PROJECT REPORT: FINAL

UGC–MRP: F. No. 40–327/2011 (SR); dt. 30th June, 2011

TITLE OF THE PROJECT

"FOLIAR ARCHITECTURE OF INDIAN MEMBERS OF THE FAMILY STERCULIACEAE AND ITS SYSTEMATIC RELEVANCE"

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1. INTRODUCTION

The family Sterculiaceae DC. is usually having trees and shrubs, rarely herbs or lianas. The family consist about 1500 species under 67 genera and this has made it much resourceful and unfathomable among the flowering plants (Mabberley, 2008). The family enjoys mostly tropical and subtropical distribution with occasional occurrence in the temperate regions of the world. Owing to its high economic value, particularly for the timber yielding, medicinal and horticultural aspects of the members of the family, several studies have been carried out in different perspectives.

In India the family is represented by 68 species distributed under 19 genera (Malick, 1993). Among the Indian representatives, members of the genera viz. *Heritiera*, *Pterospermum* produce very elastic and durable timbers. The seeds of many members like *Heritiera fomes, Pterygota alata, Sterculia foetida, S. lanceifolia, S. urens,* etc. are edible. The gum produced by *Sterculia urens* is used as medicine. The bark of *Sterculia villosa* yields a fiber used for rope making. Several members have ornamental value such as *Cola acuminata, Dombeya* spp., *Guazuma tomentosa, Pentapetes phoenicea* etc. and are cultivated in gardens for their showy flowers. The medicinally important members are *Helicteres isora, Theobroma cacao,* etc. Moreover, cocoa is obtained from *Theobroma cacao*, which is now cultivated as cash crop in the coastal regions of Karnataka and used in the manufacture of chocolate and different types of soft drinks (Malick, 1993).

The family Sterculiaceae is fairly well defined both taxonomically and palynologically (Rao, 1950; Sharma, 1969; Malick and Safui, 1982). The phytogeography and economic aspects of the family had been done by Datta (1960). Some ethnobotanical studies had also been carried out by Dagar (1989) while studying the folk medicines of Nicobarese tribals and by Kamble *et al.* (2008) on the context of traditional medicine of Bhilla tribe of Maharashtra.

The systematic use of the anatomical features as well as leaf architecture for some families has been emphasized by different workers (Dickison, 1973; Hickey and Wolfe, 1975; Hickey and Taylor, 1991; Fuller and Hickey, 2005). Later few works on this aspect have been done in the form of scattered papers by Hussin and Sani (1996) and Hussin *et al.* (1997). The anatomical study of this family was done long back by Metcalfe and Chalk (1950); however the Indian representatives were less in this account. Thus thorough anatomical study of the Indian members of the family has not yet been undertaken. The foliar architecture along with nodal and petiolar anatomy of Malvaceae, a related family has already been done by Mandal (2010) and

Mandal *et al*. (2010). But this aspect for Sterculiaceae is totally neglected. To evaluate the systematic relationship and phylogeny of the plants, vegetative anatomy as well as foliar architecture is also necessary as morphologically based phylogeny provides a more coherent understanding of the evolutionary history of different plant group than do recent phylogenetic hypotheses based on genetic data (Fuller and Hickey, 2005).

The study was thus an endeavor to fill up the lacuna that existed in the anatomical and foliar architectural studies of the Indian members of the family Sterculiacaeae. The purpose of the work was to reveal vital characteristics in the different members based on which they can be easily identified, even in non-floriferous or crude conditions. The essential features thus can be taken into account as taxonomic markers and will be helpful to the plant systematists for proper identification of these plant species and also to evaluate the interspecific relationship of the members.

2. REVIEW OF LITERATURES

Nodal anatomy:

The application of the systematic anatomy in solving practical problem has often been stressed in the treatment of taxonomic investigations (Soleredor, 1908; Metcalfe and Chalk, 1950). The attempt of investigation started from the time of Soleredor (1908) and then the nodal anatomy of angiosperms and its taxonomic significance have been much discussed by Sinnott (1914), Bailey (1956), Howard (1970), Esau (1979). But, unfortunately the nodal anatomical study is almost lacking in Indian Sterculiaceae except the effort of Metcalfe and Chalk (1950), dealing with very few Indian representative.

Petiolar anatomy:

Grew (1675) was the first botanist to recognize that a cross section of a petiole can play an important role in plant systematics. Howard (1962, 1974, 1979) advocated that petiolar anatomy along with combination of nodal configuration and other associated characters can play an important role in systematic study.

The petiole vasculature of the Sterculiaceae and its systematic significance had been considerably amplified by the investigation of Dehay (1941). Metcalfe and Chalk (1950) had also studied the petiolar anatomy of the family Sterculiaceae and evaluated some important anatomical aspects of this family. The petiolar anatomy of *Pterygota alata* and some species of *Sterculia* in relation to systematic study had been done by Hussin and Sani (1996, 1998). Hussin *et al*. (1997) had studied the petiolar anatomical aspects in some members of *Heritiera*.

Foliar vasculature:

It was Foster (1952) and his associates who had focused a new light on venation pattern of angiosperms. Foster (1952), Pray (1954) and Slade (1957) had considered foliar venation pattern from ontogenic point of view.

Hickey and Doyle (1972), Hickey (1973, 1979), Hickey and Wolfe (1975) had presented the comprehensive leaf architectural patterns of woody dicotyledons, defined new patterns and had shown their evolutionary significance. Dilcher (1974) also provided an important view regarding the same. Recent works on the importance and taxonomic evaluation of foliar architectures are those of Pole (1991) and Roth *et al.* (2001).

The revisionary work of Indian Sterculiaceae was provided by Malick (1993), while the anatomical study of very few Indian members of Sterculiaceae was executed by Metcalfe and Chalk (1950). In addition, few fragmentary works in the form of scattered papers have been published by Shanmukha Rao (1987), Shanmukha Rao and Ramayya (1983), Inamdar *et al.* (1983), Hussin and Sani (1996, 1998) and Hussin *et al.* (1997) on Malayan taxa, some of which are with common distribution to India. The ontogeny of stomata and trichomes of *Heritiera fomes* had been done by Das and Ghosh (1993). However, detail anatomical as well as micromorphological investigation is still not satisfactory in the Indian context. The foliar architectural study including the vasculature pattern on node–petiole continuum of this family needs special attention from taxonomic view points.

3. OBJECTIVES

1. Attempts will be made to find out how far the vegetative anatomy along with leaf architecture is in agreement with the present taxonomic classification and what changes it suggests.

2. To identify the key characters help in identification of different taxa in non-floriferous condition as well as fragmented or distorted materials.

3. Attempts will be made to ascertain which features in the leaf are peculiar to the family, and imply relationship, and which are to be encountered in unrelated families.

4. To represent the stages in phylogenetic development.

5. An attempt will be made to evaluate the present state of systematic anatomy.

6. To understand how the ecological situations influences the changes on vegetative anatomy and foliar architectural pattern.

4. MATERIALS AND METHODS

4.1 *Materials:*

Materials were collected from different parts of India. Proper identification of specimens were carried out with the help of relevant literatures (Masters, 1874; Malick, 1993) and even matched with earlier collections deposited at CUH and CAL. Portions of petioles were preserved in FAA [5ml Formaldehyde (40%) : 5ml Glacial Acetic Acid : 90ml Alcohol (70%)] for further detailed anatomical study.

The study deals with 61 species out of 68 species recorded from India. The rest seven species could not be collected because of rarity of their occurrence as well as few of them are known only from type collections.

Dried Herbarium specimens were prepared through conventional methods (Jain & Rao, 1977; Lakshminarasimhan, 2012) and are deposited at Calcutta University Herbarium (CUH).

4.2 *Methods:*

4.2.1 Morphology- The mature leaves were taken for description of the morphological features, viz. shape and size of lamina, apex, margin, base, surface and venation patterns, along with the shape and size of petioles, including stipules.

4.2.2 Anatomy-The anatomical studies of the nodes including the portion of internodal region in continuation to the petiolar anatomy of the same material were done to get the prolongation of vascularization pattern. Free hand transverse serial sections were made from the fresh materials, then stained with 1% safranin and mounted in 10% glycerin. In case of dried specimens and for some fresh materials where free hand sections were not possible the microtome sections of 8–10 μm were done following the method of Johansen (1940). A flow chart has been provided below.

Specimens boiled in water (for rehydration of tissues)

⬇

Fixed in FAA for12 hrs

⬇

Wax embedding and sectioning (Johansen, 1940)

⬇

All sections dehydrated, double stained with safranin and light green and mounted in canada balsam

The diagrammatic anatomical presentations of the internodes, nodes and petioles as in transverse sections were drawn under camera lucida and few photographs of the typical features of the studied specimens were also taken. In case of petiole, three distinct zones, viz. proximal, middle and distal were selected to get the continuation of the vasculature. However, in some cases in addition to this other portions of petiole, like, towards middle, towards distal, and even extreme distal end were considered for better understanding of the vasculature of the petiole.

Cellular features, arrangement and inclusions were also studied.

4.2.3 Venation of lamina - Leaf blades were cut into convenient pieces mostly selected from a portion of 1/3 from the apex and 2/3 from the base. Pieces were treated with 2.5% NaOH solution for clearing (Arnott, 1959; Hickey, 1973, 1979; Melville, 1976). The dehydrated materials were stained in 2% safranin in 70% ethanol. After gradual dehydration the permanent slides were prepared by mounting in canada balsam. Drawings were made under camera lucida and a few photographs were taken as well. Inclusions present were recorded and studied in details. The descriptions are based on the terminology used by Hickey (1973, 1979).

4.2.4 Dermal features and inclusions – The dermal study is done following Dilcher (1974) with some modifications (wherever needed). The steps are given below:

Strips of leaf blades taken from mid-way between leaf apex and base

⬇

Oxidized with 50-70% HNO_3 and washed in water (5-10 min)

⬇

Reagents decanted; water added, decanted again

⬇

Distilled water added and kept for 30min -1h

⬇

Both the leaf surfaces separate. Peelings kept on clean glass slides, stained with 5% aqueous safranin and mounted in phenol-glycerin

⬇

Types of trichomes, scales, stomata and crystals studied and drawn

4.2.5 Morphometric analysis– 98 variables, including both morphological and anatomical characters were measured and recorded from 61 Indian species of this family and a matrix of these species was used in multivariate analysis. Cluster analyses using the UPGMA method (unweighted pair-group method with arithmetic averages) were carried out (Sneath and Sokal, 1973), from which a dendrogram representing the phenetic relationships among the taxa was constructed. All analyses were carried out using the software STATISTICA (version 9.0).

4.2.6 Key to the species– Key to the species under each genus and infra specific taxa, whenever there are more than one under a species, based on foliar architecture and anatomical features is provided.

8. OBSERVATIONS

I. STUDY OF STEM AND PETIOLE

8.1 *Internodal anatomy:*

The inter-nodal configuration in all the studied species is found to be more or less same. The outline is more or less circular to oval. The vascular strand is open and collateral. Amount of xylem and phloem varies accordingly. Sclerenchymatous fibre cells are found to remain embedded within the phloem layer and even at the rind of the phloem strands (Fig.3.A & C). However, in *Pentapetes phoenicea*, fibre cells are totally absent in the phloem strand (Fig.3.D). Presence of mucilaginous cavities, trichomes and crystals are also taken into account for comparative analyses.

8.2 *Nodal anatomy:*

The study reveals that the trilacunar 3-traced condition is the nodal representative of the family Sterculiaceae (Fig.3.B, E, F). Single median and 2 peripheral traces are noted. The vascular supply to the stipules derives from these two peripheral leaf traces.

Significant observations made in case of nodal anatomy are the number, arrangement and distribution of the mucilaginous cavities. Their number varies from few to many; either arranged randomly (Fig.3.F) or in a specific pattern (mostly circular) (Fig.3.D) and may be distributed either within pith and cortex or in either of the one. However, the mucilaginous cavities may even be absent in some cases. Simple, acicular and stellate trichomes are observed at the epidermal layer. Crystals are noticed as scattered within the pith and cortical cells. The frequency of crystals varies considerably.

8.3 *Petiolar anatomy:*

The outline of the transverse sections of the petioles varies considerably. The outline may be oval to circular or semi-lunar or may have a depressed channel at the adaxial face. The number of main vascular bundles varies from single to numerous with an array of patterns of arrangement. They may either be arranged in a semi-lunar fashion (e.g., *Melochia corchorifolia*) or oval-circular (e.g., *Eriolaena hookeriana*, Fig.4.B_2) manner or may even be crescent–shaped.

Almost all the studied species have well-developed pith. Collenchymatous hypopdermis is observed in a few cases.

All the vascular bundles are open and collateral, varying in sizes with either equal or unequal distribution of xylem and phloem. Bundle sheath is always sclerenchymatous. The nature and configuration of mucilaginous cavities remain more or less the same as observed in the internodal and nodal portions.

Accessory bundles are usually present, however, absent in few species (e.g., *Melochia corchorifolia*). Accessory vascular bundles are either collateral or amphivasal, or amphicribal.

II. STUDY OF LAMINA

8.4 *Laminar shape:*

Considerable variations in the leaf shapes have been observed in the studied species. The types of leaf shapes include:

Simple and unlobed: Ovate–lanceolate (e.g., *Abroma augusta*), orbicular (e.g., *Eriolaena lushintonii*), ovate to oblong (e.g., *Guazuma tomentosa*), oblong (e.g., *Heritiera dubia*), obliquely lanceolate (*Helicteres plebeja*), elliptic to lanceolate (e.g., *Heritiera fomes*), elliptic to oblong (*Heritiera littoralis*), lanceolate (*Pterospermum lanceifolium*), elliptic to obovate (*Pterospermum reticulatum*), oblong to lanceolate (*Heritiera macrophylla*), obovate to oblong (e.g., *Pterospermum aceroides*), elliptic (*Leptonychia caudata*), linear to oblong (*Melhania incana*), deltoid or hastate to linear (*Pentapetes phoenicea*),

Simple and lobed: 5–7–lobed, lobes oblong (*Sterculia villosa*); digitately 3–5–lobed (*Sterculia urens*); broadly ovate, shortly 3–5 lobed, lobes deeply cordate (e.g., *Byttneria andamanensis*); reniform, chartaceous, shallowly 3–4 lobed (*Firmiana fulgens)*; broadly elliptic, often 3–lobed (*Helicteres isora*),

Compound: Peltate, digitately 5–7 foliolate (*Sterculia versicolor*), leaflets elliptic–lanceolate; 5–9 foliolate, leaflets elliptic–oblanceolate (*Sterculia foetida*).

8.5 *Laminar venation*:

8.5.1 Major venation – Venation patterns are of two types; **I. Pinnate** and **II. Actinodromous**. Under Pinnate type the predominant subtype is brochidodromous (e.g., *Pterospermum xylocarpum*, Fig.5.C), followed by craspedodromous (e.g., *Pterospermum reticulatum*, Fig.5.G) and semi–craspedodromous (e.g., *Helicteres elongata*, Fig.5.A). Under Actinodromus perfect basal and perfect suprabasal subtypes are noticed.

8.5.2 Minor venation – Three basic types of minor venation patterns are observed, viz. lax (e.g., *Sterculia guttata*, Fig.6.B), massive (e.g., *Pterospermum reticulatum*, Fig.6.D) and moderate (e.g., *Sterculia lanceifolia*). Highest vein order of leaf is found to be mostly 6^0 or 7^0 or even be up to 8^0. The veins are ensheathed with parenchymatous cells in most of the studied species. Areoles are either well developed with definite shape or imperfect i.e. meshes of irregular shape, more or less variable in size.

8.5.3 Margin and marginal venation – Among the studied species both entire (e.g., *Pterocymbium tinctorium*; Fig.7.B) as well as toothed margin (e.g., *Melochia nodiflora*; Fig.7.E) are observed. Marginal ultimate venation patterns are seen to be either incomplete (e.g., *Firmiana fulgens*, Fig.7.A) or looped (e.g., *Heritiera macrophylla*; Fig.7.C) or even fimbriate (e.g., *Pterospermum lanceifolium*).

8.5.4 Free vein endings – Free vein endings are of two types, viz. unbranched and branched. Unbranched vein ends may either be linear or curved (Fig. 8. E & F) and in case of branched ones they may branch once, twice or more (Fig. 8. A–D). Veinlets may also be absent, leaving many of the areoles empty (e.g., *Heritiera fomes*), where the frequency is much less than compared to others. The vein endings are often associated with parenchymatous cells and sclereids or either one.

8.6 *Dermal features and inclusions*:

8.6.1 Trichomes – Trichomes are broadly of two types, viz. 1) non-glandular and 2) glandular.

The non-glandular types may be i) simple acicular, either unicellular or multicellular (e.g., *Byttneria andamanensis*, Fig.9.B and ii) stellate (e.g., *Guazuma tomentosa*; Fig.9.D). The trichomes are seen to be present along the veins or may even be distributed randomly on the leaf surface.

Glandular Trichomes – Glandular trichomes are mostly seen along the veins and also on the surface. These are either unicellular or multicellular (e.g. *Byttneria andamanensis*; Fig.9.C).

8.6.2 Scales – Scales are found only in few cases (e.g., *Heritiera fomes*).

8.6.3 Stomata – Leaves are hypostomatic. Anomocytic stomata are more common (Fig.9.H). However, anisocytic (Fig.9.G), paracytic, cyclocytic, brachyparacytic, amphibrachyparacytic, etc. are also found in few species.

8.6.4 Crystals – Druses (Fig.9.E) and rhomboid shaped (Fig.9.F) crystals are frequently observed. In some cases both types are seen (e.g., *Eriolaena hookeriana*) while in others either of the two types is observed (e.g., *Ambroma augusta*). Distribution of the crystals also varied, in some they are found to occur along the veins (Fig.9.E) while in certain cases they are present both along the veins and on the leaf surfaces (Fig.9.F). Frequency of the crystals varies from species to species. In some species crystals are absent.

III. MORPHOMETRIC ANALYSIS

Morphometric analysis based on vegetative morphology and foliar architecture provide some interesting results. Though most of the taxa show natural grouping, the genus *Sterculia* appears heterogeneous. *Pentapetes phoenicea* separates from others at early stage because of the characters, viz. deltoid base and absence of fibre cells within the phloem layer at the internodal region, which are not present in the other members of Sterculiaceae.

6. PREPARATION OF KEY

■ **KEY TO THE SPECIES OF THE GENUS *HERITIERA*:**

1. Vascular bundles numerous (more than 30) in proximal part of the petiole…………………………………………………….. ***H. littoralis***
1. Vascular bundles 1 to 15 in proximal part of the petiole…………….. **2**
2. Accessory bundles many, more than 10 in proximal part of the petiole…………………………………………………….. ***H. papilio***
2. Accessory bundles few (1 – 4), in proximal part of the petiole……… **3**
3. Stem and lamina with stellate trichomes……………………………...***H. macrophylla***
3. Stem and lamina without any trichomes……………………............... **4**
4. Bundle sheath well developed in petiole; vein ends often associated with vesiculosecclereids; vein end frequency c. 1.4…...***H. fomes***
4. Bundle sheath absent in petiole; vein ends not associated with vesiculosesclereids; vein end frequency c. 10………………………..***H. dubia***

9. DISCUSSION AND CONCLUSION

Attempts have been made to find out how far the vegetative anatomy along with leaf architecture is in agreement with the present taxonomic classification and what changes it suggests; identification of key characters that are helpful in the identification of different taxa, particularly in their non-floriferous conditions and fragmented or distorted materials and establishment of inter– and intra–generic relationships among the members of the family.

In this study, based on foliar architectural features, most of the taxa show natural grouping and corroborated with either conventional classification system (Bentham and Hooker, 1862–1863) or phylogenetic classification system based on molecular data (Whitlock *et al.*, 2001). However, the genus *Sterculia* L. appears heterogeneous in regard to the foliar architectural features. The members of the genus *Sterculia* are with diversified anatomical characters as evident from the present study. Even the leaves are both simple (lobed and unlobed) and compound. The vasculature of petiole varies from one to numerous in different topographical level of the petiole (Mitra and Maity, 2013). Foliar venation parameters also show diverse nature as minor venation patterns both massive and lax, marginal venation with both looped and incomplete forms, free vein endings are both unbranched and branched, etc. Interestingly, the members of the Tribe *Helicterideae,* Tribe *Byttnerieae* and Tribe *Eriolaeneae* (Bentham and Hooker, 1862–1863) show homogeneity in regards to the foliar architectural features and thus grouped or aggregated under the respective tribes. Recently, the family Sterculiaceae is classified based on molecular data by Whitlock *et al.* (2011). The members of the Tribes *Byttnerieae* and *Theobromeae* are also grouped together through foliar architectural features as seen in phylogenetic study of Whitlock *et al.* (2011). The establishment of the genus *Firmiana* Marsili (in Saggi Sci. Lett. Accad. Padova i: 106. 1786) is justified by this foliar architectural study. This study do not supports the inclusion of the genus under *Sterculia* L. Sect. II *Firmiana* (Marsili) Masters as was previously done by Masters (1874). However, *Firmiana fulgens* is found to be closer to *Sterculia villosa*. Therefore, the present data may play an important role in the reassessment of classification of the family. In several foliar architectural aspects the members of the family Sterculiaceae shows close affinity with the family Malvaceae (Mandal, 2010; Mitra and Maity, 2013; Mitra and Maity, 2014). In recent time molecular systematics also well agreed to unite the two families along with Tiliaceae and Bombacaceae in a single family Malvaceae *s.l.* (*sensu* APG III, 2009). Judd and Manchester (1997) advocated monophyly of the order Malvales based on the common characters like mucilage cavities in the mesophyll, presence of stellate trichomes and anomocytic stomata. The present study also finely agreed with this view and supports the inclusion of Sterculiaceae under Malvaceae *s.l.* (*sensu* APG III, 2009) in its broader circumscription.

On the basis of the diversified anatomical features of the studied species it can be easily concluded that these characteristics play a very significant role in their proper and correct identification. It is very difficult to identify a plant in its vegetative or crude condition or even in distorted state. In order to overcome this difficulty the detailed anatomical features are thus utilized. With the help of all the gathered information it becomes easier to identify the plant in its non–flowering situation. The major venation type is predominantly brochidodromous, prevalent among majority of the species, along with actinodromous, craspedodromous, semi–craspedodromous types. Minor venation patterns are of three basic types, viz. lax, massive, and moderate. Looped marginal venation is the most prevalent one with very few ones with incomplete marginal venation patterns. However, in few cases fimbrial venation is observed as well. In some, where teeth are present, aggregation of tracheids is noticed, and these may remain associated with trichosclereids or vesiculosclereids, a unique feature. The vein ends are of two types, viz. unbranched and branched. The branched types may either branch once or more than once. The most interesting finding, which can be considered as one of the peculiar characteristics of the leaves of sterculiaceous materials is the presence of parenchymatous sheath running along the veins and vein ends, either completely or incompletely. Trichomes are mostly stellate types, prevalent in almost all the species, with very few exceptions. Apart from stellate types, non glandular acicular and glandular types are noticed in many species. Scales on leaves are also an important feature in *Heritiera*. Stomatal type is of anomocytic in general for Sterculiaceae (Metcalfe and Chalk, 1950; Hussin and Sani, 1996). In addition to anomocytic stomata, some other types like paracytic, anisocytic, etc., are also observed. The presence or absence of crystals can also be taken into account as a significant feature in plant systematics. Mostly, druses are common in the species with few having rhomboidal crystals. Their pattern of distribution may be measured as a unique feature as in some they are scattered throughout the surface of the lamina, while in others they are seen to lie along the veins only and again in some both are seen. Comparative analysis of petiolar anatomical features in the studied species reveals the diverse characteristics that prove to be significant in proper identification of taxa, especially in non-flowering form. The number and arrangement of vascular bundles and accessory bundles (where present), nature of bundle sheath, number and distribution of mucilaginous cavities, etc. are of significant observation in each taxon.

The morphometric analysis enlightens some significant facts. The genus *Sterculia* is most diversified in respect to the vegetative anatomy and foliar architecture among the studied members of the family Sterculiaceae. The leaves are either simple (lobed or unlobed) or compound, with shapes varying from ovate, broadly ovate, oblong, broadly elliptic obovate, elliptic-oblong, etc, the minor venation pattern comprises both massive and lax types whereas the marginal venation types includes both incomplete as well as looped forms, number of vascular traces varies from one to few to numerous at different topographic levels of the petiole. *Sterculia kayae* and *S. foetida* are close to each other as they possess few to many vascular traces at the proximal and distal parts of petiole, presence of accessory vascular bundles, massive type minor venation pattern, looped marginal venation, free vein endings associated with parenchymatous sheath, etc. Therefore, the species of *Sterculia* spread almost throughout the 'tree' under different clades. The genus *Sterculia* thus appears heterogeneous, at least morpho-anatomically (vegetative). The relationship of the genera *Firmiana* Marsili and *Sterculia* L. is reassessed in the present study. Masters (1874) reduced the genus *Firmiana* as Sect. *Firmiana* (Marsili) Masters under the genus *Sterculia*. However, present observation well agreed with the view of Marsili (in Saggi Sci. Lett. Accad. Padova i: 106. 1786) and supports the generic status of *Firmiana*. Anatomy and foliar architectural pattern is quite different in these two genera. Though, *Firmiana fulgens* is found to be closer to *Sterculia villosa*.

The close relationship of *Guazuama tomentosa* and *Theobroma cacao* is proved by this analysis where the two genera are closer on the basis of certain characters, viz. minor venation type massive, marginal venation looped, few to many vascular traces at the proximal parts of petiole, only one vascular bundle at the middle and distal parts of the petioles, presence of accessory vascular bundles, etc. The close relationship of these two taxa was also supported by molecular phylogeny (Whitlock *et al*., 2001). Similarly, the clad formed by *Dombeya burgessiae*, *D. walllichii*, *Kleinhovia hospita*, *Byttneria herbacea* and *Melochia umbellata* are due to the presence of certain common characters among them as, absence of accessory vascular bundles, few to many vascular traces at proximal and middle parts of the petiole, association of free vein endings with parenchymatous sheath, etc.

The main goal of this study was to describe and compare the leaf architecture and the internodal, nodal and petiolar anatomy of 68 species of the family Sterculiaceae. All of the species of Sterculiaceae share both simple and compound lamina with entire and toothed margin. The differences among the species included the venation pattern, course of secondary veins, presence or absence of inter-secondary veins, tertiary vein pattern, the number of branches in vein-lets, and the marginal ultimate venation. Studies of leaf architecture are very useful because different dicotyledonous taxa have consistent patterns of leaf architecture that are recognized at different taxonomic levels, from subclass to species (Dilcher, 1974; Hickey, 1979). Foliar anatomical data are often useful for solving problems of differentiating closely related taxa or for supporting morphological homologies (Stuessy, 1990).

Present study reveals that the family Sterculiaceae shares common features, viz. mucilage cavities in the mesophyll, stellate trichomes, parenchymatous sheath along the veins, anomocytic stomata, etc. with that of Malvaceae (*s.l.*) reflecting common monophyletic origin of both the groups as also advocated by Judd and Manchester (1997). Moreover, the relationship among the genera of the family Sterculiaceae has also been established through this study. Present investigation also provides sufficient evidence regarding the usefulness of foliar architectural data along with other related anatomical information as diagnostic characteristics of different taxa under the family Sterculiaceae.

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13. LIST OF PUBLICATIONS

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11. ACKNOWLEDGEMENTS

I am grateful to the University Grants Commission for financial support to carry out the research work.

I am thankful to the Head, Department of Botany, University of Calcutta for providing research facilities.

I am indebted to Prof. G.G. Maiti, University of Kalyani for his guidance.

I am also thankful to Sonia Mitra, Project Fellow for her sincere attitude towards carrying out the research programme.