STERCULIACEAE

Chapter 5

STERCULIACEAE

The Sterculiaceae consist of about 65 genera and a thousand species mainly distributed in the tropical or subtropical regions. **Sterculia** and **Dombeya** are the largest genera with about 200 species each. The members of this family are mostly trees or shrubs, rarely lianas or herbs wholly or partially covered by a vesture of stellate or peltate hairs. The leaves are alternate, simple, entire or infrequently palmately lobed or compound, stipules caducous. Flowers generally bisexual (unisexual and the plants monoecious in **Sterculia** and **Cola**) actinomorphic or less often zygomorphic, pentamerous, usually axillary in various inflorescence types and often cauliflorous and with an epicalyx. Perianth usually uniseriate. Sepals 3-5, valvate with nectaries consisting of tufts or glandular hairs at the base. Petals five, small, distinct, convolute, sometimes adnate to the filament tube at the base, usually clawed, sometimes hooded or absent. Stamens in two whorls monadelphously connate into a single tube often seated on an androgynophore. Those of the outer whorl reduced to staminodes (and often petalloid) or wanting. The inner whorl

stamens normal, anthers tetrasporangiate and dithecal,the pollen sacs parallel and adjacent or sometimes divergent and separated, opening by longitudinal slits or seldom by apical pores. Pistil one, (1-) 5 (-60) carpellary, generally united to form a compound ovary with as many locules as carpels. (In tribe Sterculieae the carpels united only by their styles and becoming wholly distinct at maturity or even wholly distinct from the beginning as in **Cola**). Ovules (1)2- several on each locule, ascending or horizontal, anatropous in axile (rarely marginal or deeply intruded parietal placentas in unilocular ovary where the partitions fail to meet in the centre) placentas. Styles as many as the carpels, distinct or connate. Fruit leathery or fleshy (rarely woody), dehiscent or indehiscent, sometimes the carpels spliting into cocci. Seeds sometimes arillate, embryo straight or curved with expanded cotyledons. Endosperm generally abundant, oily or starchy, or rarely (as in **Cola**) wanting.

Anatomical characters

Hairs, as in the case of the Malvaceae, consist of simple, unicellular, uniseriate, glandular, tufted, stellate or peltate types. Mucilaginous cells are seen in epidermis. The main vascular strand of the petiole is either a closed cylinder of xylem and phloem or a cylinder formed by a number of separate but closely situated vascular bundles. In both cases there are often several accessory bundles of very varying shapes in different species. Mucilage cavities are present in the primary cortex and phloem, while mucilage canals are less common. Clustered or less often solitary crystals of calcium oxalate commonly present in parenchyma. Phloem strands triangular,stratified to fibrous and non-fibrous bands. Vessels are medium-sized with simple perforations. Tracheids with simple or inconspicuously

bordered pits. Wood parenchyma of two types, (a) diffuse with a little vasicentric and (b) paratracheal to locally confluent storied bands in Buttnerioideae or broad apotracheal to confluent storied bands in the rest of the family. Rays of two distinct sizes, the larger upto 20 cells wide, heterogeneous with sheath cells, the smaller uniseriate or a few cells wide, often storied.

Palynological characters

Similar to the Malvaceae, pollengrains in this family also are of varied types ranging from tricolporate to pantoporate. The exine is smooth, reticulate or spiny. Binucleate at anthesis.

Embryological characters

In embryology also the Sterculiaceae are similar to the Malvaceae or Bombacaceae. The pollengrains are binucleate at anthesis. Ovule is anatropous or hemitropous and bitegmic. Micropyle is zig-zag. The endosperm development is nuclear.

Cytological characters

The basic chromosome number varies from 5 to many. The most common number is 20.

Chemistry

The Sterculiaceae are known for their purine alkaloids exhibiting stimulating properties, the most important sources being Cocoa and Cola. **Therobroma cacao** (the source of cocoa) contains the alkaloids theobromine, theophylline and caffeine in their seeds. The seeds of **Cola acuminata** and **C.nitida**

also contain caffeine and theobromine. The cyclopropane fatty acids, sterculic and malvalic are also common in the seed oils of this family (Varma **et al.**,1955). The flavonoid components of the family reported are (1) diosmetin and other flavonols from flowers of **Dombeya calantha** (Subramanian & Nair, 1962) and **Guazuma tomentosa** (Subramanian and Swamy, 1963).

Economic importance of the family

Economically this family is important as the source of Cocoa and Cola. Cocoa is the seed of **Theobroma cacao** and contains alkaloids like theobromine (13%) and caffeine (0.3%), fat (cocoa butter - 35-40%), starch (15%) and polyphenols (5-10%). Cocoa belongs to a special class of beverage being stimulating as well as highly nutritious. Cola nuts obtained from **Cola acuminata** and C.**nitida** contain 2-3% caffeine and 1% theobromine bound to a condensed tannin- Cola catechin (5-10%). Cola nuts are used as a masticatory and in the ground form as a stimulating drink substituting coffee or tea. Fibres are obtained from the inner bark of various members of this family. Karraya gum, one of the important commercial gums of India, is obtained from various species of **Sterculia**. The medicinal plants of this family include **Abroma angusta** (root-emmenagogue and useful against uterine haemorrhages), **Helicteres isora** (capsule-for intestinal complaints such as colic, flatulence and diarrhoea), **Pentapetes phoenica** (whole plant-emollient, demulcent) and **Pterospermum acerifolium** (antiseptic). Various species of **Dombeya**, **Firmiana**, **Fremontodendron**, **Sterculia** etc. are cultivated as ornamentals.

Taxonomy

The family Sterculiaceae is classified by Masters(1865) 1892 into six tribes.

Tribe 1.Sterculieae. Flowers unisexual or polygamous petals 0, androecium columnar or sessile. Anthers clustered or disposed in a ring.

Tribe 2. Helictereae. Flowers hermaphrodite, petals deciduous, androecium columnar below, dilated into a cup, on the margin of which are placed the anthers usually alternating with the staminodes.

Tribe 3. Eriolaeneae. Flowers bisexual, petals deciduous,androecium tubular,conical, antheriferous for nearly whole length, staminodes 0.

Tribe 4. Dombeyeae. Flowers hermaphrodite,petals flat, persistant, androecium tubular, antheriferous at the margin.Anthers solitary or in groups, alternating with the staminodes.

Tribe 5. Hermannieae. Flowers hermaphrodite,petals marcescent, flat. Androecium tubular at the base only. Stamens 5, staminodes 0.

Tribe 6.Buettnerieae. Petals concave at the base. Androecium tubular, anthers marginal, solitary or in groups between the staminodes.

Schumann (1895) divided the family into eight tribes: Eriolaeneae, Fremontieae, Dombeyeae, Hermannieae,

Buttnerieae, Lasiopetaleae, Helectereae and Sterculieae.The tribe Hermannieae is further divided to two subtribes Hermanninae and Melochinae. Similarly the tribe Buttnerieae also is subdivided into subtribes Buttnerinae and Theobrominae. Metcalfe and Chalk (1950), based on anatomical characters,divided the Sterculiaceae into two subfamilies the Sterculioideae and Buttnerioideae (Byttnerioideae), the former containing the single tribe Sterculieae and the latter containing all the remaining tribes. The Sterculioideae are characterised by apotracheal parenchyma, the petiolar vascular strand consisting of an adaxial and an abaxial arc almost united to form a ring and enclosing a central concave collateral medullary strand with adaxial xylem, while the Buttnerioideae have paratracheal parenchyma and a petiolar strand which is a deeply concave vascular crescent with the ends very much incurved. Thorne (1981) also accepts these two subfamilies as valid taxa. Since the Sterculiaceae embrace considerable range of diversity in gross floral morphology, pollen morphology and the anatomy of flowers,some authors, notably Edlin (1935) would restrict the family to the subfamily Sterculioideae (rather the traditional tribe Sterculieae) and refer the subfamily Buttnerioideae (including all the remaining genera) to a separate family Buttneriaceae (Byttneriaceae). The Sterculiaceae then become a relatively homogeneous group marked by their unisexual apetalous, more or less distinctly apocarpous flowers that are commonly borne in large panicles and produce smooth tricolporate pollen. The Buttneriaceae, on the contrary, have syncarpous, mostly perfect flowers, but they remain heterogeneous in other respects including the anatomy of the wood and petioles, the nature of inflorescence, the presence or absence of petals and an androgynophore and the structure of pollen.

Some authors consider the Sterculieae primitive due to apocarpy. But according to Takhtajan (1981), the apocarpy here is probably secondary because in **Sterculia** itself the carpels are united by style at anthesis, much similar to the condition existing in the Apocynaceae and Asclepiadaceae.

In the present work 22 members belonging to 14 genera of the Sterculiaceae have been studied for their chemical markers such as the flavonoids, phenolic acids, alkaloids, saponins and tannins, with a view to using them in understanding the classification and phylogeny of the family.

Materials and Methods

Most of the plant materials were collected from the Botanical garden and nearby areas of Baroda. **Waltheria, Theobroma, Melhania, Eriolaena** and **Cola** were collected from Museum Botanic Gardens,Trivandrum, Kerala; **Dombeya natalensis, D.calantha** and **Melochia** from Mahabaleshwar and **Pterigota** and **Heritiera** from Botanical Gardens of Ootacamund and Bangalore. The voucher specimens are deposited in the Herbarium of M.S.University of Baroda. The date and place of collection and the herbarium numbers are given in Appendix 1. Standard procedures described in Chapter 2 are followed for the extraction, isolation and identification of various phytochemicals. The confirmation of identity of the compounds is done by co-chromatography with authentic samples.

Results

The results of screening 22 plants of the Sterculiaceae for their flavonoids, phenolic acids, alkaloids, saponins and tannins are presented in table 5.

Table 5: Distribution of Phytochemicals in 22 members of the Sterculiaceae

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Tribe Eriolaeneae																												
1. **Eriolaena hookeriana** W.&A.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	.	.	.	+	.	+	+	.	.	+	.	+	.	+
Tribe Dombeyeae																												
2. **Melhania hamiltoniana** Wall.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	+	.	.	.	.	.	.
3. **Dombeya calantha** Sehum.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	+	+	+	+	.	.	+
4. **D.natalensis** Sond.	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	+	.	.	.
5. **D.spectabilis** Bojer	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.
Tribe Hermannieae																												
6. **Melochia corchorifolia** L.	.	.	.	.	.	.	.	.	+	.	.	.	+	+	+	.	+	.	.	+	+	+	.	+	.	.	.	.
7. **Waltheria indica** L	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	+	+	+	.	+	+	.	.	+	+	+	+	.
Tribe Buttnerieae																												
8. **Guazuma tomentosa** Kunth.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	+	+	.	+	+	+	+	+
9. **G.ulmifolia** Wall.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	+	.	+	+	+	.	.	+	+	+	+
10. **Theobroma cacao** L	+	+	+	.	.	.	+	+	.	.	.	.	.	.	.	.	+	.	.	+	+	.	+	.	.	+	.	+

Table - 5 (contd.)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Tribe Helictereae																												
11. Helicteres isora L	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	+	+	+	+	+	.
12. Kleinhovia hospita L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	+	.	.	.
13. Pterospermum obtusifolium Wight.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
14. P semisagitatum Ham.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	+	.	.	.	.	.	.	+
15. P.suberifolium Lam.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	+	+	+	+	+	.	.	.	.	.	.	+
16. P.acerifolium Lam.	+	.	+	+	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	+	+	.	.	.	.	.	.	.
Tribe Sterculieae																												
17. Sterculia foetida L	+	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
18. S.urens Roxb.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	+	.	+	+	+	.	.	.	.	.	+
19. S.belanghas L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	+	.	.	.	.	.	.	.
20. Pterigota alata Lam.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.
21. Heritiera littoralis Dryand	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	+	+	+	+	.	+	.	.	.	.	.
22. Cola acuminata R.Br.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	+	.	+	.	+	+	.	.

Table - 5 (contd)

1) Apigenin, 2) 7-OMe Apigenin, 3) 4'-OMe Apigenin, 4) 7,4'-diOMe Apigenin, 5) 6-OMe Apigenin 6) 6,4'-diOMe Apigenin, 7) Luteolin, 8) 4'-OMe Luteolin, 9) 4'-OMe Vitexin, 10) Kaempferol, 11) 7-OMe Kaempferol, 12) 4'-OMe Kaempferol, 13) Quercetin, 14) 3'-OMe Quercetin, 15) 3',4'-diOMe Quercetin, 16) Myricetin, 17) Proanthocyanidins, 18) p-Hydroxybenzoic acid, 19) Protocatechuic acid, 20) Vanillic acid, 21) Syringic acid, 22) Gentisic acid, 23) Melilotic acid, 24) p-Coumaric acid, 25) Ferulic acid, 26) Alkaloids, 27) Saponins, 28) Tannins.

Of the 22 plants analysed, 20 were found to contain one or the other flavonoids in them. Only **Kleinhovia hospita** and **Pterygota alata** were found to be devoid of these compounds. The various groups of flavonoids located were flavones, glycoflavones, flavonols and proanthocyanidins. Both flavones and flavonols were identified from 8 plants each. They were found to be mutually exclusive except in **Guazuma ulmifolia.** The various flavones located were apigenin, luteolin, and scutellarein and their various methoxyderivatives. Apigenin and its derivatives were more common having been detected in all the flavone-containing plants. Apigenin itself was seen in five plants of which three belonged to the tribe Dombeyeae. 7-OMe Apigenin was present in **Dombeya natalensis** (Dombeyeae),**Guazuma ulmifolia** and **Theobroma cacao** (both of tribe Buttnerieae). 4'-OMe Apigenin (acacetin) was obtained from **Dombeya calantha, Theobroma cacao** and **Pterospermum acerifolium,** while 7,4'-diOMe apigenin was seen in four plants, **Pterospermum semisagitatum, Sterculia foetida, Pterospermum acerifolium** and **Cola acuminata.** 6-Oxygenated compounds **i.e.** 6-OMe scutellarein and 6,4'-diOMescutellarein were found to be present in the leaves of **Sterculia foetida** only. Luteolin and its derivatives (4'-OMe luteolin) were rare in this family having been found in three plants **i.e.Dombeya natalensis, Theobroma** and **Pterospermum acerifolium.** The tribes Dombeyeae and Buttnerieae were particularly rich in flavones while in Helictereae and Sterculieae they were comparatively rare. In tribes Eriolaeneae and Hermannieae the flavones were entirely absent.

The glycoflavone,identified in three plants,was 4'-OMe-vitexin. These plants belong to Hermannieae (**Melochia** and **Waltheria**), **Buttnerieae (Theobroma)** and Helictereae (**Pterospermum obtusifolium**). The tribes Eriolaeneae,Dombeyeae

and Sterculieae are free of these compounds.

The leaf flavonols of the Sterculiaceae were the common compounds kaempferol, quercetin and myricetin. Of these three, kaempferol was more common, seen in six plants. Pure kaempferol was present in three plants (**Eriolaena, Waltheria,** and **Pterospermum suberifolium**), while 7-OMe kaempferol was identified in **Guazuma ulmifolia** and 4'-OMe kaempferol in **Sterculia urens** and **Heritiera littoralis.** Quercetin was located in **Eriolaena, Melochia, Pterospermum obtusifolium;** and **P. suberifolium.** Both 3'-OMe quercetin and 3',4'-diOMequercetin were seen in **Melochia.** Myricetin, the highly hydroxylated flavonol, was seen in **Waltheria** only. The tribe Dombeyeae was free of flavonols. The tribes Eriolaeneae and Hermannieae were rich in flavonols. In **Melochia, Waltheria** and **Pterospermum obtusifolium** flavonol's co-occurred with glycoflavones.

Proanthocyanidins were widespread in this family, having been synthesised in 14 plants. Helictereae and Dombeyeae were poor in these compounds. In **Melhania, Guazuma tomentosa, Helicteres and Sterculia belanghas,** proanthocyanidins were the only flavonoids present. In seven plants they co-occurred with flavonols and in four they ocurred with flavones. Almost all the glycoflavone-containing plants synthesised proanthocyanidins. Altogether 8 phenolic acids have been identified in this family, of which six were benzoic and two cinnamic acids. The benzoic acids were more or less uniformly distributed but the cinnamic acids exhibited less frequency of occurrence in the tribe Sterculieae.

Alkaloids were seen in seven plants. The tribes Eriolaeneae and Buttnerieae are rich in these compounds.

Saponins were seen in four plants belonging to Hermannieae, Buettnerieae and Helictereae. The Sterculieae, Dombeyeae and Eriolaeneae are free of these compounds. Tannins were present in eight plants. The tribes Hermannieae and sterculieae are poor in these phytochemicals.

Discussion

The family Sterculiaceae shows a characteristic association of a number of primitive and advanced characters. The primitive chemical characters present are the proanthocyanidins,flavonols and tannins. The advanced characters include flavones, glycoflavones, 6-oxygenated flavones and methoxylation of flavonols. (Swain,1975;Gornall and Bohm,1978). A number of plants are there which contained flavones and proanthocyanidins together, and such a feature is very uncommon in Angiosperms. Similar curious association of characters are also seen in some morphological characters in that some genera possess a mixture of quite primitive and highly advanced type of floral structures. The flavone-containing plants are almost equal in number to the flavonol-containing plants. In only one member the flavones and flavonols co-occur. All these features indicate that the Sterculiaceae are a heterogeneous assemblage of plants and this concept is concurrent with the considerable range of diversity exhibited in other features like floral morphology, pollen and anatomy of the flowers and petioles.

All the six tribes screened are chemically distinguishable by single chemical character or an assortment of chemical characters. Both the Eriolaeneae and Hermannieae are free of flavones. Between the two the latter contains glycoflavones. This tribe (Hermannieae) contains flavonols in great variety and an abundance of proanthocyanidins. The presence of myricetin in this tribe

is another distinct feature. Eriolaeneae contain only flavonols with traces of proanthocyanidins. The Dombeyeae are the only tribe devoid of flavonoids. The absence of glycoflavones and reduction in proanthocyanidin-containing taxa (one only; **Dombeya calantha**) are other features of this tribe. **Melhania** is devoid of flavonols. The Buttnerieae distingish themselves in containing all the four types of flavonoids **i.e.** flavones, glycoflavones, flavonols and proanthocyanidins. Both glycoflavones and flavonols are comparatively rare here; found in only one plant each.The production of alkaloids in all the plants is another noteworthy feature of this tribe.Both Helictereae and Sterculieae contain flavones and flavonols but no glycoflavones. Both these tribes contain some plants in which the flavonoid system is lost altogether. In Helictereae, **Kleinhovia hospita** is without any flavonoid, and only one plant **i.e. Pterospermum semisagitatum** is with flavones. Flavonols are seen in **Pterospermum semisagitatum** only and **Helicteres** is without flavones or flavonols. In the tribe Sterculieae, only **Pterigota** is without flavonoids. Flavonols and flavones are rare here, the former seen in **Sterculia urens** and **Heritiera littoralis** and the latter in **Sterculia foetida**.The occurrence of 6-oxygenated flavones in **Sterculia foetida** gives a distinct chemical character for this tribe.

In synthesising flavones and reducing the flavonols and proanthocyanidins the tribes Dombeyeae, Buttnerieae and Sterculieae are chemically advanced over other tribes. In eliminating the flavonols,the Dombeyeae may be considered the most advanced tribe. Two out of the four plants screened in this tribe are devoid of the flavonoid system altogether which is considered the highly advanced condition in the flavonoid evolution (Swain,1975; Gornall and Bohm,1978).

Though contain flavonols in two plants the Sterculieae distinguish themselves by producing 6-oxygenated flavones (6-OMe scutellarein and 6,4'-diOMe scutellarein) another highly advanced flavonoid character. The absence of flavones and glycoflavones and presence of alkaloids, flavonols and proanthocyanidins keep the Eriolaeneae as the most primitive tribe. Of the two remaining tribes Hermannieae and Helictereae, the former is more primitive in producing myricetin , the highly hydroxylated flavonol as also this tribe does not produce any flavone. The Helictereae contain plants devoid of flavonoids though it produces flavones. In an evolutionary sequence the tribes may be arranged:

Eriolaeneae → Hermannieae → Helictereae → Buttnerieae → → Sterculieae → Dombeyeae

The contention of restricting the family Sterculiaceae to the traditional tribe Sterculieae are suggested by Edlin and supported by Chattaway (1937) on anatomical grounds may not get much support from Chemistry. The Sterculieae possess the same compounds present in the rest of the family except for the 6-oxygenated flavones. But the 6-oxyflavones were seen only in one plant (**Sterculia foetida**) out of the six plant screened. Even the other two species of **Sterculia** studied (**S.belanghas** and **S.urens**) do not produce these compounds. In this context the presence of these compounds may not warrant undue weightage and may be considered an advanced character developed in the group. The reduction in number of flavone or flavonolcontaining taxa (two each) may be considered as an advanced trend in evolution. However, these characters corroborate the advanced nature of the tribe as evidenced by their unisexual apetalous flowers. Therefore the inclusion of the Sterculieae within the family Sterculiaceae appear to be natural. The two other groups visualised by Metcalfe and Chalk (1980) based on the wood

parenchyma **i.e.**Buttnerieae and Helictereae (parenchyma apotracheal) together as the first group and Dombeyeae, Eriolaeneae and Hermannieae (parenchyma paratracheal) as the second group also do not get concurrence from the chemistry.

The affinities of the Sterculiaceae with the other families of the Malvales are evaluated in the chapter 8 (General discussion).