4. Family *ANACARDIACEAE*

The Anacardiacee, a large tropical family of 65 genera and 500 species, are represented in Indian subcontinent by 23 genera and 59 species (Mukherjee and Chandra, 1983). Of these, 11 taxa are restricted to Burma, Andaman and Nicobar. Eight species belonging to the genera **Buchanania**, **Holigarna** and **Nothopegia** are rare and considered threatened.

The characteristic features of the family are alternate, exstipulate leaves, panicle inflorescence which are mostly unisexual by suppression of one of the sexes. Intrastaminal nectariferous disk is present which in some cases form a gynophore. Number of stamens varies from 5 to 10 but sometimes single fertile stamen is present. Gynoecium is tricarpellary but usually only one carpel contains ovule and therefore has only a single fertile carpel. Eventhough hypogynous condition is dominant, in some of the taxa (**Semecarpus**, **Holigarna**), the ovary is sunken in the receptacle making the flower perigynous. The pendulous ovule which is variously attached to the ventral raphe, is uni-or bitegmic, anatropous and crassinucellate. Fruit wall contains acrid resin which causes dermatitis on contact. In **Semecarpus**, **Anacardium** and **Holigarna** the penducle becomes fleshy and form the edible part.

Anatomy :

The family shows a tendency towards the elaboration of compound leaves and reduction of floral parts tending towards unisexuality. **Buchanania**, **Anacardium** **Mangifera**, and **Holigarna** have simple leaves while **Rhus**, **Lannea** and others possess compound leaves. Tetramerous flowers are produced in **Lannea** and **Nothopegia** while the remaining genera have primitive pentamerous flowers. **Buchanania**, possesses ten fertile stamens while **Rhus** and **Cotinus** have only five fertile stamens. In **Mangifera** only one stamen is fertile and the rest are modified into staminodes. Reduction in number of carpels and varying degrees of cohesion of the various regions of carpels are also seen in the family. Apocarpous pistil is seen in **Buchanania**. Pentacarpellary ovary with five free styles is present in **Dracantomelum** while the styles remain united in the **Spondias** and **Chaerospondias**. Only one carpel is fertile and 3 free styles occur in **Holigarna** and in **Rhus**. In **Semecarpus**, **Lannea** and **Drimycarpus** the styles are united. The monocarpellary ovary of **Mangifera** is derived from a tricarpellary ovary (Sarma, 1954).

The most striking anatomical feature of the family is the presence of radial and intercelluar schizolysigenous resin canals (Fahn and Evert, 1974; Joel, 1981; Joel and Fahn, 1980). They occur in almost all the parts of the plant and tissues including primary and secondary phloem. The presence of septate fibres and paratracheal, usually scanty, parenchyma are the features by which the Anacardiaceae differ from the closely related families. (Metcalfe and Chalk, 1950). Calcium oxalate crystals and tannin cells are located. The sieve elements of the phloem show S-type of plastids (Behnke, 1981).

Heimsch (1942), who did pioneering work on the systematic wood anatomy of the family, points out that eventhough there is no single anatomical character or group of characters by which the tribes can be differtiated, certain taxonomic trends are observed. Higher incidence of homogeneous rays and bands of parenchyma occur in Mangiferae and the tribe Rhoideae has the highest proportion of ring porous forms with advanced stages of vessel segregation. Septate fibres are present in Spondieae and absent in Semecarpae.

Embryology :

The ovule is anatropous, uni- or bitegmic, crassinucellate and with a funicular obturater. Nucellus is massive with ten parietal layers and do not possess a nucellar beak. Embryo sac ontogeny is of Polygonum type. Embryo development is Onagrad type.

Palynology :

The family is homogeneous in its pollen morphology except for **Dobinea** and **Pistacia**. Most of the plants have pollen which are prolate and 3-colporate, exception being **Spondias** (2-colporate) and **Dracantomelum** (4-colporate), (Ertdman, 1952; Ralph and Leis, 1979). Sexine is thicker than nexine. According to Ertdman 3 types of pollen grains are recognised from the family.

a) **Rhus type** : Pollen grains are of medium to large size, with a single aperture and the exine shows fine reticulation and often striato-reticulate. This type is found in most of the genera of the Anacardiaceae.

b) **Dobinea type** : Small pollen grains with single aperture and exine coarsely reticulate : **Dobinea**.

c) **Pistacia type** : Medium size pollen grains with aperture and operculum. The exine is granulate : **Pistacia**.

Classification :

The family was first established by Lindley in 1830. The name is conserved against Terebinthaceae of Jussieu (1791) and Spondieae of Knuth (1824). The Anacardiaceae are custumorily placed in the order Sapindales alongwith the other closely related families such as the Sapindaceae, Aceraceae, Hippocastanaceae and Julianaceae (Bentham and Hooker, 1862; Rendle, 1950; Hutchinson, 1973; Cronquist, 1981; Dahlgren, 1981). In the latest version of Engler's classification, the family is kept in a separate bifamilial group, Anacardineae, within the Sapindales, the other family being the Sapindaceae (Airy-shaw, 1973). In contrast, the close similarities between the Anacardiaceae with the Rutalean family Burseracee, prompted Hallier (1912), Gunderson (1950), Thorne (1976) and Takthajan (1980) to group them in Rutales. Hallier included both the Burseraceae and Anacardiaceae in the family Terebinthaceae. These two families share a number of anatomical, morphological, and chemical characters (Weber, 1941; Metcalfe and Chalk, 1950; Harborne, 1988) and they differ in the nature of the ovule; in the Burseraceae two epitropous ovules occur in a single locule, whereas in the Anacardiaceae a single apotropous ovule is present.

Hooker (1879) subdivided the Anacardiaceae into two tribes 1) Anacardieae - containing taxa with one celled ovary or if two celled one of the cell is supressed in the early stages. This tribe includes most of the genera of the family. On the basis of the point of attachment of the pendulous ovules two subgroups have been recognised within. The group A contains genera with pendulous ovule from the basal funicle. Eg. **Rhus**, **Pistacia**, **Mangifera**, **Anacardium**, **Buchanania** and **Gluta**. The group B includes genera with ovules attached at the top of the cell or above the middle half of the cell. The genera falling in this group are **Solenocarpus**, **Lannea**, **Parishia**, **Semecarpus**, **Holigarna**, **Nothopegia**.
2) Spondieae - This small tribe with three genera **Sponidas**, **Chaerospondias** and **Dracantomelum**, is characterised by the presence of 2-5 fertile carpels.

Engler (1895), based on the number of carpels and nature of the leaves, recognised three groups.

Group A is characterised by pentacarpellary apocarpous or monocarpellary ovary and simple entire leaves. This group contains only one tribe :

1) Anacardieae : contain seven genera such as **Mangifera**, **Anacardium**, and **Buchanania**.

Group-B possesses syncarpous ovary and mostly compound leaves and is classified into three tribes :

2) Spondieae : contain 13 genera such as **Chaerospondias**, **Spondias** and **Dracantomelum** having pentacarpellary ovary with one ovule in each locule **i.e.** all carpels fertile.

3) Rhoeae : characterised by one fertile carpel, ovary not embedded in the receptacle. 32 genera (**Schinus** **Rhus** etc.)

4) Semecarpeae : with one fertile carpel and sunken ovary. 5 genera (**Semecarpus**).

Group-C is characterised by naked female flowers, simple, toothed leaves and single carpel, contains one tribe :

5) Dobineae : contain one genus **Dobinea**.

The Anacardiaceae are considered a natural family except for the two genera **Dobinea** and **Pistacia**. **Pistacia** is given a unigeneric family status because of the dioecious plants; unisexual naked flowers and distinct pollen morphological features. **Dobinea**, a genus of a doubtful status, is placed in the family Podoaceae with which it shares a closer relationship. The Podoaceae are closely related to the Anacardiaceae. According to Hallier (1912), the Anacardiaceae have been evolved from the Rutaceae and form a basic stock from which the families of the Amentiferae and the Aceraceae have been evolved. Due to the tendency of the taxa to produce unisexual flowers and compound leaves, Hutchinson (1973) recognised the family as one of the advanced families of the Sapindales. These varying interpretations are due the assemblage of both primitive and advanced characters within the Anacardiaceae.

Economic Imprtance :

Pistachio nut (**Pistacia vera**) and cashew nut (**Anacardium occidentale**) are the most important nuts obtained from the family. They are used as desserts and flavouring materials. The juicy receptacle of cashew is edible, used for the preparation of squashes and wine. The most important and relished fruit of tropics, the mango (**Mangifera indica**), belongs to this family. About 500 graded varieties of mango are found in India. The sweet fruit juice of mango is used in preparation of squashes, icecreams, jellies etc. The unripe fruits are used in curries or pickles. The ripe fruits of **Spondias pinnata** (Hog palm) are eaten or used for pickling. The kernals of **Buchanania latifolia** are eaten raw and when roasted form a substitute for almond. A sweet-sour preparation is made from the fruits of **Dracantomelum mangiferum**. The gums obtained from **Buchanania, Lannea** and **Anacardium** find use in calico-printing, paper-sizing and as adhesives. **Rhus succedenea** produces snowwhite wax which is used in preparation of candles. Resins obtained from **Holigarna, semecarpus** and **Rhus** are used as natural varnishes. The resinous exudate tapped from **Rhus vernicifera**, mixed with any pigment, is used in preparation of japanese lacquer. Mastic gum is the resin obtained from **Pistacia lentiscus** and **P. terebinthifolius** and is utilised in perfumes, flavouring wine and in confectionary. Terpentine like volatile oil is obtained from the latter taxon. The various species of **Rhus** and **Cotinus** are important tanstuffs of India. **R. javanica** contains moré of hydrolysable tannins consisting of pyrogallic acid, gallic acid and tannic acid which are used industrially. The juices containing anacardol, obtained from the rinds of **Anacardium**, is employed to tar boats, preserve fishnets and as oils and varnishes. It is also used by washermen for marking cotton and linen. The juices of **Rhus**, **Toxicodendron** and **Semecarpus** are poisonous irritants.

The galls of **Pistachio integerrima** are used against cough, asthma and lung diseases. A potential antineoplasmic agent has been located from the nuts of **Semecarpus anacardium** (Chitnis et al., 1986). The kernels of this plant are also found to stimulate memory. The juices of kernels are applied externally in cases of rheumatism and leprosy. The fruits of **Rhus typhina** and **R. copallina** are active against heamorrhages and also in urinary troubles.

Many plants of this family yield important timbers. The wood of **Gluta** is the heaviest wood in India. The timber obtained from **Anacardium**, **Holigarna**, **Lannea**, **Mangifera**, **Semecarpus** and **Spondias** are very much in demand and are used for furnitures, beams, framework, match boxes etc.

Previous chemical work :

The family Anacardiaceae is notorious for its allergenic principles. The toxic substances are either alkyl catechols (**Toxicodendron**, **Semecarpus**, **Rhus**, **Holigarna**, and **Mangifera**) or alkyl resorcinols (**Anacardium**). In addition to these compounds, alkyl phenols also are found to have similar allergenic effects. Urushiol, cardanol, cardol, 3-alk-(en)-ylcatechol, (-) 5-methylellein, eriodictyol and d-catechin are some of the alkyl catechols and anacardol and anacardic acids are the alkyl resorcinols reported so far. Six-membered α-β-unsaturated lactone, a non-phenolic compound isolated from lacquer, also exhibits similar effects.

In addition to the common flavonoids, the family is known for the biflavonoids, 5-deoxyflavonoids, flavonones, aurones and chalcones. The biflavones are concentrated more in the fruits. Amentoflavone and, to a lesser extent, hinokiflavone are the biflavones reported from **Holigarna**, **Rhus**, **Semecarpus**, **Anacardium**, **Rhus** and **Schinopsis**. 5-Deoxyflavonols (fisetin and fustin) are common in the heartwood of many trees of this family. The other flavonoids reported are myricetin, quercetin, kaempferol and apigenin.

The most interesting compound characterised from the family is the copper-containing glycoprotien, stellacyanin. It has been reported first from **Rhus vernicifera** and is later found to be present in other genera also (**Mangifera** and **Spondias**). This compound is not yet reported from any other family except the Rosacee.

The gums obtained from the family contain polysaccharides consisting of 4-OMe glucuronic acid, glucuronic acid, arabinose, rhamnose and galactose. Monoterpenes, sesquiterpenes and tetracyclic triterpenes are also frequent within the family. All the recent chemical reports from the Anacardiaceae are summarised in Table-4.1.

In the present work 20 plants belonging to 13 genera are analysed for their leaf constituents and the chemical interrelationships of the taxa are assesed. In addition, all these plants have been subjected to a cladistic analysis using characters from chemistry and morphology.

Materials and Methods :

The leaf materials were collected from different regions of India; **Dracantomelum mangiferum**, **Mangifera caloneura**, **Rhus paniculata** and **Semecarpus subpandoriformis** from BSI Bot-

Table : 4.1 Previous Chemical Reports from the Anacardiaceae

1.	**Anacarduim occidentale**	Biflavonoids, triterpenes and flavonoids	nutshells	Subramanian et al. (1968); Murthy et al. (1982)
2.	**Gluta** sp.	Polyphenols and catechins	Wood	Imamura (1979)
3.	**Holigarna ferruginea**	Catechins	Resin	Srinivas et al. (1987)
4.	**L. coromendelica**	Phlobaphenes, flavonoids, proanthocyanidins and ellagic acid.	Leaves	Nair et al. 1963.
		Phlobatannins, triterpenes	Stem bark	Subramanian and Nair (1971).
5.	**Mangifera indica**	Tannins and related compounds, benzophenones	Leaves and bark	El Sissi and Saleh (1964); Tanaka et al. (1984)
		Tetracyclic triterpenes	Stembark	Anjaneyulu et al. (1985).
		Flavonols and glycoflavones	Leaves	El Sissi and Saleh (1965)
6.	**Pistacia vera**	Monoterpenes	Resin	Mangoni et al. (1982)

Table : 4.1 (Contd.)

7.	**Rhus**	Flavones and flavonols	Leaves	Young and Sheilaja (1985)
		Isoflavonols	Wood	Young (1979)
8.	**R. lancea**	Flavonols and 5-deoxy pro-cyanidins	--	Nair et al. (1983)
9.	**R. semialatus**	Biflavones and methylgallate	Leaves	Bagehi et al. (1985); Nishizawa et al. (1982)
10.	**R. succedenia**	Flavones, biflavoenes and Tannins	Leaves, Seeds and fruits	Hattori and Matsuda (1952); Lin and Chen (1974); Chen et al. (1974); Chen & Lin (1975)
11.	**R. typhina**	Monoterpenes	Leaves	Bestmann et al. (1988)
12.	**R. vernicifera**	Stellacyanin	Leaves	Bergman et al. (1988)
		Polyphenols	Resin	Tyman and Mathew (1982)
		Flavonols and gallic acid	Leaves	Subash et al. 1986)

Table : 4.1 (Contd.)

13.	**Semecarpus anacardium**	Biflavones	Leaves and nuts	Rao et. al. (1973); Ishratullah et äl. (1977)
		Catechols	Nuts	Carpenter et al. (1980)
14.	**Schinus molle**	Triterpenes	Resin	Pozzo - Balbi et al. (1978)
		Sesquiterpenes	Leaves	Devalle and Schwenker (1987)
15.	**S. terebinthifolius**	Polyphenols and triterpenes	Leaves bark and berry	Campello and Naraiote (1975) Lloyed et al. (1977)
16.	**Toxicodendron radicans**	Catechol	Leaves	Baer et al. (1980)

anical garden of Calcutta, **Anacardium occidentale, Rhus succedenea** from Kerala, **Rhus mysurensis** from Madras, **Chaerospondias axillaris**, **Schinus molle** from Ooty, **Buchanania lanzan** and **Rhus parviflora** from Panchamarhi, **Lannea coromendelica** from Baroda and **Holigarna arnottiana, Schinus terebinthifolius, Semecarpus anacardium** and **Spondias pinnata** from Waghai. The procedures adopted for the analysis of plant material are described in Chapter-2. For the construction of Wagner tree 32 characters selected from morphology (20) and chemistry (12) have been employed. Most of the characters used here are already explained in the Sapindaceae. The additional characters adopted here are :-

Character 7 : Aestivation imbricate = 0; Aestivation valvate = 1.

Evolutionary modifications occuring in the arrangment of the floral appendages is the gradual change from spiral to the whorled phyllotaxy. Therefore the imbricate arrangment is a primitive state while the valvate condition is a derived state.

Character 9 : Staminodes in female flower present = 0;
Staminodes in female flower absent = 1.

The evolution of an unisexual female flower from a bisexual one is brought about by the reduction of fertility in stamens and later complete loss of them from the flower. The staminodes or the sterile stamens represent the first stage of evolution. This later followed by the reduction of size of staminodes and finally the loss of staminodal remnants. Therefore the absence of staminodes in the female flower is an advanced character gaining a score 1.

Character 10 and 11 : Ten fertile stamens = 0; Less than 10 fertile stamens = 1.

2-5 fertile stamens = 0; Single fertile stamen = 1.

In this case, a single character is split into two since it involves two evolutionary stages. The reduction of stamens within the whorl is a feature of specialization seen in many families. Ten stamens may be reduced to 9, 6, 5 etc. Extreme reduction to a single fertile stamen also is seen in some of the genera.

The final score

Ten stamens fertile = 0.
Less than 10 stamens fertile = 1.
Single fertile stamen = 1 + 1 = 2.

The presence of vestigial vascular traces support the reduction theory.

Character 12 : Apocarpous ovary = 0; Syncarpous ovary = 1.

Most primitive woody dicots are characterised by an apocarpous gynoecium. The cohesion and later complete fusion of the carpels led to syncarpous ovary.

Character 17 : Terminal style = 0; Lateral style = 1.

Normally the style is positioned in the apex of a syncarpous ovary and therefore is terminal. The reduction in the number of ovaries results in the shifting of the style from terminal to lateral position. So the presence of a lateral style is given a score 1.

Character 19 : Hypogynous ovary = 0; Epigynous ovary = 1.

The receptacular theory as well as appendicular theory proves that an epigynous ovary has been evolved from hypogynous ovary. In Anacardiaceae the receptacle becomes fleshy and the ovary gets sunken resulting in epigyny. Therefore the epigynous condition is a derived state and given a score of 1.

Character 20 : Fleshy receptacle in fruit absent = 0; Fleshy receptacle persistant in fruit = 1.

The contribution of any sterile part of the flower in the dispersal of the fruit is advantageous to the plant and therefore is an advanced feature. The growth of receptacle into a fleshy, edible structure enclosing the nut help in the dispersal of seeds by the animals and birds and is considered an apomorphic character.

Character 25 : Absence of 5-deoxy flavonoids = 0; Presence of 5-deoxy flavonoids = 1.

Gornall and Bohm (1978) while discussing the major trends in the flavonoid evolution pointed out that a reduction in structure or a functional group occured many a times in angiosperms in different classes and in structural complexity. The cases like deoxygenation require an additional step at enzyme level. 5-Hydroxy flavonoids occur throughout the vascular plants and 5-deoxy flavonoids which are derived compounds have a restricted distribution and found in advanced families like Fabaceae.

Character 26 : Presence of biflavones = 0; Absence of biflavones = 1.

The coding of this character is mainly based on Gieger and Quinn (1988). Amentoflavone, the most common biflavones of the Anacardiaceae, occur in many of the Gymnosperms and

Table - 4.3

The Characters Selected for Cladistic Analysis of the Anacardiaceae.

Sr. No.	Characters	Plesiomorphic Score = 0	Apomorphic Score = 1
1.	Leaves	Simple	Compound
2.	Type of compound leaves	Pinnate	Trifolioate
3.	Arrangement of leaves	Alternate	Opposite
4.	Inflorescence	Only bisexual	Bisexual and Unisexual
5.	Sex of the flowers	Polygamous	Unisexual
6.	Sex of the Plant	Monoecious	Dioecious
7.	Flowers	Pentamerous	Tetramerous
8.	Aestivation	Imbricate	Valvate
9.	Staminodes in female fls.	Present	Absent
10.	No. of fertile stamens	Ten	less than ten
11.	" "	2 - 5	One
12.	Styles	Free	Connate
13.	Pistil	Apocarpous	Syncarpous
14.	Carpels	Pentacarpellary	Tricarpellary
15.	No. of locules	Pentalocular	Unilocular
16.	No. of fertile ovules	All	Single
17.	Position of style	Terminal	Lateral
18.	No. of styles	Three	One
19.	Nature of ovary	Hypogynous	Epigynous
20.	Nature of fruit	Dry	Fleshy
21.	Myricetin	Present	Absent
22.	Methoxylated flavonols	Absent	Present
23.	Flavones	Absent	Present
24.	Methoxylated flavones	Absent	Present
25.	5-Deoxyflavonoids	Absent	Present
26.	Biflavonoids	Present	Absent
27.	Glycoflavones	Absent	Present

Table : 4.3 (Contd.)

Sr. No.	Characters	Plesiomorphic Score = 0	Apomorphic Score = 1
28.	Proanthocyanidins	Present	Absent
29.	Syringic acid	Present	Absent
30.	Tannins	Present	Absent
31.	Gallic acid	Present	Absent
32.	Saponins	Absent	Present

Table : 4.4 The Distribution of 32 Characters Selected for Cladistic analysis Among 19 Taxa of the Anacardiaceae

	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	AD (I)
Ana. occ.	0	0	0	1	0	0	0	0	1	0	0	1	1	1	1	1	1	0	0	1	1	0	0	0	1	0	0	0	0	0	0	1	12
Buc. lan.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	5
Cha. axi.	1	0	0	1	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	1	1	0	0	1	1	0	0	1	1	0	14
Dra. man.	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1	1	0	0	1	0	0	0	1	0	11
Hol. arn.	0	0	0	1	1	0	0	0	1	1	0	0	1	1	1	1	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	11
Lan. cor.	1	0	0	1	1	1	1	0	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	12
Man. cal.	0	0	0	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	0	1	1	1	0	0	1	0	0	0	0	0	1	0	16
Man. ind.	0	0	0	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	0	1	1	1	0	0	1	0	0	0	0	0	1	0	16
Ple. tri.	1	0	1	1	1	1	0	0	1	0	0	0	1	0	1	1	0	0	1	0	1	1	0	0	0	1	0	1	0	1	1	0	16
Rhu. mys.	1	1	0	1	1	1	0	0	1	0	0	0	1	1	1	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1	0	14
Rhu. pan.	1	1	0	1	1	1	0	0	1	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	0	0	0	1	0	18
Rhu. par.	1	1	0	1	1	1	0	0	1	0	0	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	12
Rhu. suc.	1	0	0	1	1	1	0	0	1	0	0	0	1	1	1	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	11
Rhu. wal.	1	0	0	1	1	1	0	0	1	0	0	0	1	1	1	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	12
Sch. mol.	1	0	1	1	1	1	0	1	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	13
Sch. ter.	1	0	1	1	1	1	0	1	1	0	0	0	1	1	1	1	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	15
Sem. ana.	0	0	0	1	1	1	0	0	1	1	0	0	1	1	1	1	1	0	1	1	0	1	0	1	0	0	0	0	0	1	0	0	15
Sem. sub.	0	0	0	1	1	1	0	0	1	1	0	0	1	1	1	1	1	0	1	1	0	1	0	0	1	0	1	0	0	0	0	0	15
Spo. pin.	1	0	0	1	1	0	0	0	1	1	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	1	0	0	1	1	1	0	13

Table : 4.5 Manhattan Distances Between All The Pairs of Taxa of the Anacardiaceae

	Buc. lan.	Cha. axi.	Dra. man.	Hol. arn.	Lan. cor.	Man. cal.	Man. ind.	Ple. tim.	Rhu. mys.	Rhu. pan.	Rhu. par.	Rhu. suc.	Rhu. wal.	Sch. mol.	Sch. ter.	Sem. ana.	Sen. sub.	Spo. pin.
Ana.occ.	13	15	17	9	12	8	8	16	12	14	12	9	9	11	11	9	9	18
Buc.lan.		13	10	10	9	13	13	11	10	13	9	10	9	12	15	14	14	12
Cha. axi.			11	13	12	14	14	12	12	12	12	13	11	13	13	13	13	7
Dra. man.				18	18	17	17	15	15	13	15	16	15	16	16	20	18	14
Hol. arn.					7	9	9	11	9	13	9	8	9	8	11	6	6	10
Lan. cor.						12	12	8	4	8	4	5	4	5	8	11	10	11
Man. cal.							0	14	10	12	10	9	8	15	11	6	7	11
Man. ind.								14	10	12	10	9	8	15	11	6	7	11
Ple. tim.									6	10	8	9	8	9	13	11	13	9
Rhu. mys.										4	2	5	4	7	11	11	11	9
Rhu. pan.											6	7	6	11	11	13	11	13
Rhu. par.												3	2	7	9	9	9	11
Rhu. suc.													1	6	6	6	6	12
Rhu. wal.														5	7	6	7	12
Sch.mol.															6	12	12	14
Sch. ter.																10	10	18
Sem. ana.																	2	12
Sen. sub.																		14
Spo. pin.																		0

Pteridophytes. This group of compounds occuring in lower plants, are primitive in nature. Therefore their presence is considered as a primitive character.

The plesiomorphic and apomorphic states of the selected characters, the distribution of these characters and the Manhattan distances between all the pairs of taxa are presented in Table-4.3, 4.4 and 4.5 respectively.

Results :

The distribution of various flavonoids, phenolic acids, saponins and tannins in leaves of 20 members of the Anacardiaceae is presented in Table-4.2.

All the 20 taxa screened contained flavonoids in their leaves. The flavonoid pattern of the family is dominated by flavonols and proanthocyanidins which occur in major amounts. Flavones are located in six members and glycoflavones in three. Biflavones, a rare group of flavonoids, also are identified from the family.

Various flavonols present in the family are kaempferol, quercetin and myricetin and their methoxylated derivatives. Of these, quercetin, which is the most predominant flavonol, shows a wide range and levels of methoxylation. 3'-OMe Quercetin, (9/20), 5-OMe quercetin (2/20) and 7-OMe quercetin (2/19) are the monomethoxylated quercetins obtained. 3', 4'-DiOMe quercetin and 7, 3', 4'-triOMe quercetin are the di/trimethoxylated derivatives encountered in the family. The trimethoxylated flavonols occur in three taxa. Myricetin, located in 12 members, is another flavonol of common occurence. Kaempferol is less frequent. Fisetin (5-deoxykaempferol), presènt in 7 plants is one of the interesting compounds found in the family.

Table : 4.2 The Distribution of the Various Chemical Merkers Among 19 Members of the Family Anacardiaceae

	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
MANGIFERAE																																		
nacardium occidentale L.									+	+	+	+		+		+	+				+		+	+		+	+			+		+		+
uchanania lanzan Spreng									+		+	+						+					+			+	+	+				+		
a coromandelica Merr.											+							+	+				+			+	+		+			+		
ifera Caloneura Kurz.							+		+	+	+				+	+		+				+	+			+	+		+					
indica L.							+			+	+	+	+		+			+				+	+			+	+			+				
RHOIDEAE																																		
hus mysorensis Heyne	+	+		+					+		+		+		+								+			+	+		+					
paniculata Wall.	+	+	+	+	+					+					+						+		+			+	+		+					
parviflora Roxb.									+		+	+						+			+		+			+	+	+				+	+	
Succedenea L.	+							+			+							+			+		+	+			+			+				
wallichii H. f.				+			+			+	+									+	+		+			+	+	+	+			+		+
hinus molle Hert.											+			+	+			+					+			+	+	+		+				
terebinthifolius Raddi	+						+	+			+							+			+						+	+		+				
SEMECARPEAE																																		
mecarpus anacardium L.							+	+										+		+	+		+			+	+	+	+	+				
Subpanduriformis Wall.					+	+		+		+		+						+					+		+	+	+			+				
oligarna arnottiana Hook.											+					+		+					+			+	+	+		+	+			
SPONDIEAE																																		
racantomelum mangiferum	+	+		+	+		+					+									+		+			+	+							
haerospondias axillaris											+	+			+			+					+	+		+	+	+						
Roxb.) Burt. & Hill																																		
leiogynium timoriense Lee																								+	+	+	+						+	
ierocarya caffara							+					+											+				+			+				
pondias pinnata (Linn. f.) Kurz.											+	+			+								+	+	+	+						+		

Apigenin and its methoxylated derivatives are the flavones identified from the family. **Dracantomelum**, **Rhus**, **Pleiogynium** and **Semecarpus** are the genera which elaborated these compounds. 6-OMe Apigenin is located only in one plant, **Rhus paniculata**. The two glycoflavones obtained from the family were, 4'-OMe vitexin and 4'-OMe isovitexin (3/20). Mangiferin, a C-glycosidic xanthone, is restricted to the genus **Mangifera**. Biflavones based on apigenin and acacetin are located in 6 genera.

Proanthcyanidins occur in all plants except **Pleiogynium**. They are mostly procyanidins and prodelphinidins. The various phenolic acids separated fall into two groups: benzoic acids (7) and cinnamic acids (2). Tannins are widespread in the family and are of both hydrolysable and condensed types. Saponins and alkaloids are rare and iridoids are absent.

Discussion : The common constituents of the Anacardiaceae are the highly hydroxylated phenolic coumpounds such as quercetin, myricetin and gallic acid. The most obvious features which the members of this family have in common are the proanthocyanidins, flavonols, biflavones, 5-deoxyflavonols and tannins. The tannins obtained from these plants are a mixture of condensed and hydrolysable types. The uniformity of chemical characters appears to correlate with the morphological similarities existing within the family suggesting that the Anacardiaceae is a closely knit family. Though the number of plants screened in the present study is not quite large, the observations on these data might prove, in the future,to be of special taxonomic significance.

The chemical differences among the tribes are not very pronounced; however the data support certain groups already circumscribed within the family. The tribe Rhoideae is distinct in containing flavones, both as O-and C-glycosides, methoxylated myricetin and gallic acid. The taxa belonging to this tribe are also rich in agathisflavone (biflavone) in their leaves. The 5-deoxyflavonoids are rare (2/7) in this group.

Among the other three tribes which are rich in flavonols, the Spondieae possess flavones in atleast 2 genera, (**Dracantomelum** and **Pleiogynium**) and exhibit a low incidence of myricetin (1/5). **Dracantomelum** is different from the other genera of the tribe in containing biflavones (agathisflavone), flavones (such as apigenin and acacetin) and glycoflavones. These features being common with the Rhoideae the shifting of this genus to the tribe Rhoideae is proposed. **Pleiogynium** also is distinct in not producing proanthocyanidins and flavonols. Though some amount of similarities with the members of Rhoideae can be discerned (in containing flavones) a shifting of this genus from this tribe needs a number of additional evidences. The presence of such taxa emphasises the heterogeneity existing in the tribe Spondieae. Data from more plants and disciplines are needed to arrive at an acceptable classification of this tribe.

Though the Semecarpeae are devoid of flavones, they possess the mechanism to synthesise their dimers, the biflavones. This character keeps Semecarpeae distinct from the Mangiferae and Spondieae. Between the later two tribes which do not possess biflavones, Mangiferae produce 5-deoxy and/or 5-methoxy flavonoids and highly methoxylated flavonols. **Anacardium** appears to share a close relationship with Semercarpeae because biflavones are seen in this genus. It seems proper to shift **Anacardium** to the tribe Semecarpeae so that both the tribes Semecarpeae and Mangiferae would automatically become homogeneous. The presence of flavanone in **Lannea** is intriguing. Though morphologically advanced, the presence of flavanone, a precursor of flavone, keep it chemically primitive.

The absence of flavones in both the Mangiferae and Semecarpeae can be cited as an evidence to bring them close to each other. The latter tribe also enjoys closer ties with the Rhoideae in synthesising biflavones and ecologically important polyphenols such as urshiol, cardanol, eriodictyol, anacardol, ancardic acid etc.

Spondias axillaris Roxb, which is separated and elevated to a new genus **Chaerospondias axillaris** (Roxb) Burtt. & Hill., is chemically different from **Spondias pinnata**, with which it was associated earlier. The former taxon contains fisetin, myricetin, syringic acid and melilotic acid as against 4',-and 3',4'-dimethoxy quercetin, protocatechuic acid and p-coumaric acid of the latter species. These differences corroborate the morphological differences existing between these two taxa and the concept of **Chaerospondias** away from **Spondias** (Mukherjee and Chandra,1983) gains more support.

The introduction of flavones in Rhoideae indicate their chemical advancement over other tribes. The tribes Mangiferae and Semecarpeae possessing flavonols, especially myricetin, are the primitive groups of the family. Between these two tribes Mangiferae (methoxylated flavonols and absence of biflavones) seem to be a step ahead of Semecarpeae (with biflavones and hydroxylated flavonols). Members of Spondieae are intermediate to Rhoideae and Mangiferae-Semecarpeae in containing flavones and low incidence of trihydroxylated phenolics.

CLADISTIC ANALYSIS :

Wagner tree incorporating 18 taxa studied is presented in Fig.-4.1. The first two branches arising from the basal nodes of the tree carry only one taxon each i.e. **Dracantomelum**

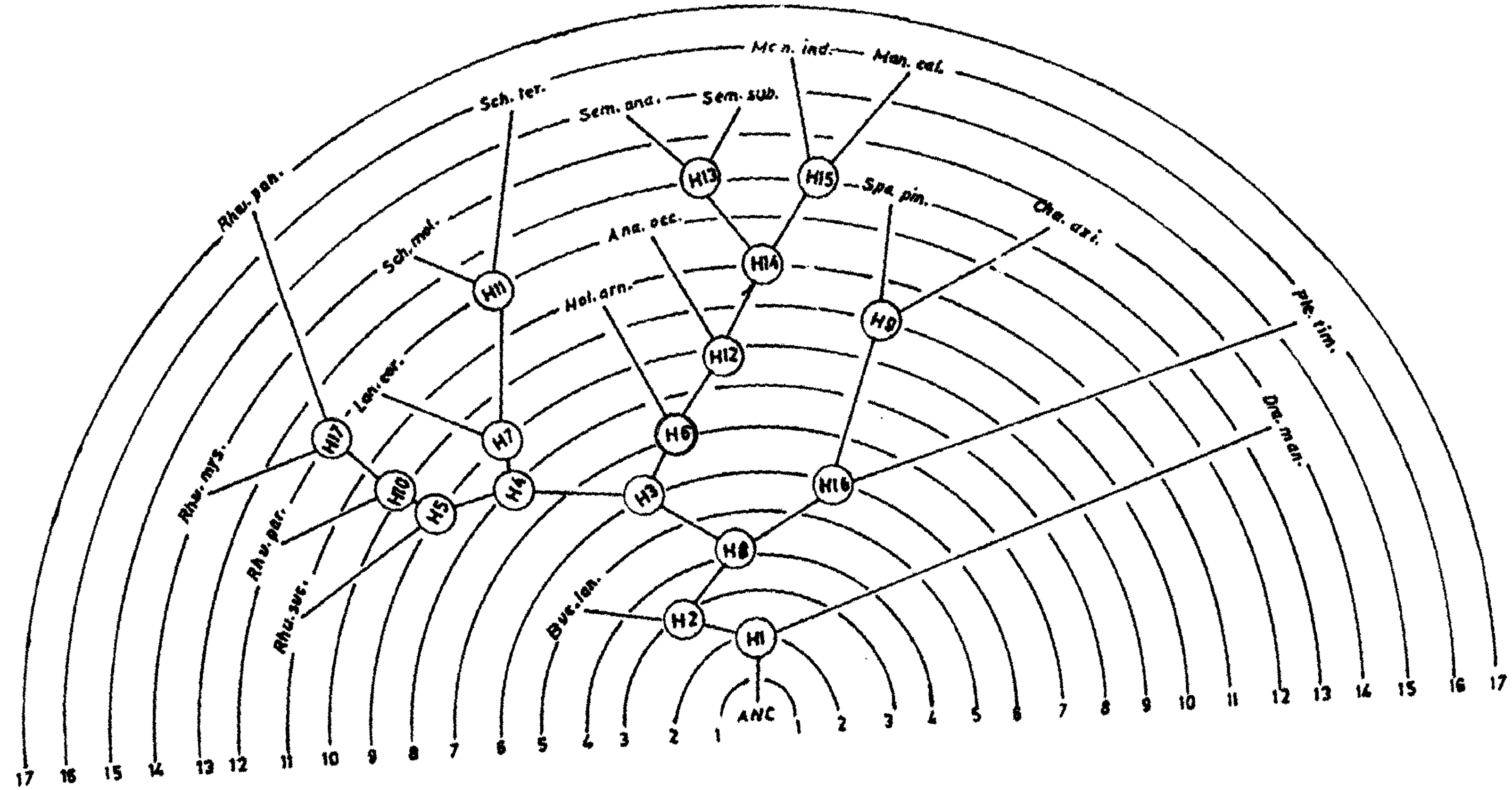

Fig. 4.1 Cladogram of the Anacardiaceae

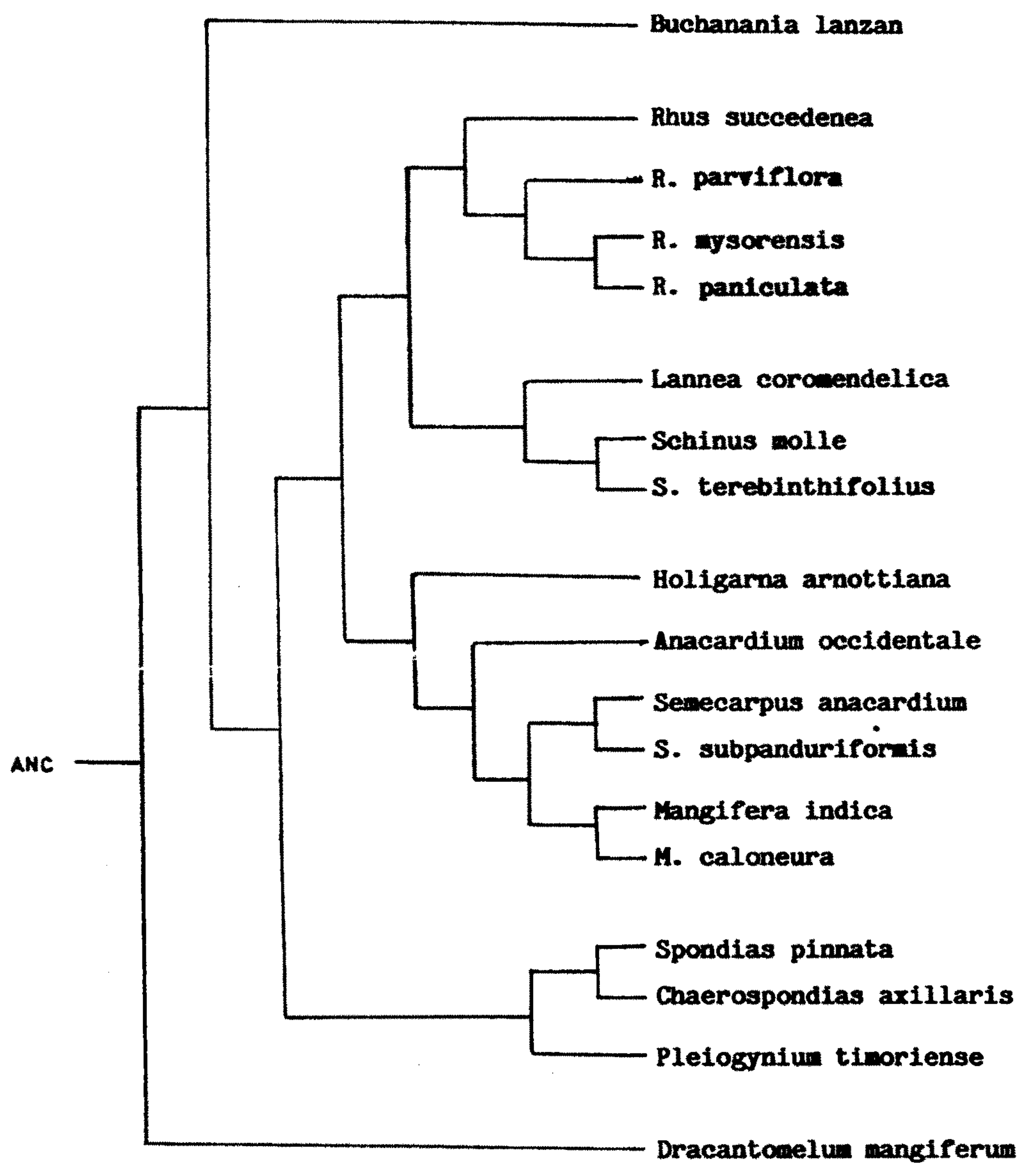

Fig. 4.2 Dendrogram of the family Anacardiaceae

on the first branch and **Buchanania** on the second. The major dichotomy occurs at the node HTU8 giving out two branches A and B. The clade A has three genera **Pleiogynium, Spondias** and **Chaerospondias** with the former genus separating from the node HTU16. Branch B carrying the rest of the genera distinctly forms two groups 1 and 2, separating from the node HTU3. Group 1 has six OTUs of the genera **Holigarna, Anacardium, Semecarpus** and **Mangifera**. Among these 4 genera, **Holigarna** first gets separated at HTU6 followed by **Anacardium** from HTU12. Finally the branch constituting group-1 bifurcates, one clade ending with two species of **Mangifera**. Group-2 includes seven OTUs belonging to the genera **Rhus, Lannea** and **Schinus**. All the four species of **Rhus** occupy a single branch which arise from HTU4. The other branch from HTU4 bears **Schinus** and **Lannea** with the latter taxon branching out first form HTU7. The dendrogram depicting these groups is presented in Fig. 4.2.

Buchanania with AD(I) value 5 is the most primitive taxon while **Rhus paniculata** with AD(I) value of 16 is the most advanced. Most of the members of the family show AD(I) values higher than 11.

Discussion :

Dracantomelum and **Buchanania,** the foremost branches separating from the tree are the two primitive genera of the family. **Dracantomelum** having pentamerous flower, five fertile carpels, flavones and biflavones share many characters with branch A. In **Buchanania,** eventhough 5 carpels are present only one is fertile and this takes the genus close to the branch B. This is further supported by the low values obtained while calculating the distances with different intervals. These two genera are closer to the ancestor and may be near to the taxa from which other advanced members are evolved.

The two major branches represent the following grouping:

1. Branch A : **Spondias**, **Chaerospondias** and **Pleiogynium** with **Dracantomelum** near their ancestral stock

2. Branch B : Consisting of two subgroups

   subgroup 1 : **Semecarpus**, **Anacarduim**, **Mangifera** and **Holigarna**
   subgroup 2 : **Rhus**, **Lannea** and **Schinus**

The major forking of the tree is similar to that of Hooker's classification of the family. The branch A corresponds to the tribe Spondieae while branch B corresponds to tribe Mangiferae. But the subgroups within the branch B closely resemble the tribes circumscribed by Engler. Subgroup-1 include the plants belonging to two tribes Semecarpeae and Anacardieae and subgroup 2 includes the plants of the tribe Rhoideae of Engler. The only exception, **Lannea** which was grouped in the tribe Anacardieae is placed next to **Schinus** in the present analysis. These results are more in line with the conclusions drawn on the basis of chemical characters.

Among the various genera of branch A, **Anacardium** on one hand has many characters common with the genus **Mangifera** (simple leaves and flavonols) while on the other hand shows similar affinity with **Holigarna** and **Semecarpus** (growth of receptacle in fruit, biflavones and flavonols). The presence of such a taxon suggest the merger of the two tribes Semecarpeae and Mangiferae. **Lannea**, a genus placed in Mangiferae in the present analysis, occupies a place near to **Schinus** of the tribe Rhoideae. This placement is more feasible because of the presence of 2'-hydroxy flavonols, flavanones, tetramerous flowers and compound leaves, the characters which are not found in the former tribe. A report of an isoflavone from **Schinus** establishes the closer relationship further.

Morphologically the Anacardiaceae show a number of primitive characters such as woody habit, simple leaves and pentamerous bisexual flowers. But alongwith these primitive characters many of the genera possess compound leaves, polygamous infloresence, tetramerous flowers and peri-or epigynous ovary. This heterogeneity is seen in the chemical characters also. The primitive forms produce myricetin, proanthocyanidins and biflavones while the advanced members synthesise flavones and 5-deoxyflavones. The co-occurence of primitive and advanced characters points out the fact that the Anacardiaceae is a predominently primitive family where some of its members attained certain evolutionary traits. This indicates the possibility of deriving the other advanced families from the Anacardiaceae.