MULBERRY

Genetic Improvement in Context of Climate Change

Editors

M.K. Razdan and T. Dennis Thomas

CRC Press
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Mulberry: Genetic Improvement in Context of Climate Change

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Preface

Mulberry is a fast growing deciduous perennial tree or shrub belonging to the genus *Morus* and family Moraceae. It grows under various climatic conditions which range from temperate to tropics and occurs at different altitudes like from sea level to altitudes as high as 4000 m. Considering that mulberry most likely evolved in sub-Himalayan tracts, owing to its wider adaptability to divergent agro-climatic conditions, yet its growth and cultivation has spread to almost all continents including Africa, Asia, South America, Europe, North and South America. This is primarily due to the fact that mulberries are grown for different purposes around the world. Mulberry leaves are sole natural source of feeding silkworm (*Bombyx mori* L.) which is involved in production of silk, thus making mulberry a valuable economic source to sericulture industry. Besides silk production, mulberry is used in medicine, as animal fodder, and in human consumption as fruit products, e.g., jam jelly, marmalade, frozen desserts, juices, etc. Mulberry wood has equal utility in making furniture.

Mulberry being valuable economic, horticultural and industrial plant genetic resource, the threats for loss of diversity in gene pools of *Morus* spp. appear significant because of habitat destruction, deforestation, spread of invasive alien species, alterations in the land-use pattern and overall impact of ongoing climate change. Further the species that are endemic cannot grow in alternative habitats as they will be vulnerable to extinction. It is estimated that 15 to 37%, plant species will be threatened with extinction due to climate change by 2050. In this context mulberry attracts special attention since about 60% silk is produced among various continents of the world and increase in silk production is directly dependent on high silk cocoon yield. This necessitates consistent efforts for maintenance of mulberry species involved in feeding silk cocoons as well as the species of *Morus* having other valuable traits despite environmental variations. Utilization of new spontaneous or experimentally generated mulberry varieties is crucial for increase in productivity, input use efficiency, and to withstand various abiotic (drought, heat, cold, alkalinity) and biotic stresses (root-rot, root-knot, mealybug, trips, mites, whitefly) vis-à-vis the climate change. Genetic improvement thus has immense potential to cope up with unpredictable and extreme climates to sustain mulberry species.

The present book is aimed at providing overview of research carried out on various aspects in mulberry species and provides a critical appraisal of the state-of-the-art of these findings. **Section A** covers Chapters highlighting Taxonomy and Importance of Mulberry; Chapters of **Section B** describe attempts being made for genetic improvement of mulberry species using conventional and non-conventional methods; whereas other research efforts that ensure sustainable growth of mulberry are mentioned in Chapters of **Section C**. The number of recognized species in major taxonomic treatments of *Morus* has varied considerably. For example, Carl Linnaeus who established the genus *Morus* in 1753 considered the genus comprises seven species: *M. alba*, *M. indica*, *M. nigra*, *M. papyrifera*, *M. rubra*, *M. tartarica* and *M. tinctoria*. However, two of these, *M. papyrifera* and *M. tinctoria*, were subsequently moved to *Broussonetia* and *Maclura*, respectively. Whereas Linnaeus considered the characters of fruit color, leaf shape and leaf hairs as parameters in identifying these species, Bureau (1853) on the contrary treated the genus *Morus* on the characteristics of leaves and pistillate catkins, thereby recognizing five species with 19 varieties and 13 sub-varieties. Further variation in number of species within genus *Morus* has been reported from various countries (e.g., China 24, Japan 16, USA 14, Korea 6, etc.). These points to no complete agreement on the origin and number of mulberry species. The genetic diversity in important mulberry species needs revaluation of the systematic status within genus *Morus* particularly considering their occurrence in different geographical and climate conditions. This has been comprehensively revaluated in **Chapters 1** and **2.** Cultivation

of mulberry is reported to have started about 5000 years back in China and it was discovered subsequently that mulberry species from different and climatic regions exist in various polyploid forms. Accordingly, the cultivation methods vary including nutrients in soil where various mulberry species grow. **Chapter 3** gives elaborative account of cultural practices of mulberry species which directly impact the productivity and yield of economic traits. Mulberry like the traditional herbs has been used in medicine for centuries. Due to its pharmacological properties mulberry fruits possess an outstanding nutritional value due to their high levels of phenolic compounds with high antioxidant activity. There are many opportunities for the food and healthcare industry to explore the health benefits of mulberry fruits as research results endorse ethnopharmacological usage of mulberry. **Chapter 4** and **Chapter 5** give an elaborative account of anti-oxidative, anti-inflammatory, anti-microbial, anti-cancer, anti-atherosclerosis, anti-Alzheimer, anti-obesity, anti-hyperlipidemic and anti-hyperglycaemic properties of mulberry fruits.

Traditionally sexual hybridisation, polyploidy and mutation breeding has contributed much to the development of high yielding mulberry varieties and other superior economic traits, particularly under the changing agro-climatic conditions created by global warming and other factors. These aspects are elucidated in **Chapter 6** and **Chapter 7.** Considering high cost of inputs like man power in conventional methods and inability of improved varieties obtained from these methods in sustaining rigors of environmental or climatic changes, the biotechnological approaches have been pursued as an alternative to genetic improvement of the existing new mulberry varieties. **Chapter 8 and Chapter 9 discusses** the applications and limitations of the plant tissue culture or *in vitro* methods in mulberry improvement, micropropagation and conservation of new genotypes; **Chapter 10** provides a general account of genetic improvement using protoplast culture and **Chapter 11** describes extent to which attempts at achieving these goals have been successful by genetic engineering.

Among other research efforts on sustainable growth of mulberry **Chapter 12** focusses on the role of various environmental factors on the growth of mulberry (*Morus alba*) under specific geographical conditions. It is apparent that impact of these factors is synergistic and with proper manipulation of these factors *Morus alba* can sustain growth when coupled with effective agro-chemical management. Similarly, the identification of tightly linked markers or candidate genes associated with trait specific QTLs have been shown to facilitate marker assisted selection (MAS) in mulberry breeding programmes for identification of stress tolerant traits resilient to climate change (**Chapter 13**). Arbuscular mycorrhizal symbiosis is another aspect that contributes significant benefits for sustainable growth and quality of mulberry plants (**Chapter 14**). A panoramic description on the development of new improved mulberry varieties by Sericultural institutes located at different climate zones and geographical regions in India including methods of their cultivation for sustainable sericulture is provided in **Chapter 15.** Furthermore this chapter mentions about protection of these varieties by management of diseases and pests in the field. Viroids, viruses and phytoplasmas are other class of most common pathogens infecting mulberry in all mulberry growing regions of the world, thus causing severe decline of the trees. The type of pathogenic symptoms induced by these agents depend on the pathogen-host combination, environment and growth conditions. There are reports of infected trees showing no symptoms of disease in some instances which can be worrisome as by the time disease shows up the damage is already done. **Chapter 16**, therefore, mentions the types of these pathogens, highlights the molecular basis of their detection, and suggests control measures for prevention of their attack on mulberry. To sustain sericulture the conservation of new mulberry genetic resources obtained through multiple research efforts is an absolute must especially when threatened under climatic change. **Chapter 17** outlines objectives and methods of germplasm conservation with reference to various mulberry species and varieties of importance.

This compendium on research findings of experts from international organizations and institutes should prove beneficial to sericulture, horticulture and pharmaceutical industry. Also it could be of use to those involved in mulberry cultivation and farming. Lastly, thanks are due to the publisher and authors of respective chapters for their sincere cooperation and support.

December 2020

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Mulberry (*Morus* spp.)

I. Subject

These Test Guidelines shall apply to all vegetatively propagated varieties, hybrids, mutants, polyploids and transgenics of **Mulberry** (*Morus* spp.)

II. Planting Material Required

1. The Protection of Plant Varieties & Farmers' Rights Authority (PPV&FRA) shall decide on the quantity and quality of the plant material required for testing of the variety and when and where it is to be delivered for registration under the Protection of Plant Varieties and Farmers' Rights (PPV&FR) Act, 2001.
2. Applicants submitting such material(s) from a country other than India shall make sure that all customs and quarantine requirements stipulated under relevant national legislations are complied with.
3. The crop (mulberry) is a perennial, heterozygous tree plant cultivated as small to high bush and small trees by regular pruning and propagated clonally by stem cuttings in tropics and grafts in temperate regions.
4. The minimum quantity of planting material required to be supplied by the applicant per centre shall be 50 stem cuttings of 12 – 15 cm length and 1.0 – 1.5 cm diameter from 6 – 8 months mature shoots with 2 – 3 healthy buds or 50 saplings of four months old of about 120 cm height or 50 saplings/grafts on the root stock (popular root stock utilized in the region).
5. The planting materials supplied shall be healthy, not lacking in vigour or nutrition as well as free from pests or diseases or any mechanical damage.
6. The stem cuttings or grafted plants will be planted in nursery for rising of 4 months old saplings / grafts required for the test following the recommended cultivation practice in mulberry.
7. The plant material should not have undergone any treatment, which would affect the expression of the characteristics of the variety, unless the competent authorities allow or request such treatment. If it has been treated, full details of the treatment must be given.

III. Conduct of tests

1. The minimum duration of DUS tests shall be normally 90 days each of 2 independent growing cycles per year (in June – August and September – November) and conducted for two years. The reproductive characteristics will be recorded after the second growing cycle during the natural flowering season (January – February) culminating with fruit development. The test will be initiated after 1 year of the establishment of the plants in an experimental plot. The tests will be conducted at two places or in on-site testing.
2. The growing cycle is considered as the period from the date of pruning of the plants followed by bud sprouting, and active vegetative growth.
3. If any essential characteristic of the candidate variety is not expressed at the time of visual observation at two locations, the variety shall be considered for further examination at another appropriate test site or under special test protocol on expressed request by the applicant, for which additional quantity of planting material shall be supplied.

4. The field tests shall be carried out under conditions favouring normal growth and expression of all test characteristics. The size of the plots shall be such that plants or parts of plants could be removed for measurement and observation without prejudice to the other observations on the standing plants until the end of the growing period.

5. **Test plot design**:

The plants shall be raised with a crown height of 60 cm and spacing of 150 cm x 150 cm in Pit system and nurtured following the package of practices recommended for the variety.

Planting system	:	Pit system
Number of rows	:	03
Row to row distance	:	150 cm
Plant to plant distance	:	150 cm
Number of replications	:	03
Number of plants per replication	:	08

6. **On-site testing**:

The applicant or his/her nominee on his/her behalf shall submit a request to the Authority for conducting a reliable trial according to Test Guidelines and the instructions from the Authority before on-site examination of the candidate variety. The applicant or his/her nominee shall submit a request to the Authority for on-site examination prior to start of growing cycle as mentioned in Test Guidelines for on-site examination of the candidate variety. On-site testing may be conducted at places specified by the applicant. The age of the plants at on-site shall be a minimum of 2 years for tropical regions and 3 years for temperate regions. As a minimum, 24 plants with uniform spacing should be available for inspection and examination for 'on-site' DUS testing. The plants must be healthy and free from pest & disease and raised under standard and uniform management practices. For farmer's variety or landraces, the authority may notify suitable guidelines on the number of plant(s) and season(s), if any. On-site examination shall be arranged during the favourable growing season, when distinguishing characteristics of candidate variety can most easily be seen. The characteristics of the candidate variety can be examined and compared with those of the reference varieties as per the Test Guidelines. The Expert Committee constituted by the PPV & FRA in consultation with the DUS centre shall be authorized to inspect on-site testing and recording of the appropriate characters. Applicant shall supply the Expert Committee with summary of distinct characteristics supported by photographs. The Expert Committee shall take notes and observations on distinctiveness and shall confirm preliminary data and/or summary of distinctiveness from the applicant. The Expert Committee shall submit examination report to the Authority.

7. Observations shall not be recorded on plants in border rows.
8. Additional tests for special purpose shall be established by the PPV & FR Authority.

IV. Methods and observations

1. The characteristics described in the Table of Characteristics (refer Section – VII) shall be used for the testing of varieties for their DUS.
2. For the assessment of Distinctiveness and Stability, observations shall be made on 9 plants or parts of 9 plants, which shall be equally divided among 3 replications.
3. For the assessment of Uniformity of vegetatively propagated varieties, a population standard of 1% and an acceptance of probability of at least 95% shall be applied.
4. All observations on leaf characters shall be measured using fully expanded matured leaves in the middle portion (15^{th} leaf) on the longest shoot.
5. All observations on shoot, leaf, bud characteristics shall be made on upper (*e.g.*, stipule nature), middle (*e.g.*, phyllotaxy), lower (*e.g.*, mature shoot color and shoot thickness in cm) $1/3^{rd}$ portion of the longest shoot.
6. Observations on reproductive characteristics shall be taken during the natural flowering season or after about 2 – 3 weeks of pruning.
7. For the assessment of colour characteristics, the latest Royal Horticultural Society (RHS) colour chart shall be used.

V. Grouping of varieties

1. The candidate varieties for DUS testing should be divided into groups to facilitate the assessment of Distinctiveness. Characteristics which are known from experience not to vary, or to vary only slightly within a variety and which in their various states of expression are fairly distributed evenly across all varieties in the collection, are suitable for grouping purposes.
2. The following characteristics shall be used for grouping mulberry varieties
   a) Inter-nodal distance (Characteristic 08)
   b) Phyllotaxy (Characteristic 09)
   c) Leaf base (Characteristic 21)
   d) Sex (Characteristic 29)
   e) Mature inflorescence length (Characteristic 30)

VI. Characteristics and symbols

1. To assess distinctiveness, uniformity and stability, the characteristics and their states of expression as given in the Table of characteristics (Section – VII) shall be used.
2. Notes (1 to 9) shall be used to describe the state of each character for the purpose of digital data processing and these notes shall be given against the states of different characteristics.
3. Legend

   (*) Characteristics that shall be observed during the active growing season and shall always be included in the description of the variety, except when the state of expression of any of these characters is rendered impossible by a preceding phenological characteristic or by the environmental conditions of the testing regions. Under such situation, adequate explanation shall be provided.

   (+) See explanations for the Table of characteristics in the section - VIII. It is noted that for certain characteristics the plant parts on which observations to be taken are given in the explanation of figure (s) for clarity and not for the colour variation.

4. A numerical code in the sixth column of Table of Characteristics is on or after the days indicated for the observation of respective characteristic during the growth and development of plants. The relevant growth stages corresponding to this numeric code are described below:

Code for the growth stages

Code	Growth stage
08	After 8 days of pruning, when the buds start sprouting
20	Matured or fully developed inflorescence in the natural flowering season or about 2 - 3 weeks after pruning
40	Fully matured fruit
45	On or after 45 days of pruning
60	On or after 60 days of pruning
90	On 90th day of pruning / planting of cuttings

5. Characteristics denoted with symbols QL, QN and PQ in the first column of the Table of Characteristics shall be indicated as;

   QL: Qualitative characteristic

   QN: Quantitative characteristic

   PQ: Pseudo-qualitative characteristic

6. Type of assessment of characteristics indicated in column seven of Table of Characteristics is as follows:

   MS: Measurement of a number of individual plants or parts of plants

   MG: Measurement by a single observation of a group of plants or parts of plants

   VS: Visual assessment by observation of individual plants or parts of plants

   VG: Visual assessment by a single observation of a group of plants or parts of plants

VII. Table of Characteristics

Sl. No.	Characteristic	State	Note	Example varieties	Stage of obser-vation (Day - on or after)	Type of assess-ment
1	2	3	4	5	6	7
1 QN (*)	Plant: vigor	Low	3	Kajli, Surat, Harmutty	45	VG
		Medium	5	Kanva-2		
		High	7	*M. laevigata* (Hybrid)		
2 PQ (*) (+)	Plant: growth habit	Erect	3	Philippines, Kanva-2, Mysore Local	60	VS
		Semi-erect	5	*M. multicaulis*, Kosen		
		Spreading	7	Kajli, Bildevalaya, Doomar Nali, Mizusawa		
		Drooping	9	Creeping mulberry		
3 QN	Sprouting (days)	Early (<10)	3	Kanva-2, Harmuty	8	MG
		Medium (10-15)	5	Birds Foot, Philippines		
		Late (>15)	7	Urgam-1, French		
4 QN	Survival % of cuttings (rooting)	Low (<40)	3	Doomar Nali	90	MG
		Medium (40 – 80)	5	Kosen, Philippines		
		High (>80)	7	Kajli		
5 PQ (+)	Shoot: type	Straight	3	Kanva-2	60	VS
		Slightly curved	5	Kosen		
		Curved	7	Doomar Nali		
6 QN	Shoot: thickness (cm)	Thin (<1.0)	3	Harmutty	60	MS
		Medium (1.0-1.5)	5	*M. multicaulis*		
		Thick (>1.5)	7	Mizusawa, Lazuraso, Kosen, Gajapathipur-2		
7 PQ	Mature shoot: color	Yellow-Green Group 147	1	Kokuso	90	VS
		Greyed-Green Group 195	3	China-34		
		Grey-Brown Group 199	5	Asiyoake, Lazuraso, Birds Foot		
		Brown Group N200	7	K2xBC (P11)		
		Grey Group 201	9	Barbat Farm		
8 QN (*)	Inter-nodal distance (cm)	Short (<3)	3	Surat, Kokuso	90	MS
		Medium (3-6)	5	Railway Quarter, Kosen		
		Long (>6)	7	Philipines, Doomar Nali, Moreti (Syringe), Birds Foot		
9 PQ (*) (+)	Phyllotaxy	Distichous (1/2)	3	Birds Foot, Doomar Nali, *M. laevigata* (Hybrid)	60	VS
		Tristichous (1/3)	5	Bildevalaya		
		Pentastichous (2/5)	7	Lazuraso, Kosen, Harmutty, Mizusawa		
		Mixed type {(1/2 & 1/3), (1/2 & 2/5), (1/3 & 2/5), (1/2, 1/3 & 2/5)}	9	French, Mysore Local, Kanva-2, Asiyoake		
10 QN (+)	Leaf: angle	Acute	3	Kanva-2, Mysore Local	45	VG
		Horizontal	5	Moreti (Seringe)		
		Obtuse	7	Philippines		

11 QN (+)	Petiole: length (cm)	Short (<3) Medium (3-5) Long (>5)	3 5 7	Malakai Local, Surat Kanva-2, Punjab Local, Badodhi Railway Quarter, Doomar Nali, Creeping CP x V-1 (P5)	60	MS
12 QN	Petiole: thickness (cm)	Thin (<0.2) Medium (0.2-0.4) Thick (>0.4)	3 5 7	Surat, Kaji, Acc.106, Harmutty Kanva-2, Barbat Farm *M. muticauls*, Philipines, Doomar Nali, China-34	60	MS
13 QL	Stipule: nature	Bud scale Free lateral Foliaceous	1 2 3	Surat, Acc.106 Mysore Local, Railway Quarter Barbat Farm	45	VS
14 QN (*)	Leaf lamina: length (cm)	Short (<10) Medium(10-20) Long (>20)	3 5 7	Surat Kanva-2, Mysore Local *M. muticauls*, Doomar Nali, Philipines, *M. laevigata* (Hybrid)	60	MS
15 QN (*)	Leaf lamina: width (cm)	Narrow (<10) Medium (10-15) Broad (>15)	3 5 7	Surat, French, Harmutty Kanva-2, Mysore Local, Railway Quarter Doomar Nali	60	MS
16 QN (*) (+)	Leaf: size (sq. cm)	Small (< 200) Medium (200-400) Large (> 400)	3 5 7	Surat Kosen, Kanva-2, Punjab Local Doomar Nali, *M. laevigata* (Hybrid)	90	MG
17 PQ (+)	Leaf: shape	Cordate (L/W ratio=<1:1) Wide ovate (L/W ratio= 1.2:1) Ovate (L/W ratio=1.5:1) Narrow ovate (L/W ratio=2:1) Lanceolate (L/W ratio =3:1)	1 3 5 7 9	Kanranjotti-1 *M. muticauls* Doomar Nali, Kanva-2, Mysore Local Harmutty French	60	MS
18 PQ (+)	Leaf: color	Light Green -141 D Green-137C Dark Green-137A	3 5 7	Kanva-2 Philippines Railway Quarter, Kaji, *M. muticauls*	60	VS
19 PQ	Leaf: hariness	Glabrous Sparsely Hairy Hairy (pubescent)	3 5 7	Kosen Birds Foot, Badodhi, Malakai Local, Ranchi-5 Urgam-1	90	VS
20 PQ	Leaf: texture	Membranaceous Charataceous Coriaceous	3 5 7	Philippines Kaji, Surat, Mysore Local French, Barbat Farm	90	VS
21 PQ (*) (+)	Leaf: base	Acute Truncate Cordate Lobate	3 5 7 9	French Kanva-2, *M. laevigata* (Hybrid) Mizusawa, *M. muticauls*, Punjab Local Kosen, Malakai Local	60	VS
22 PQ (*) (+)	Leaf: apex	Acute Acuminate Caudate	3 5 7	Philippines, French, China-34 Punjab Local, Mysore Local Barbat Farm, Harmutty, Badodhi, Ranchi-5	60	VS

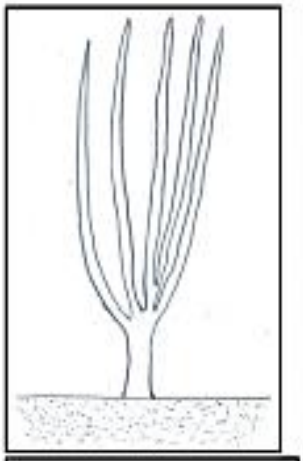
		Obtuse	9	-		
23 PQ (*) (+)	Leaf: margin	Crenate Dentate Serrate Repand	3 5 7 9	Philippines, Kosen Surat, Acc.106, Malakai Local *M. laevigata* (Hybrid) Lamia Bay	60	VS
24 PQ (*)	Leaf: type	Unlobed (entire) Lobed Mixed type	1 2 3	*M. multicaulis* Kaji, Bildevalaya Mysore Local, Badodhi, Ranchi-5	60	VG
25 QN (+)	Mature bud size	Small Medium Large	3 5 7	Philippines, Surat, Punjab Local Kosen, *M. multicaulis*, Kaji Doomar Nali	90	VG
26 QL (+)	Bud attachment	Adhering to branch Slanting out ward Tilting to one side	1 2 3	Philippines, Surat, Mysore Local *M. multicaulis*, Kaji, Barbat Farm -	60	VS
27 PQ (*) (+)	Mature bud shape	Round Acute triangle Long triangle Spindle	3 5 7 9	Acc.106, Gajapathipur-2 Philippines, Mysore Local, Punjab Local Mizusawa, *M. multicaulis*, Birds Foot, Badodhi Doomar Nali	90	VG
28 QL (+)	Accessory bud	Absent Present	1 9	French *M. multicaulis*, Mysore Local	60	VS
29 QL (*) (+)	Sex	Gynoecious Androecious Bisexual Andromonoecious Gynomonoecious Androgynomonoecious	1 2 3 4 5 6	Kaji, , Doomar Nali, *M. multicaulis* Lamia Bay Gajapathipur-2 - - -	20	VG
30 QN (*) (+)	Mature inflorescence: length (cm)	Short (<2) Medium (2-4) Long (>4)	3 5 7	Surat, Mysore Local, Bildevalaya, Harmutty Mizusawa, *M. multicaulis*, Punjab Local Birds Foot, Doomar Nali, *M. laevigata* (Hybrid)	20	MS
31 QL	Stigma: nature	Pubescent Papilate	3 7	Mysore Local, Railway Quarter Philippines, Doomar Nali, Lazuraso	20	VS
32 QL	Stigma: type	Erect Spreading Divaricate Twisted	3 5 7 9	Lasuraso, *M. multicaulis*, Kaji, Birds Foot Punjab Local, Kanva-2, Bildevalaya Mysore Local, Surat, Harmutty, Karanjotli-1 Doomar Nali, Ranchi-5	20	VS
33 QN (+)	Mature fruit: length (cm)	Short(<2) Medium (2-4) Long (4-8) Very long (>8)	3 5 7 9	Surat, Mysore Local *M. multicaulis*, China-34, Kanva-2, Karanjotli-1, Moreti (Seringe) Ranchi-5, *M. laevigata* (Hybrid) Doomar Nali	40	MS

34 QN	Mature fruit: width (cm)	Narrow (<1)	3	Surat, Harmutty, Mysore Local, *M. laevigata* (Hybrid)	40	MS
		Medium (1-1.5)	5	Kaji, *M. mutticauls*, Doomar Nali		
		Broad (>1.5)	7	Railway Quarter		
35 PQ (+)	Mature fruit: color	Black Group 203 - Bluish Black C	1	*M. mutticauls*, Kaji, Bildevalaya, Surat, Kanva-2, Mysore Local	40	VG
		Greyed-Orange Group 172 - Dark Reddish Orange B	2	*M. laevigata* (Hybrid)		
		Purple Group 76 - Very Pale Purple C	3	Punjab Local, RC-1		
		Yellow-Green Group 145 - Light Yellow Green D	4	Moreti (Seringe)		
		White	5	Ranchi-5		
		Green	6	Saravathi Tea Estate		

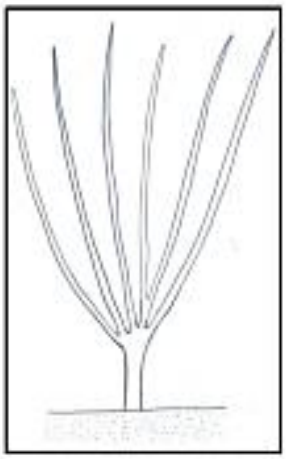
VIII. Explanation on the table of characteristics

Characteristic 2: Plant growth habit



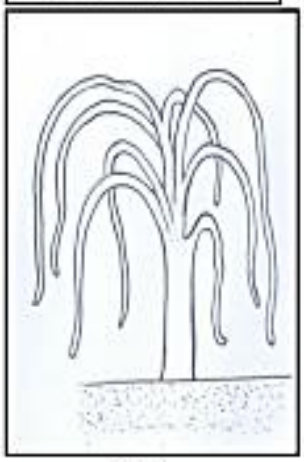



Erect
(3)



Semi-erect
(5)

Spreading
(7)



Drooping
(9)

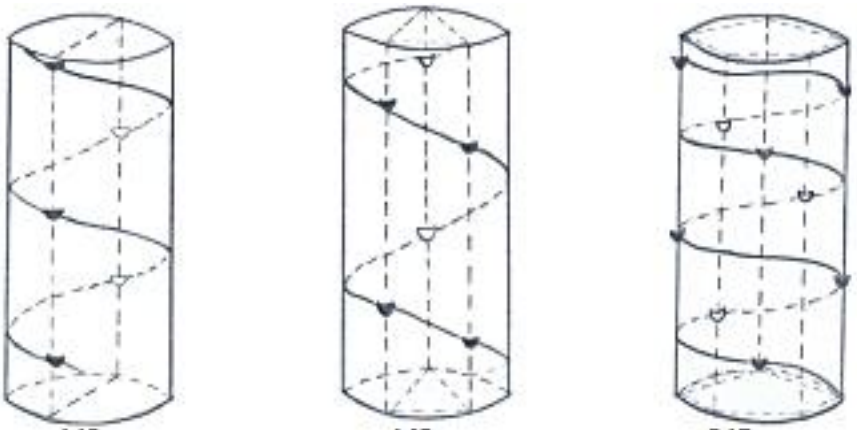
Characteristic 5: Shoot type

Straight
(3)

Slightly curved
(5)

Curved
(7)

Characteristic 9: Phyllotaxy



1/2
(3)

1/3
(5)

2/5
(7)

Mixed type (9) - Include combination of 1/2 & 1/3 or 1/2 & 2/5 or 1/3 & 2/5 or 1/2, 1/3 & 2/5

Characteristic 10: Leaf angle

Acute
(3)

Horizontal
(5)

Obtuse
(7)

Characteristic 11: Petiole length

Short (3) | Medium (5) | Long (7)

Characteristic 16: Leaf size

Small (3) | Medium (5) | Large (7)

Characteristic 17: Leaf shape

Cordate
(1)

Wide ovate
(3)

Ovate
(5)

Narrow ovate
(7)

Lanceolate
(9)

Characteristic 18: Leaf color

Light green 141 D
(3)

Green 137 C
(5)

Dark green 137 A
(7)

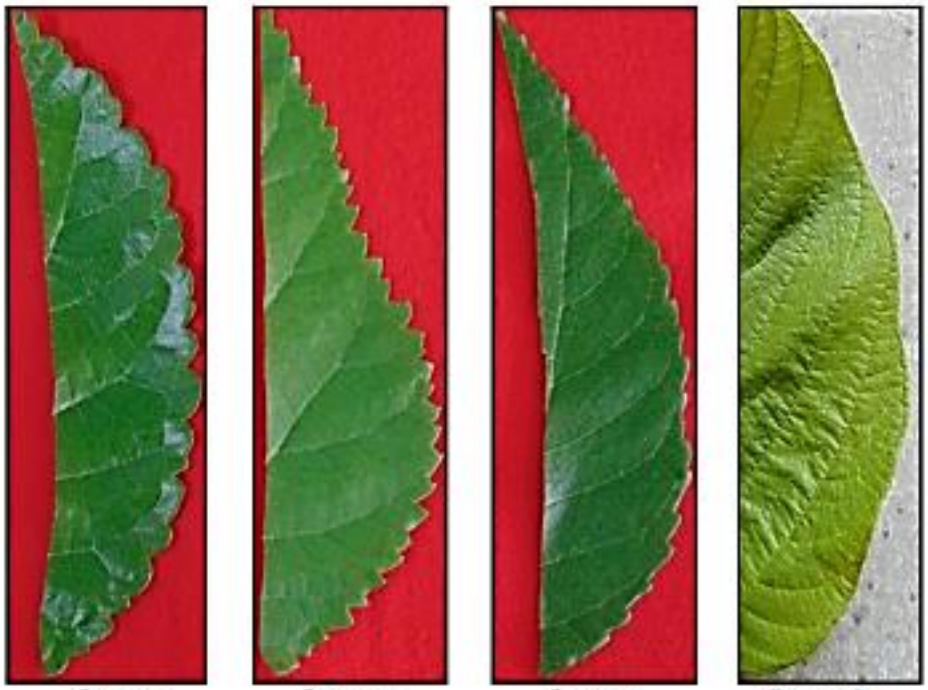
Characteristic 21: Leaf base

Acute (3) | Truncate (5) | Cordate (7) | Lobate (9)

Characteristic 22: Leaf apex

Acute (3) | Acuminate (5) | Caudate (7)

Characteristic 23: Leaf margin



Crenate (3) | Dentate (5) | Serrate (7) | Repand (9)

Characteristic 25: Mature bud size

Small
(3)

Medium
(5)

Large
(7)

Characteristic 26: Bud attachment

Adhering to branch
(1)

Slanting outward
(2)

Tilting to one side
(3)

Characteristic 27: Mature bud shape

Round
(3)

Acute triangle
(5)

Long triangle
(7)

Characteristic 28: Accessory bud

Absent
(1)

Present
(9)

Characteristic 29: Sex

Gynoecious (Female)
(1)

Androecious (Male)
(2)

Bisexual
(3)

Characteristic 30: Mature inflorescence length (Female)

Short
(3)

Medium
(5)

Long
(7)

Characteristic 30: Mature inflorescence length (Male)

Short
(3)

Medium
(5)

Long
(7)

Characteristic 33: Mature fruit length

Short
(3)

Medium
(5)

Long
(7)

Very long
(9)

Characteristic 35: Mature fruit color

Bluish black
(1)

Dark reddish orange
(2)

Very pale purple
(3)

Light yellow green
(4)

White
(5)