TRITERPENOIDS AND STEROIDS OF SRI LANKAN PLANTS : A REVIEW OF OCCURRENCE AND CHEMISTRY [†]

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Abstract : Studies on triterpenoids and steroids of Sri Lankan plants are reviewed with special reference to their occurrence, structure elucidation, biosynthetic and chemotaxonomic aspects. Triterpenoids have been classified into their structural types and under each type the work carried out is discussed. Occurrence of steroids and their derivatives in Sri Lankan plants are also presented.

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[†] Dedicated to Prof. M.U.S. Sultanbawa on the occasion of his 65th Birthday in appreciation to his contributions in the field of triterpenoids and steroids of Sri Lankan plants.

1. General Introduction

Triterpenoids and steroids are groups of natural products containing about thirty carbon atoms. They have a common origin and their structures can be considered as being derived from that of squalene by various cyclisations or other changes. Triterpenoids are mostly found in the plant kingdom, whereas steroids occur in plants (phytosterols), animals (zoosterols) and micro-organisms (mycosterols).

The triterpenoids present in the vegetable kingdom may be classified into two main groups, the tetracyclic triterpenoids and the pentacyclic triterpenoids. The tetracyclic triterpenoids, consisting of dammarane (5) and tirucallane (8) among others, are regarded by some authors as methylated steroids. The group of pentacyclic triterpenoids is by far the largest and is divided into six main groups, friedelane (1), lupane (2), ursane (3), oleanane (4), serratane (6) and Ψ -taraxastane (7) (Figure 1).

The chemistry and distribution of triterpenoids in the plant kingdom have been reviewed by Boiteau *et al.*,⁹ Kulshreshtha *et al.*,⁷⁷ Pant and Rastogi⁸⁷ and more recently by Das and Mahato.²¹ However, the scientific literature on triterpenoids occurring in Sri Lankan plants are found widely scattered. The purpose of this review is therefore to attempt to bring together the literature on triterpenoids and steroids of Sri Lankan plants. The information presented herein is limited only to the work on those plant species collected in Sri Lanka (with one exception, *Mesua myrtifolia* which has been collected from Malaysia) and/or investigated in Sri Lanka. This review covers published literature upto early 1985; some unpublished data incorporated have been obtained by writing to several active researchers in these fields, and covers upto mid 1985.

2. Survey for Triterpenoids and Steroids

Two systematic surveys of Sri Lankan plants for triterpenoids and steroids have been reported. In both surveys, the Liebermann–Burchard test was used to detect the presence of these classes of compounds.

In one of the surveys, a total of 142 Sri Lankan plant species have been screened^{97k} and the other survey included 100 medicinal plant materials purchased from local Ayurvedic shops.⁵⁴ The plants which showed a positive response towards Liebermann–Burchard test for triterpenoids and/or steroids along with the parts tested are listed in Table 1.

FRIEDELANE (1)

LUPANE (2)

URSANE (3)

OLEANANE (4)

Figure 1. Basic skeletons and numbering of some common types of triterpenoids.

DAMMARANE (5)

SERRATANE (6)

Ψ -TARAXASTANE (7)

TIRUCALLANE (8)

Figure 1 (contd.)

Table 1. Sri Lankan plants showing the presence of triterpenoids and/or steroids by Liebermann-Burchard test.

Plant species	Family	Part(s) ^a
<i>Acacia catechu</i>	Leguminosae	Re
<i>Aegle marmelos</i>	Rutaceae	Rt
<i>Alysicarpus vaginalis</i>	Leguminosae	Lf + Tw
<i>Anacyclus pyrethrum</i>	Compositae	Tw
<i>Ancistrocladus hamatus</i>	Ancistrocladaceae	Rt
<i>Anethum graveolens</i>	Umbelliferae	Sd
<i>Apurosa cardiosperma</i>	Euphorbiaceae	Wp
<i>Ardisia humilis</i>	Myrsinaceae	Rt
<i>Asteracantha longifolia</i>	Acanthaceae	Rt
<i>Azadirachta indica</i>	Meliaceae	Bk, Sd
<i>Bacopa monniera</i>	Scrophulariaceae	Wp
<i>Barleria mysorensis</i>	Acanthaceae	—
<i>Brachystelma srilankana</i>	Asclepiadaceae	Tu
<i>Bryonopsis laeciniola</i>	Cucurbitaceae	Ft
<i>Caesalpinia bonduc</i>	Leguminosae	Sd
<i>Canthium coromandelicum</i>	Rubiaceae	Ft
<i>Cardiospermum halicacabum</i>	Sapindaceae	Lf, Tw
<i>Cassia auriculata</i>	Leguminosae	Bk
<i>Cassia fistula</i>	"	Bk
<i>Cinnamomum zeylanicum</i>	Lauraceae	—
<i>Cissampelos pareira</i>	Menispermaceae	St
<i>Clausena indica</i>	Rutaceae	Bk, Sd
<i>Costus speciosus</i>	Zingiberaceae	Rh
<i>Cryptolepis buchanani</i>	Asclepiadaceae	Rt
<i>Curcumis melo</i>	Cucurbitaceae	Tw + Lf
<i>Dolichos biflorus</i>	Leguminosae	Sd
<i>Erythroxylum monogynum</i>	Erythroxylaceae	St
<i>Evolvulus alsinoides</i>	Convolvulaceae	Wp
<i>Fagaraea zeylanica</i>	Loganiaceae	Ft
<i>Ficus religiosa</i>	Moraceae	Sd
<i>Fleurysa interrupta</i>	Urticaceae	Lf, St
<i>Glochidion sp.</i>	Euphorbiaceae	Tm
<i>Glycosmis bilocularis</i>	Rutaceae	Rt
<i>Gmelina arborea</i>	Verbenaceae	Tm
<i>Gymnosporia fruticosa</i>	Celastraceae	Ft
<i>Hemidesmus indicus</i>	Asclepiadaceae	Bk
<i>Hibiscus panduriformis</i>	Malvaceae	Rt
<i>Horsfieldia iriyagbedbi</i>	Myristicaceae	Ft
<i>Hygrophila spinosa</i>	Acanthaceae	Wp

Table 1 contd.

Table 1 contd.

Plant species	Family	Part(s) ^a
<i>Lepisanthes tetraphylla</i>	Sapindaceae	Bk
<i>Madhuca longifolia</i>	Sapotaceae	—
<i>Martynia annua</i>	Martyniaceae	Ft
<i>Medinella maculata</i>	Melastomaceae	Tu
<i>Michelia champaca</i>	Magnoliaceae	Fl
<i>Mimusops elengi</i>	Sapotaceae	—
<i>Momordica denudata</i>	Cucurbitaceae	Ft
<i>Munronia pumila</i>	Meliaceae	Wp
<i>Nardostachys jatamansi</i>	Valerianaceae	Rt
<i>Nelumbo nucifera</i>	Nymphaeaceae	An
<i>Oroxylum indicum</i>	Bignoniaceae	—
<i>Paederia foetida</i>	Rubiaceae	Lf, Tw
<i>Panicum antidotale</i>	Gramineae	—
<i>Pavetta indica</i>	Rubiaceae	Rt
<i>Phaseolus latyroides</i>	Leguminosae	Rt
<i>Phyllanthus embelica</i>	Euphorbiaceae	Ft
<i>Phyllanthus sp.</i>	"	Ft
<i>Picorrhiza kurrooa</i>	Scrophulariaceae	Tw
<i>Piper chaba</i>	Piperaceae	—
<i>Piper cubeba</i>	"	Ft
<i>Piper longum</i>	"	Sd
<i>Piper nigrum</i>	"	Sd
<i>Pododendia thwaitesii</i>	Euphorbiaceae	Bk, Tm
<i>Pongamia pinnata</i>	Leguminosae	St
<i>Premna herbaceae</i>	Verbenaceae	Rt
<i>Pseudocarpa championii</i>	Meliaceae	Bk
<i>Pterocarpus santalinus</i>	Leguminosae	St
<i>Randia dumetorum</i>	Rubiaceae	Ft
<i>Rauvolfia serpentina</i>	Apocynaceae	Rt
<i>Rubia cordiflora</i>	Rubiaceae	Tw, St
<i>Salacia reticulata</i>	Celastraceae	—
<i>Samadera indica</i>	Simaroubaceae	Ft, Rt
<i>Sapindus emarginatus</i>	Sapindaceae	—
<i>Sapium indicum</i>	Euphorbiaceae	Ft
<i>Smilax prolifera</i>	Smilacaceae	Cr
<i>Solanum jacquini</i>	Solanaceae	St, Ft
<i>Solanum trilobatum</i>	"	St, Ft
<i>Stereospermum suaveolens</i>	Bignoniaceae	—
<i>Strychnos potatorum</i>	Loganiaceae	Sd

Table 1 contd.

Table 1 Contd.

Plant species	Family	Part(s) ^a
<i>Tephrosia purpurea</i>	Leguminosae	Rt
<i>Terminalia belerica</i>	Combretaceae	Ft
<i>Terminalia chebula</i>	"	Ft
<i>Tribulus terrestris</i>	Zygophyllaceae	Lf
<i>Trigonella foenumgraceum</i>	Leguminosae	Sd
<i>Vernonia anthelmintica</i>	Compositae	Sd
<i>Vetivera zizanioides</i>	Gramineae	Rt
<i>Wrightia angustifolia</i>	Apocynaceae	Rt
<i>Xanthium strimarium</i>	Compositae	Ft
<i>Xylopiia championii</i>	Annonaceae	Bk
<i>Zingiber officinale</i>	Zingiberaceae	Rh

^a An = anther; Bk = bark; Cr = creeper; Fl = flower; Ft = fruit; Lf = leaf; Re = resin; Rh = rhizome; Rt = root; Sd = seed; St = stem; Tm = timber; Tu = tuber; Tw = twig; Wp = whole plant.

3. Isolation of Triterpenoids

In nature, triterpenoids occur in the free state, as saponins or as esters. Except for a few esters and one ether derivative, most of the triterpenoids isolated from Sri Lankan plants belong to the free category. The extraction of dried plant material with a non-polar solvent followed by purification has been the method adopted to isolate these triterpenoids. Purification has been carried out by precipitation, column chromatography over silica gel and by preparative thin layer chromatography. In the case of acidic or phenolic triterpenoids, sodium carbonate or sodium hydroxide solubility have been utilized in their fractionation.

4. Triterpenoids of Friedelane Series

4.1 Introduction

The majority of triterpenoids encountered in Sri Lankan plants belong to this series. The parent hydrocarbon, friedelane (1), has not been found to occur in nature. In 1979, Chandler and Hooper reviewed the natural occurrence of friedelin (9) and associated triterpenoids¹⁴ and this included only a few friedelane triterpenoids isolated from Sri Lankan plants. However, this and Sultanbawa's review⁹⁵ which appeared in the same year covered in detail the chemistry of friedelane triterpenoids.

Table 2. Names and structures of friedelane triterpenoids in Sri Lankan plants.^a

Structure	Name ^b	Type and location of functional groups on (1) ^c								
		OH	C=O	CH ₂ OH	CHO	CO ₂ H	OMe	OAc	Nor	
(1)	FRIEDELANE									
(9)	Friedelin		3							
(10)	Friedelan-3 β -ol	3 β								
(11)	Friedelan-3 α -ol	3 α								
(12)	Friedelan-3 α -yl acetate							3 α		
(13)	Canophyllal		3		28					
(14)	Canophyllic acid	3				28				
(15)	Canophyllol		3	28						
(16)	3 β ,28-Dihydroxyfriedelane	3 β		28						
(17)	21 α ,30-Dihydroxyfriedelan-3-one	21 α	3	30						
(18)	25,28-Dihydroxyfriedelan-3-one ^d		3	25,28						
(19)	28,29-Dihydroxyfriedelan-3-one ^d		3	28,29						
(20)	Elaeodendrol	17 β	3						28	
(21)	Elaeodendradiol	17 β	3	25					28	
(22)	Friedelan-1,3-dione		1,3							
(23)	Friedelan-3,21-dione		3,21							
(24)	Friedelan-3-on-25-al		3		25					
(25)	Friedelan-3-on-30-al		3		30					
(26)	Friedelan-3-on-30-oic acid		3			30				
(27)	21 α -Hydroxyfriedelan-3-one	21 α	3							

Table 2 contd.

Table 2 contd.

Structure	Name ^b	Type and location of functional groups on (1) ^c							
		OH	C=O	CH ₂ OH	CHO	CO ₂ H	OMe	OAc	Nor
(28)	25-Hydroxyfriedelan-3-one		3	25					
(29)	29-Hydroxyfriedelan-3-one		3	29					
(30)	30-Hydroxyfriedelan-3-one		3	30					
(31)	30-Hydroxyfriedelan-1,3-dione ^d		1,3	30					
(32)	25-Hydroxyfriedelan-3-on-28-al ^d		3	25	28				
(33)	2α-Hydroxyfriedelan-3-on-28-oic acid ^d	2α	3			28			
(34)	29-Hydroxyfriedelan-3-on-28-oic acid ^d		3	29		28			
(35)	3α-Hydroxyfriedelan-2-on-28-oic acid ^d	3α	2			28			
(36)	Kokoanol ^d		3	27					
(37)	Kokoanol ^d			27					
(38)	Kokoandiol ^d		3,21	27					
(39)	Kokzeylanol ^d	21α	3	27					
(40)	Kokzeylanonol ^d	6β	3	27					
(41)	3α-Methoxyfriedelane ^d	6β	3,21	27					3α
(42)	Octandronal ^{d,e}		3		29				
(43)	Octandronol ^{d,e}		3	29					
(44)	Octandronic acid ^{d,e}		3						29
(45)	Octandrolal ^{d,e}				29				
(46)	Octandrolol ^{d,e}	3α							
(47)	Octandrolol ^{d,e}	3α		29					
(48)	Octandrolol ^{d,e}	3α							29
(49)	Trichadonic acid ^d		3						26
(49)	Trichadenic acid A ^d	3α							26

Table 2 contd.

Table 2 contd.

Structure	Name ^b	Type and location of functional groups on (1) ^c							
		OH	C=O	CH ₂ OH	CHO	CO ₂ H	OMe	OAc	Nor
(50)	Trichiadenal ^d	3β			26				
(51)	O-Acetyltrichadenal ^d				26			3β	
(52)	Acetyltrichadenic acid A ^d					26		3α	
(53)	Acetyltrichadenic acid B ^d					26		3β	
(54)	Zeylanol ^d	6β	3						
(55)	Zeylanonol ^d	6β	3,21						
(56)	Zeylandiol ^d	6β,21α	3						

^a

See Table 8 for occurrence and references.

^b

Names given are those of the literature.

^c

See Figure 1 for basic skeleton and numbering system.

^d

New report.

^eThese structures are in doubt.⁶

Friedelane triterpenoids isolated from Sri Lankan plants are listed in Table 2. Out of the 48 described, 28 are new compounds. Table 8 summarises the natural occurrence of these in Sri Lankan plants. Of the 112 plants investigated, 24 were found to contain at least one triterpenoid belonging to this type. Friedelanes are common in plants of families Celastraceae, Guttiferae and Flacourtiaceae.

4.2 Structure Elucidation

4.2.1 Spectroscopic Methods

Both ^1H and ^{13}C Nuclear Magnetic Resonance (NMR) spectroscopic methods have been widely employed in the structure elucidation of friedelanes. Of significance is the use of ^1H NMR to detect the number of methyl groups and the presence of hydroxymethylene function(s) on tertiary carbon atoms. Lanthanide induce shift (LIS) of the methyl proton resonances in 1-oxo-, 3-oxo-, 6-oxo-, 7-oxo-, 21-oxo-, and 22-oxo- friedelanes have been measured and used in assignment.¹⁰⁰ Further, the LIS data have indicated that both D and E rings in friedelanones are in the boat-boat conformation.

^{13}C NMR spectroscopic data have been recorded for friedelin (9), friedelan-6-one, friedelan-21-one, friedelane-3,6-dione, friedelane-3,21-dione, friedelane-3,6,21-trione,⁵⁵ 27-hydroxyfriedelane, kokoonol (36), kokoononol (37),⁵⁸ friedelan-7-one, putranjivadione, friedelan-22-one, friedelan-3,22-dione and *Salacia* triterpene R.⁶² Off-resonance decoupling and LIS techniques have been used in the assignment of signals. ^{13}C NMR data have provided further evidence for the boat-boat conformation of the D and E rings of friedelanes in solution.⁶²

Infra-red (IR) spectroscopic studies⁵³ of a number of mono-ketofriedelanes have indicated that their carbonyl frequencies are location specific and that in di- and tri-keto series when the carbonyl groups are far apart, their individual frequencies correspond to those in the mono-ketones within $\pm 5\text{ cm}^{-1}$.

Known fragmentation pathways in the mass spectra (MS) of friedelanes²⁸ have been used to elucidate structures of several triterpenes belonging to this series.^{10,11} MS has proved especially useful in the location of oxygen functions.⁴⁴ Detailed MS fragmentation of kokoonol (36), kokoononol (37) and kokoondiol (38) have been published.⁶¹

The structure (47) proposed for octandrolic acid was based mainly on MS fragmentation.^{44,46} However, it has been suggested recently that the structure of octandrolic acid should be revised and it may be identical with canophyllic acid (14).⁶ MS fragmentation should therefore be used for structural studies of triterpenoids with caution.

4.2.2 Molecular Rotation and Circular Dichroism

Molecular rotation differences (ΔM_D) for monosubstituted friedelanes with reference to friedelane (1) and for disubstituted compounds with reference to friedelin (9), friedelan-3 β -ol (10) and friedelan-3 α -ol (11) and their acetates have been tabulated and interpreted.⁴⁶ In monosubstituted friedelanes an oxo- or α -acetoxy group at C-3, CHO at C-9 or CO₂H at C-14 was found to give a negative ΔM_D whereas in disubstituted ones C-14 or C-20 CO₂H gave a positive ΔM_D .

Circular dichroism (CD) data for friedelan-1-one, friedelin, friedelan-6-one, friedelan-7-one, friedelan-21-one and friedelan-22-one have been obtained and the observed Cotton effects have been interpreted in terms of Octant Rule.¹⁰¹ The use of CD data to locate carbonyl function in friedelanones has also been discussed.

4.2.3 Chemical Interconversions

In many instances the spectroscopic methods have been successfully combined with chemical interconversions to solve structural problems of friedelanes. Conventional deoxygenations employing Wolff-Kishner reduction of ketones⁷⁵ and lithium aluminium hydride reduction of tosylates derived from alcohols³⁶ have recently been replaced by triphenyltin hydride reduction of thiobenzoates^{51,61} and lithium-ethylene diamine reduction of acetates,^{56,64} both derived from alcohols. The efficiency of these methods have been demonstrated by successful removal of two oxygen functions in one reaction as exemplified by the conversion of zeylandiol (56) to friedelin (9) by the former method; kokzeylanol (39) and kokzeylanonol (40) respectively, to friedelin and friedelane-3,21-dione (23) by the latter procedure. The method employing lithium-ethylene diamine reduction of the derived acetates first applied to *Kokoona* triterpenes,⁶⁴ has now being widely applied in chemical interconversions.⁸⁹

A photochemical irradiation method has been applied to locate the 21-oxo- function in friedelane-3,21-dione (23), 21 α -hydroxyfriedelan-3-one (27),⁵⁷ and kokoononol (37),⁵² all occurring in *Kokoona zeylanica*. Further, the method proved useful in locating the hydroxymethylene group in kokoononol.⁶¹

4.3 Biological Activity

Friedelin has been found to exhibit 'anti-feedant' activity upon some insects.¹ The employment of friedelanes has been considered for treatment of cancer of the bladder,⁹² convulsions, inflammation,¹⁵ topical ulcers, rheumatic inflammations, fever and dysentery.⁹⁴

4.4 Chemotaxonomic Aspects

The natural occurrence of friedelin and 3-friedelanols is extensive. Out of the Sri Lankan plants investigated friedelanones have been commonly encountered in plant families, Celastraceae, Guttiferae and Flacourtiaceae. It is interesting to note that in most of these plants friedelanones co-occur with lupanes and oleananes except in *Kokoona zeylanica* (Celastraceae) from which no lupanes and oleananes have been isolated so far. Chemotaxonomic significance of the restricted occurrence of friedelan-3,21-dione (23) and 21 α -hydroxyfriedelan-3-one (27) in *K. zeylanica*, *Siphonodon australe* and *Salacia reticulata* has been discussed.⁵⁷

4.5 Biosynthetic Aspects

Friedelan-3-ols can be considered as the most primitive friedelane triterpenoids in plants. Oxidation of these at various positions in the triterpene skeleton followed by other reactions would produce all the other known friedelanones. Friedelanones are implicated as biosynthetic precursors for quinone-methide and phenolic triterpenoids (see 5.6).

5. Quinone-methide and Phenolic Triterpenoids of Friedelane Series

5.1 Introduction

Quinone-methide and phenolic triterpenoids are treated together in view of their probable common biosynthetic origin. These compounds are peculiar to plants of the family Celastraceae and may be considered as oxidation products of friedelanones. Seven quinone-methides and six phenolic triterpenoids have been encountered in Sri Lankan plants [see Table 3, (141) and (142)], all belonging to Celastraceae. It is interesting to note that phenolic triterpenoids have thus far been reported only from *Kokoona zeylanica* which also contains a number of friedelanones. However, recent studies³¹ carried out in this laboratory had shown the presence of phenolic triterpenoids, zeylasteral (66) and zeylasterone (67) in *Celastrus paniculatus* (Celastraceae) along with quinone-methides, celastrol (57) and pristimerin (64).

5.2 Structure Elucidation

Spectroscopic techniques have played an important role in the structural studies of quinone-methides and phenolic triterpenoids. Quinone-methides have been characterized by their UV and ¹H NMR spectra and by comparison with authentic samples. The structure [(143); Figure 2], that has been proposed for a quinone-methide from *Elaeodendron balae*^{104,105} needs further clarification in view of recent criticism³³ of related structures.⁸⁵

Table 3. Names and structures of quinone-methide and phenolic triterpenoids in Sri Lankan plants.^a

Structure	Name ^b	Type and location of functional groups on (1) ^c							
		C=C	OH	C=O	CHO	CO ₂ H	CO ₂ Me	Nor	
(1)	FRIEDELANE								
(57)	Celastrol	1(10),3,5,7	3	2		29		24	
(58)	Desmethylzeylasteral ^d	1,3,5(10),7	2,3	6	23	29		24	
(59)	Desmethylzeylasterone ^d	1,3,5(10),7	2,3	6		23,29		24	
(60)	20 α -Hydroxytingenone	1(10),3,5,7	3,20 α	2,21				24,29	
(61)	22-Hydroxytingenone	1(10),3,5,7	3,22	2,21				24,29	
(62)	Iguesterin	1(10),3,5,7,20(21)	3	2				24	
(63)	23-Nor-6-oxo-desmethylpristimerol ^d	1,3,5(10),7	2,3	6		29		23,24	
(64)	Pristimerin	1(10),3,5,7	3	2			29	24	
(65)	Tingenone	1(10),3,5,7	3	2,21				24,29	
(66)	Zeylasteral ^d	1,3,5(10),7	2,3	6	23		29	24	
(67)	Zeylasterone ^d	1,3,5(10),7	2,3	6		23	29	24	

a-d: Footnotes same as for Table 2.

(130)[†]; Myrtifolic acid

(131) $R^1 = O$, $R^2 = Me$; Glutinone

(132) $R^1 = \beta-OH$, $\alpha-H$, $R^2 = Me$; Glutanol

(133)[†] $R^1 = \beta-OH$, $\alpha-H$, $R^2 = CH_2OH$

(134) $R^1 = \beta-OH$, $\alpha-H$, $R^2 = Me$; Taraxerol

(135) $R^1 = O$, $R^2 = Me$; Taraxerone

(136) $R^1 = \beta-OH$, $\alpha-H$, $R^2 = CO_2H$; Aleuritolic acid

(137) $R^1 = \beta-OAc$, $\alpha-H$, $R^2 = CO_2H$; Acetoxyaleuritolic acid

(138)[†] $R^1 = O$, $R^2 = CO_2H$; Aleuritonolic acid

[†] New Reports

Figure 2. Some triterpenoids with rearranged structures.

(139) R = β -OH, α -H; β - Simiarenol

(140) R = O; Simiarenone

(141); Isoarborinol

(142)[†]; 23-Oxoisopristerin III (143)[†]

† New reports

Figure 2 (contd.)

The structure of zeylasterone (67), the first natural phenolic triterpenoid, has been elucidated with the aid of spectroscopic data and partial synthesis of trimethylzeylasterone starting from pristimerin (64).^{37,41} Several other new phenolic triterpenes isolated have been related to zeylasterone and trimethylzeylasterone.³⁸ The structure proposed for 23-oxoisopristimerin III (142) has been based essentially on spectroscopic data and comparison of these with synthetic analogues.⁴⁰

5.3 Biological Activity

Claims of medicinal properties of plants belonging to Celastraceae had led to biological evaluation of some compounds encountered in these plants. The antibacterial activity of celastrol (57), a quinone-methide employed in human medicine in India for this purpose, has been demonstrated.⁷

Celastrol and its methyl ester, pristimerin (64), have been tested for antitumour activity in the cheekpouch test of the golden hamster and were found to be active.⁹¹ Recent studies had demonstrated the powerful cytostatic activity of iguesterin (62), tingenone (65), pristimerin, and their diacetyl-dihydro derivatives. These studies had led to the conclusion that diacetyl-dihydro derivatives are in general more active than the parent quinone-methides. It is noteworthy that tingenone (65) is used clinically in Brazil for the treatment of skin cancer.⁸⁴

Bioassay of pristimerin and tingenone with corn and lentil seeds has shown that both quinone-methides exhibited strong inhibitory activity towards the germination of lentil seeds.²⁹

The phenolic triterpene, zeylasterone (67) although showed *in vitro* antimicrobial activity,⁶⁶ was found to have no antifertility activity in the female rat.⁶⁷

5.4 Chemotaxonomic Aspects

It is of chemotaxonomic significance that quinone-methides and phenolic triterpenoids have so far been isolated only from plants of family Celastraceae and that phenolic triterpenoids occur only in *Kokoona zeylanica* and *Celastrus paniculatus*.³⁰ It is noteworthy that a recent study³¹ has indicated the absence of zeylasterone (67) in outer bark extractives of *Elaeodendron balae*, *Gymnosporia emarginata* and *Pleurostyliia opposita*, all belonging to Celastraceae and containing the quinone-methide, pristimerin (64).

5.5 Biosynthetic Aspects

Although no experimental proof has thus far been provided for the biogenetic origin of quinone-methide and phenolic triterpenoids, their co-occurrence with friedelanones in several plants of Celastraceae has prompted postulation of four biosynthetic pathways implicating zeylanol (54) and polypunic acid as precursors. Recent isolation of salaspunic acid⁹⁹ and orthopunic acid³⁵ from plants of Celastraceae further supports our proposed pathway.⁶⁵ Natural occurrence of 23-oxoisoprimerin III (142)⁴⁰ is significant as its analogue, isoprimerin III, could be the possible biosynthetic precursor of recently encountered novel quinone-methides, primerinene, hydroxyprimerinene,⁸⁵ and (143).^{104,105} A biosynthetic pathway to these compounds starting from primerin (64) *via* isoprimerin III has been postulated.⁶⁵

6. Triterpenoids of Lupane Series

6.1 Introduction

The parent hydrocarbon, lupane (2) has not been found to occur in nature. However, oxygenated lupanes are common. Lupane triterpenoids isolated from Sri Lankan plants are listed in Table 4. Out of the 25 described, 13 are new natural products. Table 8 gives the occurrence of these in Sri Lankan plants. Of the 112 plants investigated, 65 were found to contain at least one triterpenoid belonging to this class, betulinic acid (70) and lupeol (68) having wide distribution and occurring in 45 and 37 plants, respectively. Papers have appeared dealing with the distribution of betulinic acid in the plant kingdom,⁸⁸ distribution of lupeol (68), betulin (69) and betulinic acid (70) in endemic *Dipterocarpus* species of Sri Lanka,⁶⁸ and the occurrence of lupanes in plants of Celastraceae.¹⁹

6.2 Structure Elucidation

Structures of lupanes have been elucidated with the help of spectroscopic data and chemical interconversions. The deshielding of C-24 - C-26 tertiary methyl resonances in the ¹H NMR spectra have been used to infer the presence of 6 β -OH in lupanes isolated from *Pleurostylia opposita*.¹⁷ The ¹³C NMR spectral assignments of a series of lupanes obtained from *P. opposita*¹⁸ and some Sri Lankan *Glochidion* species¹³ have been reported. Chemical interconversions, especially lithium-ethylene diamine deoxygenation of acetates have also been employed in structural studies of lupane derivatives.

The structure, lup-20(29)-ene-1 α ,3 α ,23-triol(91), proposed for the first natural trihydroxy triterpene belonging to the lup-20(29)-ene series

Table 4. Names and structures of lupane triterpenoids in Sri Lankan plants.^a

Structure	Name ^b	Type and location of functional groups in (2) ^c							
		C=C	OH	C=O	CH ₂ OH	CHO	CO ₂ H	OAc	C-O-C
(2)	LUPANE								
(68)	Lupeol	20(29)	3β						
(69)	Betulin	20(29)	3β		28				
(70)	Betulinic acid	20(29)	3β				28		
(71)	Betulonic acid	20(29)		3			28		
(72)	Acetylbetulinic acid	20(29)	6β,20	3			28	3β	
(73)	6β,20-Dihydroxylupan-3-one ^d								
(74)	6β,28-Dihydroxylup-20(29)-en-3-one ^d	20(29)	6β	3	28				
(75)	2α,3α-Dihydroxylup-20(29)-en-28-oic acid ^d		2α,3α				28		
(76)	3β,6β-Dihydroxylup-20(29)-ene ^d	20(29)	3β,6β						
(77)	Glochidone	20(29)		3					
(78)	Glochidonol	20(29)	1β	3					
(79)	Glochidiol	20(29)	1β,3α						
(80)	20-Hydroxylupan-3-one		20	3					
(81)	20-Hydroxylupan-3,6-dione		20	3,6					
(82)	6β-Hydroxylup-20(29)-en-3-one ^d	20(29)	6β	3					
(83)	30-Hydroxylup-20(29)-en-3-one ^d	20(29)		3	30				

Table 4 contd.

Table 4 contd.

Structure	Name ^b	Type and location of functional groups in (2) ^c							
		C=C	OH	C=O	CH ₂ OH	CHO	CO ₂ H	OAc	C-O-C
(84)	30-Hydroxylup-20(29)-ene-3,21-dione ^d	20(29)		3	30				
(85)	3 β -Hydroxylup-20(29)-en-30-al ^d	20(29)	3 β			30			
(86)	3 β -Hydroxylup-20,29-dihydro-20,29-epoxy-3,21-dione ^d		3 β	3,21					20,29
(87)	Lup-20(29)-ene-3 β ,28-diol	20(29)	3 β		28				
(88)	Lup-20(29)-ene-3 α ,23-diol	20(29)	3 α		23				
(89)	Lup-20(29)-ene-3,21-dione	20(29)		3,21					
(90)	Lup-20(29)-en-3-on-30-al ^d	20(29)		3		30			
(91)	Lup-20(29)-ene-1 α ,3 α ,23-triol ^d	20(29)	1 α ,3 α		23				
(92)	Lupa-5,20(29)-dien-3-one ^d	5,20(29)		3					
(93)	Lup-20,29-dihydro-20,29-epoxy-3,21-dione ^d			3,21					20,29

^{a-d}Footnotes same as for Table 2.

isolated from an unidentified *Glochidion* species has been based on incomplete data due to lack of material.¹² Further work is therefore, warranted to confirm its structure.

6.3 Chemotaxonomic Aspects

Although lupeol (68), betulin (69) and betulinic acid (70) are of wide distribution, complex lupanes have been found to occur mainly in Celastraceae and Euphorbiaceae. Triterpenoid constituents of several Celastraceae have been reported. It is interesting that lupanes co-occur with friedelanes and oleananes in *Pleurostyliia* and *Salacia* species; in *Gymnosporia emarginata* they co-occur with oleananes. Lupanes have not been reported from *Elaeodendron balae*, *Elaeodendron glaucum* and *Kokoona zeylanica* all belonging to Celastraceae. It has been incorrectly noted that friedelane and lupane derivatives do not co-exist in the stem bark.¹⁹ Some Sri Lankan plants in which they co-exist in the stem-bark are, *Bridelia moonii* (Euphorbiaceae),¹² *Calophyllum tomentosum*,⁷⁴ *C. zeylanicum*^{97a} (Guttiferaceae), *Erythrospermum zeylanicum*^{97a} (Flacourtiaceae), *Euonymus revolutus*,^{78,79} *Salacia reticulata*^{83,108} (Celastraceae) and *Madhucia nerifolia* (Sapotaceae).^{97c}

Occurrence of glochidone (77) outside the genus *Glochidion* has been reported for the first time in a Sri Lankan plant, viz. *Bridelia moonii*.¹² It is noteworthy that both these genera belong to the family Euphorbiaceae.

7. Triterpenoids of Ursane Series

Fifteen ursane triterpenoids have been encountered in Sri Lankan plants (Table 5). Of these only 3 are new. Forty-two of the 112 Sri Lankan plants investigated contained at least one triterpene belonging to this class; ursolic acid (104) being the commonest occurring in 36 plants, especially those plants belonging to Dipterocarpaceae. Rare ursanes have been isolated from plants of Burseraceae and Rubiaceae. Ursanes co-exist mainly with lupanes and oleananes.

The structures of known ursanes have been established by comparison with authentic samples or by comparison of physical and spectral properties with published data, whereas the structures of new ursanes have been determined by extensive spectral analysis. The three new ursane carboxylic acids, uncaric acid (99), diacetyluncaric acid (100) and diketouncaric acid (101) occurring in *Uncaria elliptica* (Rubiaceae) have been chemically interrelated.^{70a}

Table 5. Names and structures of ursane triterpenoids in Sri Lankan plants^a

Structure	Name	Type and location of functional groups on (3) ^c				
		C=C	OH	C=O	CO ₂ H	OAc
(3)	URSANE					
(94)	Asiatic acid	12(13)	2 α , 3 β , 23 α		28	
(95)	2 α , 3 β -Dihydroxyurs-12-en-28-oic acid	12(13)	2 α , 3 β		28	
(96)	2 α -Hydroxyursolic acid		2 α		28	
(97)	Quinovaic acid	12(13)	3 β		27, 28	
(98)	Acetylquinovaic acid	12(13)			27, 28	3 β
(99)	Uncaric acid ^d		3, 6, 18		30	
(100)	Diacetyluncaric acid ^d		18		30	3, 6
(101)	Diketouncaric acid ^d		18	3, 6	30	
(102)	Neolexonol	12(13)	3 β	11		
(103)	Urs-12-en-3, 11-dione	12(13)		3, 11		
(104)	Ursolic acid	12(13)			28	
(105)	Acetylursolic acid	12(13)			28	3 β
(106)	Ursonic acid	12(13)	3		28	
(107)	α -Amyrin	12(13)	3 β			
(108)	α -Amyrenone	12(13)		3		

^{a-d} Footnotes same as for Table 2.

Table 6. Names and structures of oleanane triterpenoids in Sri Lankan plants.^a

Structure	Name	Type and location of functional groups in (4) ^c									
		C=C	OH	C=O	CH ₂ OH	CHO	CO ₂ H	OAc	O-decanoate	O-trans cinnamate	
(4)	OLEANANE										
(109)	β-Amyrin	12(13)	3β								
(110)	β-Amyrenone	12(13)		3							
(111)	β-Amyrin acetate	12(13)									
(112)	β-Amyrin decanoate	12(13)					3β				
(113)	β-Amyrin <i>trans</i> -cinnamate	12(13)						3β			
(114)	δ-Amyrenone	13(18)		3						3	
(115)	Dihydroxyolean-12-en-28-oic acid	12(13)	unknown				28				
(116)	3β-Hydroxyolean-12-en-11-one	12(13)	3	11							
(117)	Olean-12-en-3, 11-dione	12(13)		3, 11							
(118)	Olean-12-en-3β, 11α-diol (11α-hydroxy-β-amyrin)						28				
(119)	Oleanolic acid	12(13)	3β								
(120)	O-acetyloleanolic aldehyde	12(13)			28			3β			
(121)	Protobrassic acid		2α, 3β, 6β		24		28				

^{a-d} Footnotes same as for Table 2.

8. Triterpenoids of Oleanane Series

Oleanane triterpenoids occurring in Sri Lankan plants are listed in Table 6. Out of the 13 described, excluding esters of β -amyrin, none are new records. The location of the hydroxy groups in a dihydroxyolean-12-en-28-oic acid (115) present in *Doona congestiflora* (Dipterocarpaceae) has not been determined.³ Amongst Sri Lankan plants studied oleananes are predominantly found in Dipterocarpaceae. Oleananes co-exist chiefly with lupanes and ursanes and seldom with friedelanes.

9. Triterpenoids of Dammarane, Serratane, Ψ -Taraxastane and Tirucallane Series

The triterpenoids belonging to these four classes encountered in Sri Lankan plants are listed in Table 7. Five dammaranes isolated were all from *Dipterocarpus* species. Phlegmanol (127) is the only serratane encountered and occurs in *Lycopodium phlegmaria* (Lycopodiaceae).⁷³ Ψ -Taraxasterol (128) has been isolated only from the resin of *Doona congestiflora* (Dipterocarpaceae)^{97b} and tirucallol (129) was present only in *Garcinia thwaitesii* (Guttiferae).⁶⁰ The structures of these triterpenes have been elucidated by direct comparison with authentic samples and/or by comparison of physical data of isolated compounds with those reported.

10. Triterpenoids with Rearranged Structures

Triterpenoids of rearranged structures isolated from Sri Lankan plants are depicted in Figure 2 and their occurrence listed in Table 8. Of the 14, four are new reports. Myrtifolic acid (130)[†], whose structure has been determined by spectral data and correlation with baurene, was found to co-exist with lupanes, oleananes, taraxerol (134), β -simiarenol (139) and simiarenone (140) in *Mesua myrtifolia* (Guttiferae) collected in Malaysia.^{45,97a} Structure elucidation of myrtifolic acid was aided by MS fragmentation and optical rotatory dispersion (ORD) curve.⁴⁵ The structure of a new D:B-friedelane (133) isolated from *Elaeodendron balae* (Celastraceae) has been determined with the help of spectral data.^{104,105}

Taraxerol (134) and/or taraxerone (135) have been isolated mainly from *Calophyllum*, *Kayea* and *Mesua* species, all belonging to Guttiferae and several *Disopyros* (Ebenaceae) species. The structures of aleuritolic acid (136), its acetate (137) and aleuritonolic acid (138) have been established by comparison of their physical data with those reported.¹² ¹³C NMR assignments of acetoxyaleuritolic acid and aleuritonolic acid have been made by comparison with methyl oleanolate and betulonic acid (71).¹³ Structure of β -simiarenol (139) isolated from some Guttiferae has been established by

† See end of Reference Section.

Table 7. Names and structures of dammarane, serratane, Ψ -taraxastane and tirucallane triterpenoids of Sri Lankan plants.^a

Structure	Name ^b	Type and location of functional groups in the respective skeleton ^c				
		C=C	OH	C=O	C-O-C	dihydrocaffeic acid ester
(5)	DAMMARANE					
(122)	Dammarenediol 20S	24(25)	3 β , 20 β			
(123)	Dammarenediol 20R	24(25)	3 β , 20 α			
(124)	Dipterocarpol	24(25)	20 β	3		
(125)	Ocotillone 20S		25	3	20 β -24	
(126)	Ocotillone 20R		25	3	20 α -24	
(6)	SERRATANE					
(127)	Phlegmanol ^d	14(15)	21 α			3 β
(7)	Ψ -TARAXASTANE					
(128)	γ -Taraxasterol	20(21)	3 β			
(8)	TIRUCALLANE					
(129)	Tirucalol	8(9), 24(25)	3 β			

^{a-d} Footnotes same as for Table 2.

Table 8. Occurrence of triterpenoids in Sri Lankan Plants

Plant (Family)	Part ^a	Triterpenoid(s) present		Reference(s)
		Basic skeleton ^b	Structure(s) ^c	
<i>Acrotrema uniflorum</i> (Dilleniaceae)	Wp	<u>2</u>	(70)	88
<i>Apurosa cardiosperma</i> ^d (Euphorbiaceae)	Bk	<u>1</u>	(9), (10)	12
<i>Argyreia populifolia</i> ^d (Convolvulaceae)	Ft	<u>1</u>	(9), (10)	50
<i>Bridelia moonii</i> ^d (Euphorbiaceae)	Bk	<u>1</u>	(9), (10), (11)	12
		<u>2</u>	(77)	
<i>Calophyllum calaba</i> ^d (Guttiferae)	Lf	<u>1</u>	(9), (10), (13), (14), (15), (16)	63
<i>Calophyllum cordato-oblongum</i> ^d	Bk	<u>1</u>	(9)	97a
<i>Calophyllum cuneifolium</i> ^d	Bk	<u>1</u>	(9)	97a
		R	(134), (139)	
<i>Calophyllum soulattri</i>	Bk	R	(134), (135)	97a
<i>Calophyllum inophyllum</i>	Tm	<u>1</u>	(9), (10)	97a
		<u>4</u>	(109)	
<i>Calophyllum thwaitesii</i> ^d	Bk	<u>1</u>	(9)	16
		R	(134)	
<i>Calophyllum tomentosum</i>	Bk	<u>1</u>	(9), (10)	74, 97a
		<u>2</u>	(70)	
		R	(134), (135)	
	Tm	<u>1</u>	(9), (10)	
		R	(134)	
<i>Calophyllum trapezifolium</i>	Bk	R	(134), (139)	93

Table 8. (Contd.)

Plant (Family)	Part ^a	Triterpenoid(s) present		Reference(s)
		Basic skeleton ^b	Structure(s) ^c	
<i>Calophyllum walkeri</i> ^d	Bk	R	(134),(139)	16
<i>Calophyllum zeylanicum</i>	Bk	<u>1</u>	(10)	97a
		<u>2</u>	(70)	
		R	(134)	
<i>Camellia sinensis</i> (Theaceae)	Wp	<u>1</u>	(9) ^e , (11) ^e	106
		<u>4</u>	(109) ^e , (119) ^e	
<i>Canarium zeylanicum</i> ^d (Burseraceae)	Bk	<u>3</u>	(102),(103),(107)	4
		<u>4</u>	(109),(116),(117)	
		R	(134)	
	Tm	<u>3</u>	(107)	
		<u>4</u>	(109)	
	Re	<u>3</u>	(102),(103),(107),(108)	
		<u>4</u>	(109),(110),(116),(117)	
<i>Canthium dicoccum</i> ^d (Rubiaceae)	Bk	<u>3</u>	(97),(98)	71
<i>Capparis moonii</i> (Capparidaceae)	Lf	<u>2</u>	(68),(69),(70)	27
<i>Casaeria thwaitesii</i> (Flacourtiaceae)	Bk,Tm	<u>4</u>	(109)	97c
<i>Celastrus paniculatus</i> (Celastraceae)	RtBk(outer)	<u>1</u>	(57),(64),(66),(67)	31
<i>Citrus medica</i> (Rutaceae)	Lf	<u>2</u>	(68)	27.72b
<i>Citrus megaloxycarpa</i>	Lf	<u>2</u>	(68)	27
<i>Cotylelobium scabriusculum</i> ^d (Dipterocarpaceae)	Bk	<u>2</u>	(70)	68
		<u>3</u>	(104),(105)	
		<u>4</u>	(109),(111)	

Table 8. (Contd.)

Plant (Family)	Part ^a	Triterpenoid(s) present		Reference(s)
		Basic skeleton ^b	Structure(s) ^c	
<i>Dillenia indica</i> (Dilleniaceae)	Bk,Tm,Pc	<u>2</u>	(70)	88
<i>Dillenia retusa</i> ^d	Bk,Tm,Pc	<u>2</u>	(70)	88
<i>Diospyros acuta</i> ^d (Ebenaceae)	Bk,Tm	<u>2</u> R	(68) (135)	70b,97d
<i>Diospyros birsuta</i> ^d	Bk	<u>2</u>	(68),(69),(70)	70b,97d
	Ft	<u>2</u> R	(69),(70) (134)	
	Lf	<u>2</u> <u>3</u>	(68) (104)	
		<u>2</u>	(68)	
	Rt	<u>2</u>	(68)	
	Tm	<u>2</u> R	(69),(70) (134)	
		<u>2</u>	(68)	
<i>Diospyros moonii</i> ^d	Bk	<u>2</u> <u>4</u> R	(68) (119) (135)	70b, 97d
		<u>2</u>	(68)	
		R	(135)	
	Rt	<u>2</u> R	(68) (135)	
		<u>2</u>	(68)	
	Tm	<u>2</u>	(68),(69),(70)	
		<u>2</u>	(68)	
<i>Diospyros oblongifolia</i>	Bk	<u>2</u> R	(68) (135)	70b, 97d
		<u>2</u>	(68),(69)	
	Ft	<u>2</u> <u>4</u>	(68),(69) (119)	
		<u>2</u>	(68)	
<i>Diospyros oppositifolia</i> ^d	Bk,Tm	<u>2</u> R	(68) (135)	70b, 97d
		<u>2</u>	(68)	

Table 8. (Contd.)

Plant (Family)	Part ^a	Triterpenoid(s) present		Reference(s)
		Basic skeleton ^b	Structure(s) ^c	
<i>Diospyros quaesita</i> ^d	Bk	<u>2</u>	(68), (69), (70)	70b, 97d
		R	(135)	
	Tm	<u>2</u>	(68), (69), (70)	
<i>Diospyros rheophytica</i>	Bk, Tm	<u>2</u>	(68)	70b, 97d
		R	(135)	
<i>Diospyros spinscens</i>	Bk, Tm	<u>2</u>	(68), (69), (70)	70b, 97d
<i>Diospyros thwaitesii</i> ^d	Bk, Rt	<u>2</u>	(68)	70b, 97d
		R	(135)	
	Tm	<u>2</u>	(68), (69), (70)	
		R	(135)	
<i>Diospyros walkeri</i> ^d	Bk	<u>2</u>	(68), (69)	70b, 97d
	Tm	<u>2</u>	(68), (69), (70)	
<i>Dipterocarpus glandulosus</i> ^d (Dipterocarpaceae)	Re	<u>3</u>	(94), (96)	8, 24, 68
		<u>5</u>	(123), (124), (125)	
	Tm	<u>2</u>	(69) ^e , (70) ^e	
		<u>3</u>	(94) ^e , (104) ^e	
<i>Dipterocarpus hispidus</i> ^d	Bk	<u>2</u>	[(68), (109), (124)] ^f	3, 68, 97b
		<u>5</u>	(70)	
	Re	<u>3</u>	(94) ^e , (95) ^e	
		<u>5</u>	(124) ^e , (125) ^e , (126) ^e	
		<u>2</u>	(69) ^e , (70) ^e	
	Tm	<u>3</u>	(94), (104) ^e	
		<u>4</u>	(111) ^e	
		<u>5</u>	(124)	
			[(68), (109), (124)] ^f	
<i>Dipterocarpus insignis</i> ^d	Tm	<u>2</u>	(69) ^e , (70) ^e	68
		<u>3</u>	(104) ^e	
		<u>4</u>	(111) ^e	
			[(68), (109), (124)] ^f	

Table 8. (Contd.)

Plant (Family)	Part ^a	Triterpenoid(s) present		Reference(s)
		Basic skeleton ^b	Structure(s) ^c	
<i>Dipterocarpus zeylanicus</i> ^d	Re	<u>3</u>	(94),(95) ^e , (96)	3,23,68, 97b
		<u>5</u>	(123),(124), (125)	
	Tm	<u>2</u>	(69) ^e , (70) ^e	
		<u>3</u>	(94) ^e , (104) ^e [(68),(109),(124)] ^f	
<i>Doona affinis</i> ^d [= <i>Shorea affinis</i>] (Dipterocarpaceae)	Tm	<u>2</u>	(70)	68,97b
		<u>3</u>	(94),(104)	
		<u>4</u>	(109),(111)	
<i>Doona congestiflora</i> ^d [= <i>Shorea congestiflora</i>]	Tm	<u>2</u>	(70) ^e	3,68,97b
		<u>3</u>	(104) ^e	
		<u>4</u>	(111) ^e [(68),(109),(124)] ^f	
	Re	<u>3</u>	(94),(104)	
		<u>4</u>	(109),(115)	
		<u>5</u>	(122),(123),(124)	
		<u>7</u>	(128)	
<i>Doona cordifolia</i> ^d [= <i>Shorea cordifolia</i>]	Tm	<u>2</u>	(70)	97b
		<u>3</u>	(104)	
		<u>4</u>	(109),(111)	
<i>Doona macrophylla</i> ^d [= <i>Shorea magistophylla</i>]	Bk	<u>3</u>	(94),(104)	3,68,97b
		<u>4</u>	(109),(111)	
		<u>5</u>	(124)	
	Re	<u>3</u>	(94),(95),(96),(104)	
		<u>5</u>	(122),(124)	
<i>Doona oblonga</i> ^d [= <i>Doona disticha</i> = <i>Shorea disticha</i>]	Re	<u>3</u>	(104)	97b
		<u>4</u>	(109)	
		<u>5</u>	(122),(124)	
		<u>7</u>	(128)	

Table 8. (Contd.)

Plant (Family)	Part ^a	Triterpenoid(s) present		Reference(s)
		Basic skeleton ^b	Structure(s) ^c	
<i>Doona venulosa</i> ^d	Bk	<u>3</u>	(104)	97b
[= <i>Shorea worthingtonii</i>]		<u>4</u>	(109)	
		<u>5</u>	(124)	
	Tm	<u>3</u>	(104)	97b
		<u>4</u>	(109),(111)	
<i>Doona zeylanica</i> ^d	Re	<u>4</u>	(109)	68,97b
[= <i>Shorea zeylanica</i>]		<u>5</u>	(122),(124)	
		<u>7</u>	(128)	
	Tm	<u>2</u>	(70) ^e	[(68),(109),(124)] ^f
		<u>3</u>	(104) ^e	
		<u>4</u>	(111) ^e	
<i>Elaeodendron balae</i> ^{d,*}	Bk	<u>1</u>	(9),(13),(15),(19),(29)	102,104, 105
(Celastraceae)	RtBk	<u>1</u>	(61),(64),(65)	
		<u>4</u>	(118)	
	R		(133),(143)	
	Lf	<u>1</u>	(15)	103,104, 105
<i>Elaeodendron glaucum</i>	Bk	<u>1</u>	(9),(10),(13),(15),(18), (20),(24),(28),(29),(32)	
<i>Elephantopus scaber</i> (Compositae)	Wp	<u>2</u>	(68)	26a, 26b
<i>Erythrospermum zeylanicum</i> ^d	Bk	<u>1</u>	(9)	97c
(Flacourtiaceae)		<u>2</u>	(70)	
		<u>3</u>	(104)	
<i>Euonymus revolutus</i>	Bk	<u>1</u>	(33),(34),(35)	78,79
(Celastraceae)		<u>2</u>	(75)	
<i>Garcinia spicata</i> (Guttiferae)	Lf	<u>1</u>	(9),(10)	63

* Revised name : *Cassinae balae*

Table 8. (Contd.)

Plant (Family)	Part ^a	Triterpenoid(s) present		Reference(s)
		Basic skeleton ^b	Structure(s) ^c	
<i>Garcinia thwaitesii</i>	Bk & Tm	<u>4</u>	(109)	60
		<u>8</u>	(129)	
<i>Glochidion moonii</i> ^d (Euphorbiaceae)	Bk & Tm	<u>2</u>	(78),(79),(88)	12
<i>Glochidion</i> sp.	Bk	<u>2</u>	(77),(78),(79),(88), (91)	12,97h
	Tm	<u>2</u>	(79),(88)	
<i>Gymnosporia emarginata</i> ^d (Celastraceae)	Bk	<u>1</u>	(64)	107,108
		<u>2</u>	(83),(85)	
		<u>4</u>	(109),(110),(117)	
	Lf.Tm	<u>4</u>	(109)	
	Rt.Bk	<u>1</u>	(62),(64),(65)	
		<u>4</u>	(109)	
	Rt.	<u>1</u>	(62),(64),(65)	
		<u>4</u>	(109)	
<i>Hopea brevipetiolaris</i> (Dipterocarpaceae)	Tm	<u>2</u>	(69) ^e , (70) ^e	68
		<u>3</u>	(104) ^e	
		<u>4</u>	(111) ^e	
			[(68),(109),(124)] ^f	
<i>Hopea cordifolia</i> ^d	Bk & Tm	<u>2</u>	(68),(70)	68,97b
		<u>3</u>	(104)	
		<u>4</u>	(109)	
		<u>5</u>	(124)	
<i>Hopea jucunda</i> var. <i>modesta</i> ^d	Tm	<u>2</u>	(68),(69),(70) ^e	68
		<u>3</u>	(104)	
		<u>4</u>	(109),(111) ^e	
			[(68),(109),(124)] ^f	
<i>Humboldtia laurifolia</i> ^d (Leguminosae)	Bk,Tm	<u>2</u>	(68)	90
		<u>4</u>	(120)	
	Lf	<u>1</u>	(41)	

Table 8. (Contd.)

Plant (Family)	Part ^a	Triterpenoid(s) present		Reference(s)
		Basic skeleton ^b	Structure(s) ^c	
<i>Hydnocarpus octandra</i> ^d (Flacourtiaceae)	Bk	<u>1</u>	(9),(10),(11),(12),(42), (43),(44),(45),(46),(47), (48),(49)	44,46,97c
		<u>3</u>	(104)	
	Pc	<u>1</u>	(9)	
	Tm	<u>1</u>	(9)	
<i>Hydnocarpus venenata</i> ^d	Bk	<u>2</u>	(70), (72)	97c
		<u>3</u>	(104),(105)	
<i>Kayea stylosa</i> ^d (Guttiferae)	Bk	<u>2</u>	(70)	97a
		R	(134),(139)	
<i>Knoxia zeylanica</i> (Rubiaceae)		<u>3</u>	(104)	22
<i>Kokoona zeylanica</i> (Celastraceae)	Bk(inner)	<u>1</u>	(9),(23),(27),(36),(37), (38),(39),(40),(54), (55),(56)	37,38,40, 41,42,51, 52,56,57, 61,64
		<u>1</u>	(57),(58),(59),(64), (66),(67)	
		R	(142)	
<i>Lycopodium phlegmaria</i> (Lycopodiaceae)	Wp	<u>6</u>	(127)	73
<i>Madhuca fulva</i> ^d (Sapotaceae)	Bk	<u>4</u>	(110),(111),(112)	97e
	Tm	<u>4</u>	(110),(111),(113)	
<i>Madhuca longifolia</i>	Sd(coat)	<u>4</u>	(121)	76
<i>Madhuca microphylla</i> ^d	Bk	<u>2</u>	(70)	97c
		<u>4</u>	(109),(110),(111)	
	Tm	<u>4</u>	(109)	
		<u>4</u>	(109),(111),(113)	
<i>Madhuca moonii</i> ^d	Bk,Tm	<u>4</u>	(109),(111),(113)	97e
<i>Madhuca nerifolia</i> ^d	Bk	<u>1</u>	(9)	97e
		<u>2</u>	(70)	
		<u>4</u>	(111),(112)	
		R	(141)	

Table 8. (Contd.)

Plant (Family)	Part ^a	Triterpenoid(s) present		Reference(s)
		Basic skeleton ^b	Structure(s) ^c	
<i>Madhuca neriifolia</i> ^d	Tm	<u>1</u>	(9)	97e
		<u>4</u>	(110),(111),(112)	
<i>Mammea acuminata</i> (Guttiferae)	Bk	R	(131),(132)	5
<i>Mesua myrtifolia</i> [†] (Guttiferae)	Bk	<u>2</u> R	(70) (130),(134),(139)(140)	45
	Tm	<u>4</u> R	(119) (130)	
<i>Palaquium canaliculatum</i> ^d (Sapotaceae)	Bk	<u>3</u> <u>4</u>	(104) (110),(111),(112)	97e
	Tm	<u>3</u> <u>4</u>	(104) (109),(111)	
<i>Palaquium grande</i> ^d	Bk	<u>2</u> <u>3</u> <u>4</u>	(70) (104) (109),(110),(111),(112)	97e
	Tm	<u>4</u>	(109),(111)	
<i>Palaquium laevifolium</i> ^d	Bk	<u>4</u>	(109),(110),(111),(113)	97e
	Tm	<u>4</u>	(109),(111)	
<i>Palaquium petiolare</i>	Bk,Tm	<u>4</u>	(109),(110),(111),(113)	97e
<i>Palaquium rubiginosum</i> ^d	Bk	<u>4</u>	(109),(110),(111)	97e
	Tm	<u>4</u>	(109),(110)	
<i>Pentadesma butyracea</i> (Guttiferae)	Bk	<u>4</u>	(109),(111)	
	Tm	<u>4</u>	(109)	
<i>Pleurostylia opposita</i> (Celstraceae)	Bk	<u>2</u>	(73),(74),(76),(80),(82) (92)	17,18,19
	Lf	<u>1</u> <u>2</u> <u>4</u>	(9),(10) (73),(74),(76),(81) (107)	

[†] Obtained from Malaysia

Table 8. (Contd.)

Plant (Family)	Part ^a	Triterpenoid(s) present		Reference(s)
		Basic skeleton ^b	Structure(s) ^c	
<i>Podadenia thwaitesii</i> ^d (Euphorbiaceae)	Bk	R	(136),(137),(138)	12
<i>Salacia reticulata</i> <i>var. β-diandra</i> (Celastraceae)	StBk (outer)	<u>1</u>	(9),(13),(15),(17),(22) (23),(25),(26),(27),(30), (31),(64)	83,107, (108),
		<u>2</u>	(68),(70),(84),(86),(87), (89),(93)	
		<u>4</u>	(109)	
<i>Scolopia schreberi</i> ^d (Flacourtiaceae)	Bk	<u>1</u>	(9),(11)	97c
		<u>4</u>	(109)	
	Tm	<u>1</u>	(9)	
		<u>4</u>	(109)	
<i>Shorea dyeri</i> ^d (Dipterocarpaceae)	Tm	<u>2</u>	(70)	68,69
		<u>3</u>	(104)	
		<u>4</u>	(111)	
		<u>5</u>	(124)	
<i>Shorea lysophylla</i>	Tm	<u>4</u>	(111)	68,69
<i>Shorea oblongifolia</i>	Tm	<u>2</u>	(70) ^e	68,69
		<u>3</u>	(104) ^e	
		<u>4</u>	(111) ^e	
			[(68),(109),(124)] ^f	
<i>Shorea ovalifolia</i>	Tm	<u>2</u>	(70) ^e	68,69
		<u>3</u>	(104) ^e	
		<u>4</u>	(111) ^e	
			[(68),(109),(124)] ^f	
<i>Shorea stipularis</i> ^d	Bk	<u>4</u>	(109) ^e	68,69
		<u>5</u>	(124) ^e	

Table 8. (Contd.)

Plant (Family)	Part ^a	Triterpenoid(s) present		Reference(s)
		Basic skeleton ^b	Structure(s) ^c	
<i>Shorea trapezifolia</i>	Tm	<u>2</u>	(70) ^e	68,69
		<u>3</u>	(104) ^e	
		<u>4</u>	(111) ^e	
			[(68),(109),(124)] ^f	
<i>Solanum verbasifolium</i> (Solanaceae)	Lf	<u>2</u>	(68),(70)	27
<i>Stemonoporus affinis</i> ^d (Dipterocarpaceae)	Bk,Tm	<u>3</u>	(104),(106),(107)	97b
		<u>4</u>	(114)	
<i>Stemonoporus canaliculatus</i> ^d	Tm	<u>2</u>	(70) ^e	68,97b
		<u>3</u>	(104) ^e	
		<u>4</u>	(111) ^e	
			[(68),(109),(124)] ^f	
<i>Stemonoporus cordifolius</i> ^d	Bk	<u>3</u>	(96),(104),(106),(107)	68,97b
		<u>4</u>	(114)	
	Tm	<u>2</u>	(70) ^e	
		<u>3</u>	(104) ^e , (106),(107)	
		<u>4</u>	(111) ^e , (114)	
			[(68), (109), (124)] ^f	
<i>Stemonoporus elegans</i> ^d	Bk	<u>3</u>	(104),(106),(107)	97b
		<u>4</u>	(114),(119)	
	Tm	<u>3</u>	(104),(106),(107)	
		<u>4</u>	(114)	
<i>Stemonoporus lancifolius</i>	Bk	<u>3</u>	(104),(106),(107)	68,97b
		<u>4</u>	(114)	
	Tm	<u>2</u>	(70) ^e	
		<u>3</u>	(104) ^e , (106),(107)	
		<u>4</u>	(111) ^e , (114) ^e	
			[(68),(109)(124)] ^f	

Table 8. (Contd.)

Plant (Family)	Part ^a	Triterpenoid(s) present		Reference(s)
		Basic skeleton ^b	Structure(s) ^c	
<i>Stemonoporus oblongifolius</i>	Bk	<u>2</u>	(70) ^e	68,97b
		<u>3</u>	(94) ^e , (104) ^e , (105), (107)	
		<u>4</u>	(114)	
			[(68), (109), (124)] ^f	
<i>Stemonoporus petiolaris</i> ^d	Bk	<u>2</u>	(70) ^e	68,97b
		<u>3</u>	(104) ^e , (106), (107)	
		<u>4</u>	(114)	
			[(68), (109), (124)] ^f	
	Tm	<u>3</u>	(104), (106), (107)	
		<u>4</u>	(114)	
<i>Stemonoporus reticulatus</i> ^d	Tm	<u>2</u>	(70) ^e	68,97b
		<u>3</u>	(104) ^e	
			[(68), (109), (124)] ^f	
<i>Stereospermum personatum</i> (Bignoniaceae)	Bk	<u>4</u>	(109)	27
<i>Symplocos racemosa</i> (Symplocaceae)		<u>2</u>	(70)	25
		<u>4</u>	(120)	
<i>Trichadenia zeylanica</i> (Flacourtiaceae)	Bk	<u>1</u>	(48), (49), (51), (52), (53)	43,47
<i>Tricalycia erythrospora</i> ^d (Rubiaceae)		<u>2</u>	(68)	27
		<u>3</u>	(104)	
<i>Triphasia trifoliata</i> (Rutaceae)	Lf	<u>2</u>	(68), (70)	72b
<i>Uncaria elliptica</i> ^{d†} (Rubiaceae)	Wd	<u>3</u>	(99), (100), (101)	70a, 72a
<i>Vatica affinis</i> (Dipterocarpaceae)	Tm	<u>2</u>	(70)	68
		<u>3</u>	(105)	
		<u>4</u>	(109), (111)	
<i>Vatica obscura</i>	Bk, Tm	<u>4</u>	(109), (111)	97b

† Incorrectly called *Uncaria thwaitesii*^{70a}

Table 8. (Contd.)

Plant ^a (Family)	Part ^a	Triterpenoid(s) present		Reference(s)
		Basic skeleton ^b	Structure(s) ^c	
<i>Vateria copallifera</i> ^d (Dipterocarpaceae)	Bk	<u>4</u> <u>5</u>	(109),(111) (124)	68,97b
<i>Vernonia cineria</i> (Compositae)	Wp	<u>2</u>	(68)	27
<i>Vernonia zeylanica</i> ^d	Wp	<u>2</u>	(68)	27
<i>Wendlandia bicuspidata</i> (Rubiaceae)		<u>3</u>	(104)	27
<i>Wormia burbidgei</i> (Dilleniaceae)	Bk	<u>2</u>	(70)	88
<i>Wormia triquetra</i> ^d	Bk,Tm,Ft Fl(centre)	<u>2</u>	(70)	88

^aBk=bark; Ft=fruit, Lf=leaf; Pc=pericarp of fruit; Re=resin; Rt=root; Sd=seed; Tm=timber; Wp=whole plant.

^bSee Figs. 1 and 2.

^cSee Tables 1 to 6; U=unidentified.

^dSpecies endemic to Sri Lanka².

^eDetected by TLC; not isolated.

^fOne or more present (by TLC); not isolated.

comparison of its MS fragmentation with that of glutinone (131).⁹⁶ Amongst the Sri Lankan plants investigated, isoarborinol (141) has been encountered only in *Madhuca neriifolia* (Sapotaceae).^{97c} Structure elucidation and the biogenetic significance of the phenolic triterpene, 23-oxoisopristerin III (142) have been dealt with earlier along with a comment on the structure of (143) (Sections 5.2 and 5.5).

11. Steroids

11.1 Sitosterol and its Esters

Sitosterol (144) is the commonest secondary plant metabolite known. Consequently it has been isolated from 75 species and detected (by TLC) in 14 species out of a total of 111 Sri Lankan plants investigated. In most instances identification has been done by Co-TLC, Co-IR and mixed m.p. determinations.

Some esters of sitosterol have also been encountered in Sri Lankan plants, especially in those belonging to the family Dipterocarpaceae. *Humboldtia laurifolia* (Leguminosae)⁹⁰ and *Shorea dyeri* (Dipterocarpaceae)⁶⁸ contained unidentified sitosteryl esters. Sitosteryl palmitate (145) has been isolated from *Doona macrophylla* and *Shorea stipularis* whereas sitosteryl-*ortho*-methoxybenzoate (146) was found to be present in several *Stemonoporus* species, all belonging to Dipterocarpaceae (see Table 9). Occurrence of these sitosteryl esters in Dipterocarpaceae may be of some chemotaxonomic significance.

11.2 Stigmasterol

Out of the 111 Sri Lankan plants investigated, stigmasterol [22(23)-dehydrositosterol (147)] has been found to occur only in 3 species, viz. *Elephantopus scaber*, *Vernonia cinaria* and *V. zeylanica*, all belonging to the family Compositae.

11.3 α -Spinasterol and its Glycosides

α -Spinasterol (148), a double bond isomer of stigmasterol (147), has been found to occur as the free alcohol or as its β -D-glucoside (149). α -Spinasterol has been isolated from *Camellia sinensis* (Theaceae), the tea plant, and several *Madhuca* and *Palaquium* species of the family Sapotaceae, whereas, its β -D-glucoside is present in *C. sinensis* and *M. neriifolia*. Occurrence of this sterol in 6 plant species of Sapotaceae may be of chemotaxonomic significance.

Table 9. Occurrence of sterols and their derivatives in Sri Lankan plants.

Plant species	Family	Part ^a	Sterol(s) present	Reference(s)
<i>Agrostistachys bookeri</i> ^b	Euphorbiaceae	Bk	(144)	97h
<i>Apurosa cardiosperma</i> ^b	"	Bk	(144)	12
<i>Argyreia populifolia</i> ^b	Convolvulaceae	Ft	(144)	50
<i>Aristea ecklonii</i>	Iridaceae	Rh, Lf	(144)	83
<i>Bridelia moonii</i> ^b	Euphorbiaceae	Bk	(144)	12
<i>Calophyllum cordato-oblongum</i> ^b	Guttiferae	Bk	(144)	97a
<i>Calophyllum cuneifolium</i> ^b	"	Bk,Tm	(144)	97a
<i>Calophyllum soulattri</i>	"	Bk,Tm	(144)	97a
<i>Calophyllum inophyllum</i>	"	Tm	(144)	97a
<i>Calophyllum thwaitesii</i> ^b	"	Tm	(144)	16
<i>Calophyllum tomentosum</i>	"	Bk,Tm	(144)	74,97a
<i>Calophyllum trapezifolium</i>	"	Bk	(144)	93
<i>Calophyllum walkeri</i> ^b	"	Tm	(144)	16
<i>Camellia sinensis</i>	Theaceae	Wp	(148),(149)	106
<i>Campnosperma zeylanica</i> ^b	Anacardiaceae	Tm	(144)	97g
<i>Canarium zeylanicum</i> ^b	Burseraceae	Bk,Re,Tm	(144)	4
<i>Canthium dicoccum</i> ^b	Rubiaceae	Bk	(144)	71
<i>Capparis moonii</i>	Capparidaceae	Lf	(144)	27
<i>Casearia thwaitesii</i> ^b	Flacourtiaceae	Bk,Tm	(144)	97c
<i>Celastrus paniculatus</i>	Celastraceae	Rt(Bk)	(144)	31
<i>Chlorocarpa pentaschista</i> ^b	Flacourtiaceae	Bk	(144)	97c
<i>Citrus hystrix</i>	Rutaceae	Lf	(144)	72b
<i>Citrus medica</i>	"	Lf	(144)	72b
<i>Citrus megaloxycarpa</i>	"	Lf	(144)	27
<i>Diospyros acuta</i> ^b	Ebenaceae	Bk,Tm	(144)	70b
<i>Diospyros hirsuta</i> ^b	"	Ft,Lf,Rt,Tm	(144)	70b
<i>Diospyros moonii</i> ^b	"	Bk,Rt,Tm	(144)	70b

Table 9. (Contd.)

Plant species	Family	Part ^a	Sterol(s) present	Reference(s)
<i>Diospyros oblongifolia</i>	Ebenaceae	Bk, Ft	(144)	70b
<i>Diospyros oppositifolia</i> ^b	"	Bk	(144)	70b
<i>Diospyros quaesita</i> ^b	"	Bk, Tm	(144)	70b
<i>Diospyros rheophytica</i>	"	Bk, Tm	(144)	70b
<i>Diospyros spinescens</i>	"	Bk, Tm	(144)	70b
<i>Diospyros thwaitesii</i> ^b	"	Bk, Rt, Tm	(144)	70b
<i>Diospyros walkeri</i> ^b	"	Bk	(144)	70b
<i>Dipterocarpus glandulosus</i> ^b	Depterocarpaceae	Tm	(144) ^c	68
<i>Dipterocarpus hispidus</i> ^b	"	Tm	(144) ^c	68
<i>Dipterocarpus insignis</i> ^b	"	Tm	(144) ^c	68
<i>Dipterocarpus zeylanicus</i> ^b	"	Tm	(144) ^c	68
<i>Doona affinis</i> ^b	"	Tm	(144)	68, 97b
<i>Doona congestiflora</i> ^b	"	Tm	(144) ^c	3, 68, 97b
<i>Doona cordifolia</i> ^b	"	Tm	(144)	97b
<i>Doona macrophylla</i> ^b	"	Bk	(144), (145)	3, 68, 97b
<i>Doona venulosa</i> ^b	"	Bk, Tm	(144)	97b
<i>Doona zeylanica</i> ^b	"	Tm	(144) ^c	68, 97b
<i>Elaeodendron balae</i> ^{b, †}	Celastraceae	Lf	(144)	102
<i>Elephantopus scaber</i>	Compositae	Wp	(147)	26b
<i>Erythrospermum zeylanicum</i> ^b	Flacourtiaceae	Bk, Tm	(144)	97c
<i>Garcinia hermonii</i>	Guttiferae	Tm	(144)	97a
<i>Garcinia spicata</i>	"	Lf	(144)	63
<i>Garcinia thwaitesii</i>	"	Bk, Tm	(144)	60
<i>Glochidion moonii</i> ^b	Euphorbiaceae	Bk, Tm	(144)	12
<i>Glochidion</i> sp	"	Tm	(144)	97h
<i>Gymnosporia emarginata</i> ^b	Celastraceae	Bk, Lf, Rt, Tm	(144)	107
<i>Hopea brevipetiolaris</i>	Dipterocarpaceae	Tm	(144) ^c	68

† Revised name : *Cassiniae balae*

Table 9. (Contd.)

Plant species	Family	Part ^a	Sterol(s) present	Reference(s)
<i>Hopea cordifolia</i> ^b	Dipterocarpaceae	Bk,Tm	(144)	68
<i>Hopea jucunda</i> var. <i>modesta</i>	"	Tm	(144)	68
<i>Horsfieldia iryagbedhi</i> ^b	Myristicaceae	Sd	(144)	59
<i>Humboldtia laurifolia</i>	Leguminosae	Bk,Tm	(144)	90
<i>Hydnocarpus octandra</i> ^b	Flacourtiaceae	Bk,Fr,Tm	(144)	97c
<i>Hydnocarpus venenata</i> ^b	"	Bk,Tm	(144)	97c
<i>Kayea stylosa</i> ^b	Guttiferae	Bk,Tm	(144)	97a
<i>Madhuca fulva</i> ^b	Sapotaceae	Bk,Tm	(148)	97e
<i>Madhuca neriifolia</i> ^b	"	Tm	(148),(149)	97e
<i>Mammea acuminata</i>	Guttiferae	Tm	(144)	5
<i>Palaquium canaliculatum</i> ^b	Sapotaceae	Bk,Tm	(148)	97e
<i>Palaquium grande</i> ^b	"	Bk,Tm	(148)	97e
<i>Palaquium laevifolium</i> ^b	"	Tm	(148)	97e
<i>Palaquium petiolare</i>	"	Tm	(148)	97e
<i>Pentadesma butyracea</i>	Guttiferae	Bk,Tm	(144)	97a
<i>Pleurostyhia opposita</i>	Celastraceae	Bk,Lf	(144)	18
<i>Plumbago zeylanica</i>	Plumbaginaceae	Rt	(144)	39
<i>Podadenia thwaitesii</i> ^b	Euphorbiaceae	Bk	(144)	13
<i>Salacia reticulata</i>	Celastraceae	Bk	(144)	83,108
<i>Scolopia schreberi</i> ^b	Flacourtiaceae	Bk,Tm	(144)	97c
<i>Semecarpus gardneri</i> ^b	Anacardiaceae	Tm	(144)	97g
<i>Semecarpus obscura</i> ^b	"	Bk,Tm	(144)	97g
<i>Semecarpus walkeri</i> ^b	"	Tm	(144)	97g
<i>Shorea dyeri</i> ^b	Dipterocarpaceae	Tm	(144),U ^d	68,69
<i>Shorea lysophylla</i>	"	Tm	(144)	68,69
<i>Shorea oblongifolia</i> ^b	"	Tm	(144) ^c	68,69
<i>Shorea ovalifolia</i> ^b	"	Tm	(144) ^c	68,69
<i>Shorea stipularis</i> ^b	"	Tm	(144) ^c ,(145)	68,69

Table 9. (Contd.)

Plant species	Family	Part ^a	Sterol(s) present	Reference(s)
<i>Shorea trapezifolia</i> ^b	Dipterocarpaceae	Tm	(144) ^c	68,69
<i>Solanum verbasifolium</i>	Solanaceae	Lf	(144)	27
<i>Stemonoporus affinis</i> ^b	Dipterocarpaceae	Bk,Tm	(144),(146)	68,97b
<i>Stemonoporus canaliculatus</i> ^b	"	Tm	(144) ^c	68,69
<i>Stemonoporus cordifolius</i> ^b	"	Bk,Tm	(144),(146)	68,69
<i>Stemonoporus elegans</i> ^b	"	Bk,Tm	(144),(146)	69,97b
<i>Stemonoporus lancifolius</i>	"	Bk,Tm	(144),(146)	68,69
<i>Stemonoporus oblongifolius</i> ^b	"	Bk	(144) ^c , (146)	68,69
<i>Stemonoporus petiolaris</i> ^b	"	Bk	(144) ^c	68
		Tm	(144),(146)	68
<i>Stemonoporus reticulatus</i> ^b	"	Tm	(144) ^c	68
<i>Stereospermum personatum</i>	Bignoniaceae	Bk	(144)	27
<i>Tricalycia erythrospora</i> ^b	Rubiaceae		(144)	27
<i>Triphasia trifoliata</i>	Rutaceae	Lf	(144)	72b
<i>Vateria copallifera</i> ^b	Dipterocarpaceae	Bk	(144)	68
<i>Vatica affinis</i>	"	Tm	(144)	68
<i>Vatica obscura</i>	"	Bk,Tm	(144)	97b
<i>Vernonia cinerea</i>	Compositae	Wp	(147)	27
<i>Vernonia zeylanica</i> ^b	"	Wp	(147)	27

^aBk=bark; Ft=fruit; Lf=leaf; Re=resin; Rh=rhizome; Rt=root; Sd=seed; Tm=timber; Wp=whole plant.

^bSpecies endemic to Sri Lanka².

^cDetected by TLC; not isolated.

(144) R = H; Sitosterol

(145) R = $C_{15}H_{32}CO$; Sitosteryl palmitate

(146) R = O-MeO C_6H_4CO ; Sitosteryl ortho-methoxybenzoate

(147); Stigmasterol

(148) R = H; α -Spinasterol

(149) R = glucose; α -Spinasterol- β -D- glucoside

Figure 3. Structures of some sterols and their derivatives in Sri Lanka plants.

Table 10. Summary of triterpenoids occurring in Sri Lankan plants

Plant Family ^a (No. of species investigated)	No. of Triterpenoids Encountered ^b					
	Total	Friedelanes	Quinone-methide & Phenolic	Lupanes	Ursanes	Oleananes Other types
Celastraceae (07)	67(34)	33(15)	10(05)	18(11)	—	03(—) 03 ^d (03)
Dilleniaceae (05)	01(—)	—	—	01(—)	—	—
Dipterocarpaceae (32)	21(—)	—	—	03(—)	07(—)	05 ^e (—), 01 ^f (—)
Ebenaceae (10)	07(—)	—	—	03(—)	01(—)	02 ^d (—)
Euphorbiaceae (05)	11(02)	03(—)	—	05(01)	—	03 ^d (01)
Flacourtiaceae (06)	21(12)	16(12)	—	02(—)	02(—)	—
Guttiferae (16)	16(01)	06(—)	—	01(—)	—	06 ^d (01)
Rubiaceae (05)	07(03)	—	—	01(—)	06(03)	—
Sapotaceae (10)	11(—)	01(—)	—	01(—)	01(—)	01 ^d (—)
Others (15) ^c	19(02)	04(01)	—	03(—)	04(—)	06(—) 02(01)

^a Only those where more than 5 species are investigated are listed^b No. of new triterpenoids are given in parenthesis^c These include following families; Bignoniaceae, Burseraceae, Cappariaceae, Compositae, Convolvulaceae, Leguminosae, Lycopodiaceae, Rutaceae, Solanaceae, Symplocaceae and Theaceae^d With rearranged structures^e Dammaranes^f Taraxasteranes

12. Summary and Conclusions

Table 10 summarises the plant families of Sri Lanka from which various types of triterpenoids have been reported. Details such as the number of plant species of each family that have been investigated along with the total number of triterpenoids isolated, their distribution into various structural types and the number of new triterpenoids encountered are also given in Table 10.

A total of 112 plant species including 64 endemic plants belonging to 20 families have been subjected to detailed investigations and a total of 143 triterpenoids have been isolated. Triterpenoids are abundant in plants of the families Celastraceae and Flacourtiaceae. It is noteworthy that about 50% of the triterpenoids encountered in these two families are new. Of significance is that phenolic triterpenoids have thus far been found to occur only in Sri Lankan Celastraceae.

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Note added in proof : A recent report has suggested that the structure (130) proposed for myrtifolic acid needs revision [MEKSURIYEN, D., NANAYAKKARA, N.P.D., PHOEBE JR., C.H. & CORDELL, G.A. (1986), *Phytochemistry*, 25 : 1685].