Studies on the variability of indigenous mulberry germplasm for growth and yield traits

Abstract

Twenty two indigenous mulberry accessions were evaluated for growth and yield traits in three seasons. ANOVA on growth and yield showed significant variation among the accessions for the traits. The interaction between accession and season was highly significant for all traits. The co-efficient of variation was maximum for single leaf weight (17.08%) and minimum for total shoot length (0.08%). The divergence analysis grouped 22 indigenous mulberry accessions into 5 clusters. Maximum accessions were grouped in clusters I & II (8 acc.) followed by cluster V (4 acc.). The diversity among the accessions measured by inter-cluster distance (D2) showed variation. The cluster group indicates that mulberry accessions were distributed in different clusters irrespective of geographical distribution.

Key words: Mulberry, Variability, Indigenous Germplasm, Growth and yield traits.

Introduction

Mulberry is a perennial, heterozygous, important economical crop in sericulture. It belongs to the genus *Morus* L. of the family Moraceae.The mulberry leaves are the sole food for silkworm *Bombyx mori* L. which produces natural silk. The silk produced is commercially used for making excellent silk garments. It is estimated that mulberry silk contributes around 90% of the total global raw silk production helping significantly to the livelihoods of many people across the globe. In addition to this, it has many nutritional benefits and medicinal values. The mulberry fruits rich in protein and vitamins are long being exploited as many nutraceutical and food products [1].It is also highly valued for timber and fire wood. All parts of mulberry plant are useful and hence it is regarded as 'Kalpavriksha'. It thrives well under a variety of agro-climatic conditions ranging from tropical to temperate areas. An average of about 25MT to 30 MT of leaves can be harvested per annum per hectare under row system of cultivation.

The conservation of mulberry genetic materials for future research and subsequent utilization in plant breeding are two highly important spheres of activity in any genetic resource management. But, the genetic improvement depends on the availability of variability in germplasm. Selection of suitable genotype from gene pool requires a thorough knowledge on availability and distribution of traits of economic importance for effective utilization in hybridization [2]. Development of suitable mulberry variety is one of the focal point in mulberry research [3]. Precise information on the nature and degree of genetic diversity helps the plant breeder in choosing the diverse parents for purposeful hybridization [4]. Realizing the need for enhanced use of mulberry germplasm for crop improvement programmes, CSGRC has taken up experiments on evaluation of the available germplasm in *ex situ* field gene bank. Presently, it is conserving 1317 mulberry accessions including both indigenous and exotic germplasm. These mulberry accessions are continuously being characterized and documented in the form of catalogue. Knowledge of genetic variability is important for breeding [5-6] and useful to improve the specific set of characters in low yielding mulberry germplasm. Various authors reported the association of leaf yield with other traits in mulberry [7-8]. In view of the above, the present study was conducted to identify suitable mulberry accessions based on variability, association and performance over season to select better parenting material for future breeding and further utilization.

Materials and Methods

Plant materials: Twentytwo mulberry accessions were used in this study. These accessions were collected from different localities of Karnataka, South India.

Experimental layout: The experiment was set up in a partial lattice design with three replications at Central Sericultural Germplasm Resources Centre (CSGRC), Hosur, Tamil Nadu. The centre is located at 12.450 N, 77.510 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 with 9 plants per replicationfollowing standard cultural practices [9]. The pruning was done after one year of establishment of the plantation, with four harvests per year after pruning at 90 days interval.

Data recording: After 90 days of pruning seven plants were randomly sampled from each replication for evaluating eight growth and yield traits. The traits were number of branches per plant (NB), length of longest shoot (LLS), total shoot length (TSL), inter-nodal distance (IND), leaf moisture content (MC), leaf moisture retention capacity (MRC), leaf yield per plant (LY) and single weight (SLW). The data was collected 3 times per year during 2019-20. Standard procedures were followed as described by [10]. The leaf moisture content and moisture retention capacity was calculated as described by [11].

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

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

Data analysis

The data was analyzed using SPSS statistical package. The analysis of variance of the eight growth and yield traits were carried out using the adjusted values. The mean values for growth and yield traits were used for correlation matrix and cluster analysis. Pair wise distances between the accessions based on Mahalanobis distances were recorded [12]. Ward's minimum variance cluster analysis was used to group the tested mulberry germplasm accessions [13].

Results

The mulberry germplasm accessions used in this study are presented in table 1.

Table-1: Details of indigenous mulberry accessions used for the study

SN	Acc. No.	Scientific name	Acc. name	Location name
1	MI-0985	*Morus* sp.	KSSRDI	Karnataka
2	MI-0986	*Morus* sp.	Thalaghattapura-39	Karnataka
3	MI-0987	*Morus* sp.	Thalaghattapura-40	Karnataka
4	MI-0988	*Morus* sp.	Thalaghattapura-41	Karnataka
5	MI-0989	*Morus* sp.	Thalaghattapura-42	Karnataka
6	MI-0990	*Morus* sp.	Thalaghattapura-43	Karnataka
7	MI-0991	*Morus* sp.	Thalaghattapura-44	Karnataka
8	MI-0992	*Morus* sp.	Thalaghattapura-45	Karnataka
9	MI-0993	*Morus* sp.	Thalaghattapura-46	Karnataka
10	MI-0994	*Morus* sp.	Thalaghattapura-47	Karnataka
11	MI-0995	*Morus* sp.	Thalaghattapura-48	Karnataka
12	MI-0996	*Morus* sp.	Thalaghattapura-49	Karnataka
13	MI-0997	*Morus* sp.	Thalaghattapura-50	Karnataka
14	MI-0999	*Morus* sp.	Thalaghattapura-52	Karnataka
15	MI-1000	*Morus* sp.	Suvarna-1	Karnataka
16	MI-1001	*Morus* sp.	Suvarna-2	Karnataka
17	MI-1002	*Morus* sp.	Suvarna-3	Karnataka
18	MI-1003	*Morus* sp.	S-41	Karnataka
19	MI-1004	*Morus* sp.	K2	Karnataka
20	MI-1005	*Morus* sp.	RFS-135	Karnataka
21	MI-1006	*Morus* sp.	S-35	Karnataka
22	MI-1007	*Morus* sp.	Ziro valley-1	Arunachal Pradesh

Variability among mulberry accessions

Wide variations were observed among the 22 mulberry accessions for growth and yield traits. The variations are presented in table 2. The ranges for different traits are as follows: number of branches per plant (Nos.) (8.11-19.44), length of longest shoot (90.89 - 224.44 cm), internodal distance (204.91 – 945.99 cm), total shoot length (638.78-2608.22 cm), weight of single leaf (3.14 -7.63 g), leaf fresh weight (13.16-23.21 g), leaf six hours weight (8.77 -16.63 g), leaf dry weight (4.16 -8.37 g), total leaf yield (35.54 -339.97 kg), total stem yield (41.40- 669.86 kg), total moisture content (59.87 – 72.87 %), moisture retention capacity (41.95-59.32 %), and moisture loss (27.30-41.91 %).

Table 2: Mean performance of indigenous mulberry accessions

Acc. No.	NB	LLS	IND	TSL	WSL	LFW	LSW	LDF	TLY	TSY	Total MC (%)	MRC(%)	ML

MI-0985	14.78	220.78	945.99	1929.56	5.03	20.64	13.14	6.80	35.54	45.51	68.58	44.73	30.43
MI-0986	9.67	90.89	306.93	1238.44	5.82	22.89	16.63	8.37	56.78	41.40	62.88	54.73	34.41
MI-0987	11.44	175.56	426.64	1238.22	7.09	16.59	11.83	6.54	253.33	178.57	60.09	51.90	31.47
MI-0988	12.56	213.89	399.35	1884.67	6.74	18.87	13.54	6.39	263.66	669.86	66.01	56.05	37.10
MI-0989	9.89	135.67	365.19	936.11	7.54	20.79	15.02	7.05	114.24	105.90	65.12	57.42	37.24
MI-0990	10.33	132.00	398.01	1112.67	7.10	13.70	8.77	4.16	36.21	129.92	68.41	50.17	33.75
MI-0991	12.00	163.33	442.59	1296.22	6.59	23.21	15.61	7.99	77.37	165.45	65.55	49.25	32.50
MI-0992	12.78	212.00	798.22	1815.67	5.15	17.66	12.26	6.65	339.97	115.16	62.22	48.36	29.20
MI-0993	10.44	134.67	242.10	818.67	5.98	14.82	9.90	4.81	81.22	152.25	68.04	51.51	35.09
MI-0994	8.11	118.89	265.94	638.78	6.80	15.03	11.18	5.56	61.12	102.68	62.85	58.64	36.85
MI-0995	9.78	94.22	274.11	659.78	6.48	15.80	9.85	5.11	56.70	96.13	67.43	43.85	29.60
MI-0996	10.44	114.22	228.58	785.78	3.86	15.33	10.09	5.29	66.32	138.33	65.67	49.27	32.36
MI-0997	18.89	152.22	690.65	1900.67	3.14	16.84	11.13	4.63	160.00	249.45	72.87	52.04	37.96
MI-0999	9.11	155.22	286.98	891.44	6.12	14.18	10.16	4.92	49.70	58.60	65.70	56.34	36.81
MI-1000	19.44	224.44	924.28	2608.22	7.11	17.88	12.39	6.30	319.17	556.74	66.20	53.35	35.26
MI-1001	8.44	121.67	204.91	692.11	4.55	20.08	14.71	6.24	90.24	112.07	69.52	59.32	41.91
MI-1002	11.89	176.00	473.43	1286.33	7.63	16.93	10.94	5.94	75.42	154.10	65.85	46.53	30.73
MI-1003	13.11	146.11	407.75	1220.44	4.87	20.69	15.03	8.15	125.04	222.40	59.87	54.08	31.99
MI-1004	13.44	164.44	551.92	1297.44	5.18	13.16	9.27	4.40	55.09	136.81	66.50	55.98	37.35
MI-1005	12.00	135.78	332.33	1008.22	5.40	16.34	10.21	5.76	69.15	80.40	65.02	41.95	27.30
MI-1006	16.00	206.11	694.51	1945.11	5.42	16.00	10.49	5.41	199.31	310.09	69.49	44.70	29.88
MI-1007	14.22	174.89	443.99	1466.00	5.20	14.02	10.52	5.63	120.06	221.14	60.10	57.79	35.23
Mean	**12.22**	**157.41**	**459.29**	**1303.21**	**5.85**	**17.34**	**11.94**	**6.01**	**122.98**	**183.77**	**65.64**	**51.73**	**33.84**
Min	**8.11**	**90.89**	**204.91**	**638.78**	**3.14**	**13.16**	**8.77**	**4.16**	**35.54**	**41.40**	**59.87**	**41.95**	**27.30**
Max	**19.44**	**224.44**	**945.99**	**2608.22**	**7.63**	**23.21**	**16.63**	**8.37**	**339.97**	**669.86**	**72.87**	**59.32**	**41.91**
SD	**3.04**	**39.89**	**219.51**	**519.44**	**1.19**	**2.95**	**2.27**	**1.18**	**92.75**	**154.90**	**3.32**	**5.16**	**3.60**
SE	**0.66**	**8.71**	**47.90**	**113.35**	**0.26**	**0.64**	**0.50**	**0.26**	**20.24**	**33.80**	**0.72**	**1.13**	**0.79**
CV%	**24.85**	**25.34**	**47.79**	**39.86**	**20.37**	**17.03**	**19.00**	**19.68**	**75.42**	**84.29**	**5.06**	**9.97**	**10.65**

The highest coefficient of variation was maximum in total stem yield (84.29%) followed by total leaf yield/plant (75.42%), internodal distance (47.79%), total shoot length (39.86%), length of longest shoot (25.34%), number of branches/ plant (24.85%), weight of single leaf (20.37%), leaf dry weight (19.68%), leaf six hours weight (19%), leaf fresh weight (17.03%), moisture loss (10.65%), moisture retention capacity (9.97%), and total moisture content (5.06%). The F ratio indicated that all the accessions were highly significant for all the traits. The seasonal variation was also highly significant (1% probability) except number of branches per plant. The interaction between accession x season was also significant at 5% probability level.

Simple correlation matrix

Simple correlation coefficient was carried out for all the accession on different growth and yield traits (Table 3). The traits have complex association among 22 accessions. Most of the traits showed positive association such as total shoot length showed with number of branches per plant (0.89) and negative association such as moisture loss with number of branches per plant (0.12). Other traits such as inter nodal distance with number of branches per plant(0.83); Length of longest shoot (0.8); total shoot length with inter nodal distance (0.89), total leaf yield with number of branches per plant (0.51); length of longest shoot (0.65); total shoot length (0.67); total shoot length with number of branches per plant (0.55), with length of longest shoot (0.57) have positive association. Some traits are negatively correlated such as Moisture retention capacity with number of branches per plant (-0.22), with length of longest shoot (-0.15), with inter nodal distance (-0.3), with total shoot length (-0.15).

Table 3: Correlation matrix for different growth and yield traits in mulberry accessions

	NB	LLS	IND	TSL	WSL	LFW	LSW	LDW	TLY	TSY	TMC	MRC	ML
NB													
LLS	0.67**												
IND	0.83**	0.8**											
TSL	0.89**	0.84**	0.89**										
WSL	-0.29	0.09	-0.11	-0.07									
LFW	0.01	0.03	0.12	0.18	0.04								
LSW	-0.07	0	0.02	0.12	0.06	0.95**							
LDW	-0.04	0.08	0.08	0.15	0.14	0.9**	0.92**						
TLY	0.51*	0.65**	0.51*	0.67**	0.08	0.09	0.15	0.19					
TSY	0.55**	0.57**	0.32	0.65**	0.15	0.03	0.07	0.03	0.67**				
TMC	0.25	0.01	0.18	0.14	-0.26	-0.09	-0.24	-0.5	-0.19	0.07			
MRC	-0.22	-0.15	-0.3	-0.15	0.05	0.03	0.3	0.08	0.04	0.16	-0.25		
ML	-0.12	-0.17	-0.25	-0.12	-0.08	0	0.19	-0.15	-0.08	0.18	0.24	0.87**	

**Significant at 1%
*Significant at 5%

Divergence analysis

The mulberry accessions were subjected for divergence analysis and grouped into 5 clusters (Table 4). Cluster I & II consisted of 8 accessions each followed by cluster V with 4 accessions followed by cluster III and IV with one accession each.

Table 4: Distribution of mulberry accessions in different clusters

Clusters	Number of Accessions	Accession Number

I	8	MI-0986
		MI-0990
		MI-1007
		MI-1004
		MI-0991
		MI-1002
		MI-0987
		MI-1003
II	8	MI-0999
		MI-0989
		MI-1005
		MI-0993
		MI-0996
		MI-1001
		MI-0994
		MI-0995
III	1	MI-1000
IV	1	MI-0988
V	4	MI-0985
		MI-0992
		MI-0997
		MI-1006

The accessions grouped in cluster II showed the highest number of branches per plant (14.90), Internodal distance (6.01), total shoot length (1515.39), leaf fresh weight (12.68), total leaf yield per plant (655.28), total stem yield per plant (968.89) and total moisture content (67.74%). Cluster I showed highest value for length of longest shoot (154.67) and leaf dry weight (4.56). The other accessions grouped in clusters with traits having minimum values (Table 5).

Table 5: Cluster mean of growth and yield traits for mulberry accessions

Code	Variables	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
X1	NB	9.33	14.90	9.24	10.42	11.26
X2	LLS	100.47	177.78	131.42	154.67	142.89
X3	IND	2.90	6.01	3.98	5.47	4.58
X4	TSL	758.33	1515.39	801.00	954.87	1246.91
X5	WSL	5.85	5.41	6.00	4.98	4.12
X6	LFW	10.64	12.68	11.62	11.05	11.86
X7	LSW	6.96	8.04	7.96	7.65	8.15
X8	LDW	3.83	4.04	4.02	4.56	4.31
X9	TLY	275.33	655.28	249.85	350.23	452.98
X10	TSY	386.77	968.89	393.59	401.25	548.35

X11	TMC (%)	63.60	67.74	65.13	64.52	66.12
X12	MRC (%)	46.98	46.87	52.71	48.65	50.12
X13	ML	29.69	31.68	34.28	33.58	32.64

The average of inter and intra-cluster distance presented in table 6, reveals cluster V has minimum intra-cluster distance. The maximum intra-cluster distance was observed in cluster IV (36.94) and the accessions grouped in this cluster are more diverse. The inter cluster distance ranged from 27.93 to 178.61.

Table 6: Average inter and intra cluster values for clusters

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Cluster 1	**15.20**	46.59	106.06	33.49	27.93
Cluster 2		**22.92**	63.19	80.87	67.98
Cluster 3			**15.64**	178.61	117.38
Cluster 4				**36.94**	58.34
Cluster 5					**0.00**

*Normal values indicate inter cluster distance; Bold values indicate intra-cluster distance

Smith selection index

The mulberry accessions are grouped based on the overall performance through Smith selection index to select the high performing accessions for further use (Table 7). The accession MI-1000 performed better than all the other accessions MI-0994 and MI-0945 were poor performers among the tested accessions.

Table 7: List of mulberry accessions based on Smith Index

Acc. No.	Smith index	NB	LLS	IND	TSL	WSL	LFW	LSW	LDW	TLY	TSY	Total MC	MRC	ML
MI-1000	0.35	19.33	224.33	4.33	2608.00	7.00	17.67	12.33	6.33	3.00	3.33	66.33	53.33	35.33
MI-1003	0.25	13.33	146.00	4.00	1220.33	4.67	20.67	15.00	8.33	0.67	0.67	60.00	54.33	32.00
MI-0992	0.15	12.67	212.00	4.33	1815.67	5.33	18.00	12.33	6.67	1.00	3.00	62.00	48.33	29.33
MI-1006	0.15	16.00	206.33	3.67	1945.00	5.33	16.00	10.67	5.67	1.67	2.33	69.33	45.00	30.00

MI-0988	0.13	12.33	214.00	4.33	1884.67	6.67	19.00	13.67	6.33	2.33	2.00	66.00	56.33	37.00
MI-0989	0.10	10.00	135.67	2.33	936.33	7.33	21.00	15.00	7.00	1.33	1.00	65.00	57.33	37.33
MI-0991	0.10	12.00	163.33	3.67	1296.33	6.67	23.00	15.67	8.00	3.33	1.00	65.33	49.33	32.33
MI-0985	0.07	14.67	221.00	4.00	1929.33	5.33	20.67	13.33	6.67	2.00	2.00	68.33	44.67	30.33
MI-0987	0.04	11.33	175.67	4.00	1238.33	7.33	16.33	11.67	6.67	1.00	1.00	60.33	51.67	31.33
MI-0993	0.02	10.33	134.67	4.00	818.67	6.00	15.00	10.00	5.00	1.00	0.67	68.00	51.33	35.00
MI-1002	0.01	12.00	176.33	4.00	1286.33	7.67	16.67	11.00	6.00	1.33	1.00	65.67	46.33	30.33
MI-0999	0.00	9.00	155.00	4.33	891.67	6.00	14.00	10.33	4.67	1.00	1.33	65.67	56.33	36.67
MI-0986	-0.02	9.67	91.00	3.00	1238.67	5.67	23.00	16.67	8.33	1.33	1.33	63.00	55.00	34.33
MI-1001	-0.06	8.33	121.67	3.67	692.00	4.67	20.00	14.67	6.33	0.33	0.00	69.33	59.33	41.67
MI-0997	-0.09	19.00	152.33	3.00	1900.67	3.00	17.00	11.00	5.00	1.00	1.00	73.00	51.67	38.33
MI-1004	-0.11	13.67	164.33	4.00	1297.33	5.00	13.00	9.33	4.33	1.33	1.00	66.33	56.00	37.67
MI-1005	-0.12	12.00	135.67	3.33	1008.33	5.33	16.00	10.00	6.00	1.00	1.00	65.00	42.00	27.33
MI-0990	-0.16	10.33	132.00	3.33	1112.67	7.00	13.67	8.67	4.33	3.00	0.67	68.33	50.00	33.67
MI-0996	-0.17	10.33	114.00	4.00	786.00	4.00	15.33	10.00	5.33	0.33	0.33	65.67	49.33	32.67
MI-1007	-0.18	14.33	175.00	3.67	1465.67	5.00	14.00	10.33	5.33	0.67	0.67	60.00	57.67	35.33
MI-0995	-0.22	10.00	94.33	3.33	659.67	6.67	15.67	9.67	5.00	1.33	0.67	67.33	44.00	29.33
MI-0994	-0.23	8.00	119.00	4.00	638.67	6.67	14.67	11.33	5.33	0.33	0.00	62.67	58.33	37.00

Discussion

Eight varieties of *Morus alba* were characterized for different growth parameters and identified K2 as potential variety which could be exploited for sericulture activities [14]. But they have considered only four parameters where as in the present study, 13 parameters were characterized to identify the potential of accessions. The genetic diversity among the mulberry genotypes were studied using RAPD and ISSR markers. However, characterization via such markers has limitations e.g., differential environmental influences on expression of morphological characters [15]. Five mulberry accessions were examined for 12 phenotypic traits in two localities. Morphological traits clustered the five accessions into four groups.

They have stated that these five traits can be utilized in selection of mulberry accessions in breeding experiments. They have considered five accessions which are hybrid varieties and the results are less significant as the hybrids may not serve as better parents. The correlation studies in 10 accessions of mulberry for 10 agronomic characters suggested that the plant height, cumulative shoot length, leaf area, stem yield and water use efficiency exhibited positive association with leaf yield which can be considered for the selection of accessions for breeding [16]. Similarly our study revealed the positive correlation of total shoot length with number of branches, longest shoot length, inter-nodal distance, total leaf yield and stem yield. The character association in mulberry under different magnitude of salinity stress indicates the importance of interrelationships among traits for crop development [17]. The correlation coefficient between leaf yield and its component traits was found changing significantly under different salinity stresses. The genetic diversity of 50 accessions including both indigenous and exotic collections (25 each) wasstudied for 8 agronomic traits [18]. The results indicated that the exotic accessions performed better than indigenous accessions. The exotic accessions can serve as one of the parents in hybridizations. In the present study, the indigenous accessions performed well for different agronomic traits.

Conclusion

The mulberry accessions were evaluated for different growth and yield traits to estimate their potential. The data was analyzed using particular statistical design, interaction of accession and season has revealed the high potential of the accessions. The analysis of variance, correlation, genetic diversity and selection indices have shown that the selected accessions have performed equally well with the existing high yielding genotypes. The accessions (MI-1000 and MI-1003) performed better than other accessions. These accessions with desirable traits may serve as parent material for future crop improvement and breeding programmes.

Statement: There are no ethical issues in the study.

Data availability: The data presented in this study are available on request from the corresponding author.

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