6. Family RUTACEAE

The family Rutaceae (150 genera and 1500 species) is widely distributed in tropical and temperate regions, but is most abundant in Tropical America, South Africa and Australia.

The Rutaceae are aromatic shrubs, trees or rarely herbs. The family, as a rule, has pellucid or gland-dotted leaves containing schizogenous or lysigenous oil cavities storing aromatic oils. The leaves are simple or compound, alternate and exstipulate. The flowers are regular (irregular in **Dictamnus**), hypogynous in axillary or terminal cymes or panicles. Sepals 4-5, free and imbricate, corolla free or rarely united (**Ravenia**). Stamens are equal to or twice the number of petals often conspicuously dilated at the base. The outer whorl of stamens are opposite to petals having a well developed intrastaminal disk. Gynoecium is bi - or tetracarpellary, deeply lobed, free or connate, styles as many as carpels and the stigma terminal, entire or lobed. Ovules two to numerous on axile placentation, superposed, pendulous, epitropous with ventral raphae and upwardly and outwardly directed micropyle. The ovules are anatropous, bitegmic rarely unitegmic and crassinucellate. Fruit is a berry, capsule, drupe or 1-4 capsular cocci.

Anatomy

The data from floral anatomical studies by Saunder (1939) do not support Engler's classification of the family. There are about eight different types of anatomical variations existing in the family in adnation, cohesion and insertion of different vascular traces. The simplest condition is seen in the genus **Zanthoxylum**. The variations existing among the various genera do not tally with the classification. Though the family is predominantly bisexual, polygamous condition is observed in **Zanthoxylum**, **Toddalia** and **Skimmia**. The disk is found to be a reduced staminal whorl similar to that of the Meliaceae (Tillson and Bamford, 1938) Hutchinson (1973) opines that the ovary of the family has a strong tendency towards deep lobing which results in the formation of gyno- or subgynobasic style. Simple hairs are less frequent than the secretory hairs. The ground tissues of leaf, leaf axis and sepals are always characterised by secretory cells and canals (Metcalfe and Chalk, 1950).

The wood of this family is usually pale yellowish-white without any distinction of sapwood and heartwood and is fine-textured. The hardness and density of the wood vary greatly. It is diffuse porate with paratracheal parenchyma usually vasicentric with large chambered crystal cells. The rays are fine and invisible. Some of the genera have gum deposits and occasionally traumatic gum canals (similar to those of the Simaroubaceae). Septate fibres are absent and the perforation is by simple pits which are minute.

Embryology :

The anthers have 3-4 layered wall with fibrous endothecium and glandular multinucleate tapetum. The ovule does not possess endothelium. Embryo sac is Polygonum type and endosperm is nuclear. The obturator is present but the nucellar cap is absent. The occurence of polyembryony is a common feature of the family (Johri and Ahuja, 1957). Most of the plants have nucellar polyembryos. **Triphasia** has five adventitive embryos which are formed from the nucellar cap. The embryos have a massive haustoria.

Palynology :

Pollen grains are 3-6 colporate, perprolate or subprolate. The sexine is thicker than nexine and the exine has reticulate ornamentation. The ora of the pollen is lalanceolate. (Erdtman, 1952).

Classification :

Bentham and Hooker (1862) placed the Rutaceae in the order Geraniales but now it is generally accepted that the family belongs to the order Rutales (Rendle, 1950; Gunderson 1950; Thorne, 1976; Hutchinson, 1969; Takhtajan, 1980; Dahlgren, 1980). Cronquist (1981) grouped the Rutaceae in the Sapindales s.l. Burnett (1835) included Zygophyllaceae and Simaroubaceae in the Rutaceae. The Rutaceae alongwith the Anacardiaceae, Burseraceae, Meliaceae and Simaroubaceae form a closely knit group of the order Rutales. This clustering is sustained by the chemical, morphological, anatomical and palynological characters they share.

Hooker (1875) divided the Rutaceae directly into four tribes : 1. Ruteae 2. Zanthoxyleae 3. Toddalieae and 4. Aurantiaeae, based on the habit, carpel number and fruit structure. Engler (1931) divided the Rutaceae into seven subfamilies 1) Rutoideae 2) Dictyolotoideae 3) Toddalioideae 4) Spathelioideae 5) Aurantioideae 6) Rhabdodendroideae and 7) Flindersioideae. Of these 7 subfamilies, the Rutoideae, Toddalioideae and Aurantioideae are large and are subdivided into several tribes. This classification was adapted by Thorne (1976). Takhtajan (1980) separated the subfamily Rhabdodendroideae to a separate family Rhabdodendraceae. The homogeneity exhibited by a number of taxonomic groups within the Rutaceae prompted many taxonomists to raise them to distinct family levels (Gibbs, 1974). The families recognised are : 1) Amyridaceae 2) Aurantiaceae 3) Boroniaceae 4) Correaceae, 5) Cuspariaceae 6) Dictamnaceae 7) Diosmaceae, 8) Diplolaeaceae 9) Flindersiaceae 10) Fraxinellaceae 11) Hesperidaceae 12) Pilocarpaceae 13) Pteleaceae 14) Sarodiscaceae 15) Spatheliaceae and

16) Zanthoxylaceae.

The systematic position of **Chloroxylon** (C. **swietenia**), a genus which is placed either in this family or in Meliaceae (alongwith **Cedrela**) is discussed in the chapter on Meliaceae. This genus resembles the Rutaceae in having pellucid glands while its similarities with the Meliaceae are in their fruit characters. However, Hartley (1969) points out that the fruit of **Chloroxylon** differs quite a lot from that of **Cedrela**. The fruit of **Cedrela** (Meliaceae) is derived from a highly syncarpous ovary with a large and persistant central axis which is not the case in **Chloroxylon** and **Flindersia** and hence the resemblence is superficial. The isolation of coumarins (Murray et al., 1981) and alkaloids (Swain, 1969) from **Chloroxylon** and **Flindersia** are the chemical similarities of these two genera with the Rutaceae. **Peganum harmala** is another controversial genus grouped either in Zygophyllaceae or in Rutaceae (For a detailed discussion see the Zygophyllaceae). This genus differs from the Rutaceae in not producing essential oils.

The Rutaceae, having bisexual flowers, numerous free stamens and pentacarpellary ovary, are a primitive family of the Rutales. However the family shows a number of evolutionary trends in acquiring polygamous flowers, gamopetalous corolla (**Ravenia**) and the number of ovules restricted to one per locule. According to Hutchinson (1973), the Rutaceae with a wide range of floral variations are an advanced family and form a climax group from which little evolution has taken place.

The family can be considered homogeneous morphologically in containing oil glands in their leaves. It is also well-known for their alkaloids (Swain, 1969) and limonoids (Dreyer et al. 1972). These compounds are paritcularly useful in delimiting major subfamilies and to find out the affinites existing among them (Waterman, 1983). The subfamily Toddalioideae and Flindersioideae are chemically similar in containing alkaloids with 6,7-and 6,7,8-oxygenation and in elaborating complex coumarins. The chemical evolution is traced from the Aurantioideae in two lines : one oxidative pathway leading to the Rutoideae and the other degradative pathway ending in the Toddalioideae.

Flavonoids have been exhaustively investigated only in **Citrus** and therefore any generalisation on the family will be an unbalanced one. However the available data on the flavonoids agree with Engler's grouping of the family (Harborne, 1983). Flavanones are the useful chemical markers of the family reported from all the subfamilies while methoxylated flavones occur only in Aurantioideae (?) and Rutoideae. Within the Aurantioideae the morphological advancement is accompanied by the replacement of flavonols by flavones.

Economic Importance :

From the economic point of view, the most important genus of the family is **Citrus** which provides several well-known fruits such as orange, grapefruit, lemon, pumello and tangerine. A large number of byproducts are also obtained from various parts of these fruits. The pulp is a good source of ascorbic acid (Vitamin C) and fruit acids, and the inner fruit wall yields pectin. The rind contains a number of essential oils, limonoids and flavonoids. The essential oils find use in perfumes, pharamaceuticals and as flavouring materials. Limonoids exhibit antifeedant acitivity by causing disruption in the growth and reproductive stages of insects, even at very low concentrations and therefore are used for insect control. Flavanones are a group of flavonoids concentrated in rind of the fruit. Being bitter in taste, flavanones such as naringenin, hespiridin and neohespiridin are used as bitter principles in tonics, carbonated and non-carbonated beverages and in confections and marmalades. Dihydrochalcones (DHC) from the rind being 15 times sweeter than sugar form the commercial sources of non-calorific sweetners. The DHC also exhibits a suppressing activity of the bitter taste and therefore employed in foods, beverages and pharmaceuticals to reduce the bitter taste of the products. Diosmetin and other flavonoids with **ortho** dihydroxy systems find use in drugs which brings about resistance to the capillary walls. The family yields oils such as bergamot oil from **Citrus aurantium** subsp. **bergamia** , petite grain oils (rind of orange) and neroli oil (flower of bitter and sweet grape fruit). Edible fruits are also obtained from **Feronia**, **Aegle** and **Zanthoxylum**. The leaves of **Murraya** and **Zanthoxylum** are used as spices.

A number of plants of this family are known for their medicinal properties. The leaves of **Barosma betulina** are diuretic, carminative, disinfectant and used in the treatment of indigestion and urinary disorders. The active principles isolated are volatile oils containing diosphenol, d-limonene, l-methone and diosmin. **Pilocarpus jaborandi** leaves, containing imidazole alkaloids such as pilocarpine, isopilocarpine, pilocarpidine and pilosine, are used in treating glaucoma, conjunctiva and other eye diseases. The unripe fruit of **Evodia rutaecarpa** is a stimulant and antihelmintic and is used against abdominal pain, postpartum haemorrhages and dysentry. It also has an uterotonic activity. The active principles are the alkaloids - rutaecarpine hydrochloride and dehydro-evodiamine chloride and evodiamine. The coumarins of **Murraya paniculata** are found to exhibit antithyroidal activity. Biological activity is exhibited by most of the compounds found in this family. The essential oils widespread in the Rutaceae show antibacterial activity. The alkaloids which show antitumor activity include berberine, fagaronine (**Zanthoxylum**) nitidine (**Fagara**), 5-methoxy canthin-6-one, 4-methyl thiocanthin-6-one (**Pentaceras**,

Toddalia) and acronychine (**Acronychia**). Coumarins having cytotoxic activity are also isolated from the family. Coumarins are found to produce photosensitive irritation on the skin causing erythrema (**Ruta chalpensis**). 2-Hydroxy methyl benzoic acid, p-hydroxybenzoic acid and vanillic acid isolated from **Fagara**, exhibit antisickling activity. All these biological active compounds are used in the preparation of various medicines.

Other economically valuable products of the family are the woods. The woods in Rutaceae are hard, dense and resistant to decay. The most important timbers of the family are produced by **Chloroxylon**, **Flindersia** and **Zanthoxylum**. 'Queensland maple' is the wood obtained from **Flindersia**. This wood is equal to mahogani and is the best for cabinet works. **Zanthoxylum** provides the satinwood which is creamy or golden yellow in colour used in preparing muscial instruments, caskets, cabinets etc. The wood of **Chloroxylon swietenia** is in great demand for poles, posts, rafts, in railway sleepers, bridge contruction, furniture, panelling, carving, etc. The lesser known woods are obtained from **Atlantia monophyla**, **Murraya exotica** and **Limonia acidissima** which are very hard and fine-textured used for carving, engraving etc.,

Previous Chemical Reports :

The Rutaceae, containing a wide variety of secondary metabolites, were a taxon extensively studied. The various chemical compounds synthesised by this family are alkaloids, limonoids, coumarins, essential oils, lignans, organic acids and flavonoids.

Alkaloids are reported from almost all the plants belonging to this family. Due to the great structural diversity seen among the alkaloids, they are classifed based on their biogenesis. They are ; 1) Anthranilic acid-derived such as quinolines, furo-or pyranoquinazolines, acridones, quinazolines and indolo-pyranoquinazolines (**Citrus**, **Haplophyllum**, **Almeida**, **Thamnosia**, **Ptelea**, **Zanthoxylum**); 2) Tryptophan-derived - simple indoles (**Murraya**, **Flindersia**), carbazoles, (**Murraya**, **Glycosmis**, **Clausena**) β -carbolines (**Zanthoxylum**), canthin-6-one (**Zanthoxylum**); 3) Phenylalanine and/or tyrosine-derived - simple quinolines and oxazoles (**Citrus**, **Aegle**), isoquinolines (**Zanthoxylum**), benzophenanthridines (**Fagara**, **Toddalia** and **Zanthoxylum**) and 4) Derived amines - histidine derivatives (**Pilocarpus**, **Casimiroa**), ornithine and lysine derivatives (**Citrus** and **Zanthoxylum**). Among these four types of alkaloids, anthranilic acid-derived alkaloids are widespread in Rutaceae while simple phenylalanine or tyrosine-derived alkaloids are restricted to the subfamily Aurantioideae. The more complex forms of tyrosine-derived alkaloids are found in the subfamily Toddalioideae while histidine-derived compounds are confined to **Pilocarpus** and **Casimiroa**.

Coumarins, simple as well as complex types, are widespread in the family. Simple furo-and pyranocoumarins occur throughout the family, while dimeric coumarins are isolated from **Murraya** and **Toddalia**. Coumarins substituted in the pyrone ring are located only from **Halfordia**. The essential oils reported from the family contain mono- and sesquiterpenoids, aliphatic ketones and phenylpropanoids. A number of lignans also are isolated from the family which can be segregrated into five groups; 1) 1,4-diarylbutanes, 2) 6-diaryl - 3,7, dioxabicyclooctanes, 3) naphthalines, 4) substituted furans and 5) dibenzlbutyrolactones.

In addition to the above mentioned compounds, the family contains a group of triterpenoids, the limonoids. The Rutaceae characteristically contain A-and D-secolimonoids. Limonin, nomilin, obacunone, 7- α -obacunyl, 7- α -obacunol, 7-acetylnomilin and 7- α -nomilin are widespread in members of all the major subfamilies. The modification of C-methyl group through oxidation occurs only at C-19 methyl group in the Rutaceae. The simplest and unmodified C-19 methyl group occurs in Toddalioideae, while modified C-19 methyl group occurs in Aurantioideae and Rutoideae. Oxidized C-19 methyl group is present in protorutaceae members such as **Fagaropsis**.

Much of the flavonoid data available pertain to the single genus **Citrus**. The known flavonoids include flavanones (naringenin, hesperidin, neohespiridin), dihydrochalcones, flavones (apigenin, diosmetin, luteolin, acacetin), glycoflavones (vitexin, isovitexin, orientin, isoorientin, 6-8-and 6, 8-glucosyl diosmetin, 6, 8 diarabinosylgenkwanin, and flavonols (kaempferol, quercetin, myricetin, gossypetin, herbacetin, and their methoxylated derivatives) and highly methoxylated flavones (exoticin, nobiletin and tangeretin). Unusual oxygenation patterns such as 7-deoxygenation and 2' methoxylation in flavones are reported from **Casimiroa** and **Sargentia**. **Melicope**, **Evodia** and **Phellodendron** produce a wide variety of isoprenoid flavonols.

A detailed chemistry of the family and their chemotaxonomic implications are available (Waterman and Grundon, 1983).

In the present work 26 members belonging to 18 genera of the Rutaceae are analysed for their constitutents.

Materials and Methods :

The materials for the present work are collected from Kashmir, Nainital, Baroda, Ooty and Kerala. The methods followed for the isolation and characterisation of the constituents are already explained in Chapter 2. All the genera studied (18) are subjected to a cladistic analysis considering 33 characters selected.

Results :

The distribution of various chemical compounds are presented in Table-6.1. Flavonoids are present in the leaves of all the plants screened. Flavones, glycoflavones and flavonols are the various flavonoids encountered in the family. Apigenin, 7-OMe apigenin, 4'-OMe apigenin are the three flavones having about 50 % incidence. Glycoflavones such as vitexin, 4'-OMe, 7-OMe-and 7,4'-diOMe vitexin, and isovitexin are located in 7 plants. The various flavonols identified are kaempferol, 4'-OMe Kaempferol, herbacetin, 5-deoxy kaempferol, quercetin, 3'-OMe-, 4'-OMe, 7-OMe- and 3'-4'-diOMe quercetin, gossypetin, 3'-4'-diOMe gossypetin and myricetin. Among these, quercetin and its methoxylated derivatives are widespread having 65% incidence while kaempferol and gossyptein are located in seven plants each. Myricetin is restricted to only two genera **Chloroxylon** and **Clausena**. Proanthocyanidins are rare occuring in three plants, **Aegle**, **Chloroxylon** and **Ravenia**. Nine phenolic acids belonging to benzoic acid and cinnamic acid groups are identified. Of these, benzoic acids are more frequent than cinnamic acids. Tannins and saponins are less frequent occuring in only five plants out of 27 screened. Alkaloids are located in all the plants.

Discussion :

The present anlysis gives a generalised idea on the distribution of flavonoids in the family. Though the three types of leaf flavonoids i.e. flavones, glycoflavones and flavonols occur in the family, flavonols form the dominant phenolic pigments located in all the plants except those belonging to the subfamily Toddalioideae (**Toddalia** and **Skimmia**).

	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	29	30	31	32	33	34
OIDEAE																																		
Boenninghausenia alba Riech									+				+										+		+	+		+		+				+
Choisya ternata HBK									+			+	+								+			+		+	+	+		+				+
Dictamnus alba L.		+	+							+				+		+			+							+				+	+			+
Evodia lunu-ankend Merril										+				+										+		+	+						+	+
Ravenia spectabilis Griseb													+				+						+	+	+	+	+					+		+
Ruta graveolens L.													+	+	+	+	+			+			+			+	+				+			+
Peganum harmala L.	+								+																									+
Zanthoxylum rhetsa DC									+				+											+	+	+		+	+	+			+	+
ALIOIDEAE																																		
Casimiroa edulis L. & L.													+	+			+								+	+	+				+			+
Skimmia laureola Hk. f.	+	+																						+	+	+	+	+	+		+			+
Toddalia angustifolia Miq.	+																							+	+	+		+			+			+
T. asiatica Lamk.	+																							+	+	+	+	+						+
RANTIOIDEAE																																		
Atalantia monophyla Carr.		+											+	+			+							+		+	+	+						+
Aegle marmelos Corr.														+			+						+		+	+	+					+	+	+
Clausena wampii Oliv.													+											+		+	+	+	+					+
C. willdenvii W. & A.									+	+			+									+			+	+	+	+						+
Citrus acida Roxb.	+	+		+																				+	+	+	+	+		+				+
C. aurantium L.		+	+																					+		+	+							+
C. grandis Osbek.	+	+			+								+													+	+	+		+			+	+
C. reticulata	+																							+		+	+							+
Citrus sp.	+												+											+		+	+	+				+	+	+
Feronia elephantum Corr.														+										+		+	+	+	+	+				+
Glyeosmis pentaphylla Corr.		+				+																		+		+	+		+		+			+
G. pentaphylla var. linearifoliola tanaka						+																		+		+					+			+
Murraya koenigii Spreng.							+			+																+	+	+						+
M. exotica L.							+			+	+		+													+	+	+						+

Table : 6.1 (Contd.)

1. Apigenin 2. 7-OMe Apigenin 3. 4'-OMe Apigenin 4. Vitexin 5. 7-OMe Vitexin 8. 4'-OMe Vitexin 7. 7',4'-DiOMe Vitexin 8. Isovitexin 9. Kaempferol 10. 4'-OMe Kaempferol 11. Herbacetin 12. 5-Deoxy kaempferol 13. Quercetin 14. 3'-OMe Quercetin 15. 4'-OMe Quercetin 16. 5-OMe Quercetin 17. 3',4'-DiOMe Quercetin 18. 3'-OMe Gossypetin 19. 3'-OMe Gossyepetin 20. 3'4'-DiOMe Gossypetin 21. 8,3',4'-TriOMe Gossypetin 22. Myricetin 23. Proanthocyanidins 24. p-Hydroxybenzoic acid 25. Gentisic acid 26. Vanillic acid 27. Syringic acid 28. p-Coumaric acid 29. Protocatechuic acid 30. Melilotic acid 31. Ferulic acid 32. Tannins 33. Saponins 34. Alkaloids

The subfamily Toddalioideae is chemically isolated from the other three subfamilies (Rutoideae, Aurantioideae and Flindersioideae) in containing only flavones and in the absence of flavonols. The other distinguishing characters of this subfamily are the ability to synthesise a narrow range of very complex coumarins and unmodified C-19 methyllimonoids. The Aurantiodieae and Rutoideae are intimately connected with each other in containing flavonols, flavones, similar type of limonoids such as limonin, nomilin, deacetyl derivatives and a wide range of simple coumarins. However they differ from each other in that the glycoflavones are restricted to Aurantioideae and 6/8 oxygenated flavonols to Rutoideae. The chemical identity of each subfamily is in sharp contrast with the results of Moore (1936) who opined that the morphological and anatomical characters did not correlate with the subdivisions of the family.

The subfamily Rutoideae is more or less homogeneous, with flavonols as dominant pigments and limonoids having higher oxidation levels. The genus **Dictamnus** differs from the other members of this subfamily in containing flavones in their leaves. This genus is also peculiar in having irregular flowers. The morphological advancement achieved by the tribes and the subtribes of the subfamily Aurantioideae (Swingle 1938) is more or less comparable with the chemical advancement. The subtribe Clauseninae (**Clausena**, **Glycosmis** and **Murraya**) has hydroxylated flavonols especialy myricetin and therefore is primitive. The Triphasinae (**Triphasia**) with the introduction of flavones is a step ahead and the Citrinae, one of the more advanced subtribes is flavone-rich. However the Balsamocitrinae (**Aegle** and **Feronia**) has primitive chemical characters such as flavonols though it is morphologically advanced. Grieve and Scora (1980) arrived at similar conclusions based on the distribution of glycoflavones. The subtribe Balsamocitrinae does not contain any of the typical citrus limonoids and therefore this taxon is not well-placed in the tribe Citreae (Waterman and Grundon, 1983).

The controversial genus **Chloroxylon swietenia** of the subfamily Flindersioideae contains gossypetin and herbacetin and can be comfortably accomodated in the Rutaceae. The isolation of Rutaceous coumarins, alkaloids and limonoids confirm the affinities of the genus with the Rutaceae especially with the subfamily Rutoideae. Though the flavonoid profile of **Peganum harmala** is similar to that of the Rutaceae, it does not contain essential oils, the wide range of limonoids and coumarins characteristic to the latter family. This genus differs from the Zygophyllaceae also within which it sometimes included, in not containing steroidal saponins. Therefore a separate unigeneric family Peganaceae as suggested by Soueges (1953) seems to be taxonomically valid.

The distinct identity of **Glycosmis pentaphylla** var. **linearifoliola** is established chemically. The typical species **Glycosmis pentaphylla** is chemically different from the var. **linearifoliola** in containing 7-4'diOMe apigenin, coumarins, syringic acid, p-coumaric acid and salicylic acid which are not located in the latter taxon. The differences existing between these two taxa warrant a specific status of **Glycosmis pentaphylla** var. **linearifoliola** and therefore it is proposed that this taxon should be named as **Glycosmis linearifoliola** **(Sp. nov.)**.

Among the 4 subfamilies, the Rutoideae having flavonols are primitive, the Toddalioideae with only flavones are advanced and Aurantioideae having flavones, glycoflavones and flavonols are intermediate. This conflicts with that proposed by Waterman (1983) on the limonoid chemistry, who suggested that the Aurantioideae is primitive with all the oxidative systems intact and from which two lines of evolution occurred, one specialising in oxidative pathways as in Rutoideae and the other characterised by degradation mechanisms terminating in the Toddalioideae.

The family characteristicaly contain a wide variety of alkaloids, coumarins, essential oils, flavonoids and limonoids. The distribution of various types of these compounds is more or less in tune with Engler's classification of the family. Therefore, there exist homogeneity within the obvious heterogeneity. The advanced characters the family possess are the highly methoxylated flavonols, flavones and absence of tannins and proanthocyanidins. Obviously the Rutaceae are a specialized family which forms a climax group in containing all these compounds which are not as widespread in other closely related families. However, it retains some of the primitive characters such as the presence of flavonols especially myricetin and limited structural variation of limonoids in some of its members and therefore the Rutaceae occupy a slightly lower level of evolution when compard to the Meliaceae (methoxylated flavonols, wide range of limonoids) and the Simaroubaceae (flavone-rich, simaroubolides).

CLADISTIC ANALYSIS

The cladogram of the genera belonging to the Rutaceae is presented in Fig. 6.1. **Peganum harmala** deviates from the first node, HTUI and positions itself in the semicircle 11. The wagner tree divides into two main branches, A and B, at the node HTU2 at level 7. Nine OTUs form the branch A of which **Aegle** and **Feronia** branch out from nodes HTU4 and HTU5 respectively. Rest of the 7 OTUs proceed from the HTU7 through various nodes. Of the two branches forked from HTU7, one carries **Zanthoxylum** and **Evodia** and the other branch bears **Choisya**, **Chloroxylon**, **Dictamnus**, **Ruta** and **Skimmia**. Among these five

Table - 6.2

Characters Selected for the Construction of Wagner Tree of the Family Rutaceae.

Sr. No.	Characters	Plesiomorphic State	Apomorphic State
1.	Habit	Trees or Shrubs	Herbs
2.	"	Unarmed	Armed
3.	Leaves	Simple	Compound
4.	"	Multifoliolate	Unifoliolate
5.	"	Not gland-dotted	Gland-dotted
6.	Flowers	Bisexual	Unisexual
7.	"	Regular	Irregular
8.	No. of Stamens	30-20	less than 20
9.	"	10	less than 10
10.	Gynoecium	Apocarpous	Syncarpous
11.	No. of locules	Pentalocular	Bi/Unilocular
12.	No. of ovules	More than 2	One
13.	Fruit	Berry	Drupe
14.	Seeds	Wingless	Winged
15.	Flavonols	Present	Absent
16.	Myricetin	Present	Absent
17.	Gossypetin	Present	Absent
18.	Glycoflavones	Absent	Present
19.	Flavones	Absent	Present
20.	Methoxylated flavonoids	Absent	Present

Table : 6.2 (Contd.)

Sr. No.	Characters	Plesiomorphic State	Apomorphic State
21.	Proanthocyanidins	Present	Absent
22.	Tannins	Present	Absent
23.	Coumarins	Absent	Present
24.	Simple Coumarins	Present	Absent
25.	Furanocoumarins	Absent	Present
26.	Pyranocoumarins	Absent	Present
27.	Limonoids	Absent	Present
28.	Higher Oxidation of limonoids	Absent	Present
29.	Degraded limonoids	Absent	Present
30.	Alkaloids-Phenylalanine/amide	Present	Absent
31.	Carbazolines	Absent	Present
32.	Quinazolines	Absent	Present
33.	Acridones	Absent	Present

Table : 6.3 The Distribution of Selected Character for Cladistic Analysis of the Rutaceae

	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	29	30	31	32	33	AD (I)
1. **Atlantia**	0	1	1	1	1	0	0	0	1	1	0	1	1	0	0	0	1	1	0	1	0	1	0	1	1	1	1	0	0	1	1	1	1	20
2. **Aegle**	0	1	1	0	1	0	0	0	0	1	1	0	0	1	0	0	1	1	0	0	0	1	0	1	1	0	0	0	0	1	1	0	0	13
3. **Clausena**	0	0	1	0	1	0	0	1	1	1	0	0	1	0	0	0	0	1	0	0	0	1	0	1	1	1	0	1	0	0	0	1	1	14
4. **Citrus**	0	1	1	1	1	1	0	0	0	1	0	1	0	0	0	0	1	1	1	1	0	1	0	1	1	1	1	0	1	1	1	1	1	21
5. **Dictamnus**	1	0	1	0	1	0	1	1	0	1	0	1	1	1	0	0	1	0	0	1	0	1	0	1	0	1	0	0	1	1	1	1	1	19
6. **Evodia**	0	0	1	0	1	0	0	1	1	1	1	1	1	1	0	0	1	1	0	0	0	1	0	0	0	1	1	0	1	1	1	1	1	19
7. **Feronia**	0	1	1	0	1	1	0	0	0	1	1	0	0	1	0	0	1	1	0	0	0	1	0	1	0	0	0	0	1	1	1	1	1	16
8. **Glycosmis**	0	0	1	0	1	0	0	1	0	1	0	0	1	0	0	1	1	1	1	1	0	1	0	1	1	0	0	0	1	0	1	1	1	17
9. **Murraya**	0	0	1	0	1	0	0	1	0	1	0	0	1	0	1	0	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0	1	1	14
10. **Peganum**	1	0	1	0	0	0	0	0	0	1	0	1	0	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	1	0	0	1	1	11
11. **Ruta**	1	0	1	0	1	0	0	1	0	0	0	1	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1	0	1	1	1	0	1	19
12. **Skimmia**	0	0	0	0	1	1	0	1	0	0	0	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	0	1	1	1	1	1	1	21
13. **Toddalia**	0	1	1	0	1	1	0	1	1	1	0	0	1	0	0	1	1	1	0	1	0	1	0	0	1	1	0	1	0	1	1	1	1	20
14. **Triphasia**	0	1	1	0	1	0	0	1	1	1	0	0	0	0	0	1	1	1	1	1	0	1	1	0	0	1	1	0	1	1	1	1	1	20
15. **Zanthoxylum**	0	1	1	0	1	1	0	1	1	0	1	1	1	1	0	0	1	1	0	0	0	1	0	0	1	0	0	1	0	0	1	1	1	17
16. **Chloroxylum**	0	0	1	0	1	0	0	1	0	1	0	1	0	1	1	0	0	0	0	0	0	1	0	1	1	1	1	0	1	1	0	1	1	16
17. **Choisya**	0	0	1	0	1	1	0	1	0	0	0	1	0	1	0	0	1	0	0	0	0	1	1	1	0	1	1	0	1	1	0	1	1	16

Table : 6.4 Manhattan Distances Between Pairs of OTUs. in the Rutaceae.

	Aeg.	Cla.	Cit.	Dic.	Evo.	Fer.	Gly.	Mur.	Peg.	Rut.	Ski.	Tod.	Tri.	Zan.	Cho.	Cio.
Ata.	11	10	5	11	9	12	11	14	15	13	13	8	10	11	12	14
Aeg.		13	12	14	12	5	12	13	14	14	16	13	15	10	13	15
Cla.			15	13	11	14	9	8	15	15	13	8	14	11	10	14
Cit.				12	12	9	10	13	14	14	12	11	9	14	11	11
Dic.					8	11	10	11	10	8	10	13	13	14	9	9
Evo.						9	12	11	12	10	12	11	9	8	9	9
Fer.							11	10	11	15	13	12	12	9	12	10
Gly.								5	12	14	10	9	9	12	13	15
Mur.									11	13	13	14	12	13	10	12
Peg.										16	16	17	15	14	13	13
Rut.											10	17	15	14	7	7
Ski.												9	15	12	11	11
Tod.													8	9	16	16
Tri.														15	14	12
Zan.															15	13
Cho.																6
Cio.																0

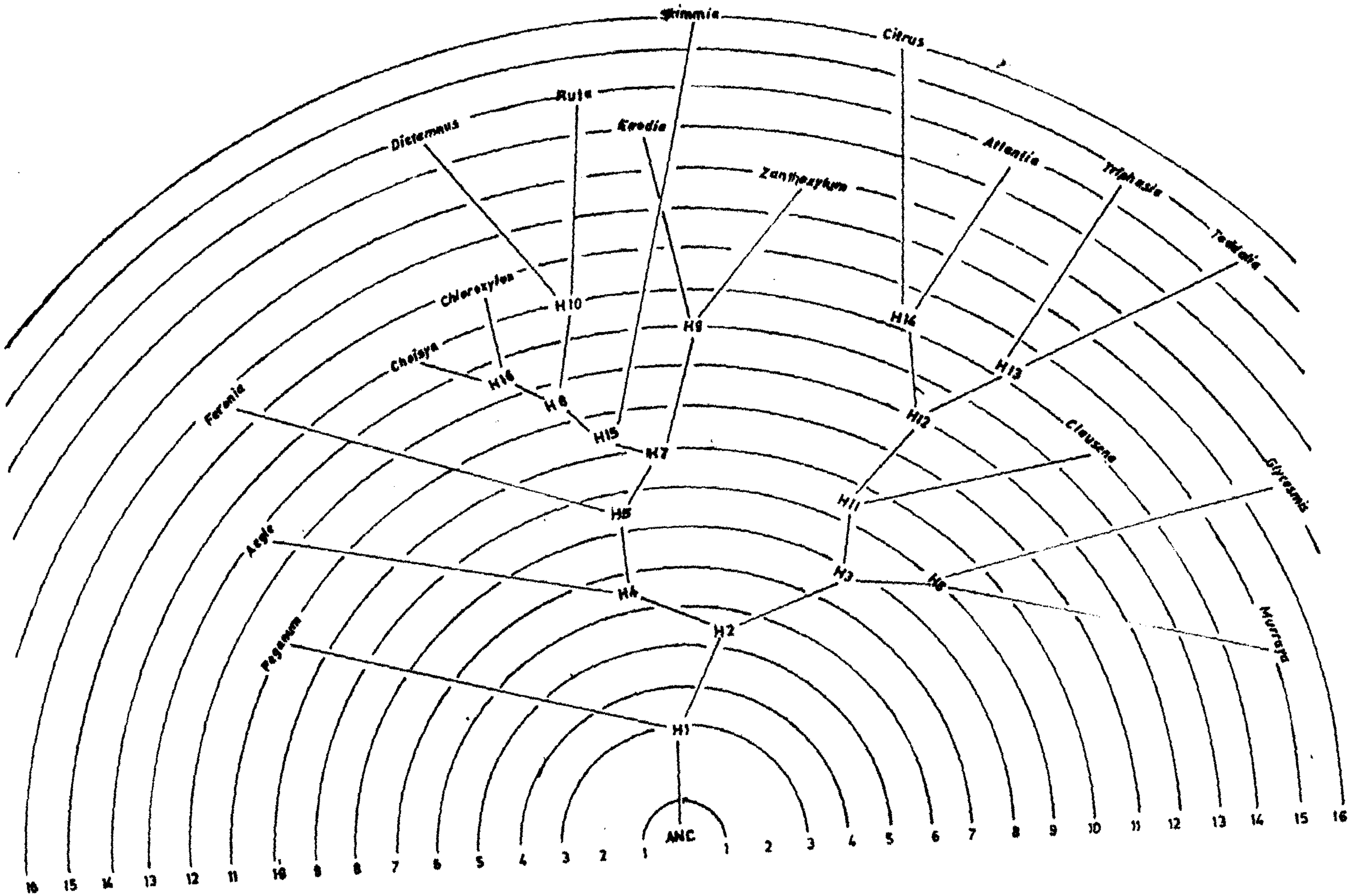

Fig 6.1 Cladogram of relationships in the Rutaceae

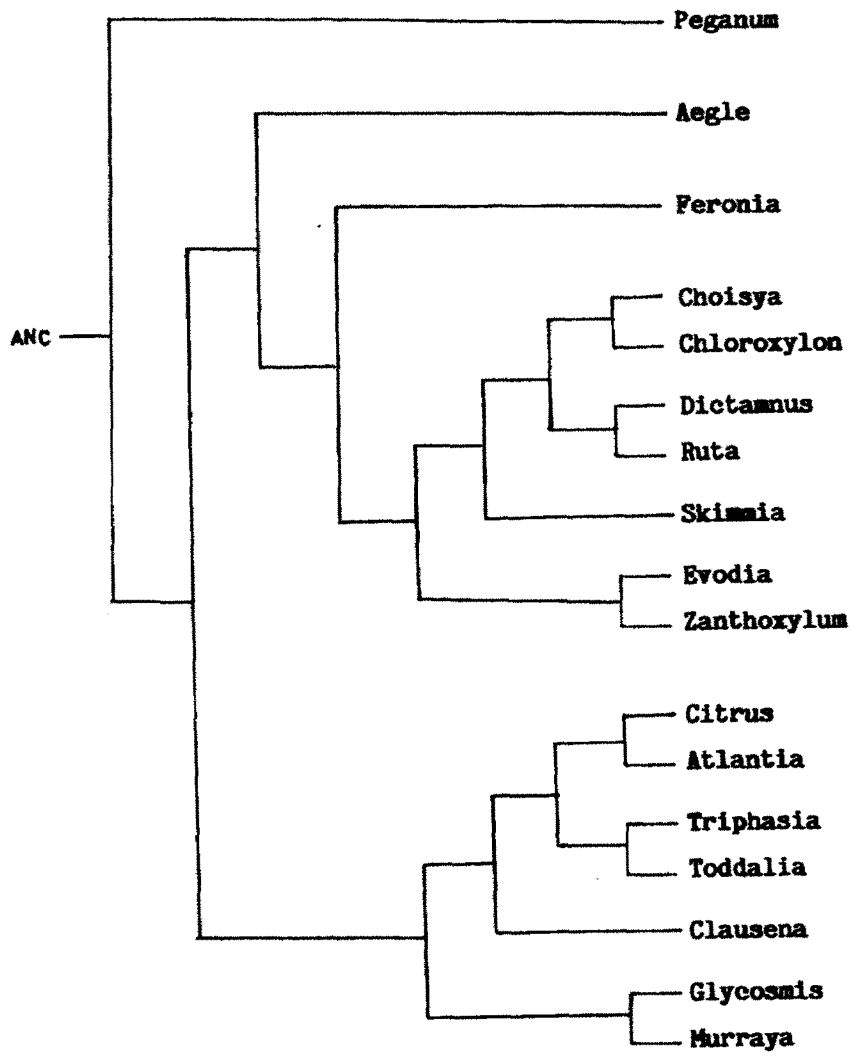

Fig. 6.2 Dendrogram of some genera of the Rutaceae

OTUs, **Skimmia** gets separated first from HTU15. The other branch from HTU15 further gives out two dichotomies, with **Ruta** and **Dictamnus** occupying one and **Choisya** and **Chloroxylon** occupying the other. **Skimmia** with AD(I) value 21 is the most advanced taxon and **Aegle** with AD(I) value 13 is the most primitive taxon of the branch A.

Branch B consist of seven OTUs. Among these OTUs one of the clades formed from HTU3 dichotomises and each ends in **Murraya** and **Glycosmis** respectively. The second branch from HTU3 gives out **Clausena** from HTUII and then bifurcates at HTU12 with one branch bearing **Atlantia** and **Citrus** and the other branch, **Toddalia** and **Triphasia**. **Citrus** with 21 as AD(I) value is the most advanced genus and **Clausena** with AD(I) value 14 is the most primitive taxon of branch B.

Discussion :

Except **Peganum**, all the taxa of the Rutacae studied form a closely knit group. The earlier separation of **Peganum harmala** and the large values obtained during the calculation of the affinity of various taxa with it confirms that this taxon is not at home with the members of the Rutaceae. **Chloroxylon swietenia**, has very low minimal distances from all the members of the subfamily Rutoideae, thus showing that it is related to the Rutoideae. In the present analysis, the genus arises from HTU8 alongwith **Choisya**.

The groupings proposed on the branching pattern of the tree(Fig. 6.2.) agrees more or less with Engler's (1931) classification of the family. After giving out **Peganum**, the main trunk divides into two branches A and B, each branch is taken as a group. **Group A** with genera **Atlantia, Citrus, Clausena, Glycosmis, Murraya, Toddalia** and **Triphasia** corresponds to the subfamily Aurantioideae. **Group-B** with **Aegle**, **Chloro-**

xylon, **Choisya**, **Dictamnus**, **Feronia**, **Ruta** and **Skimmia** corresponds to the subfamily Rutoideae. The subfamily status of the Toddalioideae does not get support from cladistics. Of the two genera of Toddalioideae, **Toddalia** is placed next to **Triphasia** and **Skimmia** is placed in between the 2 tribes of the subfamily Rutoideae.

Further dichotomous branching of group A is similar to the division of subfamily Aurantioideae by Grieve and Scora (1980). All the 3 genera **Clausena**, **Murraya** and **Glycosmis** of the tribe Clauseneae form a branch and other 3 genera, **Atlantia**, **Citrus** and **Triphasia** of the tribe Citreae occupy the other branch, **Atlantia** and **Citrus** which separate out from node HTU12 belong to the subtribe Citrinae and **Triphasia** occupying the second branch belongs to subtribe Triphasiinae.

The group B contains the plants of subfamily Rutoideae and also **Aegle** and **Feronia** of the subfamily Aurantioideae. Here also the grouping corresponds to the division of the subfamily. The placements of **Aegle** and **Feronia** on the branch B is in support of the view proposed by Waterman (1983) wherein it is suggested that the subtribe Balsamocitrinae of the tribe Citreae (**Aegle** and **Feronia**) does not accomodate well in the tribe because of their inability to synthesise limonoids. The present analysis shows that the affinity of these two genera lies with the Rutoideae. The two tribes Zanthoxyleae (**Zanthoxylum** and **Evodia**) and Rutineae (**Dictamnus** and **Ruta**) get separated from the node HTU15. **Choisya** of tribe Zanthoxyleae occur between the two tribes. The incidence of two or more equal minimal distances for **Choisya**, **Skimmia**, **Chloroxylon** and **Dictamnus** shows the close relationships existing among these members. However the higher Manhattan distances obtained for some of the taxa indicate the diversity achieved by those genera. The advanced nature of family is evidenced by the higher AD(I) values.