

# Intraspecific Variation and Taxonomic Delimitation of *Munronia pinnata* (Meliaceae) in Sri Lanka

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**Abstract** *Munronia pinnata* (Wall) The ob (Meliaceae) is a rare, therapeutically important medicinal plant used in traditional and folklore medicine in Sri Lanka. Available species/morphotypes/ecotypes of *M. pinnata* in different locations exhibit diverse range of variations suggesting the possible revision of current taxonomic status. Present study compares seventy different vegetative and reproductive morphological characters in order to suggest the possible taxonomic delimitation of 13 populations of *M. pinnata* available in Sri Lanka. A cluster analysis and a Principle Component analysis (PCA) were performed using average taxonomic distance. A single access (sequential), key to sub specific taxa was constructed using stable morphological characters. In the cluster, APRG - 5 populations (Population collected from Ritigala forest) has got separated from all the other populations at a distance of about 100%. Populations collected from the same geographical areas (Gampaha district GPPW - 3, GPWP - 3; Moneragala district MGMT - 9 MGWW - 7; Nuwara Eliya district NEKP - 3, NEMR - 3) have grouped closely either in the dendrogramme or in PCA or both. Based on the results, it could be concluded that population APRG - 5 is distantly related to all others and deserved placing as a sub specific taxon of *M. pinnata*. Further, populations collected from the same geographical area seem to be closely related with one another. Sequential key prepared using morphological characters could be used for the identification of *M. pinnata* populations even in the absence of flowers.

**Keywords:** cluster analysis, intraspecific variation, meliaceae, morphology, munronia pinnata

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## 1. Introduction

The Genus *Munronia* Wight. (Meliaceae), comprising 13 - 15 species, is naturally distributed in China, Sri Lanka, India, Indonesia, Malaysia Vietnam and the Philippines [1,2]. *Munronia pinnata* (Wall) The ob. is a rare medicinal plant species that occurs in Sri Lanka. Populations with an array of variable phenotypic characters (e.g. compound leaf with leaflet number varying from 3 to 11, different types of leaf margins etc.) are available in various locations in Sri Lanka [3,4,5]. Moreover, earlier literature showed that *M. pinnata* was abundant and widely distributed in Sri Lanka in early days [1,2]. Further, all populations growing in Sri Lanka are treated as a single species due to inadequacy of available data for the recognition of infraspecific taxa [2]. It also suggests a correlation between geographical distribution and phenotypic variation in *M. pinnata* of Sri Lanka. Even though studies on the geographical distribution, comparative pharmacognostic studies of *M. pinnata* and *Andrographis paniculata* [6], preliminary taxonomic status, and the genotypic variation of some populations using Randomly Amplified Polymorphic DNA) are

available [7,8], no detailed taxonomic study of *M. pinnata* populations has been carried out. Present study focused on a comprehensive morphological investigation of Sri Lankan populations of *M. pinnata* for elucidating the taxonomic status and developing an identification key.

## 2. Materials and Methods

### 2.1. Plant materials

After getting permission from the relevant authorities, same aged, seed propagated *M. pinnata* plants, were collected from different climatic zones (wet, intermediate and dry zones) of the country (Map 1; Plate 1 & Table 1). These were identified by comparing them with authentic herbarium specimens deposited at National Herbarium. Voucher specimens (HTS1 - HTS13) for all populations were prepared and deposited in the institutional herbarium. As a measure to minimize the impact of environmental factors on the data collected, all plants were potted in the same mixture of potting medium (sand: topsoil: compost =1:1:2) and maintained in the green house under same controlled conditions for five years before taking samples. At least twenty individuals per population were used to record morphological data.

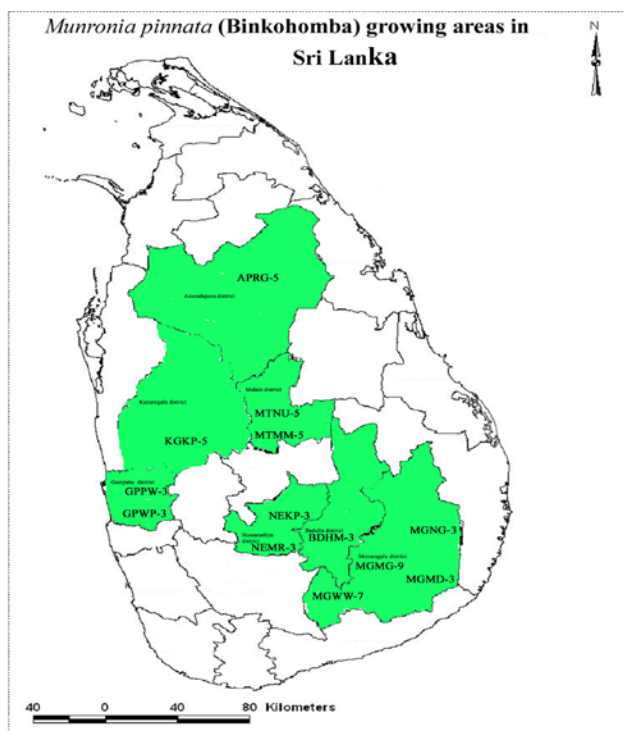


**Plate 1.** Different populations of *Munronia pinnata* used for the study. [Details of population codes are as given in Table 1. The last number of each code denotes the number of leaflets in the compound leaf of each population]

**Table 1.** The detailed locations of thirteen populations of *Munronia pinnata* used for the morphological study

Population code	Locality	District	Number of Leaflets	Altitude(M)	Agro- climatic zone	Rainfall(cm)
APRG-5	Ritigala	Anuradhapura	5	396	DL-3	100-150
BDHM-3	Haldummulla	Badulla	3	960	IU-1	200-250
GPPW-3	Pallewela	Gampaha	3	35	WL-1	350-400
GPWP-3	Warakapola	Gampaha	3	125	WL-1	350-400
KGKP-5	Kuliyapitiya	Kurunegala	5	30	DL-1	150-200
MGMD-3	Madulla	Monaragala	3	196	IL-1	250-300
MGMG-9	Srivijayapura	Monaragala	9	220	IL-1	250-300
MGNG-3	Nilgala	Monaragala	3	283	IL2	250-300
MGWW-7	Wellawaya	Monaragala	7	192	IL-1	150-200
MTMM-5	Meemure	Matale	5	420	WM-2	200-250
MTNU-5	Naula	Matale	5	375	WM-2	200-250
NEKP-3	Kithulpe	Nuwaraeliya	3	720	WU	300-350
NEMR-3	Mathurata	Nuwaraeliya	3	1050	WU	300-350

DL- Low country dry zone; IU- Up country intermediate zone; WL- Low country wet zone; IL- Low country intermediate zone; WM-Mid country wet zone; WU-Up country wet zone



**Map 1.** Geographical distribution of *Munronia pinnata* in Sri Lanka [Details of population codes are as given in Table 1. The last number of each code denotes the number of leaflets in the compound leaf of each population]

## 2.2. Selecting and Recording Morphological Characters

Seventy different vegetative and reproductive features, including the characters, which have not been previously recorded, were assessed by using either fresh material or material preserved in 70% ethanol. The protocols for clearing, staining and mounting of the materials were adopted from literature with slight modifications whenever necessary [9,10,11]. Characters were then coded into discrete states as either binary state variables or those with extended variation as multistate variables (Annexure 1 & Annexure 2) as described by previous studies [12,13]. Photographs of study material were taken using digital microscope (Olympus, Model CX 31, Japan).

## 2.3. Cluster Analysis

The variation range of each character of the plant was divided into two or more character states and ranked them by giving a numerical value for each character state. When interpopulational variation was absent for a given character, data of all individuals of that population were considered as a single value for the data matrix. UPGMA cluster analysis and ordination (correspondence analysis) of the basic data matrix was performed with NTSYS 1.8 [14].

## 2.4. Construction of Taxonomic Keys to Identify *Munronia pinnata* Populations

A single access (sequential), indented (Yoked) key was constructed using stable morphological characters

recorded to identify different populations of *M. pinnata* collected from different localities.

## 3. Results and Discussion

### 3.1. Morphological Variation

Present study identified 25 monomorphic characters of which six were vegetative characters and the rest was reproductive characters, as common features to all populations collected from the three major climatic zones in Sri Lanka. This is acceptable as all these are currently classified under a single species [2]. However, with respect to the rest of the characters, a large interpopulational variation (about 66% of the characters) was observed among the populations studied supporting the idea of the existence of clearly defined taxa below species level.

As all plants used for the study were acclimatized for at least five years under same soil and climatic conditions, the morphological characters recorded could be considered as a true reflection of genetically determined morphology of the plants concerned. An intra specific monomorphism in some common floral characters was evident in this study supporting the existing classification, which considers all morphotypes as a single species. In contrast, a considerable level of polymorphism was also found in some vegetative characters and in fine floral characters such as stamina tube length, stigma shape and style length. Some of these seem very promising in differentiating populations.

All characters used in the key are vegetative and therefore, could be used even in the non-flowering season of the plant. Since flowering is very rare in certain populations [3], it is essential to prepare a key based on vegetative characters. Moreover, these plants were maintained under the same environmental conditions for 5 years and hence, can be considered as very stable and highly reliable taxonomic features of the plant.

The principle component analysis shows that 3-leaflet bearing types (except GPPW - 3 & GPWP - 3) are well separated from rest of the populations at a distance of 80-85% in the 3<sup>rd</sup> cluster (Figure 1 & Figure 2). Interestingly, there is a close genetic relatedness among the populations collected from the same geographical area [(MGMD - 3 and MGNG - 3 from intermediate zone (IL); GPPW - 3 & GPWP - 3 from low country wet zone (WL); NEKP - 3, NEMR - 3 from up country wet zone (WU)]. The presence of phenotypic variation, which could be correlated with the geographical distribution, was suggested by previous studies and results of the present study have proved it [2].

As shown in Figure 1 & Figure 2, the population collected from Ritigala area (APRG - 5) has got well separated from other populations at a distance of 95% in the cluster and along the first axis at one extreme end (left side) in principle component analysis. This is acceptable as it bears several unique characters such as undulate distal leaf margin, crenate proximal leaf margin, wide leaves, droopy plants, exceptionally high vein islet number, veinlet termination number, low number of flowers per inflorescence, a globose shape

style base and a very low number of seeds per fruit. The microclimate surrounding Ritigala reserve forest is very much different from that in other locations. This might have favored the growth and survival of APRG - 5 population. These Geographically isolated populations tend to become genetically specific due to the absence of mixing of genes with other populations. The phenetic distance observed between APRG - 5 population and other populations in the dendrogramme support the idea that this population has diverged in another direction. In the process of evolution, because of isolation and adaptation, vegetative parts of organism change prior to reproductive parts. Therefore, observations of this study are in accordance with the natural process of speciation and evolution and strengthen the idea of placing APRG - 5 population in a separate sub specific taxon of *M. pinnata*. A broader comparison with respect to characters of other disciplines such as micromolecules, proteins and DNA might help to decide the exact position or taxonomic status (whether it has to be a different variety or sub species). Presence of phenotypic variation, which could be correlated with the geographical distribution, was suggested in the Flora of Ceylon and results of this research have proved it. Further, the observed separation of the 3 - leaflet group was similar to the findings reported by previous workers who analyzed eight morphological characters together with some DNA evidence in five populations of *M. pinnata* [7].

Populations collected from Gampaha district (GPPW - 3, GPWP - 3) and Moneragala district (MGMD - 3, MGNG - 3) have grouped closely in dendrogramme. Clustering of populations GPPW - 3, GPWP - 3 is acceptable as these populations bear many similar morphological features such as the habit of the plant (medium sized plants), smooth shiny texture of the leaves, terminal leaflet length, shape of the terminal leaflet base (acute), leaf margin (entire), and proximal leaflet margin (undulate). It shows that, populations collected from the same area have some kind of genetic relationship, which might not be noticeable at once

when we consider the morphological traits in these populations.

Populations bearing more than three leaflets except NEKP-3 got separated from others at a distance of about 75% (Cluster 3b). In the cluster, NEKP - 3 has got separated from other populations at a distance of about 80%. Since all 3- leaflet types were clustered together, in both dendrogramme and Principle component analysis, it clearly indicates a close genetic relatedness among 3 - leaflet bearing populations (Figure 1 & Figure 2).

### 3.2. Sequential Indented Key Based on Vegetative Morphology

Leads of each couplet of sequential indented key prepared give reliable characters, which could be used to differentiate very closely resembling populations of *M. pinnata*.

All characters used in the key are vegetative and therefore, could be used even in the non-flowering season of the plant. Since flowering is very rare in certain populations [3], it is essential to prepare a key based on vegetative characters. Moreover, these plants were maintained under the same environmental conditions for 5 years and hence, can be considered as very stable and highly reliable taxonomic features of the plant.

The principle component analysis shows that 3 - leaflet bearing types (except GPPW - 3 & GPWP - 3) are well separated from rest of the populations at a distance of 80-85% in the third cluster (Figure 1 & Figure 2). Interestingly, there is a close genetic relatedness among the populations collected from the same geographical area [(MGMD - 3 and MGNG - 3 from intermediate zone (IL); GPPW - 3 & GPWP - 3 from low country wet zone (WL); NEKP - 3, NEMR - 3 from up country wet zone (WU)]. The presence of phenotypic variation, which could be correlated with the geographical distribution, was suggested by previous studies and results of the present study have proved it [2].

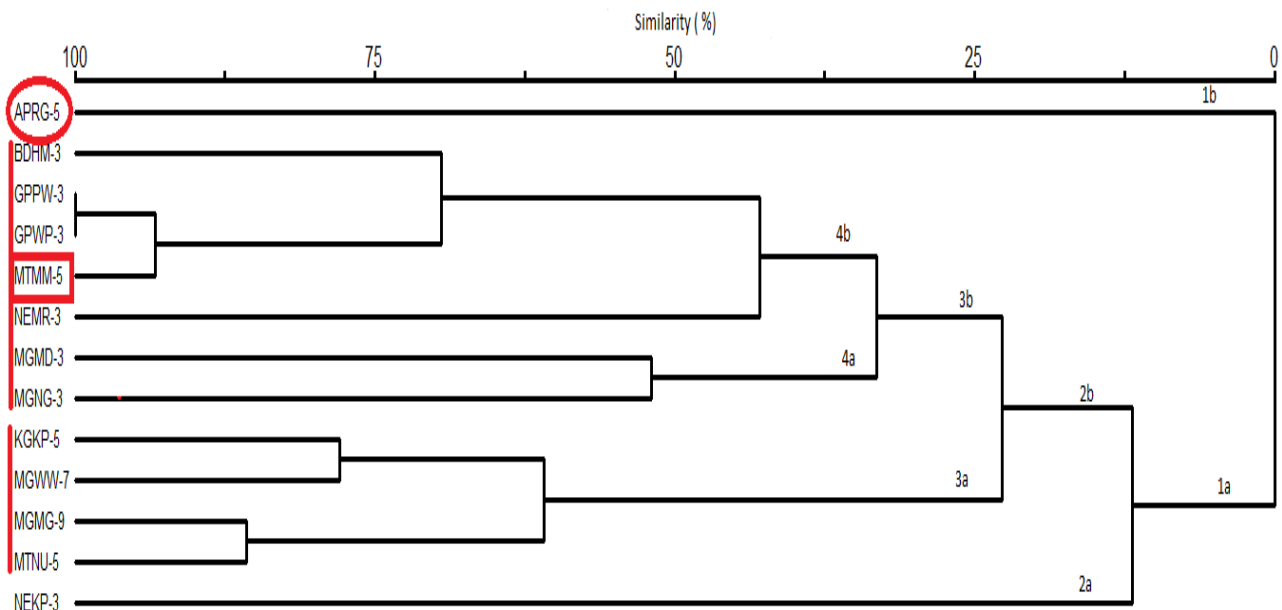
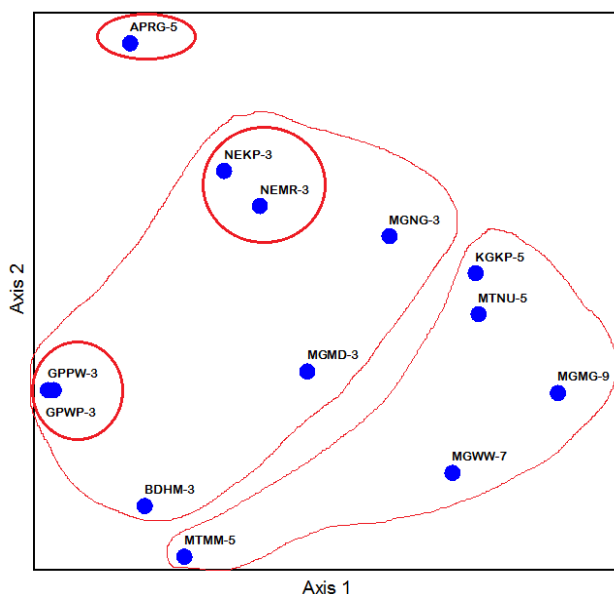


Figure 1. Dendrogramme generated by combining 45 polymorphic vegetative and reproductive characters of 13 populations of *Munronia pinnata*



**Figure 2.** Principle Component analysis on basis of 45 polymorphic vegetative and reproductive characters of 13 populations of *Munronia pinnata*

### 3.3. Sequential Indented Key Prepared to Identify Different Populations of *Munronia pinnata*

1. Number of leaflets three ... GPPW-3, NEMR-3, NEKP-3, MGNG-3, BDHM-3, MGMD-3, GPPW-3
2. End leaf margin entire... EMR-3, NEKP-3, BDHM-3, GPWP-3
3. Side leaflet base oblique ... NEMR-3
3. Side leaflet base not oblique... NEKP-3, GPWP-3, BDHM-3
4. End leaflet veins 14... BDHM-3
4. End leaflet veins less than 14... NEKP-3, GPWP-3
5. Side leaflet margin undulate..... GPWP-3
5. Side leaflet margin not undulate .... NEKP-3
2. End leaflet margin not entire... MGMD-3, MGNG-3, GPPW-3
6. End leaflet veins less than 10 ... MGNG-3
6. End leaflet veins more than 10 ..... MGMD-3, GPPW-3
7. Side leaflet primary-secondary vein angle at base 45-60°..... GPPW-3
7. Side leaflet primary-secondary vein angle less than 45-60° ..... MGMD-3
1. Number of leaflets more than three..... APRG-5, MTMM-5, MTNU-5, MGGMG-9, MGWW-7, KGKP-5
8. Secondary-tertiary vein angle less than 60°... MTMM-5
8. Secondary-tertiary vein angle not less than 60°.... APRG-5, MTNU-5, MGGMG-9, MGWW-7, KGKP-5
9. End leaflet veins less than 10 .. MTNU-5
9. End leaflet veins more than 10 APRG-5, MGGMG-9, MGWW-7, KGKP-5
10. End leaf margin not dentate.... APRG-5
10. End leaf margin dentate ... MGGMG-9, MGWW-7, KGKP-5
11. Side leaflet apex acute- MGGMG-9
11. Side leaflet apex not acute... MGWW-7, KGKP-5
12. Side leaflet base rounded.... MGWW-7
12. Side leaflet base not rounded ..... KGKP-5

## 4. Conclusions

Population collected from Ritigala forest (APRG-5) is distantly related to all others and deserved placing as a sub specific taxon of *M. pinnata*. Further, populations collected from the same geographical area (Gampaha and Moneragala districts) seem to be closely related with one another *M. pinnata* populations could be identified even in the absence of flowers using the key constructed in the study.

## Acknowledgement

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## Annexures

### Annexure 1

**Table 2. List of morphological characters together with their character states recorded in *Munronia pinnata***

Character	Character state
A. Vegetative characters	
Plant habit	Droopy (1), Erect (2), Intermediate (3)
Nature of the plant	Robust (1), Medium (2), Small (3)
Plant height (cm)	<10 (1), 10-14 (2), 15-19 (3), >20 (4)
No. of leaflets	3 (1), 5 (2), 7 (3), 9-11 (4)
Stem trichomes	Present (1)
Stem trichome type	Glandular (1), simple unicellular (2), bifurcate (3)
Phyllotaxy	Whorled (1)
Leaf venation	Pinnately reticulate (1)
Leaf texture	Velvet (1), Smooth shiny (2), Rough (3)
Leaf type	Imparipinnate (1)
Petiole length (cm)	<4 (1), 4-6 (2), >6 (3)
Leaf length (cm)	<10 (1), 10-15 (2), >15 (3)
Leaf width (cm)	<5 (1), 5-7 (2), >7 (3)
Leaf L/W ratio	1-2 (1), 2.1-3 (2), >3 (3)
Terminal leaflet length (cm)	<6 (1), 6-8 (2), >8 (3)
Terminal leaflet width (cm)	<3 (1), >3 (2)
Terminal leaflet L/W ratio	1-2 (1), 2.1-3 (2), >3 (3)
Terminal leaflet apex	Acute (1), Obtuse (2)
Terminal leaflet base	Rounded (1), Oblique (2)
Terminal leaflet margin	Entire (1), Dentate end leaf lobed (2), Undulate (3)
Number of veins in terminal leaflet	<10 (1), 10-12 (2), >12 (3)
Proximal leaflet length (cm)	3-4 (1), 4.1-5.1 (2)
Proximal leaflet width (cm)	<2 (1), 2 (2), >2 (3)
Proximal leaflet L/W ratio	1-2 (1), >2 (2)
Proximal leaflet apex	Acute (1), Obtuse (2)
Proximal leaflet base	Rounded (1), Oblique (2)
Proximal leaflet margin	Entire (1), Dentate (2), Undulate (3) crenate (4)
Proximal leaflet petiole	Prominent (1), Not prominent (2)
Number of veins in proximal leaflet	<8 (1), 8 (2), >8 (3)
Stipules	Absent (1)
Leaf trichomes	Present (1)
P. vein to secondary vein angle (base)	<450, (1), 45-600 (2)
P. vein to secondary vein angle (apex)	<450, (1), 45-600 (2)
S. vein to tertiary vein angle	45-600 (1), 600 - 900 (2), >900 (3)
Areole type	Polygonal (1)
Vein islet No.	0.5-1 (1), 1.1-1.5 (2), 1.6-2 (3), 2.1-2.5 (4), 2.5<(5)
Vein termination No.	<3.5(1),3.6-.5 (2), >5 (3)
B. Reproductive characters	
Number of flowers/inflorescence	<4 (1), 4 (2), >4 (3)
Corolla type	Salver form (1)
Flower color	white (1)
Flower symmetry	Actinomorphic (1)
Corolla length (cm)	<2.5 (1), 2.5-3 (2)
Pedicel	Present (1)
Number of sepals	5 (1)
Sepal trichome upper surface	Present (1)
Sepal trichome lower surface	Present (1)
Sepal length (mm)	<6 (1), >6 (2)
Sepal width (mm)	<1.5 (1), >1.5 (2)
Number of petals	5 (1)
Petal length (cm)	<1.5, (1) 1.5- 2 (2), >2 (3)
Sepal L/W ratio	2-4.9 (1), 5-7 (2)
Petal width (cm)	<0.5, (1) 0.5-0.7 (2), >0.7(3)
Petal L/W ratio	1.5-2.5 (1), 2.6-3.5 (2), 3.5<(3)
Flower length	2.5-3 (1), 3.1-3.5 (2), 3.6<(3)
Petal apex	Acute (1), Truncate (2), Rounded

	(3)
Petal venation	Pinnately reticulate (1)
Petal upper surface trichomes	Absent (1)
Petal lower surface trichomes	Dense (1)
Petal margin trichomes	Present (1), Absent (2)
Androceum type	Monodelphous (1)
Staminal tube length (cm)	2> (1), 2-2.5 (2), >2.5
Anther filament attachment	Dorsifixed (1)
Anther collar attachment	Double cordate (1)
Style length (cm)	:2-2.5 (1), 2.6-3(2)
Anther apex	Mucronate (1)
Stigma shape	Globose (1)
Style length (cm)	<2.5 (1), >2.5 (2)
Stigma hairs	Absent (1)
Ovary	Superior (1), Inferior (2)
Number of carpels	5 (1)
Placentation	Axillary (1)
Fruit type	Capsule (1)
Number of seeds per fruit	<7 (1), 7-9 (2), >9 (3)
Seed colour	Brown (1)
Seed length (mm)	<4 (1), >4 (2)
Seed width (mm)	<2 (1), >2 (2)
Seed L/W ratio	1-2 (1), >2 (2)

**Table 3. List of morphological characters together with their character states recorded in *Munronia pinnata***

Character	Character state
A. Vegetative characters	
Plant habit	Droopy (1), Erect (2), Intermediate (3)
Nature of the plant	Robust (1), Medium (2), Small (3)
Plant height (cm)	<10 (1), 10-14 (2), 15-19 (3), >20 (4)
No. of leaflets	3 (1), 5 (2), 7 (3), 9-11 (4)
Stem trichomes	Present (1)
Stem trichome type	Glandular (1), simple unicellular (2), bifurcate (3)
Phyllotaxy	Whorled (1)
Leaf venation	Pinnately reticulate (1)
Leaf texture	Velvet (1), Smooth shiny (2), Rough (3)
Leaf type	Imparipinnate (1)
Petiole length (cm)	<4 (1), 4-6 (2), >6 (3)
Leaf length (cm)	<10 (1), 10-15 (2), >15 (3)
Leaf width (cm)	<5 (1), 5-7 (2), >7 (3)
Leaf L/W ratio	1-2 (1), 2.1-3 (2), >3 (3)
Terminal leaflet length (cm)	<6 (1), 6-8 (2), >8 (3)
Terminal leaflet width (cm)	<3 (1), >3 (2)
Terminal leaflet L/W ratio	1-2 (1), 2.1-3 (2), >3 (3)
Terminal leaflet apex	Acute (1), Obtuse (2)
Terminal leaflet base	Rounded (1), Oblique (2)
Terminal leaflet margin	Entire (1), Dentate end leaf lobed (2), Undulate (3)
Number of veins in terminal leaflet	<10 (1), 10-12 (2), >12 (3)
Proximal leaflet length (cm)	3-4 (1), 4.1-5.1 (2)
Proximal leaflet width (cm)	<2 (1), 2 (2), >2 (3)
Proximal leaflet L/W ratio	1-2 (1), >2 (2)
Proximal leaflet apex	Acute (1), Obtuse (2)
Proximal leaflet base	Rounded (1), Oblique (2)
Proximal leaflet margin	Entire (1), Dentate (2), Undulate (3) crenate (4)
Proximal leaflet petiole	Prominent (1), Not prominent (2)
Number of veins in proximal leaflet	<8 (1), 8 (2), >8 (3)
Stipules	Absent (1)
Leaf trichomes	Present (1)
P. vein to secondary vein angle (base)	<450, (1), 45-600 (2)
P. vein to secondary vein angle (apex)	<450, (1), 45-600 (2)
S. vein to tertiary vein angle	45-600 (1), 600 - 900 (2), >900 (3)
Areole type	Polygonal (1)
Vein islet No.	0.5-1 (1), 1.1-1.5 (2), 1.6-2 (3), 2.1-2.5 (4), 2.5<(5)
Vein termination No.	<3.5(1),3.6-.5 (2), >5 (3)
B. Reproductive characters	
Number of flowers/inflorescence	<4 (1), 4 (2), >4 (3)
Corolla type	Salver form (1)
Flower color	white (1)
Flower symmetry	Actinomorphic (1)
Corolla length (cm)	<2.5 (1), 2.5-3 (2)
Pedicel	Present (1)
Number of sepals	5 (1)
Sepal trichome upper surface	Present (1)
Sepal trichome lower surface	Present (1)
Sepal length (mm)	<6 (1), >6 (2)
Sepal width (mm)	<1.5 (1), >1.5 (2)
Number of petals	5 (1)
Petal length (cm)	<1.5, (1) 1.5- 2 (2), >2 (3)
Sepal L/W ratio	2-4.9 (1), 5-7 (2)
Petal width (cm)	<0.5, (1) 0.5-0.7 (2), >0.7(3)
Petal L/W ratio	1.5-2.5 (1), 2.6-3.5 (2), 3.5<(3)
Flower length	2.5-3 (1), 3.1-3.5 (2), 3.6<(3)
Petal apex	Acute (1), Truncate (2), Rounded



19. Terminal leaflet margin	Undulate	Entire	Entire end leaf lobed	Entire	Dentate end leaf lobed	Dentate end leaf lobed	Dentate end leaf lobed	Dentate end leaf lobed	Dentate end leaf lobed	Entire	Dentate end leaf lobed	Dentate end leaf lobed	Entire
20. Number of veins in Terminal leaflet	14	14	14	12	10	11	10	8	10	10	10	10	12
21. Proximal leaflet length (cm)	3	5	3	3	3	3	3	3	3	3	3	3	3
CHARACTER	APRG-5	BDHM-3	GPPW-3	GPWP-3	KGKP-5	MGM-D-3	MGM-G-9	MGN-G-3	MGW-W-7	MTM-M-5	MTNU-5	NEKP-3	NEMR-3
22. Proximal leaflet width (cm)	1.5	3	1.5	1	1.2	2	1.5	1.5	2	1.5	1.7	1.2	2.5
23 P. leaf L/W ratio	2	1.6	2	3	2.5	1.5	2	2	1.5	2	1.7	2.5	1.2
24 Proximal leaflet apex	Obtuse	Acute	Acute	Acute	Obtuse	Acute	Acute	Obtuse	Obtuse	Acute	Acute	Obtuse	Acute
25. Proximal leaflet base	Oblique	Round	Round	Round	Oblique	Round	Oblique	Round	Round	Oblique	Oblique	Oblique	Oblique
26 Proximal leaflet margin	Crenate	Entire	Undulate	Undulate	Dentate	Dentate	Dentate	Dentate	Dentate	Undulate	Dentate	Dentate	Entire
27. Proximal leaflet petiolule	NP	P	P	P	P	NP	NP	NP	NP	P	NP	P	P
28 No. veins in proximal leaflet	8	10	6	6	8	8	8	8	8	10	8	8	8
29. Stipules*	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
30. Leaf trichomes *	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present
31. P-S angle(a)	45-60	45-60	45-60	45-60	45-60	45-60	< 45	45-60	45-60	45-60	45-60	45-60	45-60
32. P-S angle (b)	< 45	< 45	45-60	45-60	45-60	< 45	< 45	< 45	45-60	< 45	< 45	45-60	< 45
33. S-T angle	60-90	60-90	60-90	60-90	60-90	60-90	60-90	90	60-90	45-60	60-90	60-90	60-90
Reproductive characters													
34. No. of flowers in inflorescent	4	2	2	2	2	3	2	3	2	3	2	6	2
35. Corolla type*	S	S	S	S	S	S	S	S	S	S	S	S	S
36. Flower colour*	White	White	White	White	White	White	White	White	White	White	White	White	White
37. Flower symmetry *	AM	AM	AM	AM	AM	AM	AM	AM	AM	AM	AM	AM	AM
38. Corolla length (cm)	2.4	2.8	3	2.2	2.5	2	3.0	2	2.6	3	3	2.5	2.5
39. Pedicel *	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present
	APRG-	BDHM	GPPW	GPWP	KGKP	MGM	MGM	MGN	MGW	MTM	MTNU	NEKP-	NEMR





66. Ovary*	Superior	Superior	Superior	Superior	Superior	Superior	Superior	Superior	Superior	Superior	Superior	Superior	Superior
67. No. of Carpels*	5	5	5	5	5	5	5	5	5	5	5	5	5
68. Placentation*	Axillary	Axillary	Axillary	Axillary	Axillary	Axillary	Axillary	Axillary	Axillary	Axillary	Axillary	Axillary	Axillary
	APRG-5	BDHM-3	GPPW-3	GPWP-3	KGKP-5	MGM-D-3	MGM-G-9	MGN-G-3	MGW-W-7	MTM-M-5	MTNU-5	NEKP-3	NEMR-3
69. Fruit type*	Capsule	Capsule	Capsule	Capsule	Capsule	Capsule	Capsule	Capsule	Capsule	Capsule	Capsule	Capsule	Capsule
70. Seed No.	5	8	7	8	5	7	9	8	5	8	6	10	8
71. Seed colour*	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown
72 Seed length (mm)	4	4	4	4	4	4.5	4	4	4	4	4	4	4
73. Seed width (mm)	2.5	2.5	2	2.5	2	2	2	2	2	2.5	2.5	2.5	2
74 Seed L/W	1.6	1.6	2	1.6	2	2.2	2	2	2	1.6	1.6	1.6	2
75. Areole shape	PG	PG	PG	PG	PG	PG	PG	PG	PG	PG	PG	PG	PG
76. Vein islet No	3.70	1.85	2.78	2.78	1.39	1.39	0.93	1.39	1.39	2.31	0.93	1.85	1.85
77. Vein let termin. No.	7.41	3.70	6.45	6.48	3.24	2.78	3.24	3.24	3.24	5.09	3.24	3.70	3.70

PG-Polygonal; P-Prominent; NP-Not prominent; IM-Intermediate; D-Droopy; E-Erect \*Denotes the monomorphic characters; PR- Pinnately reticulate; MD- Monodelphous; DC-Double cordate; AM- Actinomorphic; S- Salverform; IP-Imparipinnate; P-S angle- Primary-secondary vein angle; S-T angle-secondary vein- tertiary vein angle; DF-Dorsifixed;

**Annexure 2**

**Table 5. Numerical data table for cluster analysis of different populations of *M. pinnata***

Character	Population												
	MGM D-3	MGM G9/11	GPW P-3	NGN G-3	NEM R-3	BDH M-3	APR G-5	MTM M-5/7	NEK P-3	MTN U-5	GPP W-3	MGW W-7	KGK P-5
a. Vegetative characters													
Plant habit	3	3	1	3	2	3	1	2	3	2	3	3	2
Plant size (Nature)	2	2	2	3	3	2	1	1	2	2	2	1	2
Plant height(cm)	2	1	2	3	1	2	3	1	3	2	2	2	1
Leaflet no.	1	4	1	1	1	1	2	3	1	2	1	3	2
Stem trichome	1	1	1	1	1	1	1	1	1	1	1	1	1
Phyllotaxy	1	1	1	1	1	1	1	1	1	1	1	1	1
Leaf venation	1	1	1	1	1	1	1	1	1	1	1	1	1
Leaf texture	2	3	4	3	1	1	1	2	1	3	2	3	3
Leaf form	1	1	1	1	1	1	1	1	1	1	1	1	1
Petiole length (cm)	2	1	2	2	1	3	1	3	1	1	2	1	2
Leaf length (cm)	3	3	2	1	1	3	2	2	1	1	2	2	1
Leaf width (cm)	1	3	1	1	1	1	3	1	3	2	1	1	2
E.leaflet length(cm)	3	2	2	1	1	3	1	2	2	1	2	1	1
E.leaflet width (cm)	2	2	1	1	1	1	1	1	1	1	1	2	1
End leaflet apex	2	2	1	2	2	1	2	1	1	1	1	2	2
End leaflet base	1	1	1	1	1	1	1	1	1	1	1	1	1
End leaflet margin	2	2	1	2	1	1	3	3	1	2	3	2	2
E leaflet vein no.	2	2	2	1	2	3	3	2	2	2	2	2	2
Side leaflet length	1	1	1	1	1	1	2	1	1	1	2	1	1
Side leaflet width	3	3	3	3	2	3	2	2	3	2	3	2	1

Side leaflet apex	1	1	1	2	1	1	2	1	1	1	1	2	2
Side leaflet base	1	2	1	1	2	1	2	2	1	2	1	1	2
Side leaflet margin	2	2	3	2	1	1	4	3	1	2	3	2	2
Side leaflet petiolule	2	2	1	2	1	1	2	1	1	2	1	2	1
Side leaflet vein no.	2	2	1	2	2	3	2	3	2	2	1	2	2
Stipules	2	2	2	2	2	2	2	2	2	2	2	2	2
Leaf Trichome	1	1	1	1	1	1	1	1	1	1	1	1	1
P-S angle (a)	2	1	2	2	2	2	2	2	2	2	2	2	2
P-S angle (b)	1	1	2	1	1	1	1	1	2	1	2	2	2
S-T angle	2	2	2	2	2	2	2	2	2	2	2	2	2
Epidermal cell	3	1	3	2	3	1	1	2	3	3	1	1	1
Stomata index	1	1	2	1	1	1	1	3	1	1	2	2	1
Sub. Cells	1	2	2	2	2	2	2	2	2	2	2	2	2
b. Reproductive characters													
No. of flowers in inflo.	1	1	1	1	1	1	2	1	2	1	1	1	1
Corolla type	1	1	1	1	1	1	1	1	1	1	1	1	1
Flower colour	1	1	1	1	1	1	1	1	1	1	1	1	1
Flower symmetry	1	1	1	1	1	1	1	1	1	1	1	1	1
Corolla length (cm)	1	2	1	1	1	2	1	2	2	2	2	2	2
Pedicel	1	1	1	1	1	1	1	1	1	1	1	1	1
No. of sepals	1	1	1	1	1	1	1	1	1	1	1	1	1
Sepal trichome (u)	1	1	1	1	1	1	1	1	1	1	1	1	1
Sepal trichome (l)	1	1	1	1	1	1	1	1	1	1	1	1	1
Sepal length (mm)	1	1	2	1	1	2	1	2	1	1	2	1	1
Sepal width (mm)	1	2	1	1	1	1	1	1	1	1	2	1	1
No. of petal	1	1	1	1	1	1	1	1	1	1	1	1	1
Petal length (cm)	1	2	2	1	1	2	1	2	2	3	2	3	3
Petal width (cm)	1	1	3	1	1	2	1	3	3	2	2	3	2
Petal apex	1	1	1	2	1	1	1	1	1	1	1	2	2
Petal margin tri	1	1	1	1	1	1	1	1	1	1	1	1	1
Petal tri lower	1	1	1	1	1	1	1	1	1	1	1	1	1
Petal tri upper	1	1	1	1	1	1	1	1	1	1	1	1	1
Petal venation	1	1	1	1	1	1	1	1	1	1	1	1	1
Androceium type	1	1	1	1	1	1	1	1	1	1	1	1	1
Stamina tube L (cm)	1	2	2	1	1	2	1	2	1	2	1	1	1
Anther fil. Attach.	1	1	1	1	1	1	1	1	1	1	1	1	1
Anther collar attach.	1	1	1	1	1	1	1	1	1	1	1	1	1
Anther apex	1	1	1	1	1	1	1	1	1	1	1	1	1
Stigma appendages	1	1	1	1	1	1	1	1	1	1	1	1	1
Stigma shape	1	1	1	1	1	1	1	1	1	1	1	1	1
Style length (cm)	2	3	2	1	1	3	2	3	1	3	3	3	2
Style base	1	1	1	1	1	1	1	1	1	1	1	1	1
Stigma hairs	2	2	2	2	2	2	2	2	2	2	2	2	2
Ovary	1	1	1	1	1	1	1	1	1	1	1	1	1
Placentation	1	1	1	1	1	1	1	1	1	1	1	1	1
Carpel No	1	1	1	1	1	1	1	1	1	1	1	1	1
Fruit type	1	1	1	1	1	1	1	1	1	1	1	1	1
Seed No.	1	2	2	2	2	2	1	2	3	1	2	1	1
Seed colour	1	1	1	1	1	1	1	1	1	1	1	1	1
Seed length (mm)	2	1	1	1	1	1	1	1	1	1	1	1	1
Seed width (mm)	1	1	2	1	1	2	2	2	2	2	1	1	1