

SUMMARY AND HIGHLIGHTS

Chapter 9

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The Malvaceae and their allies, the Bombacaceae, Sterculiaceae, Tiliaceae and Elaeocarpaceae constitute the order Malvales which is considered one of the most homogeneous orders of Magnoliopsida. This order is characterised by stellate or lepidote hairs and usually with mucilage cells/sacs/cavities, young stems with stratified phloem and very wide wedge-shaped phloem rays, hypogynous flowers with valvate sepals, sepaline nectaries, variously united or free stamens and seeds containing cyclopropenyl fatty acids. The Malvaceae and Sterculiaceae are the larger families. The Malvales, conceived by the earlier taxonomists consisted of few families whereas at a later stage more families, which are often the splinter-groups of the large families, were added or removed, resulting in a large cluster. The Sphaerosepalaceae, Sarcolaenaceae, Scytopetalaceae, Dipterocarpaceae, Huaceae, Bixaceae,

Cochlospermaceae, Cistaceae and Plagiopteraceae are some of the families treated thus. Of these, the first four families are sometimes grouped in the Theales and the rest in Violales. Within the order, large number of stamens or carpels are considered primitive by some while such a condition is treated as a secondary adaptation by others. The former group of taxonomists derive the Malvales from the Theales. To find out the interrelationships and the phylogeny of the groups in question, the available members of these families have been subjected to a chemotaxonomic analysis using chemical markers such as leaf flavonoids, phenolic acids, alkaloids, saponins and tannins.

The Malvaceae are the largest family of Malvales. This family is characterised by monadelphous stamens, reniform anthers and spiny pollen grains. The Malvaceae contain a number of medicinal plants besides fibres, mucilages and vegetables. The tribe Hibisceae producing capsular fruits often is referred to the Bombacaceae. The generic status of **Azanza**, **Abelmoschus** and **Senra** are controversial. The results of analysis of leaves of 42 species belonging to 15 genera of the Malvaceae showed the family to contain various flavonoids such as flavonols, flavones, glycoflavones and proanthocyanidins in 31 plants. Flavonols formed the dominant flavonoids in the family with flavones and glycoflavones in about 25% of plants each. Proanthocyanidins were rare. Eleven plants did not elaborate any flavonoid. The phenolic acids were ubiquitous. Alkaloids, saponins and tannins also were few in this family. Of the three tribes represented in the present study. Malveae and Ureneae are found to be homogeneous chemically while the Hibisceae exhibit a great amount of heterogeneity. The Malveae are devoid proanthocyanidins and are poor in flavones. Within this tribe the subtribe Abutilinae is free of glycoflavones and contains fewer

flavonols. Both *Abutilinae* and *Malvinae* are devoid of tannins. The *Abutilinae* are the most advanced subtribe, *Sidinae* primitive and *Malvinae* intermediate in evolution. The tribe *Ureneae* do not contain any flavone or quercetins. This tribe contains the maximum number of plants in which the flavonoid system is lost. Within the *Ureneae*, *Urena* and *Malchra* are the advanced genera. The tribe *Hibisceae* produces all four types of flavonoids and is heterogeneous in nature. *Abelmoschus* is different from *Hibiscus* in its inability to produce flavones, kaempferol, glycoflavones, proanthocyanidins and tannins. Similarly *Azanza* is distinct from *Hibiscus* in not synthesising flavonoids, glycoflavones and proanthocyanidins. *Azanza* is similar to *Thespesia* in possessing flavones and tannins but these two genera differ in other chemical characters. Similarly *Senra* and *Gossypium* also are different in their flavonoids. The genus *Hibiscus* also is highly complex and may need subdivisions. The identity of *Hibiscus schizopetalus* away from *H. rosa-sinensis* also is established.

The *Bombacaceae* are accepted to be the closest ally of the *Malvaceae*. Three members belonging to the genera *Adansonia*, *Bombax* and *Ceiba* are examined for their leaf phytochemicals. *Adansonia* contains flavonols while the other two genera, flavones. In containing both flavones and flavonols *Bombacaceae* are similar to the *Malvaceae*. The tribe *Hibisceae* of *Malvaceae* which are referred to the *Bombacaceae* on the basis of fruit characters, are different from the latter in producing glycoflavones and methoxylating their flavonols. However the *Hibisceae* are the group in *Malvaceae* closest to be *Bombacaceae* because of their reliance of flavones.

The *Sterculiaceae*, the second largest family of *Malvales*, are similar to the *Malvaceae* and *Bombacaceae* in

many of their morphological, anatomical, embryological and palynological features. Some taxonomists restrict the family to a single tribe Sterculieae and refer the rest to another family Buttneriaceae. The analysis of the leaves of 22 members revealed that the family contains flavones, flavonols, glycoflavones and proanthocyanidins. Flavones and flavonols are equally distributed. 6-Oxyflavones are seen in **Sterculia foetida**. Myricetin is located in **Waltheria**. Glycoflavones are seen in 3 plants and proanthocyanidins in 14. This family is peculiar in having a curious association of advanced and primitive characters which in turn reflects the heterogeneity of the group. The presence of all the above-mentioned flavonoids brings the Sterculiaceae closer to the Malvaceae. The various tribes also are distinguishable on the basis of their flavonoids. Both the Eriolaeneae and Hermannieae are free of flavones. Between the two, the latter contains glycoflavones. Eriolaeneae contain only flavonols alongwith traces of proanthocyanidins. The Buttnerieae distinguish themselves in containing all the four types of flavonoids i.e. flavones, glycoflavones, flavonols and proanthocyanidins. Both Helectereae and Sterculieae contain flavones and flavonols but no glycoflavones. The latter tribe is peculiar in containing 6-oxyflavones. In synthesising flavones and reducing flavonols and proanthocyanidins the tribes Dombeyeae, Buttnerieae and Sterculieae are the advanced tribes. The Eriolaeneae are the most primitive tribe due to flavonols, proanthocyanidins, alkaloids and in the absence of flavones and glycoflavones. The contention of restricting the family Sterculiaceae to the traditional tribe Sterculieae does not get any support from chemistry, because this tribe, in no way, is distinct from the rest of the family.

The family Tiliaceae is considered primitive on all the available characters. On anatomical, palynological and embryological grounds this family is similar to the rest of the order Malvales. Chemically it is peculiar in possessing cardiac glycosides and ellagic acid. A number of fibres and medicinal plants are reported from this family. A study on leaves of 20 members of the Tiliaceae reveals that the family possesses flavones and flavonols in equal amounts. The flavones include highly advanced 6-hydroxyflavone, the scutellarein and their derivatives, located in three plants. Gossypetin is seen only in one plant and proanthocyanidins in four. The family is free of glycoflavones. The prevalence of flavones that also the 6-oxycompounds, and reduction in proanthocyanidins are two advanced chemical characters found in the Tiliaceae which are otherwise considered primitive and these features keep the family as one of the advanced families of the Dilleniidae. Among the three tribes represented in the present study, the Brownlowieae are distinct in being devoid of flavonoids and thus isolate themselves from the rest of the family. The tribe Tiliaceae is characterised by the uniform presence of flavonols, abundance of alkaloids and saponins, absence of proanthocyanidins and rarity of flavones. The tribe Grewieae elaborate all types of flavonoids notably flavones which are widely distributed. The genus **Grewia** is peculiar in having a curious association of both advanced (flavones), and primitive (flavonols and proanthocyanidins) characters. The retention of primitive features is due to the woody habit. **Triumfetta** is the most advanced genus in producing 6-substituted flavones.

The Elaeocarpaceae are a splinter-group of the Tiliaceae kept always close to the latter family in almost all systems of classifications. But, strange enough, this

family does not exhibit any of the typical characters of the Malvales i.e. stellate/peltate trichomes, mucilage cells/cavities, triangular stratified phloem, wedge-shaped rays, sepaline nectaries and cyclopropenoid fatty acids. The genera **Muntingia** and **Dicraspidia** differ from the rest of the Elaeocarpaceae on many morphological features and is kept in Tiliaceae or Flacourtiaceae at times. Four members belonging to **Elaeocarpus**, **Tricuspidaria** and **Muntingia** have been analysed presently and the data show the family to be flavonol-rich. Myricetin is seen in this family. Flavones are absent but glycoflavones and proanthocyanidins are not rare. In being flavonol-rich and in possessing glycoflavones and proanthocyanidins, the Elaeocarpaceae are similar to the Tiliaceae. **Muntingia** is similar to the rest of the Elaeocarpaceae in its flavonoid chemistry and therefore finds a better place here. It does not fit in comfortably in both Tiliaceae and Flacourtiaceae since these two families have been flavone-rich.

Bixaceae, Cochlospermaceae, Flacourtiaceae and Dipterocarpaceae are the other families, of controversial relationships with the Malvales *sensu lato*, analysed in the present study. Bixaceae are rich in flavones and proanthocyanidins and are devoid of flavonols and glycoflavones. Cochlospermaceae are essentially flavonol-rich and are free of flavones or glycoflavones. These chemical estrangements set the arguments in favour of their merger together in one family, at rest. Flacourtiaceae contain both flavones and flavonols alongwith glycoflavones and proanthocyanidins while the Dipterocarpaceae possess only flavonols.

The families Malvaceae, Bombacaceae, Sterculiaceae and Tiliaceae form a close-knit group. These families share a number of chemical characters such as flavones,

glycoflavones, flavonols, proanthocyanidins, mucilages and cyclopropenoid fatty acids. The absence of gallic acid, quinones and the tendency to eliminate the flavonoid system are the other features common among these families. Within the group, each family developed independently with its own specialisation in phenolic chemistry. The Malvaceae reduced hydroxy flavonols, proanthocyanidins and tannins and introduced flavones and glycoflavones and successfully eliminated flavonoids in about 25 % of plants. The Bombacaceae retained tannins and proanthocyanidins useful in the woody habit but replaced flavonols by flavones in the big way. Similarly the woody Sterculiaceae reduced flavonols to the minimum while retaining tannins and proanthocyanidins. This family introduced 6oxyflavones and tried to eliminate flavonoids in many plants. The Tiliaceae retained flavonols but alongwith produced flavones and glycoflavones in Grewieae. The 6-oxygenation arose in this family also. The different trends in evolution and the almost equal evolutionary levels attained by these families indicate that all the four families arose from a common stock and not from one another.

Even though the earlier taxonomists brushed the obvious dissimilarities of the Elaeocarpaceae with the other four families aside with much ease, the pronounced chemical differences of this family with the other members of Malvales, obtained from the present study, compels one to have a rethinking on the 'accepted' affinities of the Elaeocarpaceae. The Elaeocarpaceae do not possess any of the typical characters of the Malvales such as mucilages, stellate/ peltate trichomes, triangular stratified phloem, triangular distal ends of rays traversing the phloem, sepaline nectaries, cyclopropenoid fatty acids and flavones. In addition, this family produces gallic acid, a typical constituent of the Violales. it makes one wonder as to what

made the students of taxonomy to overlook the obvious long array of differences and give unusual weightage to a few common characters which the Elaeocarpaceae share with many families of the Theales or Violales also. Therefore the removal of the Elaeocarpaceae from the Malvales is suggested. This family finds kinship among some anomalous members of the Flacourtiaceae, which family itself is highly heterogeneous.

Bixaceae, Cochlospermaceae and Dipterocarpaceae share much more characters with the Malvales *sensu lato* than the Elaeocarpaceae. These families, which are distributed between the Theales and Violales, are to be subjected to a critical and exhaustive study before assigning them to any taxon.

In addition to the contribution to the taxonomy of the Malvaceae and related taxa, the thesis contains new chemical reports on sources of bioflavonoids, alkaloids, saponins and tannins.

The highlights of the present investigation are as follows:

1. redefining the Malvales by including only the Malvaceae, Bombacaceae, Sterculiaceae and Tiliaceae and excluding the highly dissimilar Elaeocarpaceae. The Malvales, thus defined, is a greatly homogeneous monophyletic group in the subclass Dilleniidae.
2. Position of the tribe Hibisceae. The tribe Hibisceae, the transfer of which is proposed, on the nature of fruits, to the Bombacaceae, is found to be chemically similar to the rest of the Malvaceae in producing all

the four types of flavonoids i.e. flavones, glycoflavones, flavonols and proanthocyanidins. It is dissimilar to the Bombaceae in producing glycoflavones which are not found in the latter family. Therefore the Hibisceae find a better place in the Malvaceae itself.

3. The status of the tribe Sterculieae. The family Sterculiaceae was restricted to the single tribe Sterculieae by some taxonomists who would like to group the remaining tribes of the family into another family, Buttneriaceae. The Sterculieae are found to be similar to the rest of the Sterculiaceae and do not exhibit any separate chemical identity and therefore this tribe is to be kept in Sterculiaceae alongwith the other tribes.
4. The evolutionary status of the Sterculieae is found to be very high in the Sterculiaceae because this tribe contains 6-oxyflavones, higher incidence of flavones and very less flavonols. This is in line with the morphological advancement evidenced in the unisexuality, apetal, and polygamous nature of the flowers. Therefore the apocarp in Sterculieae can be considered secondary.
5. The taxonomic status of the Brownlowieae is clear from the present study in that, this tribe is distinct from the rest of the Tiliaceae in eliminating the flavonoids from leaves. Therefore the subfamily status accorded to this tribe is supported.

6. The Cochlospermaceae are found to be distinct chemically from the Bixaceae. The former family is flavonol-rich and is unable to synthesise flavones or glycoflavones while the latter family produces flavones and gallic acid and does not produce any flavonol.
7. The affinities of the Bixaceae, Cochlospermaceae and Dipterocarpaceae are established. None of these families can be included in the Malvales because they do not possess the characteristic compounds of the latter order. The Cochlospermaceae and Dipterocarpaceae are close to each other and these families and Bixaceae appear to be evolved close from a pro-Malvales group.
8. All the four families of the order Malvales appear to have attained almost similar levels in an evolutionary ladder. All families diverged in separate directions.
9. The ancestral group of Malvales appears to be the Theales which elaborate the primitive type of flavonoids and are without any specific metabolic virtuosity. The Violales and Bixales are chemically too evolved than the Malvales to give rise to the latter.
10. **Muntingia** which is shuttled among the Tiliaceae, Elaeocarpaceae and Flacourtiaceae finds a proper place in the Elaeocarpaceae. The flavones and cyclic fatty acids (cyclopentenoid in Flacourtiaceae and cyclopropenoid in Tiliaceae) characteristic to both the Flacourtiaceae and Tiliaceae are not produced by **Muntingia**.

11. **Azanza** and **Abelmoschus** are found to be chemically distinct from **Hibiscus** to which they were included once. **Azanza** is different from **Hibiscus** in not possessing flavonols, glycoflavones and proanthocyanidins prevalent in the latter genus. It keeps its identity from **Thespesia** also in being devoid of flavonols present in latter. Similarly **Abelmoschus** is distinct in not synthesising flavones, kaempferol, glycoflavones and tannins common in **Hibiscus**.
12. **Senra** and **Gossypium** are chemically isolated from each other in producing different flavonols.
13. The separate identity of **Hibiscus schizopetalus** from **H.rosa - sinensis** is established because the former produces a c-glycosyl flavonol while the latter contains a glycoflavone.
14. A number of new sources of bioflavonoids, alkaloids, saponins and tannins are discovered in the present study.