GENERAL DISCUSSION

Chapter 8

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The distribution of various flavonoids and other phytochemicals, which show significant evolutionary trends, in the Malvaceae and related families (Table 8) show interesting reading. Among the other four families of the Malvales i.e. Bombacaceae, Sterculiaceae, Tiliaceae and Elaeocarpaceae,the first three are similar to the Malvaceae in their flavonoids. All of them contain flavonols as the main phenolic pigments (except for the Bombacaceae) and produce flavones, glycoflavones (except in Bombacaceae and Tiliaceae), proanthocyanidins and tannins. None of these families exhibits a distinct chemical character to isolate itself away from the rest. This corroborates the data on other chemical compounds, such as the mucilages and cyclopropenoid fatty oils and establishes the Malvales (excluding the Elaeocarpaceae) as a well-knit homogeneous assemblage of a number of natural taxa. The various chemical evolutionary trends seen in this group are (1) methoxylate flavonols, (2) replacing quercetin with less

Table 8: The distribution of various phytochemicals in Malvaceae and related families

	Advanced characters %							Primitive characters %					
	1	2	3	4	5	6	Total 1 - 6	7	8	9	10	11	Total 7-11
1. Malvaceae	26	21	-	24	28	42	141	30	-	12	-	25	67
2. Bombacaceae	..	66	..	..	..	33	99	33	..	33	.	66	132
3. Sterculiaceae	14	41	05	14	20	31	125	18	05	65	.	38	126
4. Tiliaceae	05	55	15	35	..	25	135	60	..	20	..	20	100
5. Elaeocarpaceae	..	..	..	25	75	50	150	75	25	25	50	50	225

1) Absence of flavonoids, 2) Flavones, 3) 6-O-Flavones, 4) Glycoflavones, 5) Methoxyflavonols 6) Kaempferol, 7) Quercetin, 8) Myricetin, 9) Proanthocyanidins, 10) Gallic acid, 11) Tannins.

hydroxylated counterpart, the kaempferol, (3) reduction in proanthocyanidins and tannins and (4) introduction of glycoflavones and flavones. The two highly evolved chemical features are the introduction of 6-hydroxyflavones and the ultimate loss of the flavonoid skeleton altogether. An assessment of the component families of Malvales in the light of these trends provides the level of advancement each family has attained in an evolutionary hierarchy.

The Malvaceae, the principal family of the Malvales, show trends in the reduction of the primitive features and introduction of a number of advanced features. Among the primitive features, quercetin is present in only about 30% of plants and kaempferol is prevalent in above 40% of plants. The primitive pyrogallol systems (seen in myricetin, gallic acid etc.) are completely eliminated. Tannins are reduced to 25% and proanthocyanidins to a mere 12%. Methoxylation of flavonols is attained in about 25% of plants. Flavones and glycoflavones are introduced in about 20% and 25% of plants respectively. A singificant feature in Malvaceae flavones is that all of them are methoxylated derivatives of apigenin. The pure hydroxy flavones, especially luteolin, with a higher number of hydroxyl groups,are absent. The same is the case with glycoflavones in that they also are methoxylated compounds. Though 6-oxygenation of flavones could not be attained, this family contains the maximum number of plants without flavonoids i.e. 26%. On a rough numerical scale the total of advanced characters amounts to 141 while the total of primitive characters come down to 67. This indidcates that the Malvaceae may be considered a chemically advanced family. Within the family, the Hibisceae are the most versatile and advanced tribe with its comparatively higher incidence of flavones, glycoflavones, kaempferol and methoxyflavonols.

The Bombacaceae, surprisingly, show a number of advanced characters such as the induction of flavones as the dominant flavonoid and reduction in the flavonols and proanthocyanidins. Though the number of plants screened is comparatively small, the trends in evolution exhibited by this family warrant careful considerations. The two plants, **Bombax** and **Ceiba**, are free of flavonols and contin flavones instead. Among the two common flavones found in higher plants, apigenin and luteolin, these plants preferred to produce the less hydroxylated flavone, the apigenin. A far more interesting feature is to methoxylate flavones in that all the three flavones in these genera are methoxylated. These features take these taxa to a very high level of evolutionary specialisation. This does not mean that they are devoid of primitive characters. In fact, **Ceiba** exhibits two primitive characters, the pranthocyanidins and tannins (of course in lower concentrations). The retention of primitive characters may be due to the woody nature of these trees. **Adansonia**, on the other hand, possesses many primitive characters. It contins only simple flavonols quercetin and kaempferol. Even the trend of methoxylating flavonols is absent here. Of course the absence of proanthocyanidins may be taken as a single evolutionary significant advanced character exhibited by this genus. From the present investigation it can be definitely said that in many of the chemical characters the Bombacaceae is definitely advanced over the Malvaceae.

The question of annexing the tribe Hibisceae (Malvaceae) to the Bombacaceae is already discussed in chapter 4. Though the Hibisceae resemble the Bombacaceae in fruit characters and apotracheal parencyma, they are similar to the rest of the Malvaceae in pollen characters. Chemically also the Hibisceae are more at home with the

Malvaceae where it shares the characters like loss of flavonoid system, methoxylation of flavonols, glycoflavones etc. with the rest of the family. Within the Malvaceae, the Hibisceae occupy a peripheral position and are the group closest to the Bombacaceae. The cited similarities between the petiolar vascular bundle of **Hibiscus** with the least complex type of petiolar vascular bundles of Bombacaceae (Metcalfe and Chalk,1950) add additional support to this contention.

In many chemical features the Sterculiaceae are similar to the Malvaceae. But this family produces more flavones than flavonols, so that the former group predominates over the latter. Flavones are present in about 40% of plants (as against 20% of Malvaceae) and flavonols in 36% (53% in malvaceae). Among the flavones,the methoxylated compounds are seen in more plants than the simple hydroxylated ones. But the most signficiant feature is the production of highly advanced 6-hydroxy/methoxy flavones, which are located in **Sterculia foetida.** In the case of flavonols, both hydroxy flavonols and methoxy flavones occur in five plants each **i.e.** upto 25%. A higher content of kaempferol over quercetin also is noted. But the presence of myricetin, the highly hydroxylated flavonol (a primitive feature) in **Waltheria** contradicts all claims of evolutionary advancement of this family. Added to this, a comparatively higher percentage of proanthocyanidin and tannin-containing plants in the family, tend to question the higher evolutionary status assigned to this family. It is quite possible that the primitive characters are retained because of the woody nature of the family.

The Tiliaceae spring a number of surprises for a chemotaxonomist. Considered primitive by all standards, this family was expected to contain bounteous primitive chemical characters. But the Tiliaceae contain the maximum incidence of flavones (55 %) among the major families, and thé highest number of plants containing the highly advanced 6-oxy flavones. In as many as 45% of plants the flavones are methoxylated. Luteolin is present in four plants but at least in 3 it exists as methoxy derviatives. Equally abundant are the flavonols where the hydroxy compounds and methoxy derivatives are almost equal in distribution. The Tiliaceae are free of glycoflavones and the plants without flavonoids also are few. Among the primitive characters, quercetin is the most abundant one having been located in atleast 60% of plants. Proanthocyanidins are few (20%) as also tannins (20%). On a rough numerical scale the sum total of advanced characters (125) outweigh the primitive features (100) in this family.

The Elaeocarpaceae present their chemical budget in accordance with their accepted place in an evolutionary sequence. This family does not produce any flavone and is rich in flavonols and tannins and poor in glyflavones and proanthocyanidins. Quercetin predominates in this family, though methoxy-quercetins also are seen in equal amounts. Kaempferol is present in half the plants. Myricetin, the most primitive flavonol,also is present in this family. In its failure in producing flavones which are the most distinctive compounds of the Tiliaceae and in possessing gallic acid and glycoflavones, the Elaeocarpaceae are distinctly different from the Tiliaceae. These features give enough credentials for the Elaeocarpaceae to remain independent. Only the prevalence of quercetin is the feature of similarity between the said two families. The absence of flavones and presence of gallic acid make the Elaeocarpaceae distinct from all other families grouped in the Malvales. The total amount of primitive characters (225) are much higher than the advanced features (150) indicating that the

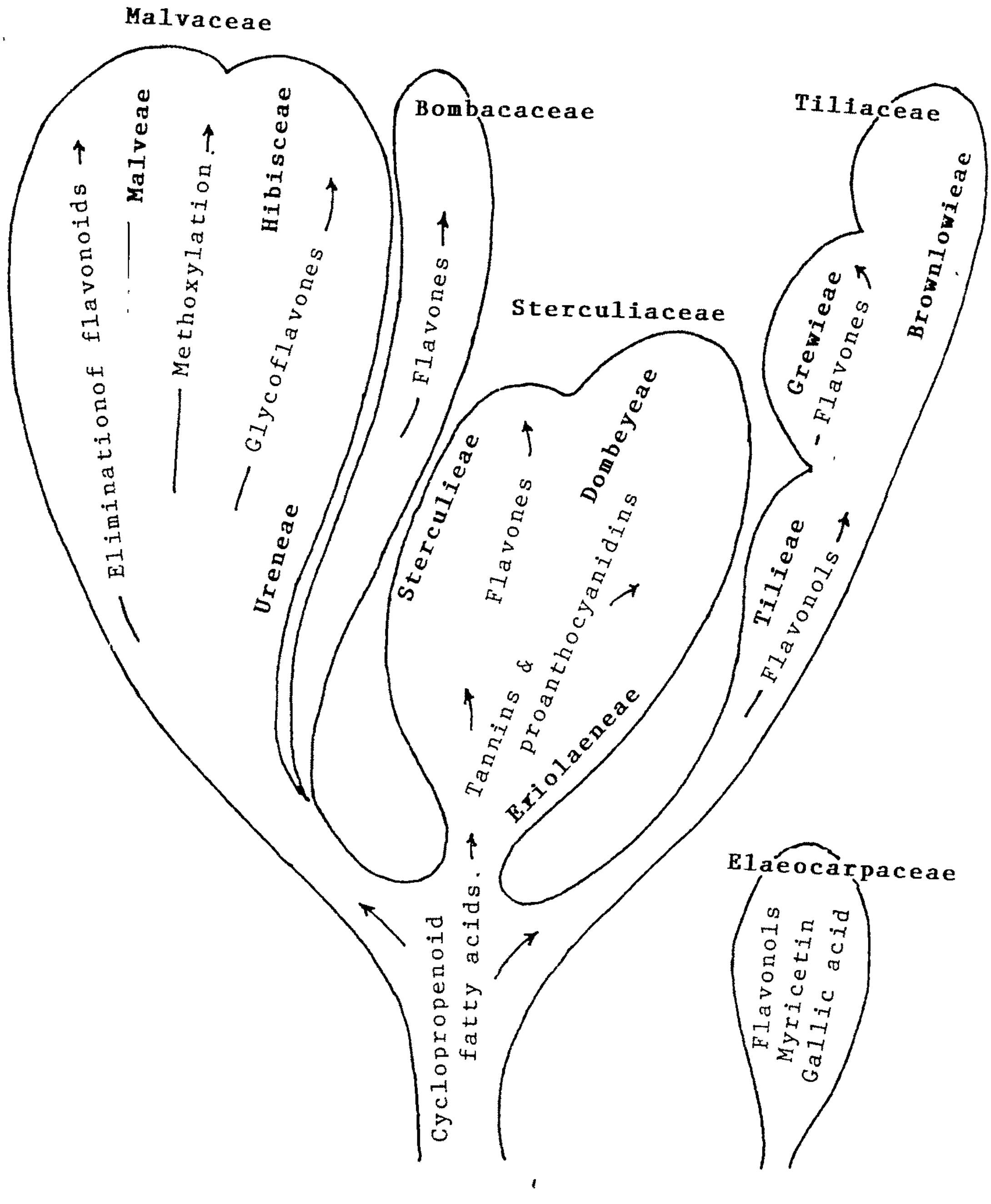

Fig. 1. The various evolutionary pathways operative in and the levels of advancement achieved by the families of the Malvales.

family occupies a lower rung in the evolutionary ladder.

The few available members of the Bixaceae (**Bixa orellana**), Cochlospermaceae (**Cochlospermum religiosum**), Flacourtiaceae (**Hydnocarpus wightiana**) and Dipterocarpaceae (**Shorea robusta**) have also been screened for their phytochemicals in the present work. The distribution of chemical markers in these plants are presented in Table 9 .

Bixa orellana L.contained in its leaves flavones such as apigenin and 7-OMe apigenin, and proanthocyanidins. The phenolic acids present in this plant are gallic, vanillic, syringic, gentisic and melilotic acids. Flavones and glycoflavones are absent. In containing flavones as dominant flavonoids, **Bixa** is similar to the Tiliaceae and the gallic acid brings it closer to the Elaeocarpaceae.

Cochlospermum gossypium DC. produces flavonols such as quercetin (in large amounts) and 3',4'-diOMe quercetin and proanthocyanidins. This plant is devoid of flavones, glycoflavones and gallic acid. The dominant phenolics of **Bixa**, the flavones and gallic acids, are characteristically absent in **Cochlospermum.** In morphological characters such as stellate indument and parietal placentation and in anatomical characters as diffuse wood parenchyma, **Bixa** differs from **Cochlospermum** which possesses no indument, ovary partitioned towards the base and broad apotracheal bands of sometimes vasicentric parenchyma. It is to be recalled that the Bixaceae and Cochlospermaceae were kept in separate suborders of Parietales, Cistineae and Cochlospermineae by Engler and Diels. All these differences between the two genera give strong support for keeping them as two distinct families the Bixaceae (**Bixa**) and Cochlospermaceae (**Cochlospermum**). Cochlospermaceae are more similar to the Malvaceae which contain the flavonols as the dominant flavonoids.

Table 9: Chemical characters in some members of the families related to the Malvales

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	Bixaceae																					
1.	**Bixa orellana** L.	+	+	.	.	.	.	.	.	+	+	+	+	.	+	+	.	.	.	.	.	.
	Cochlospermaceae																					
2.	**Cochlospermum gossypium** D.C.	.	.	.		.	+	.	+	+	.	.	+	+	.	.	+	.	.	.	.	.
	Flacourtiaceae																					
3.	**Hydnocarpus wightiana** Bl.	.	.	+	+	.		+		+	-	+	+	.	.	+	.	+	+			
	Dipterocarpaceae																					
4.	**Shorea robusta** Gaertn.	.	.	.	.	+	+	.	.	.	+	.	+	+	.	.	+	.	.			

1) Apigenin, 2) 7-OMe Apigenin, 3) Luteolin, 4) Glycoflavone, 5) Kaempferol, 6) Quercetin 7) 3'-OMe Quercetin, 8) 3',4'-diOMe Quercetin, 9) Proanthocyanidins, 10) Gallic acid, 11) Vanillic acid, 12) Syringic acid, 13) p-Hydroxybenzoic acid, 14) Gentisic acid, 15) Melilotic acid, 16) p-Coumaric acid, 17) o-Coumaric acid, 18) Ferulic acid, 19) Alkaloids, 20) Saponins, 21) Tannins.

The single member of the Flacourtiaceae screened, **Hydnocarpus wightiana**,Bl., possessed flavonols, glycoflavones and proanthocyanidins. 3'-OMe Quercetin was the sole flavonol present while the flavone seen was luteolin. **Hydnocarpus** contained phenolic acids such as vanillic, syringic, ferulic, o-coumaric and melilotic acids. In containing all the four types of flavonoids the Flacourtiaceae are similar to the Malvalean families.

The leaves of **Shorea robusta** Gaertn.,of the Dipterocarpaceae,contained simple flavonols quercetin and kaempferol and phenolic acids such as gallic, syringic, p-hydroxy benzoic and p-coumaric acids. It did not possess flavones, glycoflavones or proanthocyanidins.

Evidently the Malvaceae, Bombacaceae, Sterculiaceae and Tiliaceae form a closely knit group. These families share a number of chemical characters such as flavones (both 6-deoxy and 6-oxy-), glycoflavones, flavonols, proanthocyanidins, mucilages (structural polysaccharides) and cyclopropenoid fatty acids. The absence of gallic/ ellagic acids, quinones and the tendency to eliminate the flavonoid skeleton altogether, form other features common among them. Each family developed independently with its own specialisation in phenolic chemistry. The Malvaceae reduced hydroxyflavonols, pronathocyanidins and tannins, introduced flavones and glycoflavones and tried to achieve the highest state in flavonoid evolution **i.e.** the elimination of flavonoid system, in about 25%of plants. The resortment of flavones is marked in tribe Hibisceae while the other characters are prevalent in remaining tribes also. The Bombacaceae, on one side, retained the tannins and to some extent proanthocyanidins (probably due to the woody nature), but on the other side, proceeded to synthesise flavones in a big way. This family may be derived from the base of the Malvaceae. The Sterculiaceae reduced flavonols to the minimum while retaining the tannins and proanthocyanidins (another example of adaptation to the woody habit), but tried to depend on flavones on a larger scale and introduced 6-oxyflavones in Sterculieae. The loss of flavonoid system is another evolutionary trait seen successful here. The Tiliaceae relied on the flavonols in large amounts, but alongwith, they produced flavones and glycoflavones in comparatively greater amounts in Grewieae. Though elimination of flavonoid skeleton operated in this family, greater emphasis is on the 6-oxygenation of flavones. The various evolutionary pathways operating in these families and the levels of advancement achieved by them are depicted in Fig.2. All these different trends in evolution in this order indicate that all the four families are derived from a promalvaliann group rather than from one another. Elevating the Malvaceae to a unifamilial order, the malvales by Hutchinson (1969), considering it as a climax group, does not get credence from chemistry. Chemically the Malvaceae are almost at par with the other families of the order.

Earlier, based on the available evidences, it was commented that the Elaeocarpaceae stand somewhat isolated from the rest of the Malvales. This family was considered the most archaic group in the order. But a critical assessment brings out a strange fact that the Elaeocarpaceae exhibit more differences than similarities with the rest of the order. The differences are in :

(1) Aestivation of sepals. The sepals in some of the Elaeocarpacee are imbricate as against the valvate aestivation of the rest of the malvales. (This character is critical because the Sarcolaenaceae and Sphaerosepalaceae, though possess mucilage cells and stratified phloem, are

kept away from the Malvales because they have imbricate sepals).

(2) Mucilage cells, cavities and canals: These structures which are omnipresent in the other four families are absent in Elaeocarpaceae.

(3) Stellate or peltate hairs. These are some of the most distinctive micromorphological characters of the Malvales, found absent in the Elaeocarpaceae.

(4) Triangular stratified phloem and the triangular distal ends of rays are not seen in any of the Elaeocarpaceae.

(5) Specialised sepaline nectaries, which are the adaptations due to the polypetalous nature of corolla, are found in all the Malvalean families but for the Elaeocarpaceae.

(6) Cyclopropenoid fatty acids such as sterculic and malvalic acids are reported from the seed-fats of all the families except those of the Elaeocarpaceae.

(7) Flavones. Elaeocarpaceae are the only family in the Malvales which do not elaborate flavones. These compounds are widely prevalent in other families and in Bombacaceae and Tiliaceae they form the dominant flavonoid pigments.

(8) Gallic/ ellagic acid. These acids are found to occur in the members of the Elaeocarpaceae and not from any other family discussed above.

From the data presented above, it becomes clear that the Elaeocarpaceae do not contain any of the typical characters of the Malvales, questioning the logics of keeping the Elaeocarpaceae in Malvales. At present it sems that the exclusion of the Elaeocarpaceae would make the Malvales one of the highly natural orders of the Angiosperms.

The placement of Elaeocarpaceae elsewhere may not pose many problems. Some of the Elaeocarpaceae are very similar to a few of the Flacourtiaceae and this similarity extends even to the pollen morphology. The genus **Muntingia** of Elaeocarpaceae, with its valvate calyx, plurilocular ovary and short broad longitudinally dehiscent anthers, is very much like the Flacourtiaceous genera **Prockia** and **Hasseltia** and all these genera lie in the indefinite boundary land between the highly diversified family Flacourtiaceae and the more narrowly limited Elaeocarpaceae (Cronquist, 1981). The proper place of Elaeocarpaceae would, therefore, be near the Flacourtiaceae in the order Violales.

If only anatomical characters such as stratified phloem and the nature of rays where they traverse the phloem and the nature of the petiole are considered, the Bixaceae, Cochlospermaceae, Dipterocarpaceae and Flacourtiaceae (in part, especially the genera **Erythrospermum**, **Prockia**, **Hasseltia** etc. which are almost anomalous in Flacourtiaceae) appear to be closely related. Among these four families, only Bixaceae possess unilocular ovary with parietal placentation. The Dipterocarpaceae have a plurilocular ovary with axile placentation and the Cochlospermaceae exhibit partly axile (both at the base and at the top of the ovary) and partly parietal (at the centre of the ovary) placentation. The anomalous genera of the Flacourtiaceae, mentioned above also possess a pluriocular ovary and axile placentation. Chemically, the screened members of the Bixaceae contain flavones while those of the Cochlospermaceae and Dipterocarpaceae contain flavonols with

Flacourtiaceae producing both flavones and flavonols. Whether these families together with the Elaeocarpaceae form a taxonomically valid group will be known only after a substantial amount of additional chemical data are made available.

The proposed derivation of Malvales **sensu lato**, from the less modified members of the Theales, as proposed by Cronquist (1981) sems plausible. The Theales are characterised by primitive flavonols and tannins and are free of complex secondary metabolites. The presence of purine alkaloids (Theaceae) similar to those of the Sterculiaceae, stellate hairs (Sarcolaenaceae), peltate scales (Dipterocarpaceae), mucilage cells (Sarcolaenaceae, Dipterocarpaceae), stratified phloem (Sphaerosepalaceae, Sarcolaenaceae, Dipterocarpaceae) and wedge-shaped rays (Dipterocarpaceae) in members of the Theales, evidently places the ancestry of the Malvales firmly on them. The Violales (Takhtajan 1980) are too specialised in their chemistry to be a pro-Malvalean group. The same is true of the Bixales which are considered ancestral to the Malvales by Hutchinson (1969).