

*S. Family SIMARUBACEAE*

The family Simaroubaceae contains approximately 32 genera and 200 species of tropical/subtropical woody plants. Of these only 6 genera and 12 species, mostly belonging to the subfamily Simarouboideae, are found in India.

The Simaroubaceae (including Alvaradoideae, Irvingioideae, Kirkioideae, Picramnioideae, Simarouboideae and Surianoideae), are characterised by alternate compound exstipulate leaves and 3 - 5 merous, regular, unisexual or functionally unisexual or bisexual flowers in axillary racemes/cymes/panicles/corymbs. Calyx is always connate at the base; petals 3 - 5, free, greenish to variously colored. Stamens equal to or twice the number of petals, obdiplostemonous and free. Filaments slender often with an inner scale at the base and anthers usually versatile. Intrastaminal disk is very prominent, generally gynophorous. Carpels 4-5, apocarpous or syncarpous, ovary 2-5, unilocular and style free or connate. Ovule single in each locule in axile placentation. Fruit a capsule, samara or schizocarp, rarely drupe/berry. Seeds are with membranous or leathery testa; endosperm scanty or absent. The stem, leaves and flowers are covered with unicellular or multicellular hairs and glands.

Anatomy :

Detailed floral anatomical data on the plants belonging to the subfamily Simarouboideae are available with Narayana and Sayeedudin (1958), and Nair and Sukumaran (1960). The family shows a tendency towards unisexuality (as seen in the other families of the order) and reduction in the number of floral parts. Except *Brucea*, all the other genera are found to have unisexual flowers which are derived from a basically bisexual flower. This is evidenced by the remnants of the reduced floral parts or the vascular traces found in flowers. But recently Basak (1980) discovered a few flowers of *Brucea*

to be unisexual. The study of the vasculature of the inflorescence of *Samadera indica* showed that it is a condensed dichasium and not an umbel as described by Hooker (1875). The scales of the anthers, a common feature of the family, are stipular in nature, as they do not receive any vascular supply. The well-developed intrastaminal disk receives its supply from staminal traces suggesting their formation from a whorl of reduced stamens. A similar condition is seen in the Meliaceae also. But Nair and Sukumaran (1960) interpret the disk in *Samadera* as a remnant of the outer third whorl of sterile carpels since the dorsal carpel trace gives out a vascular strand to the disk. The apocarpous pistil of the family usually connates at the styler region. Saunder (1939) and Hutchinson (1973) consider the apocarpous nature to be derived from the syncarpous ovary by an early splitting of the carpel at the median radial region. This theory gains support from the floral anatomical studies, where the carpels are seen having some residual vascular strands which fuse with the ventral strand (principal strand) to form the placental strands. The floral and extrafloral glands have a head (glandular) supported by unicellular or multicellular uniseriate stalk. (Clair-Muczulaj-tys and Bory 1983).

#### Embryology :

Tapetum is secretory and multinucleate. The pollen are shed at two-celled stage. The ovules are bitegmic, anatropous, crassinucellate and epitropous or very rarely apotropous. Nucellar beak and hypostase are present. The development of the embryo sac is Polygonum type with coenocytic massive nucellus. The embryo undergoes free nuclear division. A prominent haustorium is present.

#### Palynology :

Basak (1967) and Milagros and Machado (1987) studied the pollen of the family in great detail. Pollen grains are found to be more or less uniform throughout the family. They are 2-3 zonocolporate, medium to small size, narrow with colpi having long tapering ends. Exine is as thick as or more than nexine. The pollen of *Quassia* and *Irvingia* differ from the rest in having elliptic pollen grains with anguloaperture, triangular amb and square ora while the rest of the family have elliptic to spherical pollen with circular amb, distinctly lalongate ora and reticulate surface.

#### Wood Anatomy :

A systematic study on wood anatomy was carried out by Webber (1936) and Metcalfe and Chalk (1950). The wood is diffuse-porous but some members of *Ailanthus* show a tendency towards ring-porous nature. The wood is characterised by vasicentric to aliform parenchyma which vary in quantity and visibility among the genera. Traumatic gum vessels similar to those of the Anacardiaceae and Burseraceae are found in *Ailanthus*, *Samadera* and *Simarouba*. *Samadera* and *Picrasma* contain para-tracheal parenchyma, a character frequent in the Anacardiaceae. The family Simaroubaceae (with all the 7 subfamilies) is found to be a heterogeneous taxon by all these workers.

#### Classification :

The Simaroubaceae are always associated with the Rutaceae. Both these families were placed in Geraniales by Bentham and Hooker (1862) and Engler and Prantl (1931). Lawrence (1951), Gunderson (1950) and Rendle (1950) removed them alongwith Burseraceae and Meliaceae from Geraniales and placed in a separate order Rurales.

Bennett (1875) divided the family to two tribes,

Eusimarouboideae and Picramnoideae. Engler and Prantl (1931) recognised six subfamilies, - Alvaradoideae, Irvingiodieae, Kirkioideae, Picramnoideae, Surianoideae and Simarouboideae. Takhtajan's (1980) classification is similar but he raised the Kirkioideae to a family (Kirkiaceae) which is placed next to the Meliaceae. Dahlgren (1980) treats the Surianoideae as a separate unigeneric family Surianaceae while Thorne (1976) creates a new subfamily Balanitoideae for *Balanites* away from the Eusimarouboideae. The Simaroubaceae inclusive of all these subfamilies are very heterogeneous and show forth diverse morphological, anatomical, palynological and chemical characters. As a result of this heterogeneity the delimitation and content of the family became ambiguous. Therefore, on the basis of wood anatomy Webber (1936) preferred to treat all these subfamilies as independent families.

Nooteboom (1962) proposed the merger of all the genera except *Harrisonia* and *Euryoona* (of the subfamily Simarouboideae) into one genus *Quassia*. This idea is supported by Basak (1967) who prefers to keep only *Quassia* separate from the other genera. The taxonomic position of *Balanites aegyptiaca* also remained controversial. Bentham and Hooker (1862) and Cronquist (1981) included this genus in the family Simaroubaceae while Engler and Prantl (1931) placed it in the Zygophyllaceae. Hutchinson (1973) creates a new unigeneric family Balanitaceae, which is accepted by Takhtajan (1980) and Dahlgren *et al.* (1981). Based on the floral anatomical and chemical characters Parvathi and Narayana (1978) prefer to keep *Balanites* in the family Zygophyllaceae as a tribe, Balanitoideae (see also the Zygophyllaceae).

Hutchinson considered the Simaroubaceae, Rutaceae and Burseraceae as climax groups derived from Theales through Celastrales while Hallier (1912) derived Simaroubaceae from the Capparidaceae. Hallier places the Simaroubaceae at the

end of the side branch which arises from the Rutaceae through Cneoraceae. On the basis of wood anatomy Heimsch (1942) did not agree with this view. Nair and Sukumaran (1960) proposed that the Simaroubaceae with woody habit, more than five whorled flowers and apocarpous pistil are primitive and would have originated from the woody Ranales rather than from the Rutaceae. Waterman (1983) regards the Simaroubaceae as an advanced family which have separated early from the proto-Rutaceae retaining the tryptophan-derived alkaloids and elaborating the quassinoid pathway.

**Economic Importance :**

The family Simaroubaceae is known for its medicinal values which it owes to a group of tetranortriterpenoids known as quassinoids. The most significant property of these compounds is their antileukemic activities and that they are active against P-388 murine lymphocytes. In addition, the quassinoids possess antiviral, antimalarial, antifeedant, insecticidal and amoebicidal properties also. These compounds are present in every member of the sub-family Simarouboideae and thus all the plants in the subfamily are medicinally important. The plants which are used in conventional systems of medicine are (1) *Brucea antidysenterica* (against leprosy, tumours, diarrhoea, dysentery, fever and asthma) (2) *Quassia amara* (antiamoebic, antimalarial and antianemic) (3) *Samadera indica* (emetic and antirheumatic), and (4) *Ailanthus excelsa* and *Ailanthus triphysa* (febrifuge and tonic). Most of these plants contain indole alkaloids (canthin-6-ones and  $\beta$ -carboline). These compounds are found to be cytotoxic and contribute to the medicinal values of these plants.

The other important economic products from the family are the gums (used as adhesives) and resins containing volatile oils (used in agarbattis and in perfumes). The wood of the

family is soft and light and thus are not commercially exploited much. They are suitable for making smaller items such as toys, footrules, light packing cases etc. The wood is best used for match boxes.

Previous Chemical Reports :

Due to their excellent pharmacological properties the quassinoids attracted the attention of the chemists from very earlier times (Reinhold and Liwschitz, 1970). In fact, except for these compounds, the chemistry of the plants is almost unknown. The quassinoids are the bitter principles of the Simaroubaceous plants. They are  $C_{20}$  and  $C_{19}$  tetranortriterpenoids with heavily oxygenated lactones and have a varying number of different oxygen-containing groups. With the exception of C-5 and C-9 and on the methyl groups at C-4 and C-10, these oxygenated functions have been found on all the carbon atoms. The precursors of these compounds are found to be tirucallol or euphol ( $C_{30}$  triterpenes). About 75 quassinoids have been isolated which may be divided into five groups based on their basic skeleton. Of these, the  $C_{25}$  tirucallol derivatives are reported from *Ailanthus* and *Simarouba*. Majority of the quassinoids are  $C_{20}$  compounds with a range of structural diversity and distribution.  $C_{19}$  and  $C_{18}$  quassinoids have a limited distribution reported only from *Samadera indica*. These triterpenes have assumed great importance because of their antileukemic properties. The structural requirements for the antileukemic activity are (1)  $\alpha - \beta$  -unsaturated ketol group in ring A, (2) an epoxy methano-bridge and (3) an ester chain (lipophilic) at C-15. Most of the plants of the subfamily Simarouboideae contained alkaloids alongwith quassinoids. All the alkaloids reported are the indoles belonging to canthin-6-ones,  $\beta$  -carbolines and their derivatives. Very few reports on the phenolics of the family are available (Nootboom, 1966). Flavonols, kaempferol, quercetin and myricetin, are the dominant

Table : 8.1 Previous Chemical Reports on the Family Simaroubaceae

<i>Allanthus altissima</i>	Root	Shinjulactone C	Ishibashi <u>et al.</u> , (1982)
	Leaves	Indole alkaloids $\beta$ -Sitosterol, vitexin	Crespi - perrllina <u>et al.</u> (1986) Kapoor <u>et al.</u> , (1971)
<i>A. glandulosa</i>	Bark	C <sub>20</sub> Triterpenes	Sherman <u>et al.</u> , (1980); Khan and Shamsuddin (1978).
	Bark	Amarolide	Casinovi <u>et al.</u> , (1965)
<i>A. grandis</i>		6-OC-Trigloxychaparrinone	Polonksy <u>et al.</u> (1980)
<i>A. giraldii</i>		Alkaloids	Khan and Shamsuddin (1981).
<i>Brucea antidysenterica</i>		Indole alkaloids	Harris <u>et al.</u> (1985)
		Simaroubolides	Darwish <u>et al.</u> (1980).
<i>Picrasma quassinoides</i>		Indole alkaloids and Simaroubolides	Koike and Ohomoto (1988); Ohomoto and Koike (1983)

Table : 8.1 (contd.)

Quassia amara	Alkaloids, quassin	Barbetti <u>et al.</u> (1987); Valenta <u>et al.</u> (1962)
Samadera indica	Indacanthinone, Simarou -bolides and triterpenes	Iyer and Rangaswami (1972); Wintersteiner <u>et al.</u> (1965)
Simarouba amara	Simaroubolides, alkaloids	Brown and Sim (1964); Lassak <u>et al.</u> (1977); Polonsky <u>et al.</u> (1976).

Table - 8.3

Characters Selected for the Cladistic Analysis of the Simaroubaceae.

Sr. No.	Character	Plesiomorphic State	Apomorphic State
1.	Habit	Trees	Shrubs
2.	Leaves	Compound	Bifoliolate
3.	Leaf margins	Entire	Serrate
4.	Inflorescence	Panicle	Umbel like
5.	Flowers	Bisexual	Polygamous
6.	No. of unisexual flowers	Few	All
7.	Perianth	Glabrous	Hairy
8.	Stamens	Ten	Five
9.	Filament	Long	Short
10.	Scale	Absent	Present
11.	Ovary	Syncarpous	Apocarpous (derived)
12.	No. of ovules	Two	One
13.	Fruit	Drupe	Samara
14.	Seeds	Wingless	Winged
15.	Flavonols	Present	Absent
16.	Flavones	Absent	Present
17.	Glycoflavones	Present	Absent
18.	Quinones	Absent	Present
19.	Proanthocyanidins	Present	Absent
20.	Gallic acid	Absent	Present

Table : 8.3 (Contd.)

Sr. No.	Character	Plesiomorphic State	Apomorphic State
21.	Ferulic acid	Absent	Present
22.	Saponins	Absent	Present
23.	Tannins	Present	Absent
24.	Simaroubolides	Absent	Present
25.	Tirucallane	Present	Absent
26.	C <sub>20</sub> Quassinoids	Present	Absent
27.	C <sub>19</sub> Quassinoids	Absent	Present
28.	C <sub>18</sub> Quassinoids	Absent	Present
29.	Alkaloids	Canthinones	- Carbolines

Table : 8.5 Manhattan Distances Between Pairs of OTUs. of the Simaroubaceae.

	A. exc.	A. tri.	Bal.	Bru.	Sam.	Sim.	Qua.
A. alt.	9	7	15	9	13	12	9
A. exc.	-	6	12	10	16	9	14
A. tri.	-	-	16	10	14	13	12
Bal.	-	-	-	12	18	11	14
Bru.	-	-	-	-	16	11	10
Sam.	-	-	-	-	-	7	12
Sim.	-	-	-	-	-	-	9
Qua.	-	-	-	-	-	-	-

pigments. Ellagic and gallic acids are also frequent. Quinones (benzo and anthraquinones) are located from wood and roots of a few members (*Quassia*, *Ailanthus* and *Picrasma*) of the family. Coumarins are rare and only simple coumarins such as scopoletin are isolated. The family is a rich source of hydrolysable tannins. A detailed chemistry of the family is available elsewhere (Watermann and Grundon, 1983). Previous chemical reports are summarised in Table-8.1

#### Materials and Methods :

Ten plants belonging to seven genera of the subfamily Simaroubaceae are screened in the present work. *Ailanthus excelsa*, *Balanites aegyptiaca* and *Quassia amara* were collected from Baroda; *A. altissima* from Kashmir; *A. triphysa*, *Samadera indica* and *Brucea javanica* from Tropical Botanical Garden, Trivandrum (Kerala); *Picrasma quassioides* from Dehradun and *Simarouba amara* from Amravati (Maharashtra). The isolation and identification of various compounds are done following standard methods (Chaper-2). All these plants have been subjected to a cladistic analysis. A total of 30 characters are selected of which 15 are morphological and 15, chemical. The apo- and plesiomorphic states of characters and their distribution in the OTUs are presented in Tables 8.3 and 8.4. Manhattan distances between the taxa are presented in table 8.5.

#### Results :

The results obtained from the chemical analysis of the leaves are presented in Table-8.2. All the plants screened contained flavonoids in their leaves. The flavones, glycoflavones and flavonols are widespread in the subfamily. The various flavones encountered are apigenin, luteolin and their methoxylated derivatives. Of these, luteolin and its derivatives are more frequent. Kaempferol, quercetin and 3',4'-diOMe

Table : 8.2 The Distribution of Phenolics, Tannins and Saponins Among Nine Members of the Simaroubaceae

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
<i>Allanthurus altissima</i> Swingle	+			+			+	+	+			+	+	+	+	+	+	+	+	+	+	+	+
<i>A. excelsa</i> Roxb.					+	+	+					+	+	+	+	+	+	+	+	+	+	+	+
<i>A. triphysa</i> Alston						+	+	+					+	+	+	+	+	+	+	+	+	+	+
<i>Balanites aegyptiaca</i> Delile	+							+					+	+	+	+	+	+	+	+	+	+	+
<i>Brucea javanica</i> Merr.			+	+				+					+	+	+	+	+	+	+	+	+	+	+
<i>Picrasma quassioides</i> Bennet							+	+	+			+	+	+	+	+	+	+	+	+	+	+	+
<i>Samadera indica</i> Gaertn.			+			+		+				+	+	+	+	+	+	+	+	+	+	+	+
<i>Simarouba glauca</i> DC.					+						+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Quassia amara</i> L.					+	+	+				+	+	+	+	+	+	+	+	+	+	+	+	+

Apigenin 2. Acacetin 3. 7,4'-DiOMe Apigenin 4. Luteolin 5. 7-OMe Luteolin 6. 7-OMe Vitexin 7. Kaempferol 8. Quercetin  
3',4'-DiOMe Quercetin 10. Myricetin 11. Quinones 12. Coumarins 13. Proanthocyanidins 14. p-Hydroxy benzoic acid 15. Vanillic  
d 16. Syringic acid 17. Gallic acid 18. p-Coumaric acid 19. Sinapic acid 20. Ferulic acid 21. Tannins 22. Saponins

quercetin are the flavonols identified. Kaempferol is found in only one plant, *Ailanthus triphysa*, while the latter two flavonols showed 75% incidence of occurrence. Coumarins identified are scopoletin and 7-OMe scopoletin. Proanthocyanidins, though occur in about 50% of plants are present in very low concentrations. Hydrolysable tannins are located in five plants. Out of seven phenolic acids identified, vanillic, syringic and ferulic acids are present in all the plants screened. Gallic/ellagic acids are frequent (6/10). All the ten plants analysed contained alkaloids and saponins.

#### Discussion :

The subfamily Simarouboideae is a homogeneous taxon with flavones, glycoflavones and flavonols distributed evenly. However, the two genera *Simarouba* and *Quassia* are distinct in not containing flavonols while the absence of flavones in *A. triphysa* keep this species apart from other members. *Simarouba*, *Balanites* and *Brucea* are closer to each other in containing glycoflavones in their leaves. Among the three species of *Ailanthus*, *A. triphysa* differs from the other two species in containing kaempferol and in the absence of flavones.

The present chemical analysis is not in support of merging all the genera (except *Harrisonia* and *Eurycoma*), of the subfamily Simarouboideae into a single genus *Quassia*, because each genus has a distinct flavonoid profile. *Balanites*, a genus variously placed in Zygophyllaceae and Simaroubaceae, shares a number of chemical characters with both the families (similar type of flavonols and flavones). However this genus does not synthesise the quassinoids which are omnipresent in the Simaroubaceae. The occurrence of diosgenin and their related sapogenins in *Balanites*, a character common to the Zygophyllaceae, is in favour of including this genus in the latter family (see also the Zygophyllaceae).

*Ailanthus triphysa* is the most primitive species of the family containing only hydroxylated flavonols. The flavone-rich *Simarouba amara* is the most advanced plant, which has lost the primitive chemical characters such as flavonols and glycoflavones. The uniform occurrence of canthin and -carboline type of indole alkaloids and simaroubolides along with flavones, glycoflavones and flavonols indicate the subfamily Simarouboideae to be a natural closely knit group. These advanced chemical features as well as the hydrolysable tannins, reduced amounts of proanthocyanidins and cinnamic acids keeps the Simaroubaceae as one of the highly evolved families of the Sapindales. In addition to the above characters, this family also contains a highly degraded group of triterpenoids, the quassinoids. These advanced chemical characters can be correlated well with morphological advancement the family attained (predominance of unisexuality, winged seeds and the secondary apocarpous condition). The family would have probably originated from the Burseraceae which exhibit a number of primitive characters such as bisexual flowers, resin ducts, tannins and flavonols and possess the precursors of the quassinoids (Khalid, 1983). The Simarouboideae are closely related to the Meliaceae and Rutaceae in both morphological and most of the chemical characters, but are definitely advanced over them in certain chemical features.

#### CLADISTIC ANALYSIS

Fig. 8.1 depicts the cladogram showing the phylogeny and Fig 8.2 presents the dendrogram showing the groupings of the members of the subfamily Simarouboideae. The first dichotomy results in the formation of two unequal branches. The smaller branch contains only one taxon, *Balanites aegyptiaca* while the larger branch contains rest of the taxa. The second branch forks at the node HTU3 into two branches, one of them bearing *Quassia* and *Brucea* while the other gives out *Samadera* from HTU7 and then branches to *Ailanthus altissima*

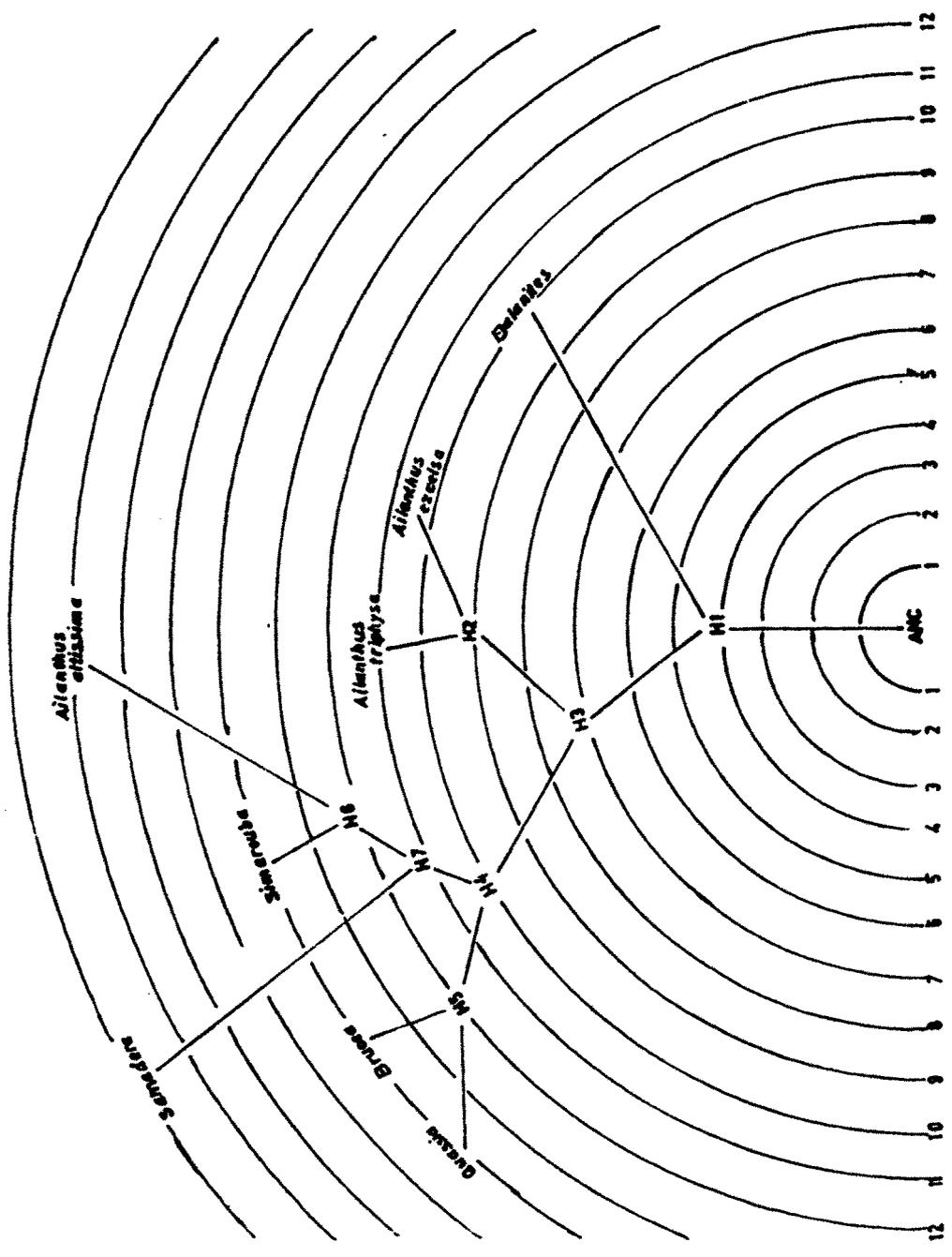


Fig. 8.1 Cladogram of the Simeroubaceae

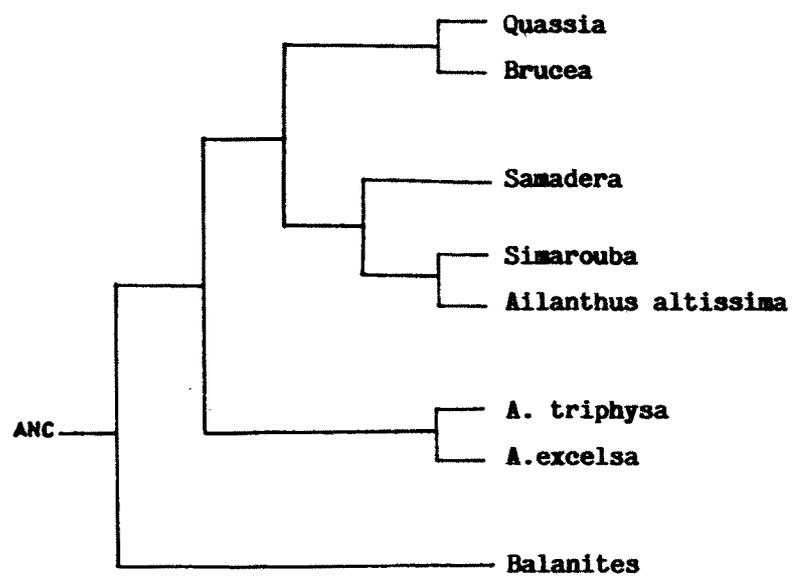


Fig. 8.2 Dendrogram of some members of the Simaroubaceae

and *Simarouba*. The lowest AD(I) value is 10 (*Balanites* and *A. altissima*) and the highest is 18 (*Samadera*).

Discussion :

From the cladogram it is clear that the genus *Balanites* deviates from the base of the family. The high values obtained during the calculation of the minimal distances indicate that the genus is very distant from the other members of the subfamily. All these features support the segregation of *Balanites* from the Simaroubaceae. But the genus has a clear affinity to *Samadera* of this family, evidenced by the low minimal value between them.

The present analysis proves that the subfamily Simarouboideae excluding *Balanites* is a natural taxon. *A. altissima* is distinct from the other two species and is closer to *Simarouba*. *Quassia* and *Brucea* occupying the same branch are closer to each other. The high AD(I) values ranging from 10 to 18, indicate that the family is an advanced taxon.