Characterization of Mulberry Genetic Resources for Multiple Traits

M.C. Thriveni, Raju Mondal, G. Thanavendan, G. Ravikumar, B.T. Sreenivasa

Abstract: Mulberry plants have wide range of variations in characters in view of its adaptability to cross pollination with no inter-specific reproduction barrier rendering it a heterozygous species. Every plant being different from the other in natural population, this great diversity makes it difficult to gather information and carry out studies on effect of different edaphic factors on the expression of genotypic characters for adjudging the variations. In lieu of this known diversity for posterity, the collection of mulberry genotypes from diverse genetic sources, their conservation, evaluation and consequent documentation is of prime importance. In the present study, 69 mulberry accessions were characterized for morphology, anatomy, and reproductive parameters. Evaluation for propagation, growth and yield characters were also carried out. Based on multiple trait analysis, 14 top performing accessions viz., MI-0879, MI-0882, MI-0908, MI-0931, MI-0907, MI-0940, MI-0881, MI-0941, MI-0892, MI-0913, MI-0937, MI-0934, MI-0865, MI-0886 were identified. These accessions could serve as resources for further evaluation aimed at trait-specific crop improvement.

Keywords: Characterization, Conservation, Mulberry (Morus sp.), Germplasm, Genetic resources

I. INTRODUCTION

Mulberry is a perennial, highly heterozygous, out breeding tree of the genus *Morus* within the family Moraceae. *Morus* species are widely distributed in Asia, Europe, North and South America. Mulberry leaf is the exclusive food for domestic silkworm *Bombyx mori* which produces natural silk. Hence, it has been regarded as the 'Queen of textiles'. However, the fine grain timber and tasty fruits of mulberry are also well known. Mulberry natural habitats in India are being explored for the collection and conservation. Central Sericultural Germplasm Resources Centre (CSGRC), Hosur is maintaining 1300 mulberry germplasm in the form of ex situ field gene bank.

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Characterization of germplasm resources is one of the prerequisite for efficient utilization. *Morus* species exhibits rich phenotypic diversity. Many improved varieties are developed to meet the sericulture industry demand. The improvement in quantity and quality of mulberry genotypes over existing ones is a continuous process and breeders want suitable parental material for developing superior genotypes. Moreover, at present, there is an increasing demand to develop region and season specific mulberry varieties for rearing hybrid silkworm breeds. Standard characterization and evaluation of mulberry accessions are continuously carried out using different methods and traditional practices such as use of descriptor lists for morphology, anatomy, reproductive and growth characters. Characterization includes recording highly heritable phenotypic characters, which can be visually observed and expressed in various environments (Tikader and Kamble, 2010).

In order to identify the best performers and evolve new varieties suitable for specific zones, evaluation is essential. There is an increasing demand for new varieties suitable for various climatic conditions. To achieve this, identification of suitable parents from the germplasm accessions available is the need of the hour. In the present study, characterization of mulberry germplasm for different morphological, anatomical and reproductive characters was done. The germplasm was also evaluated for different growth and propagation traits. The trait-specific best performers were identified that can be utilized in future breeding programs.

II. MATERIALS AND METHODS

In the present study, 69 mulberry accessions were characterized for morphological, anatomical reproductive characters. They are also evaluated for propagation traits, growth and biochemical parameters. The data recorded was stored in the Mulberry Germplasm Information System (MGIS) database for further analysis.

III. RESULTS

Morphological characterization of mulberry germplasm

All the 69 mulberry germplasm accessions were characterized for 30 morphological descriptors as detailed in Table 1. Different morphological characters were recorded mainly by visual observations (branching pattern, colour of young and mature shoot, phyllotaxy, stipule nature, leaf colour, shape, texture, leaf apex and base, lobation type and margin). Among the accessions characterized, most of the accessions (47.83%) were with spreading branching nature, 2/5 (37.68%) phyllotaxy followed by 1/2 (34.78%), unlobed leaves (42.03%) and homophyllus leaf nature (55%).

Leaf texture was mostly chartaceous (63.77%), acuminate leaf apex (88.4%), leaf margin serrate (59.42%), cordate leaf base (72.46%) and ovate leaf shape (71%).

Table 1: Morphological characterization of mulberry

Branching nature			Leaf surface		
Parameter	Frequency	%	Parameter	Frequency	%
Erect	11	15.94	Rough	25	36.23
Semi erect	25	36.23	Slightly rough	13	18.84
Spreading	33	47.83	Smooth	31	44.93
Total	69	100.00	Total	69	100.00
Phyllotaxy			Leaf texture		
1/2	24	34.78	Chartaceous	44	63.77
1/2, 1/4	1	1.45	Coriaceous	11	15.94
1/2, 2/5	1	1.45	Membranous	14	20.29
1/2,2/5	1	1.45	Total	69	100.00
1/3	8	11.59	Leaf apex		
1/3, 2/5	5	7.25	Acuminate	61	88.40
2/5	26	37.68	Acute	5	7.25
2/5, 1/3	3	4.35	Caudate	3	4.35
Total	69	100.00	Total	69	100.00
Leaf lobation type			Leaf margin		
Deep lobed	3	4.35	Crenate	10	14.49
Medium lobed	24	34.78	Dentate	18	26.09
Shallow lobed	13	18.84	Serrate	41	59.42
Unlobed	29	42.03	Total	69	100.00
Total	69	100.00			

Anatomical characterization of mulberry germplasm

In order to study leaf anatomical characters, fully expanded leaves from 7th to 9th position from top of the longest shoot in descending order were collected in morning hours between 9 and 10 AM from 3 month old shoots. The stomata and idioblasts were studied by taking a thin layer of Wimbley's quick fix impressions of the abaxial (lower) and adaxial (upper) leaf surface and observed under Leica microscope. Stomata and idioblasts were counted per unit area and the frequency per mm^2 was calculated.

Studies on the cuticle, epidermal, palisade and spongy mesophyll, leaf thickness and idioblast length and breadth were carried out by making thin hand sections using steel razor blade (super max) that were observed under the Leica microscope. The chloroplast number per stomata was counted using epidermal peelings of freshly collected leaf samples stained with 2% potassium iodide-iodine solution observed under the microscope. The data was subjected for statistical analysis *viz.* mean, maximum, minimum, standard error (SE) and co-efficient of variation (CV %) for completely randomized design to determine the significance of treatment (Table 2). The top performing ten accessions for different anatomical traits and range of variation for these accessions are presented in the Table 3.

Table 2: Anatomical characterization of mulberry germplasm

Parameters	Mean	Min.	Max.	SE	CV%
Stomatal size (sq.µm)	244.71	176.76	341.45	4.36	14.69
Stomatal frequency (no./sq.mm)	796.16	320.29	1728.32	38.59	39.97
Idioblast length (µm)	29.78	18.28	70.69	1.20	33.11
Idioblast width (µm)	33.91	21.72	64.18	0.95	23.04
Idioblast frequency no./sq.mm)	18.92	8.63	34.54	0.65	28.33
Palisade thickness (µm)	61.72	35.86	103.45	1.72	22.99
Spongy thickness (µm)	65.23	35.17	103.45	1.50	18.98
Palisade-spongy ratio	0.94	0.71	1.46	0.02	13.81
Upper cuticle thickness (µm)	7.75	3.45	12.74	0.22	22.73
Lower cuticle thickness (µm)	4.26	2.93	6.99	0.14	27.29
Upper epidermis thickness (µm)	23.07	14.18	41.38	0.67	23.97
Lower epidermis thickness (µm)	9.43	3.45	16.48	0.32	27.56
Leaf thickness (µm)	171.28	111.72	272.41	3.25	15.66
No. of chloroplast/stomata (no.)	11.98	8.67	19.11	0.35	19.51

Table 3: Top performing accessions for different anatomical characters

Parameters	Range	Top performing accessions
Stomatal size (sq.µm)	176.76 - 204.30	MI-0866, MI-0942, MI-0931, MI-0867, MI-0932, MI-0913, MI-0964, MI-0927, MI-0908, MI-0928
Stomatal frequency (no./sq.mm)	320.29 - 476.50	MI-0883, MI-0886, MI-0882, MI-0887, MI-0889, MI-0879, MI-0884, MI-0892, MI-0873, MI-0868
Palisade thickness (µm)	73.791-103.45	MI-0926, MI-0892, MI-0946, MI-0867, MI-0884, MI-0951, MI-0870, MI-0911, MI-0879, MI-0906
Palisade-spongy ratio	1.062-1.46	MI-0892, MI-0911, MI-0864, MI-0873, MI-0870, MI-0913, MI-0883, MI-0914, MI-0881, MI-0946
Upper cuticle thickness (µm)	9.66-12.74	MI-0884, MI-0947, MI-0866, MI-0930, MI-0939, MI-0868, MI-0881, MI-0916, MI-0963, MI-0917
Lower cuticle thickness (µm)	5.52-6.99	MI-0872, MI-0919, MI-0904, MI-0923, MI-0926, MI-0928, MI-0907, MI-0920, MI-0874, MI-0959
Leaf thickness (µm)	195.69-272.41	MI-0926, MI-0867, MI-0870, MI-0951, MI-0872, MI-0884, MI-0879, MI-0946, MI-0892, MI-0928
No. of chloroplasts/ stomata	13.4-19.11	MI-0889, MI-0959, MI-0963, MI-0912, MI-0870, MI-0885, MI-0872, MI-0887, MI-0886, MI-0917

Reproductive characterization of mulberry germplasm

The reproductive characterization was recorded in the main flowering season (February- March). Fully bloomed catkins of different accessions were collected and the length as well as breadth of pedicel was measured. The number of flowers/ catkins of different sexes were counted by dissecting the individual flowers around the rachis of the inflorescence. Length of style and stigma, nature and type of the female flowers were recorded by dissecting them under the stereomicroscope at receptive stage. The male catkins were collected in plastic bags at 10 AM at the time of anthesis and the length of stamen and anther were measured under stereomicroscope. To study the pollen diameter, viability and number of pollen germ pores, the mature pollen grains were dusted on a clean slide and stained with 2% acetocarmine solution for 30 minutes. After 30 minutes, the slides were observed under microscope. Fruit characters were studied using fully ripened sorosis and recording of the length, breadth, pedicle length, weight, colour and taste of the fruit. The data was subjected to statistical analysis like mean, maximum, minimum, standard error (SE) and co-efficient of variation (CV %) to determine the significance of treatment (Table 4).

Top performing accessions for different anatomical traits and range of variation for these accessions are presented in table 5.

Table 4: Reproductive characterization of mulberry germplasm

Parameters	Mean	Min.	Max.	SE	CV%
Male inflorescence length (cm)	2.29	0.86	8.54	0.30	63.45
Female inflorescence length (cm)	1.33	0.42	4.98	0.13	71.74
Bisexual inflorescence length (cm)	1.42	0.62	2.10	0.20	35.14
Male inflorescence diameter (cm)	0.53	0.34	0.78	0.02	17.21
Female inflorescence diameter (cm)	0.52	0.38	0.80	0.01	15.14
Bisexual inflorescence diameter (cm)	0.48	0.38	0.56	0.03	15.77
No. of flowers/catkin (male)	33.29	16.00	147.60	5.02	73.90
No. of flowers/catkin (female)	37.81	9.00	152.00	3.40	67.35
No. of flowers/catkin (bisexual)	25.24	14.00	54.60	4.78	50.05
Male peduncle length (cm)	0.60	0.26	1.20	0.04	36.63
Female peduncle length (cm)	0.69	0.18	1.76	0.04	43.43
Bisexual peduncle length (cm)	0.50	0.26	0.80	0.08	38.59
Stamen length (mm)	3.32	1.54	4.90	0.21	30.94
Anther length (cm)	1.13	0.44	2.78	0.10	42.29
Pollen diameter (µm)	17.97	0.62	26.80	0.90	24.91
Pollen viability (%)	96.43	1.60	99.00	8.32	43.17

Style length (mm)	0.62	0.12	1.76	0.05	60.02
Stigma length (mm)	4.93	1.40	8.58	0.20	31.39
Fruit length (cm)	1.97	0.94	4.98	0.13	46.67
Fruit width (cm)	0.84	0.24	1.24	0.03	23.40
Fruit weight (g)	0.95	0.18	2.81	0.08	62.42

Table 5: Top performing accessions for different reproductive characters

Parameters	Range	Top performing accessions
Male inflorescence length (cm)	1.54-1.56	MI-0815, MI-0860
Male inflorescence diameter (cm)	0.54-0.58	MI-0980, MI-0815
No. of flowers/ catkin (male)	34.2-49.2	MI-0980, MI-0860
Male peduncle length (cm)	0.36-0.5	MI-0860, MI-0980
Style length (cm)	0.44-2.9	MI-0974, MI-0975, MI-0970, MI-0973, MI-0900, MI-0877, MI-0962, MI-0878, MI-0869, MI-0857
Stigma length (cm)	3.06-8.84	MI-0973, MI-0974, MI-0975, MI-0878, MI-0900, MI-0857, MI-0970, MI-0877, MI-0838, MI-0869
Fruit length (cm)	1.8-3.74	MI-0878, MI-0857, MI-0962, MI-0814, MI-0974, MI-0975, MI-0966, MI-0900, MI-0816, MI-0973
Fruit diameter (cm)	0.86-1.28	MI-0962, MI-0839, MI-0966, MI-0973, MI-0974, MI-0838, MI-0975, MI-0814, MI-0837, MI-0900
Fruit peduncle (cm)	0.2-0.44	MI-0966, MI-0859, MI-0970, MI-0962, MI-0816, MI-0877, MI-0814, MI-0838, MI-0837, MI-0975
Fruit weight (g)	0.86-2.54	MI-0962, MI-0966, MI-0839, MI-0814, MI-0878, MI-0973, MI-0837, MI-0975, MI-0974, MI-0816

Evaluation of mulberry germplasm for growth and yield parameters

After 70 days of pruning the growth and yield traits were recorded. The total number of shoots/ plant was harvested from the basal node and the number of primary shoots/ plant was counted considering four plants for each accession. The longest shoot which attained maximum growth in the plant was considered for assessing the length of longest shoot. The intermodal distance and lengths of 10 internodes on the longest shoot leaving 1/3rd top portion were measured. The largest leaf between 7th to 9th positions from the top was considered for measuring lamina length and weighing lamina weight. Total aerial biomass of the plant was determined considering shoot weight along with the foliage; the entire foliage was harvested and total leaf yield was calculated. Leaves were collected from the longest shoot and fresh weight was recorded. Dry weight was recorded leaves dried in the oven at 60^0 C for 48 h. The moisture content of the excised leaves was calculated using the formula:

$$\text{Moisture content (MC)} = \frac{\text{(Fresh weight – oven dry weight)} \times 100}{\text{Fresh weight}}$$

The leaf moisture content after 6 h was measured taking fresh weight of the leaves immediately after collecting from the longest shoot and then after 6 h. The leaf dry weight was recorded after drying the leaf samples in oven for 48 h at 60^0 C. The moisture retention capacity (MRC) was calculated as using the following formula:

$$\text{Moisture retention capacity (MRC)} = \frac{\text{(6 h weight – oven dry weight)} \times 100}{\text{Fresh weight – dry weight}}$$

Statistical analysis such as mean, maximum, minimum, standard error (SE) and co-efficient of variation (CV %) was conducted to determine the significance of treatment (Table 6). Among the accessions characterized, top performing accessions for different propagation traits and range of variation for these accessions are presented in the Table 7.

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Table 6: Evaluation of mulberry germplasm for growth and yield parameters

Parameter	Mean	Range	SE	CV%
No. of branches	29.8	8-72	1.69	46.64
Length of the longest shoot (cm)	148.47	74-258	4.45	24.72
Inter nodal distance (cm)	5.13	1.9 - 10.56	0.19	31.27
Wt. of single leaf (g)	3.73	0.75 - 10.35	0.27	60.58
Leaf yield/plant (kg)	1.61	0.30- 4.84	0.11	58.61
Biomass/plant (kg)	2.98	0.45 - 11.58	0.24	65.30
Leaf Moisture Content %	71.23	65.89 - 79.45	0.29	3.39
MC % after 6 hours	63.22	45.42 - 72.09	0.68	8.91

Table 7: Better performing accessions for different growth and yield parameters

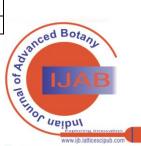| Parameter	Range	Better performing accessions
No. of branches	72.5-44.5	MI-0928, MI-0938, MI-0872, MI-0958, MI-0927, MI-0907, MI-0881, MI-0931, MI-0917, MI-0913
Length of the longest shoot (cm)	258-186	MI-0883, MI-0908, MI-0907, MI-0886, MI-0879, MI-0918, MI-0919, MI-0889, MI-0872, MI-0880
Inter-nodal distance (cm)	1.9-3.77	MI-0926, MI-0914, MI-0931, MI-0906, MI-0959, MI-0912, MI-0875, MI-0913, MI-0964, MI-0917
Wt. of single leaf (g)	10.35-6.17	MI-0887, MI-0883, MI-0907, MI-0963, MI-0925, MI-0941, MI-0885, MI-0934, MI-0960, MI-0944
Total leaf yield (kg)	4.84-2.74	MI-0907, MI-0882, MI-0938, MI-0925, MI-0928, MI-0872, MI-0923, MI-0908, MI-0922, MI-0936
Biomass (kg)	11.58-5.08	MI-0907, MI-0908, MI-0882, MI-0928, MI-0938, MI-0922, MI-0872, MI-0925, MI-0887, MI-0936
Moisture Content (%)	79.45-73.57	MI-0922, MI-0884, MI-0904, MI-0885, MI-0889, MI-0886, MI-0908, MI-0864, MI-0882, MI-0868
MC % after 6 hours	72.09-68.65	MI-0922, MI-0885, MI-0908, MI-0904, MI-0879, MI-0884, MI-0889, MI-0870, MI-0864, MI-0868

Evaluation of mulberry germplasm for propagation traits

Mulberry is generally vegetatively propagated through stem cuttings. To understand the genetic potential of the mulberry accessions, propagation traits evaluated. The rooting ability and root characters were recorded which help in proper establishment of the plant. To evaluate mulberry accessions for propagation traits, 6 months old mulberry shoots are used to prepare cuttings with 3-4 buds and planted in the nursery in RBD in 3 replications along with the checks. 20 cuttings per replication were planted at a spacing of 10 cm between the cuttings and 20 cm between the rows. The evaluations are carried out after 90 days of planting when the saplings are uprooted carefully without damaging the roots for recording observations on roots. The statistically analyzed data is given in Table 8. Among the evaluated accessions, 10 top performing accessions for each character were identified as given in Table 9.

Table 8: Evaluation of mulberry germplasm for propagation traits

Parameter	Mean	Min.	Max.	SE	CV%
Rooting ability (%)	79.63	0.00	95	2.76	25.23
No. of roots/sapling	4.64	1.17	8.83	0.29	46.03
Length of longest root	25.55	5.5	48.5	1.36	38.77
Dry root weight (g)	1.37	0.05	6.63	0.17	89.63
Root Volume	3.08	0.17	14.5	0.37	86.58

Root shoot Ratio by dwt	0.34	0.06	0.85	0.02	43.10
Root shoot Ratio by length	0.90	0.25	1.76	0.05	37.19

Table 9: Better performing accessions for different propagation traits

Parameter	Range	Better performing accessions
Rooting ability (%)	95-95	MI-0938, MI-0922, MI-0882, MI-0928, MI-0893, MI-0864, MI-0916, MI-0934, MI-0913, MI-0921
No. of roots/sapling	8.83-6.83	MI-0940, MI-0907, MI-0882, MI-0942, MI-0964, MI-0913, MI-0871, MI-0875, MI-0935, MI-0916
Length of longest root	48.5-34.67	MI-0916, MI-0879, MI-0940, MI-0906, MI-0933, MI-0873, MI-0941, MI-0931, MI-0886, MI-0908
Dry root weight (g)	6.63-2.28	MI-0940, MI-0875, MI-0964, MI-0916, MI-0941, MI-0935, MI-0931, MI-0937, MI-0873, MI-0934
Root Volume	14.5-5.33	MI-0940, MI-0875, MI-0935, MI-0964, MI-0941, MI-0937, MI-0942, MI-0931, MI-0916, MI-0882
Root shoot Ratio by weight	0.85-0.44	MI-0959, MI-0865, MI-0932, MI-0935, MI-0943, MI-0906, MI-0870, MI-0963, MI-0941, MI-0950
Root shoot Ratio by length	1.76-1.18	MI-0920, MI-0933, MI-0921, MI-0950, MI-0881, MI-0870, MI-0959, MI-0914, MI-0941, MI-0943

Evaluation of mulberry germplasm for biochemical parameters

With respect to biochemical characterization, the leaf chlorophyll content from fresh leaves, and water soluble protein and carbohydrates from dry leaf powders were studied. The amount of chlorophyll present in the leaf extract was calculated using the formula:

Chlorophyll a (mg/ g F.W.) = $(12.7 A_{663} - 2.69 A_{645})$ x v/ 1000 x wt.

Chlorophyll b (mg/ g F.W.) = $(22.9 A_{645} - 4.68 A_{663})$ x V/ 1000 x wt.

Total Chlorophyll (mg/ g F.W.) = $(20.2 A_{645} + 8.02 A_{663})$ x V/ 1000 x wt.

where,

A_{645} = Absorption value at 645 nm, A_{663} = absorption value at 663 nm

V= total volume of chlorophyll extract (i.e., DMSO)

Wt. = weight of the leaf tissue

The statistically analyzed data is given in Table 10. Among the evaluated accessions, 10 top performing accessions for each character were identified as given in Table 11.

Table 10: Evaluation of mulberry germplasm for biochemical parameters

Parameter	Mean	Min.	Max.	SE	CV%
Chlorophyll a (mg/g f.wt.)	1.711	1.035	2.298	0.037	17.65
Chlorophyll b (mg/g f.wt.)	0.308	0.149	0.786	0.013	33.90
Total Chlorophyll (mg/g f.wt.)	2.013	1.198	2.889	0.047	19.20
Chlorophyll a/b	5.918	2.681	8.49	0.136	18.99
Protein soluble (% f.wt.)	2.169	1.083	3.64	0.067	25.61
Protein soluble (% d.wt.)	7.719	4.060	12.81	0.225	24.08
Carbohydrate soluble (% f.wt.)	3.742	1.293	6.78	0.168	37.02
Carbohydrate soluble (% d.wt.)	12.921	4.617	22.53	0.536	34.19

Table 11: Better performing accessions for different biochemical parameters

Parameter	Range	Better performing accessions
Chlorophyll a (mg/g f.wt.)	2.30 - 2.06	MI-0886, MI-0882, MI-0884, MI-0964, MI-0908, MI-0931, MI-0892, MI-0887, MI-0885, MI-0883
Chlorophyll b (mg/g f.wt.)	0.41-0.79	MI-0887, MI-0885, MI-0883, MI-0870, MI-0908, MI-0886, MI-0881, MI-0882, MI-0922, MI-0889
Total Chlorophyll (mg/g f.wt)	2.47-2.89	MI-0887, MI-0886, MI-0882, MI-0884, MI-0908, MI-0964, MI-0885, MI-0883, MI-0892, MI-0931
Chlorophyll a/b	7.13-8.49	MI-0929, MI-0911, MI-0936, MI-0934, MI-0952, MI-0932, MI-0912, MI-0938, MI-0917, MI-0959
Protein soluble (% f.wt.)	2.72-3.64	MI-0936, MI-0932, MI-0867, MI-0871, MI-0959, MI-0951, MI-0872, MI-0950, MI-0864, MI-0921
Protein soluble (% d.wt.)	9.66-12.81	MI-0937, MI-0867, MI-0871, MI-0864, MI-0933, MI-0872, MI-0904, MI-0916, MI-0868, MI-0960
Carbohydrate soluble (% f.wt.)	5.31-6.78	MI-0916, MI-0951, MI-0914, MI-0913, MI-0960, MI-0912, MI-0949, MI-0958, MI-0904, MI-0950
Carbohydrate soluble (% d.wt.)	17.04-22.53	MI-0916, MI-0914, MI-0904, MI-0913, MI-0960, MI-0912, MI-0951, MI-0963, MI-0937, MI-0949

The 69 accessions studied were subjected to multiple trait analysis (anatomical, growth, yield, biochemical and propagation traits) resulting in the identification of 14 promising accessions viz., MI-0879, MI-0882, MI-0908, MI-0931, MI-0907, MI-0940, MI-0881, MI-0941, MI-0892, MI-0913, MI-0937, MI-0934, MI-0865, MI-0886 (Table 12).

Table 12: Top performing accessions based on multiple traits

Acc.No.	No. of traits	Trait No. (value)
MI-0879	18	1(33), 2(195.333), 4(4.787), 5(2.736), 6(4.64), 7(229.144), 8(446.582), 9(78.925), 10(1.044), 11(9.195), 12(206.03), 13(85), 15(45), 17(3.67), 19(0.97), 20(2.153), 23(73.03), 24(69.82),
MI-0882	18	1(31.667), 2(164), 5(3.829), 6(7.37), 7(238.76), 8(394.472), 9(62.834), 10(1.047), 13(95), 14(8), 15(33), 16(2.15), 17(5.33), 18(0.34), 20(2.718), 21(7.96), 23(73.79), 24(68.61),
MI-0908	16	2(234), 4(6.017), 5(3.052), 6(7.42), 7(204.072), 9(64.826), 10(1.046), 14(5), 15(35), 16(1.463), 17(3.27), 18(0.38), 19(1.04), 20(2.683), 23(74.27), 24(70.54),
MI-0931	16	1(47), 2(162), 3(33), 5(1.662), 6(3.51), 7(183.183), 8(605.226), 11(8.276), 13(85), 14(5), 15(36), 16(2.863), 17(5.73), 18(0.43), 20(2.468), 22(13.427),
MI-0907	16	1(50.5), 2(215.5), 4(8.987), 5(4.841), 6(11.58), 9(70.343), 10(0.996), 12(179.306), 13(95), 14(9), 15(26), 19(1.12), 20(2.332), 21(8.887), 22(16.377), 24(66.11),
MI-0940	16	1(36), 3(23), 4(4.017), 5(2.323), 6(4.64), 7(227.258), 8(682.179), 13(85), 14(9), 15(39), 16(6.632), 17(14.5), 18(0.34), 20(2.374), 21(9.07), 22(14.217),
MI-0881	16	1(47.333), 2(152.667), 3(23), 5(1.779), 6(3.12), 8(497.422), 9(69.73), 10(1.063), 11(9.961), 12(184.67), 13(80), 15(26), 19(1.47), 20(2.276), 23(73.43), 24(67.54),
MI-0941	16	4(7.633), 5(2.092), 6(3.83), 8(540.751), 9(70.343), 12(188.961), 13(95), 14(5), 15(36), 16(3.107), 17(6.75), 18(0.49), 19(1.18), 22(15.837), 23(72.69), 24(66.26),
MI-0892	15	2(170), 3(26), 5(1.969), 6(3.26), 8(464.838), 9(97.929), 10(1.456), 12(198.616), 13(95), 14(6), 18(0.41), 20(2.539), 21(9.19), 23(73.19), 24(66.28),
MI-0913	15	1(44.5), 3(28), 7(194.202), 8(617.704), 9(64.826), 10(1.093), 11(9.655), 12(175.858), 13(95), 14(8), 15(33), 16(1.482), 17(3.1), 19(1.02), 22(21.13),
MI-0937	15	4(5.78), 5(2.183), 6(3.79), 8(542.831), 13(90), 14(5), 15(30), 16(2.75), 17(6.25), 19(1.02), 20(2.267), 21(12.81), 22(17.687), 23(72.87), 24(66.56),
MI-0934	14	4(6.727), 5(2.166), 6(3.44), 7(224.733), 13(95), 14(7), 15(34), 16(2.275), 17(4.67), 18(0.39), 19(1.1), 22(14.597), 23(71.98), 24(66.1),
MI-0865	14	1(43), 3(24), 7(221.289), 8(538.672), 10(0.988), 11(8.965), 13(95), 18(0.69), 19(0.99), 20(2.167), 21(8.05), 22(13.86), 23(71.95), 24(65.56),
MI-0886	14	2(200), 5(1.753), 6(3.74), 8(385.921), 9(70.88), 12(188.214), 13(95), 15(36), 17(3.33), 19(1.06), 20(2.749), 21(8.053), 23(74.53), 24(67.69),

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IV. DISCUSSION

In the present investigation, 69 mulberry germplasm were characterized for different morphological, anatomical, reproductive, biochemical, growth and yield characters. The basis of conservation is availability of sufficient knowledge on species diversity and the ecosystem in which they are present. *Ex situ* conservation is the practical way of preservation to date for storage of mulberry germplasm i.e., in a gene bank which usually means a seed bank. However, in case of mulberry, seed storage is difficult or almost impossible as the genetic integrity of a particular clone or genotype cannot be preserved due to high degree of heterozygosity. In mulberry, the inherited characteristics of the parental stocks can be perpetuated only by vegetative propagation (Bindroo *et al.*, 2012).

Peris *et al.* (2014) studied five mulberry accessions for genetic divergence using 12 phenotypic traits in two localities, Nairobi and Eldoret. Their results indicated that the tested accessions were clustered in four groups. The traits tested across the five accessions can be utilized for future breeding for high yielding varieties. Chatterjee *et al.* (2004) have studied morphological and molecular variation in *Morus laevigata* collected from wide agro-climatic zones using 12 morpho-biochemical parameters and RAPD profiles. The study established significant variability for only two morpho-biochemical parameters (100 leaf weight and stomata number). Jayeoba *et al.* (2014) has studied the morphological and chemical analysis of eight varieties of *Morus alba* to determine the differences among them. The results revealed that K2 and S34 were significant varieties.

V. CONCLUSION

In the present study, it is evident that, effective and efficient utilization of germplasm depends on the detailed and systematic characterization. Phenotypic characterization is essential in the description and classification of the germplasm. In addition, it facilitates in addressing the trueness and detecting the duplicates. However, the present work needs to be complemented with molecular studies to strengthen the morphological differences.
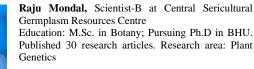
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