly and at short distances in response to both climatic, edaphically, biological, and cultural factors (Bradshaw 1977; William 1987). Adaptation to a marginal condition is an adjustment to the physical than to the biological environment. In such environment, the ability to survive and reproduce are more important than competitive ability (Heide 1985; Tigerstedt 1994).

The role of exotic accession is enormous and the result revealed that a good number of exotic accessions performed well with Indian accessions. From 1940 onwards, when sericulture were practiced in traditional states of India, the exotic accessions have been introduced for development of sericulture, and presently the important commercial variety has been developed by using it as one of the parents in hybridizations.

CONCLUSION

In conclusion, the variation and association of the Indian and exotic mulberry germplasm accessions were consistent. The exotic accessions adapted to tropical dry climate and competed with the locally available germplasm accessions. The genetic diversity also favors the performance of indigenous and exotic accessions to express their ability in a given climatic condition. So, both groups of accessions particularly the exotic have distinguished features particularly leaf quality that could be important genetic resources to enrich the genetic background of Indian mulberry germplasm accessions.

REFERENCES

BRADSHAW AD. 1977. Some of the evolutionary consequences of being a plant. Evol Biol 5: 25 – 47.

CAPPELLOZZA L, CORADAZZI AT, and TORNADORE N. 1995. Studies on phenotypic variability of seven cultivars of *M. alba* L. and three of *M. multicaulis* P. (Moraceae) Part I. Sericologia 35: 257 – 270.

CAPPELLOZZA L, CORADAZZI AT, CAPPELOZZA S, BALDAU B, and MARIANI P. 1996. Studies on phenotypic variability of seven cultivars of *M. alba* L. and three of *M. multicaulis* P. (Moraceae) Part II. Sericologia 36: 91 – 102.

FOTEDAR RK and DANDIN SB. 1988. Genetic divergence in mulberry. Sericologia 38: 115 – 125.

HEIDE O. 1985. Physiological aspects of climatic adaptation implants with special reference to high latitude environments, In: Kaurin A, Junttila O & Nilson J eds. Oslo: Norwegian University Press pp. 1 – 22.

KATSUMATA F. 1972. Mulberry species in West Java and their peculiarities. Journal Seric Sci Japan 43: 213 – 223.

MACHII H, KOYAMA A, YAMANOUCHI H, MATSUMOTO K, KOBAYASHI S, and KATAGIRI K. 2001. Morphological and agronomical traits of mulberry. Misc Pub Natl Inst Seric Ent Sci 29: 1 –307.

MAHALANOBIS PC. 1936. On the generalized distance in statistics. Proc Natl Inst Sci India 2: 49 – 55.

RABBANI MA, MURAKAMI YAI, SUZUKI T, and TAKAYANGI K. 1998. Phenotypic variation and the relationship among mustard (*Brassica juncea* L.) germplasm from Pakistan. Euphytica 101: 357 – 366.

RAJAN MV, CHATURVEDI HK, and SARKAR A. 1997. Multivariate analysis as an aid to genotypic selection for breeding in mulberry. Indian J Seric 36: 111 – 115.

RAO AA, TIKADER A, and THANGAVELU K. 2004. Assessment of genetic diversity on growth and reproductive behaviour in mulberry germplasm and utilization. Indian J Forestry 27: 372 – 380.

SARKAR A, ROY BN, GUPTA KK, and DAS BC. 1987. Character association in mulberry under close planting. Indian J Seric 26: 76 –78.

THANGAVELU K, TIKADER A, RAMESH SR, RAO AA, NAIK GV, SEKAR S, and DEOLE AL. 2000. Catalogue on mulberry (*Morus* spp.) germplasm. 2: 1 – 225.

TIKADER A, RAO AA, RAVINDRAN S, NAIK GV, MUKHERJEE P, and THANGAVELU K. 1999. Divergence analysis in different mulberry species. Indian J Genet 59: 87 – 93.

TIKADER A and ROY BN. 1999. Genetic variability and character association in mulberry germplasm (*Morus* spp.). Indian J Forestry 22: 26 –29.

TIKADER A and RAO AA. 2002. Phenotypic variation in mulberry (*Morus* spp.) germplasm. Sericologia 42: 221 – 233.

TIKADER A and ROY BN. 2002. Genetic divergence in mulberry (*Morus* spp.) Indian J Genet 62: 52 –54.

TIKADER A, RAO AA, and THANGAVELU K. 2003. Genetic divergence in exotic mulberry (*Morus* spp.) germplasm. Sericologia 43:495 – 501.

TIKADER A and KAMBLE CK. 2007. Mulberry breeding in India – A critical Review. Sericologia 47:367-382.

TIGERSTEDT PMA. 1994. Adaptation, variation and selection in marginal areas, In: ROGNLI OA, SOLBORG ET, SCHJELDERUP I. eds. Breeding Fodder Crops for marginal conditions. Proceedings of the 18th Eucarpia Fodder Crop Section Meeting; 1993 August 25-28; Loen, Norway: Development in Plant Breeding 2: 13 – 19.

VIJAYAN K, TIKADER A, DAS KK, ROY BN, and PAVAN KUMAR T. 1996. Genotypic influence on leaf moisture content and moisture retention capacity in mulberry (*Morus* spp.). Bulletin Seric Res 7: 95 – 98.

VIJAYAN K, TIKADER A, DAS KK, DOSS SG, CHAKROBORTI SP, and ROY BN. 1997. Correlation studies in mulberry (*Morus* spp.). Indian J Genet 57: 455 – 460.

VIJAYAN K, DAS KK, DOSS SG, CHAKROBORTI SP, and ROY BN. 1999. Genetic divergence in indigenous mulberry (*Morus* spp.) genotypes. Indian J Agric Sci 69: 851 – 853.

WARD JH. 1963. Hierarchical grouping to optimize an objective function. J Am Stat Ass 58: 236 – 244.

WILLIAMS WM. 1987. Adaptive variation. In: Baker MJ & Williams WM eds. Commonwealth Agricultural Bureaux International (CABI) p. 299 – 321.