

Chapter 6

SUMMARY

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Present study explored the diversity of foliar architecture within 61 species of the family Sterculiaceae out of 68 species belonging to 19 genera in India (Malick, 1993). The rest seven species are of rare occurrence and in some cases the species are known only from their *Type* collections. Due to rarity only leaf venations have been studied in some cases.

Foliar architecture in general, in angiosperms, has been done for various families. However, for Sterculiaceae in Indian context the attempts are very few. Therefore, a thorough approach has been made to highlight the different anatomical and foliar architectural aspects of the family. The study helps to find out how far the vegetative anatomy along with foliar architecture is in agreement with the taxonomic classifications and what changes it suggests. It also helps in recognition of key characters that are helpful in the identification of different taxa, particularly in their non-floriferous conditions and in fragmented or distorted materials. Finally the establishment of inter- and intra-generic relationships among the members of the family have been done.

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). In general, majority of genera followed natural grouping reflecting the conventional classification system.

The internodal cellular configurations are more or less the same in all the studied species. The outline of the transverse section of the internodal portion is almost circular to oval in outline. The cortical portion is more or less thin to thick than the stelar part. Amounts of xylem and phloem varies accordingly, however, xylem in most of the cases is present in more amounts than phloem. Both xylem and phloem are conjoint collateral and arranged in continuous layers. Sclerenchymatous cells in the form of bundle cap remain at the rinds of the phloem. Bundle cap may be continuous or discontinuous. Fibre cells remain embedded within phloem layer in patches. The number of fibre cells varies from species to species. In rarest case [as observed in the internodal and nodal portion of *Sterculia foetida* (Fig.47A.c,d₁andd₂)] brachysclereids remain embedded within cortical cells of internodal part. They either

remain isolated as a single cell or in few-celled groups. Number, arrangement, shape and size of mucilaginous cavities vary consequently. Their number may vary from very less or few [*Ambroma augusta* (Fig1A.h₁)] to numerous [*Pterospermum acerifolium* (Fig.34A.d₄)] and they remain either in circular to random pattern or sometimes both [*Byttneria andamanensis* (Fig.2A.d₁)] and distributed in either cortex or pith or both. Trichomes (acicular, stellate and glandular) are seen in the transverse section as well. Crystals of various shapes (druses, diamond, rhomboid, etc.) and sizes are seen in internodal region (Fig.2B.f; 47B.f). The general anatomical features are well agreed with the observation of Metcalfe and Chalk (1950).

The nodal configuration of entire family is highly static showing typical trilacunar three-traced condition as also pointed out by Sinnott (1914), Metcalfe and Chalk (1950), Bailey (1956), Takhtajan (1976), Cronquist (1981). However, from the present study it is evident that the cutting plane and its time varies from species to species. In many cases the median trace cuts off from the main cylinder followed by the two laterals (Fig.2A.c₁ and c₂), whereas in others the lateral traces cuts off first followed by median and even one of the laterals cuts off first followed by the next (Fig.1A.g). Thus it can be used as a taxonomic marker to separate respective taxa. Even the size of the traces also varies and in general, median traces are larger than laterals. In general, the stipules are served by small part of lateral traces and major part of lateral trace joint with median trace and ultimately take part to serve as petiolar trace. Noticeably, the lateral traces provide vasculature to the stipules successively, particularly for large and broader stipules as in case of *Pterospermum acerifolium* (Fig.34A.c₉), *P. semisagittatum* (Fig.41A.c₂), amount of vascular traces have been more than four or five times the normal, whereas, in case of linear stipules it is lesser in amount. In case of some cauducous stipules, like *Pentapetes*, *Byttneria herbacea*, only few tracheids devoid of any phloem cell has been noticed to serve as stipular trace.

The most important feature is the petiole vasculature. The vasculature of petioles varies from one (*Melochia corchorifolia*) to numerous (*Heritiera littoralis*) in different topographical level of the petiole (Mitra and Maity, 2013, 2015). The outline of the t.s. of petioles are mostly circular to oval in shape though very less are

uneven and some may have a deep groove at the adaxial face as in *Melochia corchorifolia*. The number, shape, size and arrangement of the vascular traces differ accordingly among the species. During the study three zones, viz. proximal end, middle part and distal end of the petiole are fixed in order to maintain a parity of the observation following Howard (1962, 1970, 1974 and 1979). However, apart from these three specific portions some other zones in some cases viz. the portion between proximal and middle, from middle to towards distal, from distal to towards distal and extreme distal have also been encountered. Features of mucilaginous cavities remain alike to the internodal and nodal parts, however, in some cases mucilaginous cavities are absent too (Fig.4A.d₁,d₂andd₃). Characteristics of xylem, phloem and bundle sheath are almost similar to internodal and nodal regions. The bundle sheath surrounds the vascular bundles either completely or in patches. Amounts of xylem and phloem and thickness of bundle sheath varies subsequently. Patches of sclerenchymatous cells remain associated with some vascular bundles at their internal region adjacent to pith [e.g., Petiole of *Eriolaena hookeriana* (Fig.6A.d₆), middle part of petiole of *Sterculia guttata* (Fig.48A.d₁)].

The most captivating observation in the petiole anatomy is the presence of accessory vascular bundles. Some members may have these bundles throughout their petiolar length [e.g., *Sterculia balanghas* (Fig.46A.b₁–b₆)], while some have only at proximal or at middle part [e.g., *Sterculia lanceifolia* (Fig.52A.d₇)], or at distal end [e.g., *Theobroma cacao* (Fig.61A.d₆)]. The formation of the accessory vascular bundles are always from the parent strands or bundles. The parent strand (s) branches towards the pith or central portion and branch off once, twice or more and forms the accessory bundles. The accessory bundles occupy almost whole of the pith in some cases making pith totally inconspicuous [e.g., *Heritiera littoralis* (Fig.19A.d₁), *H. papilio* (Fig.21A.b₁)]. These bundles vary considerably in their number, shape and size. The species have one to numerous accessory vascular bundles at different levels of their petiolar lengths and may be either rounded to circular, oval, triangular, semi-lunar, semi-circular, etc. The bundles may be amphivasal or ampicribal or may sometimes be observed to have phloem in the center surrounded by incomplete xylem layer or vice versa. Notably, accessory vascular bundles are also formed by only either xylem or phloem cells. Some

species do not have accessory vascular bundles in their petioles (e.g., three species of *Dombeya*). Howard (1979) considered the presence of accessory vascular bundle as advanced character.

Pith is parenchymatous and prominent as in most of the cases, though it may also be inconspicuous as in *Sterculia lanceifolia* where the presence of vascular bundles at centre makes it totally invisible (Fig.52A.d₁).

Foliar architectural features in general have high value in systematics of plants (Hickey and Wolfe, 1975; Hickey and Doyle, 1977; Hickey, 1977; Doyle, 1978). According to Hickey and Wolfe (1975) leaf venation can be classified into four ranks based on the increase in regularity of secondary, high order veins and intercostals areas.

Leaves in this family are generally usually simple, whereas, in India, two members, viz. *Sterculia foetida* and *Sterculia versicolor* possess palmately compound leaves. Leaves are petiolate with free lateral stipules. However, the shape and size, apex and margin vary greatly from species to species and thus have immense taxonomic value as also discussed by earlier authors (Bentham and Hooker, 1862; Masters, 1874; Malick, 1993). Though the stipules are free lateral in all members and in majority of cases they are linear lanceolate, however, in few cases as in *Pterospermum acerifolium*, *P. semisagittatum* stipules are much larger, ovate and with fringed margins, thus have taxonomic value. The apex of lamina (or leaflets) shows great diversity from acute (*Abroma augusta*, *Firmiana fulgens*, etc.), acuminate (*Helicteres elongata*, *Sterculia guttata*, *S. hamiltonii*, etc.) to obtuse–rounded (*Byttneria aspera*, *Heritiera fomes*). Leaf margin similarly also exhibit great variations from entire (*Heritiera fomes*, etc.), serrate (*Helicteres elongata*), dentate (*Byttneria herbacea*, *Melhania magnifolia*), crenate (*Melhania magnifolia*). The base of the lamina are sometimes unique and varies from cuneate (*Heritiera papilio*, *Pterospermum obtusifolium*, etc.), rounded (*Reevesia pubescens*, *Sterculia balanghas*, etc.), cordate (*Abroma augusta*, *Byttneria andamanensis*, *Firmiana fulgens*, *Helicteres isora*, etc.) and even auricled (*Pterospermum semisagittatum*). The symmetry of lamina is important. Though majority of species show the symmetric configuration, however, *Eriolaena wallichii*, *Guazuma ulmifolia*, *Melochia umbellata*, *Pterospermum diversifolium* shows strongly asymmetric leaves

where the midrib is placed on one side of the lamina dividing it into two unequal halves. Few species like *Ambroma augusta* exhibit dimorphic leaves in vegetative and reproductive stage showing apophysis.

Venation pattern is thoroughly studied for all members. The diversity of foliar venation is significant. The studied members are broadly classified into three groups depending on the type of major venation patterns, i.e. brochidodromous (Fig.17A.a, 18A.a, 19A.a, 20A.a, 21A.a), actinodromous (Fig.1A.a, 2A.a, 3A.a, 4A.a) and semicraspedodromous (Fig.15A.a). Hickey and Wolfe (1975) considered simple leaves with entire margin and pinnate brochidodromous venation pattern as primitive leaf type. Almost all the leaves with entire margin have this type of venation (e.g., *Heritiera fomes*, *H. littoralis*, *Sterculia guttata*, *S. lanceifolia*, etc). The species with toothed margin (e.g., *Dombeya bugessiae*, *Helicteres isora*, *H. elongata*, *Pterospermum acerifolium*, *Pterygota alata*, etc.) show actinodromous type of venation, whereas *Helicteres hirsuta* and few others show semicraspedodromous type of venation.

Apart from major venation types the minor venation patterns also play a very significant role in this study as they show diverse nature of both massive and lax. Majority of the species (e.g., *Ambroma augusta*, *Byttneria andamanensis*, *B. aspera*, *B. herbacea*, *Firmiana fulgens*, *Guazuma ulmifolia*, etc.) show massive type of minor venation, whereas members (e.g., *Firmiana colorata*, *Helicteres elongata*, *Melochia corchorifolia*, *M. umbellata*, *Sterculia lanceifolia*, *Waltheria indica*) show lax type of minor venation pattern. Markedly the two species of the genus *Firmiana*, *F. colorata* and *F. fulgens* show different types of minor venation pattern as massive and lax respectively. Free vein endings are both branched and unbranched types and usually composed of few to several spirally thickened tracheids. Some of the species have very less number of branched free vein endings [e.g., *Heritiera dubia* (vein end frequency 10/mm²), *H. papilio* (vein end frequency 5.5/mm²), *H. littoralis* (vein end frequency 5.5/mm²), *Melochia umbellata* (vein end frequency 3.2/mm²), etc.]. The branched types may either branch once or more than once. Noticeably, most of the leaves of Sterculiaceae species have parenchymatous sheath running along the veins and vein ends, either completely or incompletely. The vein ends in rarest case remain associated with specialized sclereids (vesiculosclerids) as seen in *Heritiera*

fomes (Fig.18B.c₁). *Melochia corchorifolia* collected from Bankura district show thick continuous parenchymatous sheath cell along the veins and vein ends, but specimens collected from Kolkata lack the same. Probably some ecological factors may be associated with this type of association. Similarly the marginal venation types are important in distinct way. Marginal venation with both looped and incomplete types are seen, however, looped type is predominant. Members showing looped venation along the margin includes species of *Heritiera*, *Kleinhovia*, *Eriolaena*, *Theobroma*, etc. and those with incomplete marginal venation are species of *Leptonychia*, *Melhania*, *Melochia*, *Dombeya*, etc.

Trichomes are of two types, as nonglandular and glandular. Nonglandular type can be sub-divided into acicular and stellate forms. In case of acicular trichomes presence or absence of basal cells, number of basal cell are of taxonomic significance. Stellate stout forms have mostly unicellular arms, though the three species of *Dombeya* have multicellular arms. Stellate trichomes are usually of two forms; in one form the arms are all stout whereas in the other form arms are all flexuose and this is one of the characteristic features of the genus *Pterospermum*. Glandular trichomes are of various shape and size. The globular or ovoid body is formed of one to several cells. But the stalk and apical cells are unicellular (e.g., *Ambroma augusta*, *Byttneria andamanensis*, etc.) with some exceptions where stalk appears multicellular (e.g., *Byttneria herbacea*, *Eriolaena lushingtonii*, etc). In *Ambroma augusta* few globular trichome is only one-celled. Globular bodies of the trichomes are with septations, either transverse or longitudinal or both (*Byttneria andamanensis*). Trichomes remain distributed along the veins and also on the laminar surface and this distribution varies among the species. Significantly, scales on leaves are also an important feature in *Heritiera*.

Stomatal type is of anomocytic in general for Sterculiaceae (Metcalf and Chalk, 1950; Hussin and Sani, 1996). In addition to anomocytic stomata, some other types like paracytic, anisocytic, etc., are also observed (*Pterygota alata*). Thirteen types of stomata along with 18 subtypes and 3 intermediate subtypes between brachyparahexacytic monopolar and dipolar are reported to be present in the leaves of *Pterygota alata* (Roxb.) R. Br. var. *alata* and *Pterygota alata* (Roxb.) R. Br. var. *irregularis* (W. W. Sm.) Deb & S. K. Basu (Mitra *et al.*, 2015). The observed

stomata are amphibrachyparacytic, amphicyclocytic, anisocytic, anomocytic, anomotetracytic, brachyparacytic, brachyparahexacytic, brachyparatetracytic, cyclocytic, paracytic, parahexacytic (dipolar), paratetracytic and stephanocytic. Besides these, the presence of giant stomata is a significant finding. Cuticular striations are present on the subsidiary cells, epidermal cells and sometimes even on guard cells.

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 or other type of 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 and in some species crystals are present in the stem and petiole. Crystals are even absent in some species.