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Performance of exotic mulberry (*Morus* spp.) germplasm on growth and yield traits in Indian condition

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Exotic mulberry germplasm accessions were evaluated under tropical dry agro-climatic condition of India. Mulberry accessions showed great extent of variation in growth and yield traits. The analysis of variance revealed significant differences in all growth and yield traits. The interaction between accession x season was significant for all traits except number of branches per plant, total shoot length and Internodal distance. The coefficient of variation was maximum in leaf yield per plant followed by total shoot length and minimum in leaf moisture content. The relationship among different growth traits indicated that leaf yield is depended on number of branches per plant and total shoot length. The CIMMYT selection index was used to identify the best accessions studied in the experiment. The divergence analysis using R statistics grouped the accession into 7 clusters of which maximum numbers of accessions were in cluster IV and minimum in cluster V. Inter-cluster distance was maximum in between cluster V and VII whereas minimum in cluster IV and I. The intra cluster distance was higher in cluster VI and minimum in cluster V. The diversity among the accessions measured by D^2 values may be used for selection of exotic mulberry accessions for crop improvement.

Key words: Genetic diversity, mulberry, exotic germplasm, yield traits, cluster analysis.

INTRODUCTION

Mulberry (*Morus* spp.) is a perennial heterozygous plant originated from China, which is the primary center of origin (Vavilov, 1926). Mulberry the primary food plant of silkworm (*Bombyx mori* L.) belongs to family Moraceae. For crop improvement, the exotic collection was introduced into India from different countries as a result, it is very difficult to know the exact geographical distribution of Indian mulberry varieties and behaviour of the plants in respect to expression of various traits.

Evaluation of any crop is a continuous process to evolve new varieties suitable for specific zones for commercial utilization. The present scenario of sericulture industry demands new varieties suitable for various agro-climatic conditions. Suitable parent material needs to be identified from large number of germplasm accessions for the purpose. Central Sericultural Germplasm Resources Centre (CSGRC) Hosur is presently maintaining 264 exotic mulberry accessions that were collected from 25 countries and are being maintained in field gene bank under tropical dry climatic condition. Earlier the performance of different exotic accessions was highlighted by various authors (Cappellozza et al., 1995, 1996; Tikader and Roy, 1999a; Tikader and Rao, 2002a).

More over, estimates of genetic diversity and relationship between various collections from diverse origin helps in efficient management and utilization of germplasm (Rabbani et al., 1988). Several studies have already highlighted the variability of mulberry germplasm (Thangavelu et al., 2000; Tikader and Rao, 2002a) and association of different agronomical traits was also studied in detail (Vijayan et al., 1997; Tikader and Roy, 1999a).

Genetic diversity forms the basis of agriculture and the usefulness of a genetically diverse gene pool in plant breeding cannot be overemphasized (CGR, 2005). More over, genetic diversity within and among the population is the backbone of conservation of plant genetic resources for both present and future use (Quedraogo, 2001). Mulberry breeders' will require as much genetic diversity as

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Table 1. List of exotic mulberry accessions used for the study.

Accession	Accession name	Sex	Species	Collection/origin
ME-0007	Shrim-2	Monoecious	*Morus alba* Lin.	Bangladesh
ME-0025	Shrim-8	Female	*Morus alba* Lin.	Bangladesh
ME-0033	Thailand male	Male	*Morus alba* Lin.	Thailand
ME-0041	Shrim-2	Female	*Morus alba* Lin.	Bangladesh
ME-0052	Papua New Guinea	Monoecious	*Morus alba* Lin.	Papua New Guinea
ME-0058	Thailand	Male	*Morus alba* Lin.	Thailand
ME-0066	Kosen	Monoecious	*Morus latifolia* Poir.	Japan
ME-0084	Bogura-1	Monoecious	*Morus indica* Lin.	Bangladesh
ME-0129	Zimbabwe-3	Female	*Morus latifolia* Poir.	Zimbabwe
ME-0130	Zimbabwe-4	Female	*Morus alba* Lin.	Zimbabwe
ME-0132	Zimbabwe-6	Female	*Morus latifolia* Poir.	Zimbabwe
ME-0134	Zimbabwe-8	Monoecious	*Morus alba* Lin.	Zimbabwe
ME-0143	SRDC-1	Female	*Morus latifolia* Poir.	Not known
ME-0144	Muki	Monoecious	*Morus latifolia* Poir.	France
ME-0156	Xuan-5	Monoecious	*Morus alba* Lin.	China
ME-0157	SRDC-3	Female	*Morus alba* Lin.	Not known
ME-0160	SRDC-2	Female	*Morus alba* Lin.	Not known
ME-0165	China black-A	Male	*Morus alba* Lin.	China
ME-0167	Vietnam-3	Monoecious	*Morus alba* Lin.	Vietnam
ME-0168	*M.multicaulis*	Monoecious	*Morus latifolia* Poir.	Indonesia
ME-0169	Georgia	Monoecious	*Morus alba* Lin.	Georgia
ME-0170	Tonkin	Female	*Morus latifolia* Poir.	China
ME-0173	Vietnam-2	Monoecious	*Morus alba* Lin.	Vietnam
ME-0174	Xuan-9	Female	*Morus alba* Lin.	China
ME-0179	Furcata	Female	*Morus alba* Lin.	France

ME = *Morus* exotic

as possible from which to select and recombine favourable traits through cross breeding (Tikader and Dandin, 2007a; Tikader and Dandin, 2008a, 2008b) to develop varieties that are adopted to Indian environment. Improvement through breeding or clonal selection depends on the extent of magnitude of diversity between the accessions. The process requires grouping the accessions into different clusters and select for utilization. Different authors highlighted grouping and selection of accessions from different clusters for crop improvement (Fotedar and Dandin, 1998; Rajan et al., 1997; Tikader et al., 1999b, 2003; Tikader and Roy, 2001, 2002; Vijayan et al., 1999). The exotic collection from temperate climate is superior in quality aspects like leaf moisture content, moisture retention and biochemical parameters which can be incorporated in locally adopted varieties through breeding. Such reports are available and produced a good number of varieties in India (Tikader and Kamble, 2007). In India 4 mulberry species are reported and 68 recognized species of mulberry in world, practically there is less crossing barrier among the species and within the species (Das and Krishnaswami, 1965; Dwivedi et al., 1989; Tikader and Dandin, 2007, 2008).

Thus the present study was conducted to know the performance of exotic mulberry germplasm accessions on growth and yield traits and group them using divergence analysis for effective utilization in crop improvement.

MATERIALS AND METHODS

Accessions' passport information

The accessions were collected from different research Institutes of different countries. During collection, available passport information was also collected from the source Institutes. The morphometric information generated at Central Sericultural Germplasm Resources Center (CSGRC) Hosur after establishment in *ex-situ* field gene bank. Each tree was assigned accession number and used for data recording. The reproductive behaviour with other relative information was also generated and presented in Table 1. The accessions belong to *Morus indica, Morus alba* and *Morus latifolia* etc. the similar data was also verified in experimental site which was propagated through clone to maintain the true to type.

Plant materials

Twenty-five exotic mulberry germplasm accessions were selected from 264 collections based on preliminary observation on growth and yield traits in field gene bank. The mulberry accessions distributed 4 each from Bangladesh, China and Zimbabwe, two each from France and Vietnam, 1 each from Papua New Guinea, Indonesia, Japan, Georgia and three accessions of unknown source (Table 1).

Experimental design

The experimental site 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 experiment was set up in Partial lattice design with three replications at Central Sericultural Germplasm Resources Center (CSGRC), Hosur, Tamil Nadu, India. The plantation was maintained as low bush with 90 x 90 cm spacing 9 plants per replication with standard cultural practices (Thangavelu et al., 2000; Tikader and Rao, 2002). The first pruning was done after one year of establishment of plantation, four times leaf harvest per year after pruning of 90 days interval.

Data collection

After 90 days of pruning 7 plants were randomly sampled from each replication for evaluating eight agronomic traits. The traits were number of branches per plant (NBR), 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 4 times per year for 3 years and completed 13 harvests form 2003 – 2007. Standard procedure was followed as described by various authors (Thangavelu et al., 2000; Machii et al., 1997, 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 6 h keeping at room temperature and 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 by earlier authors (Tikader and Roy, 1999; Vijayan et al., 1996).

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

$$\text{Moisture retention capacity (\%)} = \frac{\text{Leaf weight after 6 hours dry} - \text{Oven dry leaf weight}}{\text{Fresh leaf weight} - \text{Oven dry leaf weight}} \times 100$$

Data analysis

After recording the data, it was compiled and statistically analysed following the standard statistical package. Variance of analysis 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 (Pearson, 1904)) 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 select the better performed accessions compared to other test accessions. The standardized selected agronomical traits were provided target value, intensity to get desired target.

RESULTS

Analysis of variance

The mean standard error, F-test, coefficient of variation and cumulative index value of 25 accessions are presented in Table 2. Variance analysis of 8 agronomic traits indicated that significant variation exists among the accessions. Significant difference at 1% level was observed among all the traits that is, number of branches per plant, length of the longest shoot, total shoot length, Internodal distance, moisture content, moisture retention capacity, leaf yield per plant and single leaf weight. The seasonal variation was also highly significant. The interaction between accession x season was significant for all the traits except number of branches per plant, total shoot length and Internodal distance (Table 2).

Selection index

The performance of exotic mulberry germplasm was assessed through CIMMYT selection index. (Table 2). ME-0058 from Thailand performed better among the test accessions followed by ME-0169 from Georgia, ME-0129 from Zimbabwe, ME-0033 from Thailand and ME-0052 from Papua New Guinea. The result indicated that lower the index value, the accessions showed better cumulative performance among the test materials. The accession ME-0066 from Japan was used as control as the variety has introduced long back and acclimatized in Indian condition and repeatedly used for breeding for crop improvement. The diverse mulberry accession collected from different agro-climatic condition have adjusted in Indian condition and performed well.

Correlation coefficient matrix

The association of different growth and yield traits were analyzed through simple correlation matrix (Table 3). The relationship of different traits indicated that leaf yield is dependent on number of branches (0.67**) and total shoot length (0.58**). Other traits are associated with each other and contribute to leaf yield directly or indirectly exhibiting complex relationship.

Cluster analysis

Wards' minimum variance cluster analysis based on Mahalanobis' distance grouped 25 mulberry accessions into 7 clusters (Table 4 and Figure 1). The grouping pattern showed 6 accessions in cluster VI followed by 5 accessions each in cluster whereas cluster II and IV includes 3 accessions each. Cluster VI is having 2 accessions and only one accession in cluster V. The cluster means values are presented in Table 5. The accessions grouped in cluster V is having the important traits like leaf moisture retention, leaf yield per plant and single leaf weight whereas number of branches per plant and leaf moisture content in cluster II. The inter and intra cluster distances is presented in Table 6. The maximum inter-cluster distance was observed between cluster V and VII whereas minimum between IV and I Intra-cluster distance was maximum in cluster VI and minimum in cluster V.

Table 2. Mean performance of exotic mulberry accessions.

Accessions	NB	LLS	TSL	INTD	MC	MRC	LYD	SLW	SI
ME-0007	12.26	149.39	1435.28	5.22	72.83	67.93	891.89	4.33	21
ME-0025	11.16	198.41	1635.95	5.46	73.48	65.19	711.69	3.83	22
ME-0033	13.08	152.52	1540.66	5.46	74.92	67.04	891.23	3.68	19
ME-0041	10.90	204.64	1679.87	5.67	73.00	64.65	744.49	3.61	23
ME-0052	10.04	169.63	1294.50	5.07	73.50	70.40	872.80	5.37	20
ME-0058	13.12	174.75	1791.07	5.05	74.39	64.58	940.28	3.44	18
ME-0066	7.74	134.85	794.03	4.75	74.68	71.04	573.63	5.37	27
ME-0084	11.65	180.92	1473.23	5.67	73.98	62.66	722.28	3.03	23
ME-0129	12.11	156.65	1291.65	6.03	74.60	68.71	869.03	4.78	19
ME-0130	10.55	162.12	979.42	6.00	73.99	74.37	783.13	5.35	22
ME-0132	8.41	154.43	1195.22	5.20	73.60	73.60	688.51	6.70	26
ME-0134	10.90	152.04	1276.96	5.19	72.27	66.42	573.31	3.38	27
ME-0143	9.56	177.47	866.90	6.39	73.24	71.30	902.63	5.73	20
ME-0144	7.13	162.16	1823.73	5.70	75.18	74.39	586.63	7.04	28
ME-0156	11.82	191.11	1068.26	4.55	70.42	60.85	791.17	3.38	28
ME-0157	10.15	133.51	1200.84	5.03	74.55	71.36	717.68	3.89	23
ME-0160	9.69	164.67	549.49	4.99	74.53	67.58	738.69	4.09	22
ME-0165	5.69	123.62	1351.80	4.84	75.06	74.25	416.81	5.28	22
ME-0167	10.68	169.32	1230.40	5.65	72.06	70.14	785.57	3.26	32
ME-0168	9.85	159.84	1475.18	5.98	73.94	70.29	856.09	6.44	23
ME-0169	11.72	160.69	1213.41	5.56	73.63	72.50	1233.21	7.21	21
ME-0170	9.72	157.22	1157.59	5.46	73.58	72.83	849.66	6.08	19
ME-0173	10.17	140.91	1819.26	5.60	73.47	70.47	794.00	5.72	21
ME-0174	11.70	206.76	1818.26	5.60	72.95	65.06	823.56	3.52	23
ME-0179	9.58	184.58	1321.78	6.60	72.74	71.45	789.01	5.97	22
Mean	10.38	164.89	1324.15	5.46	73.62	69.16	781.88	4.80	25
SE	0.36	4.30	64.54	0.09	0.22	0.76	31.05	0.27	
CV%	17.14	13.05	24.37	9.08	1.46	5.52	19.85	27.66	
F-test									
Accession	**	**	**	**	**	**	**	**	
Season	**	**	**	**	**	**	**	**	
Acc x Sea	NS	**	NS	NS	*	*	**	**	

*, Significant at 5% level, **, significant at 1% level, NS = Non-significant
NB = Number of branches per plant, LLS= Length of the longest shoot (cm), TSL = Total shoot length (cm), INTD=Internodal distance (cm), MC= Leaf moisture content (%), MRC=Leaf moisture retention capacity (%), LYD= Leaf yield per plant (g), SLW= Single leaf weight (g), SI= CIMMYT Selection index.

Table 3. Correlation coefficient in growth traits of exotic mulberry germplasm accessions.

Traits	X1	X2	X3	X4	X5	X6	X7	X8
X1	---							
X2	0.43**	---						
X3	0.89**	0.77**	---					
X4	-0.02	0.35	0.14	---				
X5	-0.33	-0.51**	-0.48*	-0.11	---			
X6	-0.67**	-0.60**	-0.79**	0.18	0.44**	---		
X7	0.67**	0.27	0.58**	0.19	-0.17	-0.10	---	
X8	-0.55**	-0.36	-0.56**	0.51**	0.30	0.81*	0.15	---

*, **, Significant at 5% and 1% level, respectively

X1 = number of branches per plant, X2 = length of the longest shoot, X3 = total shoot length, X4 = Internodal distance, X5 = leaf moisture content, X6 = leaf moisture retention capacity X7 = leaf yield per plant X8 = Single leaf weight.

Table 4. Distribution of exotic mulberry accessions in different clusters.

Clusters	No. of mulberry accessions	Accession details with country
I	5	ME-0007- Shrim-2 (Bangladesh)
		ME-0167-Vietnam-3 (Vietnam)
		ME-0134- Zimbabwe-8 (Zimbabwe)
		ME-0157-SRDC-3 (Unknown)
		ME-0160 - SRDC-2 (Unknown)
II	3	ME-0033- Thailand male (Thailand)
		ME-0129- Zimbabwe-3 (Zimbabwe)
		ME-0058- Thailand (Thailand)
III	5	ME-0025- Shrim-8 (Bangladesh)
		ME-0041- Shrim-5 (Bangladesh)
		ME-0174- Xuan-9 (China)
		ME-0084- Bogura-1 (Bangladesh)
		ME-0156- Xuan-5 (China)
IV	6	ME-0052- Papua New Guinea (Papua New Guinea)
		ME-0143- SRDC-1 (Unknown)
		ME-0168- *M.multicaulis* - Indonesia
		ME-0170- Tonkin (China)
		ME-0173- Vietnam-2 (Vietnam)
		ME-0130- Zimbabwe-4 (Zimbabwe)
V	1	ME-0169- Georgia (Georgia)
VI	3	ME-0132– Zimbabwe-6 (Zimbabwe)
		ME-0144- Muki (France)
		ME-0179- Furcata (France)
VII	2	ME-0066- Kosen (Japan)
		ME-0165- China black-A (China)
Total	**25**	

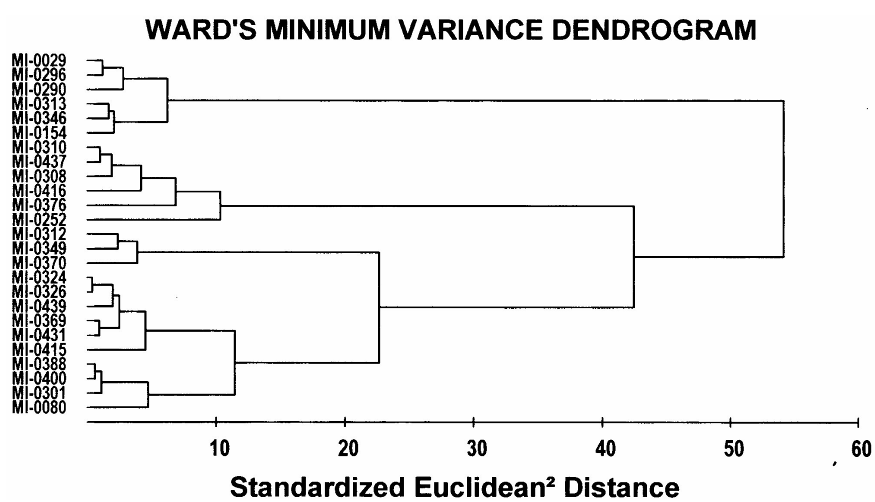

Figure 1. Dendrogram produced using Wards' Minimum Variance cluster analysis based on D² matrix demonstrating to the association among 25 exotic mulberry germplasm accessions.

DISCUSSION

The experiment was conducted in partial lattice design with 25 diverse exotic mulberry germplasm accession for eight growth and yield traits. The accessions were collected from different agro-climatic regions of 9 different countries. Highly significant differences of growth and yield traits were observed (Tikader and Kamble, 2008c).

Table 5. Cluster mean of growth traits of exotic mulberry based on D^2 values.

	Clusters						
Traits	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
X1	10.73	12.77	11.44	9.98	11.72	8.38	6.72
X2	153.79	161.31	196.37	161.20	160.69	167.06	129.24
X3	1250.28	1601.65	1719.21	1244.09	1475.18	1056.03	671.76
X4	4.97	5.39	5.56	5.49	5.98	6.33	4.87
X5	73.25	74.64	72.77	73.62	73.63	73.84	74.87
X6	66.69	66.78	63.68	71.61	72.50	73.15	72.65
X7	741.43	900.18	758.64	843.05	1233.21	688.05	495.22
X8	3.79	3.97	3.38	5.78	7.21	6.57	5.32

X1 = Number of branches per plant,
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 6. Average inter and intra-cluster D^2 values in 7 cluster

Clusters	I	II	III	IV	V	VI	VII
I	**2.63**	3.21	3.79	2.94	5.07	4.65	4.55
II		**1.89**	3.36	3.24	4.10	5.05	5.98
III			**2.21**	4.13	5.44	5.40	6.83
IV				**1.63**	3.33	3.07	4.36
V					**0.00**	4.59	6.95
VI						**2.83**	4.60
VII							**2.07**

Normal values indicate inter cluster distance
Bold values indicate intra-cluster distance.

The exotic accession are either from temperate or sub-tropical climate adjusted with local tropical condition and performed well at CSGRC, Hosur (Tikader and Rao, 2002).

The mulberry accessions were considered for overall performance and assed through CIMMYT selection indices. The combined analysis indicates the superiority of some accessions over the other tested accessions (Tikader and Kamble, 2008c). 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 in response to climatic, edaphically, biological and cultural factors (Bradshaw, 1977; Williams, 1987). Adaptation is one adjustment where the ability to survive and reproduce are more important than competitive ability (Heide, 1985; Tigerstedt, 1994). In spite of all the factors the exotic accessions performed well.

Knowledge about the sign and magnitude of correlations are important for understanding the relationship between agronomical traits and fitness in natural populations and prediction of correlated response to selection in breeding programme (Falconer, 1989; Herbert et al., 1994). The relationship of different growth and yield traits were worked out and found association with leaf yield. Several authors reported the similar findings (Tikader and Roy, 1999; Tikader and Dandin, 2005, 2008a; Vijayan et al. 1997). The highly correlated traits that is, number of branches per plant and total shoot length should considered during selection.

The cluster analysis grouped the accessions into seven clusters irrespective of geographic origin. The cluster I includes accession from Bangladesh, Vietnam, Zimbabwe and others. Cluster II contains accessions from Thailand and Zimbabwe. Like wise in other clusters the accessions grouped in same cluster originated from different geographical origin and countries. The findings indicated that there is no relationship between geographical and genetic diversity (Fotedar and Dandin, 1998; Rajan et al., 1997; Tikader and Roy, 2002; Tikader et al., 1999b, 2003). 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 parent and here lies the importance of using exotic germplasm (Tikader and Kamble, 2007a).

The genetic diversity is being assessed by single trait leaf yield which is the end product used by farmers for silkworm rearing to produce cocoon. This confirms the importance of understanding how individual trait or farmers use group of traits to identify different genotypes. Morphological identity along with growth and yield traits has the direct relevance to the farmers as well plant breeders to select, utilize and conservation of germplasm (Tikader and Kamble, 2008c). It is important to note that growth and yield traits have a number of limitations to express in different environmental condition and influence the performance either positive or negative (Tikader and Kamble, 2008d).

The role of exotic accession is enormous and the result indicated a good number of accessions performed well in Indian condition. From 1940 onwards, the exotic accession have been introduce in traditional sericultural belt for better crop production. Breeders also used as one of the parent for breeding and developed improved varieties. Thus the exotic mulberry accession, which has performed well, may be suitable for further utilization and conservation of genetic resources.

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