Eudesmane sesquiterpenoids from the Asteraceae family†

Quan-Xiang Wu,[a] Yan-Ping Shi*[a,b] and Zhong-Jian Jia[a]

Received (in Cambridge, UK) 30th April 2006
First published as an Advance Article on the web 7th August 2006
DOI: 10.1039/b606168k

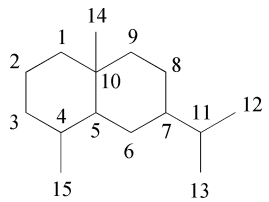
Covering: 1983 to 2005

This review covers the structures and biological activities of eudesmane-type sesquiterpenoids from the plants of the Asteraceae family. Biosynthetic studies or chemical syntheses leading to the revision of structures or stereochemistries have also been included, and 593 references are cited.

1 Introduction

The large family Asteraceae (= Compositae) contains 25 000–30 000 species belonging to over 1000 genera. Many species have been used as sources of rubber, medicines, edible oils, vegetables, pesticides and so on. Some are popular ornamental plants. The genera *Aster*, *Inula*, *Xanthium*, *Eupatorium*, *Carpesium*, *Saussurea* and *Taraxacum* are sources of various medicines; the whole plants of *Taraxacum kok-saghyz* and *Parthenium hysterophorus* are a source of rubber, and the seeds of *Helianthus annuus*, *Guizotia abyssinica* and *Xanthium sibiricum* are sources of edible oils. The extract from the leaves of *Blumea balsamifera* are used for the manufacture of borneol, and *Oxalis corymbosa* is used as a source of pyrethrum pesticides.[1] This family is a rich source of sesquiterpenoid natural products, especially those with the eudesmane framework.

The eudesmanoids are biosynthesised from farnesyl pyrophosphate,[2] and approximately 1000 natural eudesmanoids have been identified from the Asteraceae family, with many different oxygenation and cleavage patterns. The configuration and numbering of eudesmane (**1**, 2-isopropyl-4a,8-dimethyldecahydronaphthalene) is shown below.



1

During the last two decades, eudesmane-type sesquiterpenoids and their biological activities from Asteraceae species have been the focus of numerous phytochemical, pharmacological and synthetic studies. Because the sesquiterpenoids exhibit a wide range of biological activities, and include compounds that are plant growth regulators, insect antifeedants, antifungals, anti-tumour compounds and antibacterials, there has been much interest in relating structure and oxygenation patterns to function.

This article reviews the structures and biological activities of novel eudesmane-type sesquiterpenoids from Asteraceae species. Studies involving biosynthesis and chemical synthesis and leading to a deeper chemical and biological understanding of these metabolites are discussed. The review highlights 972 compounds, and includes those with re-assigned structures or newly established stereochemistry where appropriate.

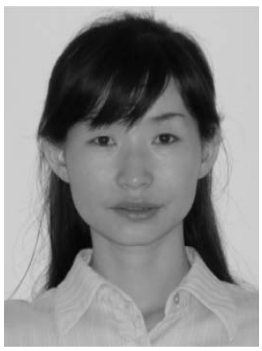
[a]*State Key Laboratory of Applied Organic Chemistry, Lanzhou University, Lanzhou, 730000, China*
[b]*Key Laboratory for Natural Medicine of Gansu Province, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou, 730000, China. E-mail: shiyp@lzb.ac.cn; Fax: +86-931-8277088; Tel: +86-931-4968208*

† This paper was published as part of a special issue on natural products chemistry in China.

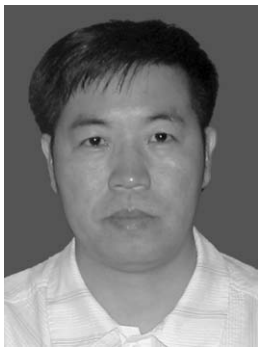
Quan-Xiang Wu received her M.Sc. and Ph.D. degrees in Organic Chemistry from Lanzhou University, China. Her research interests focus on natural products chemistry, including isolation and structural elucidation of biologically active secondary metabolites, especially in the field of terpenes from the higher plants. She obtained a permanent position in Lanzhou University as Senior Lecturer in 2005.

Yan-Ping Shi was born in Gansu (P. R. China) in 1965 and received his M.Sc. and Ph.D. degrees in Organic Chemistry from Lanzhou University, China in 1992 and 1996, respectively. He completed periods as a post-doctoral research associate in cell biology at Lanzhou University in 1998, and in marine natural products chemistry at the University of Puerto Rico in 2001, as well as being honoured with an Award from the Special Foundation for 'Bairen Jihua" at the Chinese Academy of Sciences (CAS) in 2000. He obtained a permanent position in the Lanzhou Institute of Chemical Physics (CAS) as a Research Professor in 2001, and was appointed Research Professor at Lanzhou University in 2003. Since 2004, he has been the Director of the Key Laboratory for Natural Medicine for Gansu Province. His research interests cover the chemistry of natural products, especially the isolation, purification, and structural elucidation of pharmacologically active terpenoids, together with determination of natural products in plant materials. He has authored over 100 scientific publications and was honoured with two 2nd Prizes for the Advancement of Science & Technology by the National Education Department of China in 1999 and 2005, respectively.

Zhong-Jian Jia was a Professor of Organic Chemistry at Lanzhou University, China, from 1959 to 2006. Her research interests focus on the chemistry of natural products from medicinal and toxic plants, mainly those of China. She serves on the Editorial Board of Asia Natural Products Research *and is a member of the Evaluation Committee of Chinese Risk Investment of New Drug Development. She has authored more than 350 scientific publications and has been honoured with four 2nd Prizes and one 3rd Prize for the Advancement of Science & Technology by the National Education Department of China, and with one 3rd Prize for the Advancement of Science & Technology by the Sciences Commission of Gansu Province. She has also received the "Gold Cattle' Prize from the National Development Program Commission (the Ministry of Education of China and the Ministry of Sciences and Techniques of China).*

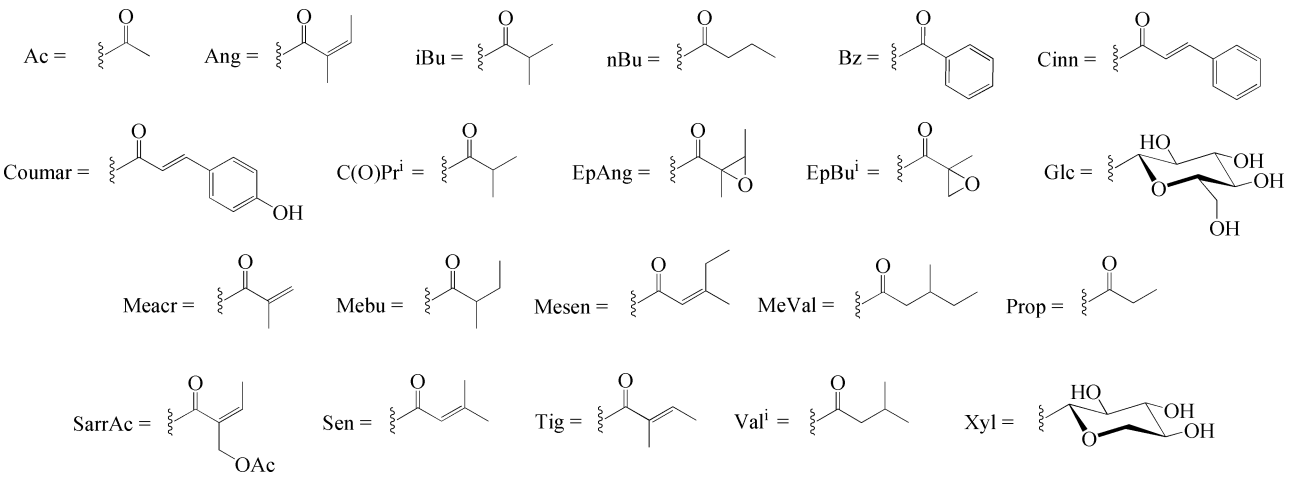


Quan-Xiang Wu



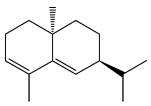
Yan-Ping Shi

Zhong-Jian Jia



2 Eudesmenes

Non-oxygenated eudesmane sesquiterpenoids are hardly represented in the Asteraceae family. Eudesmene **2** was isolated from *Ursinia trifida*,[3] and its isomer, 10-*epi*-eudesma-3,5-diene, has been prepared from santonin.[4] The total syntheses of 4(15),7-dieneudesmane and (±)-vetiselinene have been reported.[5]



2

3 Oxygenated eudesmanes

Oxygenated eudesmanes form the major class of sesquiterpenoids in Asteraceae species, and include alcohols, ethers, epoxides, peroxides, aldehydes, ketones, carboxyl acids and lactones. The different functional groups are important in determining the individual biological activities of the various sesquiterpenoids. These compounds are discussed in more detail below.

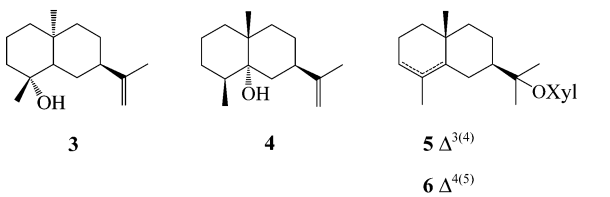
3.1 Hydroxyl-substituted eudesmanes

3.1.1 Eudesmanols. The novel eudesmanols **4–34** and their plant sources are detailed in Table 1. 4-Hydroxy-10-*epi*-eudesma-11-ene **3**[23] was synthesised from (−)-carvone, and the structure was established by X-ray analysis. The eudesmanols (±)-6-eudesmen-4α-ol[5] and (±)-selina-3,11-dien-9-ol[24] have also been the subject of synthetic studies, as has been the synthesis of α-dictyopterol[25] and platyllide.[26] A shorter route to the synthesis of (+)-junenol and isojunenol (together with their coumarate esters) starting from (−)-santonin has been developed, and (+)-junenol has been shown to be identical to 6-*epi*-β-verbesinol.[27]

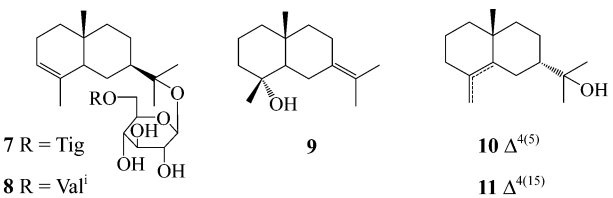
Table 1 Sources of eudesmanols

Sources	Compounds
Artemisia annua	**29**, **33**, **34**[18,19]
Calendula persica	**20**, **21**[13]
Carthamus lanatus	**18**, **19**[12]
Cassinia subtropica	**29**, **32**[16]
Helichrysum italicum	**22**[14]
Iphiona mucronata	**23**, **24**, **26**, **28**[15]
Iphiona scabra	**5**, **6**, **25**, **27**[7]
Kleinia pendula	**4**[6]
Laggera alata	**10**, **11**[10]
Laggera pterodonta	**9**[11]
Ligularia veitchiana	**31**[20–22]
Melampodium camphoratum	**12**–**17**[9]
Pegolettia oxydonta	**7**, **8**[8]
Santolina rosmarinifolia	**30**[17]

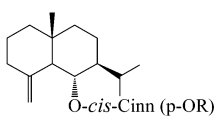
3.1.2 Eudesmandiols. New eudesmandiols **35–93** isolated from various plants are highlighted in Table 2. Kikkanol B **88** showed inhibitory activity against rat lens aldose reductase.[53] The structure of teucdiol A was determined by X-ray analysis.[57] Eudesmane sesquiterpenes from the rhizomes of the Chinese



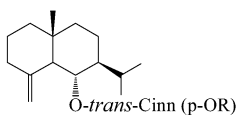
3 **4** **5** $\Delta^{3(4)}$ **6** $\Delta^{4(5)}$



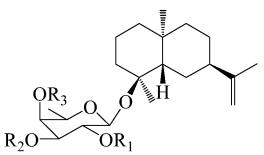
7 R = Tig **8** R = Val[i] **9** **10** $\Delta^{4(5)}$ **11** $\Delta^{4(15)}$



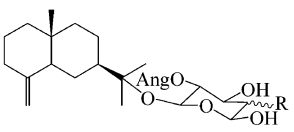
12 R = H **13** R = Ac



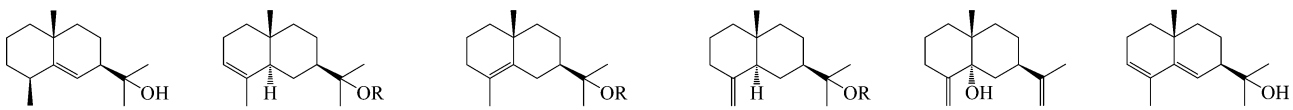
14 R = Me **15** R = $CO(CH_2)_{16}CH_3$ **16** R = $CO(CH_2)_{14}CH_3$ **17** R = $CO(CH_2)_7CH{=}CH(CH_2)_5CH_3$



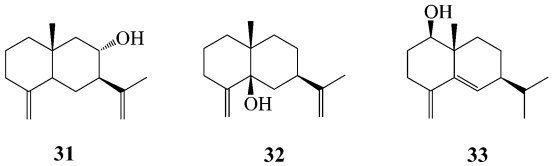
18 $R_1 = R_2 = R_3$ = Ac **19** $R_1 = R_2$ = H, R_3 = Mebu



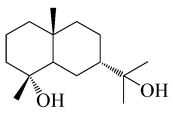
20 R = α-OH **21** R = β-OH



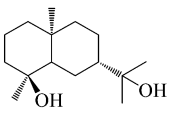
22 **23** R = Xyl **24** R = Xyl (2'-OAc) **25** R = Xyl **26** R = Xyl (2'-OAc) **27** R = Xyl **28** R = Xyl (2'-OAc) **29** **30**



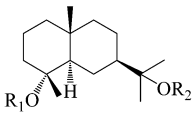
31 **32** **33** **34**



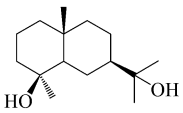
35



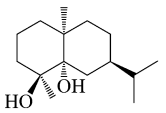
36



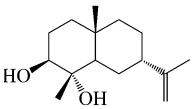
37 R_1 = Glc, R_2 = H
38 R_1 = H, R_2 = Glc



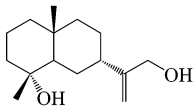
39



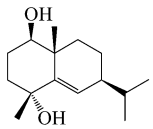
40



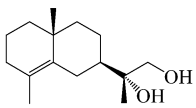
41



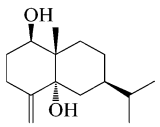
42



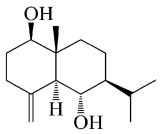
43



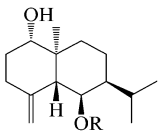
44



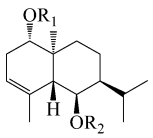
45



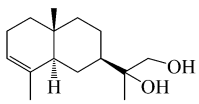
46



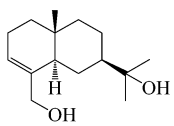
47 R = Ang
48 R = Cinn



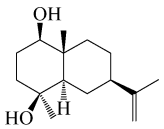
49 R_1 = Cinn, R_2 = H
50 R_1 = H, R_2 = Cinn
51 R_1 = H, R_2 = Bz(*p*-OMe)
52 R_1 = H, R_2 = Glc



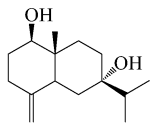
53



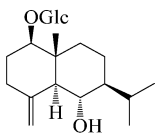
54



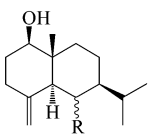
55



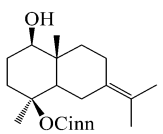
56



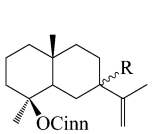
57



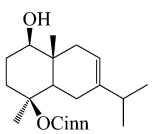
58 R = α-OH
59 R = β-OH



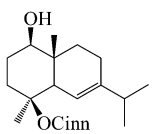
60



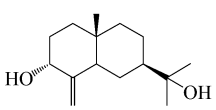
61 R = α-OH
62 R = β-OH



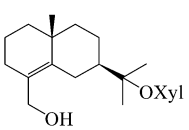
63



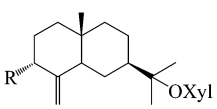
64



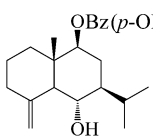
65



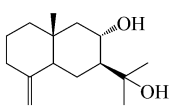
66



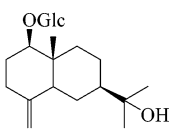
67 R = H
68 R = OH



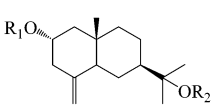
69



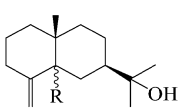
70



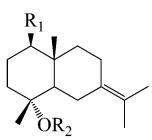
71



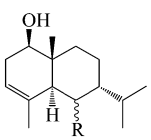
72 R_1 = H, R_2 = Glc
73 R_1 = Glc, R_2 = Glc
74 R_1 = Glc-Glc, R_2 = Glc
75 R_1 = Glc-Glc, R_2 = Glc-Glc



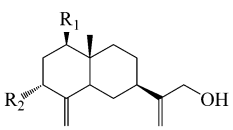
76 R = α-OH
77 R = β-OH



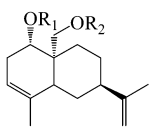
78 R_1 = OH, R_2 = Glc
79 R_1 = OGlc, R_2 = H



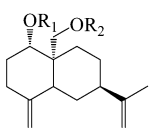
80 R = α-OH
81 R = β-OH



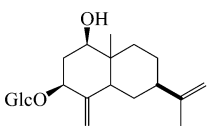
82 R_1 = OH, R_2 = H
83 R_1 = H, R_2 = OH



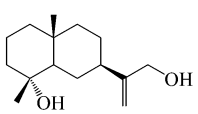
84 R_1 = R_2 = H
85 R_1 = H, R_2 = Ac



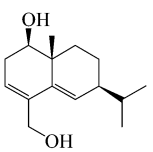
86 R_1 = R_2 = H
87 R_1 = H, R_2 = Ac
88 R_1 = Ac, R_2 = H



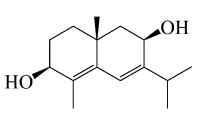
89



90



91



92

93

Table 2 Sources of eudesmandiols

Sources	Compounds
Ageratina glechonophylla	**58**[41]
Ambrosia artemisioides	**47**–**52**[38]
Ambrosia elatior	**46**, **69**[37]
Artemisia arenaria	**43**[35]
Artemisia eriopoda	**59**[42]
Atractylodes lancea	**72**–**75**[47]
Cassinia uncata	**53**, **54**[16]
Chrysanthemum indicum	**65**,[44] **91**[53]
Erigeron annuus	**55**–**57**[39]
Gonospermum fructicosum	**82**, **83**, **90**[50]
Hypochoeris radicata	**89**[52]
Iphiona scabra	**66**, **67**, **68**[7]
Isodon grandifolia	**35**[29]
Jasonia candicans	**42**[34]
Jasonia glutinosa	**44**[36]
Jasonia montana	**76**, **77**[48]
Laggera alata	**70**[45]
Laggera crispata	**41**[33]
Laggera pterodonta	**36**–**38**, **78**, **79**[30,31]
Ligularia duciformis	**92**[54,55]
Ligularia hodgsonii	**45**[21]
Pluchea arguta	**35**, **39**[28,32]
Pluchea dioscoridis	**80**, **81**[49]
Pluchea indica	**71**[46]
Polyachirus sphaerocephalus	**84**–**88**[51]
Santolina insularis	**93**[56]
Senecio microglossus	**58**[40]
Ursinia trifida	**39**, **40**[3]
Verbesina oerstediana	**60**–**64**[43]

herb*Atractylodes ovata* have been shown to have cytotoxic activity against leukaemia cell lines.[58] The microbiological transformation of ilicic acid and kutdiol by cultures of *Cunninghamella echinulata* has been studied.[59,60] The microbiological transformations of 4α- and 4β-hydroxyeudesmane derivatives by the filamentous fungus *Gliocladium roseum* have also been reported.[61]

A general enantiospecific approach to the synthesis of polyfunctional eudesmanes based on ring-closing metathesis has been reported.[62] (+)-Dihydrocarvone has been used as a starting point for the syntheses of (−)-10-*epi*-5β,11-dihydroxyeudesmane and (−)-4,10-*epi*-5β,11-dihydroxyeudesmane.[63] The first total synthesis of both C-11 epimers of 13-hydroxy-α-eudesmol has been completed. This work has permitted the absolute configuration of the natural diol to be established as **53**, and also the preparation of (+)-α-selinene to be accomplished.[64] The first enantioselective total syntheses of (+)-chrysanthemol,[65] (+)-selina-3,11-dien-9-ol[66] and (−)-rishitin[67] have been described, and racemic preparations of dehydrochamaecyneol[68] and balanitol have been reported.[69] α-Eudesmaol,[70] occidol[71] and tavacpallescensin[72] have been the subject of total synthesis, and a formal total synthesis of (−)-dehydrochamaecynenol has been presented.[73] Eudesman-4-en-1β,11-diol has been synthesised as its racemate.[74]

3.1.3 Eudesmantriols. Recently isolated eudesmantriols **94**–**138** and their plant sources are listed in Table 3. The structure of mucrolidin **104** was determined by X-ray analysis.[79] Kikkanol A **118** showed inhibitory activity against rat lens aldose reductase.[53] The microbiological transformation of β-selinene by the plant pathogenic fungus *Glomerella cingulata* has been studied.[91] Enantioselective total syntheses of kudtriol, 5-*epi*-kudtriol and its C-11 epimer[92–94] have been accomplished.

Table 3 Sources of eudesmantriols

Sources	Compounds
Achillea clypeolata	**129**[87]
Ainsliaea cordifolia	**124**, **125**[82]
Artemisia eriopoda	**96**[42]
Artemisia monosperma	**132**[88]
Atractylodes lancea	**114**, **115**, **131**[47,86]
Chrysanthemum indicum	**118**[53]
Erigeron brevicaupus	**127**[84]
Iva frutescens	**103**, **104**[78]
Jasonia glutinosa	**108**[36]
Laggera alata	**130**[85]
Laggera pterodonta	**97**–**100**,[30,31] **105**, **106**,[11] **109**–**112**[80]
Pallenis spinosa	**121**, **122**[81]
Pluchea indica	**113**, **123**[46]
Polyachyrus fuscus	**135**–**138**[90]
Rhaponticum uniflorum	**134**[89]
Santolina chamaecyparissus	**126**[83]
Santolina insularis	**133**[56]
Saussurea laniceps	**94**[75]
Santolina rosmarinifolia	**119**[17]
Tanacetopsis mucronata	**107**[79]
Tessaria integrifolia	**101**, **102**[77]
Verbesina eggersii	**95**[97]
Verbesina oerstediana	**116**, **120**, **128**[43]
Verbesina virgata	**116**, **117**[76]

3.1.4 Polyhydroxylated eudesmanes. 3,4,7,8-Tetrahydroxy eudesmenes **139** and **140** have been isolated from the methanolic extract of *Tessaria integrifolia.*[77] The tetrahydroxy eudesmenes **141**, **142** and **143** have also been found in the Asteraceaeous plants *Ainsliaea cordifolia*,[82] *Senecio flammeus*,[95,96] and *Verbesina eggersii*,[97] respectively. The pentahydroxy eudesmene **144** was isolated from *Calendula arvensis.*[98]

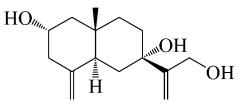
Two novel polyhydroxyl 7-*epi*-eudesmane derivatives have been isolated from the microbial transformation of a (1α,10β),(4β,5α)-diepoxygermacrane using the hydroxylating fungus *Rhizopus nigricans.* The absolute configurations of these compounds was confirmed by single-crystal X-ray analyses.[99] The 1α- and 2α-hydroxyselinane derivatives have been prepared by chemical semi-synthesis and biotransformation with *Rhizopus nigricans*, using vulgarin as starting material.[100]

3.2 Eudesmane epoxides

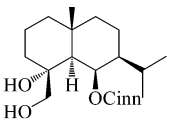
The eudesmane epoxides **146–171** and their corresponding plant sources are indicated in Table 4. The structure of epoxyoplodiol **145** has been determined by single crystal X-ray diffraction

Table 4 Sources of eudesmane epoxides

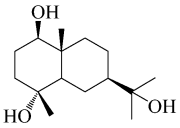
Sources	Compounds
Ambrosia artemisioides	**154**, **155**[38]
Atractylodes japonica	**161**[107]
Baccharis dracunculifolia	**153**[103]
Calendula arvensis	**148**, **149**, **150**[98]
Chrysanthemum indicum	**159**[106]
Curculigo capitulata	**152**[104]
Epaltes gariepina	**164**–**168**[45]
Erigeron philadelphicus	**156**[105]
Ixeris repens	**162**, **163**[108]
Liabum floribundum	**151**[102]
Ondetia linearis	**169**, **170**[109]
Pluchea quitoc	**146**, **147**,[101] **171**[110]
Polyachirus sphaerocephalus	**157**, **158**[51]



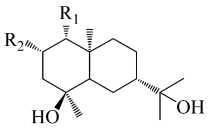
94



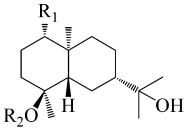
95



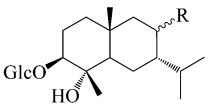
96



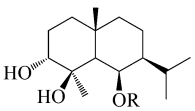
97 R_1 = H, R_2 = OH
98 R_1 = OH, R_2 = H



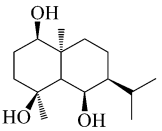
99 R_1 = OH, R_2 = Glc
100 R_1 = OGlc, R_2 = H



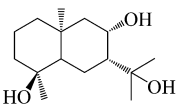
101 R = α-OH
102 R = β-OH



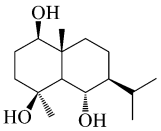
103 R = Bz
104 R = Cinn



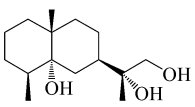
105



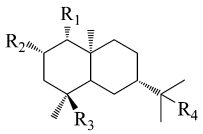
106



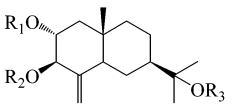
107



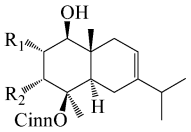
108



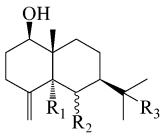
109 R_1 = H, R_2 = R_3 = OH, R_4 = OGlc
110 R_1 = R_4 = OH, R_2 = H, R_3 = OGlc
111 R_1 = H, R_2 = R_3 = R_4 = OH
112 R_1 = R_3 = R_4 = OH, R_2 = H



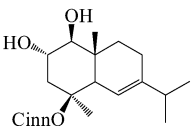
113 R_1 = R_2 = R_3 = H
114 R_1 = R_2 = H, R_3 = Glc
115 R_1 = Glc-Glc, R_2 = H, R_3 = Glc



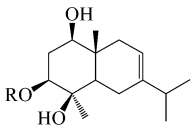
116 R_1 = OH, R_2 = H
117 R_1 = H, R_2 = OH



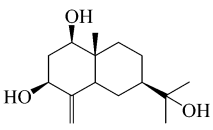
118 R_1 = OH, R_2 = β-OH, R_3 = H
119 R_1 = H, R_2 = α-OH, R_3 = OH



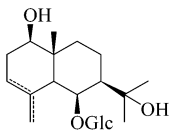
120



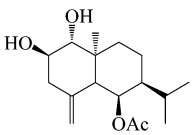
121 R = H
122 R = Ac



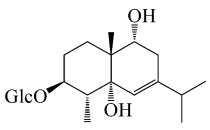
123



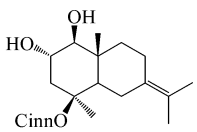
124 $\Delta^{3(4)}$
125 $\Delta^{4(15)}$



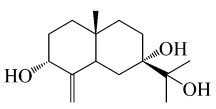
126



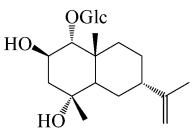
127



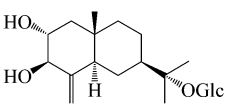
128



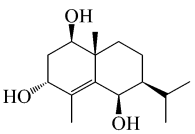
129



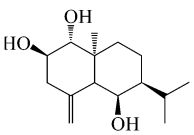
130



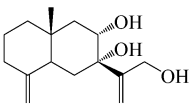
131



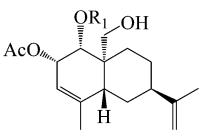
132



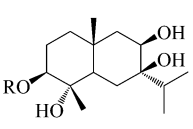
133



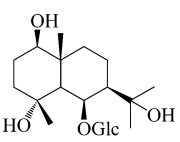
134



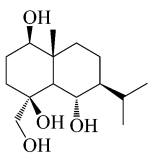
135 R_1 = Tig
136 R_1 = Sen
137 R_1 = Val^i
138 R_1 = Ang



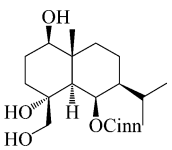
139 R = H
140 R = Glc



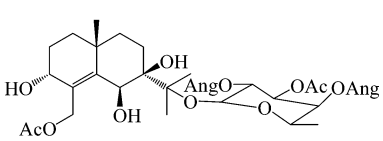
141



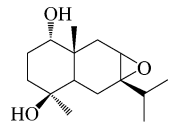
142



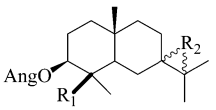
143



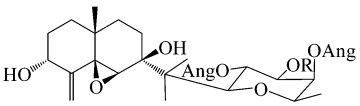
144



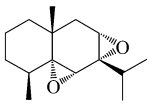
145



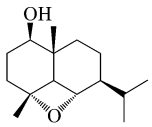
146 R_1 = α-OH, R_2 = β-epoxy
147 R_1 = β-OAc, R_2 = α-epoxy



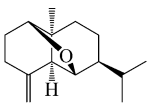
148 R = Ac
149 R = C(O)Pr^i
150 R = Mebu



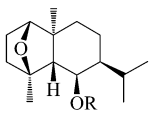
151



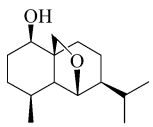
152



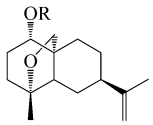
153



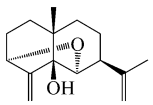
154 R = Cinn
155 R = COC_6H_4OMe



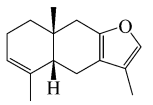
156



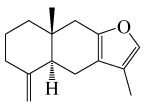
157 R = H
158 R = Ac



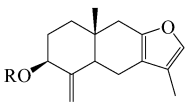
159



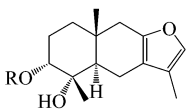
160



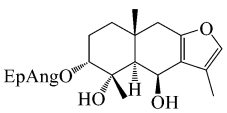
161



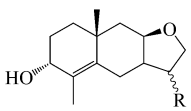
162 R = H
163 R = Ac



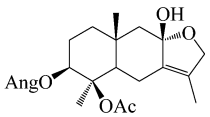
164 R = H
165 R = EpAng
166 R = Val^i
167 R = Ang



168



169 R = α-Me
170 R = β-Me



171

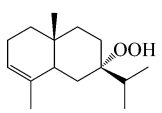
analysis.[111] The furanosesquiterpene atractylon showed moderate, but selective, 5-lipoxygense inhibitory activity.[112] (+)-Dihydrocarvone has been used as a starting material for the first syntheses of (+)-5α-hydroxy-β-selinene and (−)-5β-hydroxy-β-selinene.[113] The synthesis of (+)-1,2-dihydrotubiopofuran **160**, starting from α-santonin, has been completed.[114] Synthetic studies towards the furosesquiterpenes have been developed,[115] and a synthesis of both enantiomers of acetoxytubipofuran has been reported.[116]

3.3 Eudesmane peroxides

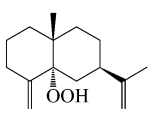
Novel peroxide-substituted eudesmanes **172–187** and their corresponding plant sources are detailed in Table 5. There is very

Table 5 Sources of eudesmane peroxides

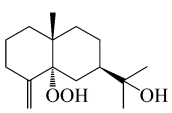
Sources	Compounds
Achillea clypeolata	**184**[121]
Ambrosia artemisioides	**180**–**182**[38]
Artemisia annua	**173**[19]
Artemisia douglasiana	**174**[118]
Aster oharai	**172**[117]
Brontonia discodea	**183**, **185**[120]
Calea prunifolia	**177**[119]
Dittrichia viscosa	**187**[123]
Isocoma coronopifolia	**186**[122]
Verbesina oerstediana	**175**, **176**, **178**, **179**[43]



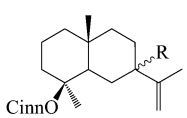
172



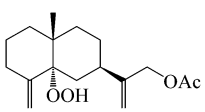
173



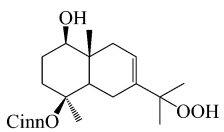
174



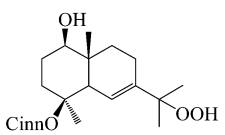
175 R = α-OOH
176 R = β-OOH



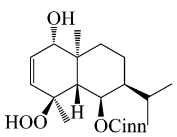
177



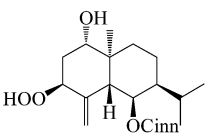
178



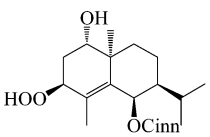
179



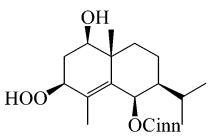
180



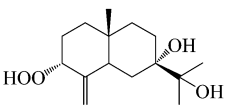
181



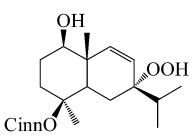
182



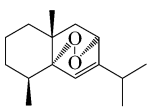
183



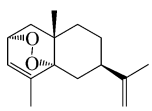
184



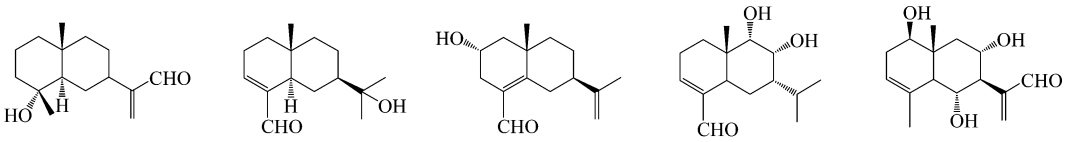
185



186



187



188 **189** **190** **191** **192**

little literature on the bioactivity or synthesis of these structurally interesting eudesmane sesquiterpenoids.

3.4 Eudesmane aldehydes

The eudesmane aldehyde **188** has been found in *Vernonia glabra* var. *glabra.*[124] The other α,β-unsaturated aldehydes **189**, **190**, **191** and **192** have been identified in *Cassinia uncata*,[16] *Tetragonotheca ludoviciana*,[125] *Chrysanthemum indicum*,[53] and *Tanacetopsis mucronata*,[126] respectively. The inhibitory activity of compound **191** against rat lens aldose reductase has been studied.[53] A series of sesquiterpene compounds possessing eudesmane carbon skeletons were tested as gastric cytoprotetctive agents on male Wilstar rats. The presence of an α,β-unsaturated aldehyde on the C-7 side chain together with a hydroxyl group at C-4 appears to be a prerequisite for their observed anti-ulcerogenic activity. In an attempt to establish new molecular structural requirements for this gastric cytoprotective activity, a structure–activity study has been performed.[127]

A new salen–manganese(III) complex bearing a sesquiterpene salicylaldehyde derivative has been used in the catalytic epoxidation of unfunctionalised olefins, with iodosylbenzene and molecular oxygen–pivalaldehyde as the terminal oxidant.[128]

3.5 Eudesmane ketones

A series of recently isolated eudesmane ketones **193–272** and their plant sources are highlighted in Table 6. The novel sesquiterpene ketone **194** was the isomer from the genus *Nephtha*.[130] The new cauthemone derivatives **212**–**218**, **220** and **221** have been identified from plants of the genus *Tessaria*, while **237**, **240**, **241**, **243** and **250** have been found in *Pluchea symphytifolia*, indicating that there is a phytochemical relationship between these two Asteraceae genera. The structure of 5-*O*-acetylcuauhtemonyl-6-*O*-2′,3′-epoxy-2-methylbutyrate, isolated from *Pluchea carolinensis*, has been determined by X-ray analysis.[163] Sesquiterpene **250**, which was isolated from *Pluchea suaveolens*[164] and *Epaltes brasiliensis*,[165] has been revised from the 11-hydroxy- to the 11-peroxy-derivative.[142] The structure of the sesquiterpene ketone carissone has been confirmed by X-ray analysis,[166] and the absolute configuration of cuauhtemone has been revised to **210**.[167]

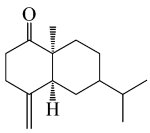
The antibacterial activities of **246**[152] and **263**[159] have been studied. The antiprotozoal activity of a range of known sesquiterpenes from *Jasonia glutinosa* has been explored and the antibacterial activities of carissone, dehydrocarissone and carindone have been evaluated.[168]

The biotransformation of 4β-hydroxyeudesmane-1,6-dione by the fungi *Gliocladium roseum* and *Exserohilum halodes* has been studied.[169] Alantolactone has been shown to induce apoptosis in jurkat leukaemia T cells.[170] A chemical–microbiological synthesis of 6β-eudesmanolides has been achieved with the fungus *Rhizopus nigricans.*[171] The microbiological transformation of eudesmane derivatives by the fungus *Curvularia lunata* has also been reported.[172] The atractylon content of clonally propagated plants of *Atrsctylodes japonica* has been determined[107] and the allelochemical effects of eudesmane sesquiterpenes on *Tribolium castaneum* larvae have been investigated.[173]

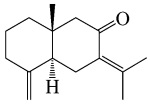
Table 6 Sources of eudesmane ketones

Sources	Compounds
Achillea clypeolata	**208**, **227**[121]
Achillea holosericea	**233**[155]
Ambrosia artemisioides	**209**[38]
Artemisia afra	**200**[136]
Artemisia caerulescens	**199**, **268**[133,134]
Artemisia eriopoda	**204**, **226**[42]
Artemisia herba-alba	**269**[161]
Atractylodes japonica	**194**[107]
Atractylodes lancea	**198**,[86] **228**[47,86]
Baccharis boliviensis	**271**[162]
Blumea alata	**210**, **211**, **255**–**258**, **264**, **265**[139]
Cassinia uncata	**225**, **270**[16]
Epaltes divaricata	**219**[143]
Epaltes mexicana	**222**,[144,145] **241**,[144] **263**[159]
Hypochoeris radicata	**199**[135]
Iphiona scabra	**196**[7]
Laggera alata	**224**[45]
Laggera crispata	**235**[33]
Laggera pterodonta	**205**, **226**[11]
Liabum floribundum	**195**[102]
Parthenium argentatum	**201**, **229**, **272**[137]
Pluchea arguta	**213**,[141] **236**,[147] **238**,[145] **239**,[149] **245**, **246**,[151,152] **248**,[32] **250**,[150] **252**,[153] **253**,[154] **254**,[151] **260**–**262**,[147,151,158] **266**, **267**[160,158]
Pluchea carolonesis	**223**[146]
Pluchea indica	**212**[140]
Pluchea odorata	**237**,[148] **242**, **244**, **247**, **251**[150]
Pluchea quitoc	**243**, **249**,[110] **231**, **259**,[101] **206**, **207**[101,110]
Pluchea symphytifolia	**241**, **243**, **250**[142]
Santolina insularis	**232**[56]
Saussurea lappa	**230**[25]
Saussurea parviflora	**234**[156,157]
Senecio bracteolatus	**199**[132]
Solidago gigantea	**193**[129]
Sphaeranthus indicus	**197**[131]
Tessaria integrifolia	**202**, **203**,[138] **214**–**218**, **220**, **221**, **240**[142]

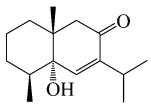
A preparation of the HS-toxin A aglycone, starting from (−)-carvone, has been described.[174] (+)-Carvone has been used as the starting material in the synthesis of (+)-α-cyperone,[175] and the first total synthesis of (+)-5α-hydroxyisopterocarpolone, starting from (+)-dihydrocarvone, has been described.[176] The hydroxylation of sesquiterpenes by enzymes from chicory roots has been investigated.[177] 3β-Angeloyloxy-4β-hydroxyeudesman-8-one **206** has been synthesised by an unambiguous route,[178] but its spectroscopic data was different from that of the natural product, to which this structure had been assigned.[101,179] An efficient and stereoselective synthesis of (+)-α-cyperone has been devised,[180] and the eudesmanolide artemsin has been used as a starting material in the preparation of 9-oxy-functionalised natural eudesmanes.[181] The total syntheses of (±)-cuauhtemone[182]



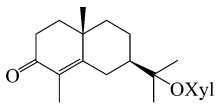
193



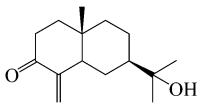
194



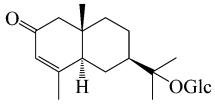
195



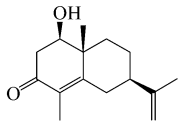
196



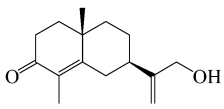
197



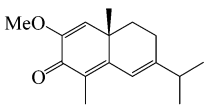
198



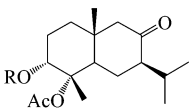
199



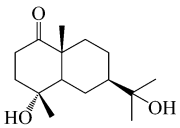
200



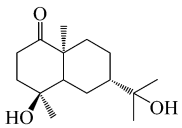
201



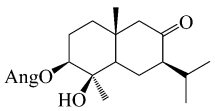
202 R = Ang
203 R = EpAng



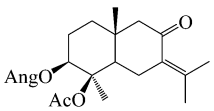
204



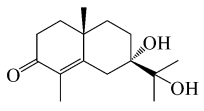
205



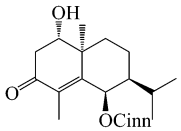
206



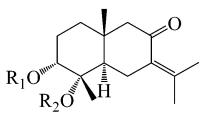
207



208

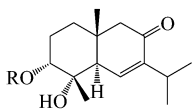


209

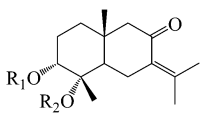


210 $R_1 = R_2 = H$
211 R_1 = Mebu (2'-OH, 3'-OAc), R_2 = Ac
212 R_1 = Mebu (2'-OAc, 3'-OAc), R_2 = H
213 R_1 = Mebu (2'-OAc, 3'-OH), R_2 = Ac
214 R_1 = C(O)Pr^i, R_2 = H

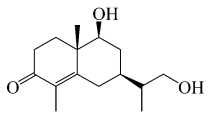
215 R_1 = Sen, R_2 = H
216 R_1 = MeSen, R_2 = H
217 R_1 = MeVal, R_2 = H
218 R_1 = Ac, R_2 = H
219 R_1 = Ang, R_2 = Ac



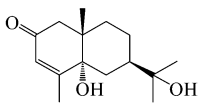
220 R = Sen
221 R = Ang



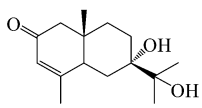
222 R_1 = Mebu (2'-OH, 3'-OH), R_2 = H
223 R_1 = Mebu (2'-OH, 3'-Cl), R_2 = H
224 R_1 = EpAng, R_2 = CHO



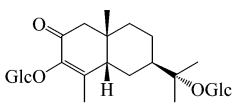
225



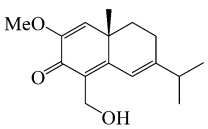
226



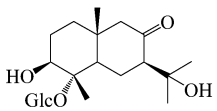
227



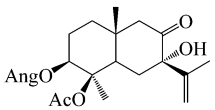
228



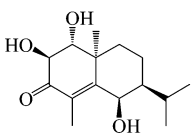
229



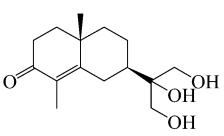
230



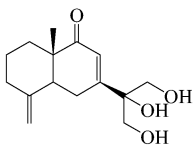
231



232



233

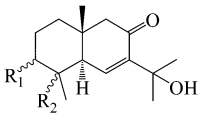


234

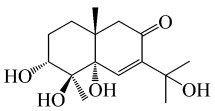
and (±)-eudesma-5,7(11)-dien-8-one has been reported.[183] The chemical transformation of α-santonin into two 8-oxo-β-cyperone derivatives has been reported.[184] A shorter, more efficient method for the preparation of 11,12-dihydroxyeudesmanolides, starting from α-santonin, has been reported,[185] and a total synthesis of the naphthofurandione maturinone has been achieved.[186] Phytuberin has been synthesised starting from carvone.[187] A facile synthesis of 3-oxo-7α*H*-eudesma-4β,12-diol, previously isolated from *Casina uncata*, has been described.[188] An enantioselective synthesis of selina-1,3,7(11)-trien-8-one has been accomplished.[189]

3.6 Eudesmane carboxylic acids

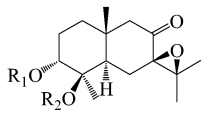
Recently isolated eudesmane carboxylic acids **273–423** from a number of different plants are listed in Table 7. The structure of vachanic acid[258] and **411**[259] have been conformed by X-ray studies. X-Ray crystallographic studies have also revealed catemeric carboxyl-to-ketone hydrogen bonding in the bicyclic sesquiterpene keto acid **406**.[242] The aerial parts of *Flourensia thurifera* contain 3β-hydroxycostic acid **283** and a mixture of two acyl derivatives **284** and **285**. The toxicity of these substances toward *Artemia salina*



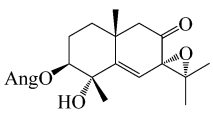
235 R_1 = α-OMebu (2'-OH, 3'-OH), R_2 = α-OH
236 R_1 = α-OMebu (2'-OH, 3'-OH), R_2 = β-OH
237 R_1 = β-OMebu (2'-OH, 3'-OH), R_2 = α-OH
238 R_1 = β-OMebu (2'-OH, 3'-Cl), R_2 = α-OH
239 R_1 = β-OH, R_2 = α-OH
240 R_1 = α-OSen, R_2 = α-OH
241 R_1 = α-OAng, R_2 = α-OH
242 R_1 = α-OAng, R_2 = α-OAc
243 R_1 = β-OAng, R_2 = α-OH
244 R_1 = α-OMebu (2'-OH, 3'-Cl), R_2 = α-OAc
245 R_1 = α-OMebu (2'-OH, 3'-Cl), R_2 = β-OAc
246 R_1 = α-OMebu (2'-OH, 3'-Cl), R_2 = α-OAc
247 R_1 = α-OMebu (2'-OH, 3'-Cl), R_2 = α-OH
248 R_1 = α-OMebu (2'-OH, 3'-OH), R_2 = α-OAc
249 R_1 = β-OAng, R_2 = β-OAc
250 R_1 = α-OEpAng, R_2 = α-OH
251 R_1 = α-OEpAng, R_2 = α-OAc
252 R_1 = α-OEpAng, R_2 = β-OAc
253 R_1 = β-OMebu (2'-OH, 3'-Cl), R_2 = β-OAc



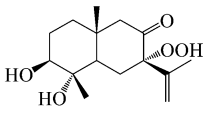
254



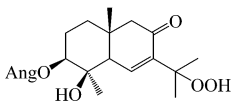
255 R_1 = Ang, R_2 = H
256 R_1 = Ang, R_2 = Ac
257 R_1 = EpAng, R_2 = H
258 R_1 = EpAng, R_2 = Ac



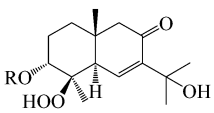
259



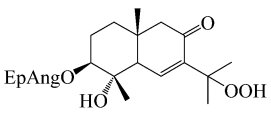
260



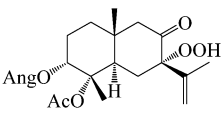
261



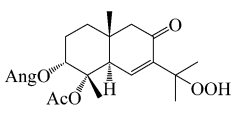
262 R = Mebu (2'-OH, 3'-Cl)



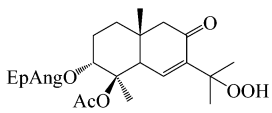
263



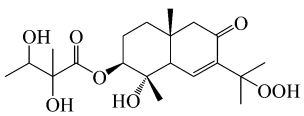
264



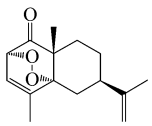
265



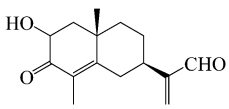
266



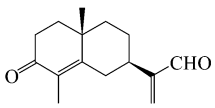
267



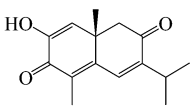
268



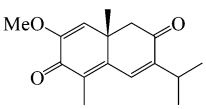
269



270



271



272

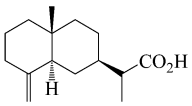
and their antifeedant properties against *Spodoptera littoralis* have been evaluated.[199] Compound **411** exhibited potent antimicrobial activity against the six bacteria *Staphylococcus aureus*, *Bacillus subtilis*, *Micrococcus luteus*, *Escherichia coli*, *Bacillus cereus* and *Salmonella enteritides.*[260] The sesquiterpene 12-carboxyeudesma-3,11(13)-diene and the xanthnolide tomentosin were the major compounds responsible for the ichthyotoxicity shown by *Dittrichia graveolens.*[261] A mechanistic approach to study the *in vivo* anti-inflammatory activity of various sesquiterpenes isolated from *Inula viscosa* has been carried out.[262] The anti-inflammatory properties of other sesquiterpenes from *Jasonia glutinosa*[263] have also been tested.

The bioconversion of several eudesmane derivatives using the fungi *Rhizopus nigricans* and *Curvularia lunata* has been studied.[264,265] The microbiological transformation of the eudesmane sesquiterpenes ilicic acid and plectranthone by the fungi *Aspergillus niger*[266] and *Beauvaria bassiana*,[267] respectively, have been described, and the microbiological transformation of ilicic acid by cultures of *Cunninghamella echinulata* has also been evaluated.[59,60]

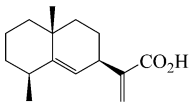
(±)-Dihydrocarvone has been used as the starting material in the synthesis of (+)-3-oxoeudesma-4,11(13)-dien-12-oic acid,[268] and santonin has been employed in the preparation of furanoeudesma-1,3-diene and tubipofurane.[269] The total synthesis of the eudesmanic acid **415**, starting from (+)-dihydrocarvone, has been achieved.[249,250] An enantioselective total synthesis of eudesma-3,11(13)-dien-12-oic acid.[270] has also been completed. The recombinant sesquiterpene synthases from grand fir δ-selinene synthase produces more than 30 sesquiterpene olefins from the acyclic precursor farnesyl diphosphate.[271]

3.7 Eudesmanolides

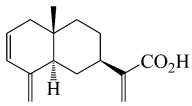
3.7.1 Eudesmane-12,6-olides. A wide range of structurally diverse eudesmane-12,6-olides have been reported from the Asterceae family, and a good deal of biological activity,



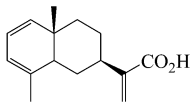
273



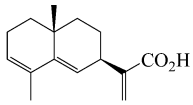
274



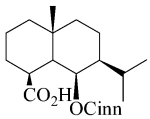
275



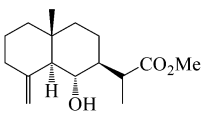
276



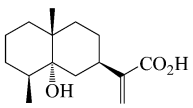
277



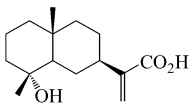
278



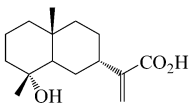
279



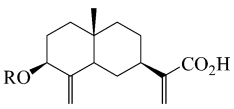
280



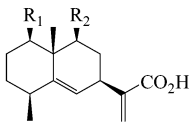
281



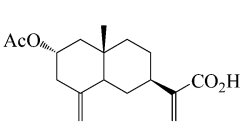
282



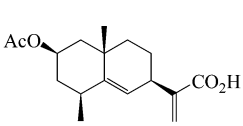
283 R = H
284 R = Ang
285 R = Mebu



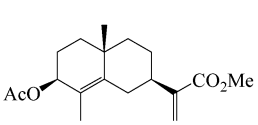
286 R_1 = OGlc, R_2 = H
287 R_1 = H, R_2 = OGlc



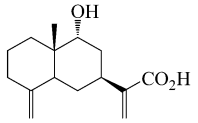
288



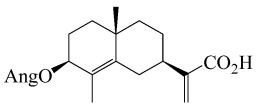
289



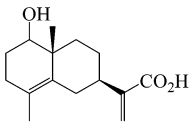
290



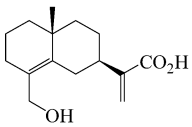
291



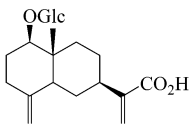
292



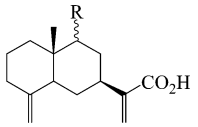
293



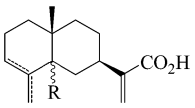
294



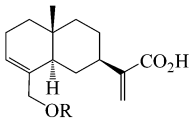
295



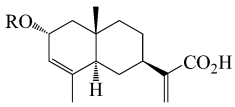
296 R = α-OH
297 R = β-OH



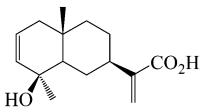
298 R = β-OGlc, $\Delta^{4(15)}$
299 R = α-OGlc, Δ^{3}



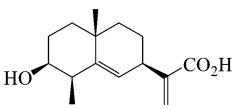
300 R = H
301 R = *cis*-Coumar
302 R = *trans*-Coumar
303 R = *cis*-Cinn



304 R = *trans*-Cinn
305 R = Prop
306 nBu
307 Tig

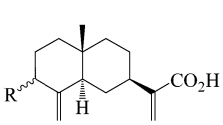


308 R = Me
309 R = H
310 R = C(O)Pr^{i}

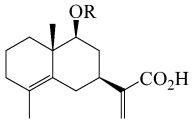


311

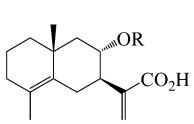
312



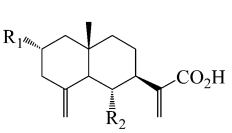
313 R = α-OH
314 R = α-OAc
315 R = β-OAc



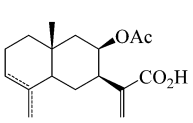
316 R = H
317 R = Ac



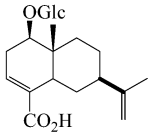
318 R = H
319 R = Ac



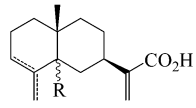
320 R_1 = OH, R_2 = H
321 R_1 = H, R_2 = OH



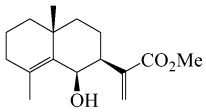
322 $\Delta^{3(4)}$
323 $\Delta^{4(15)}$



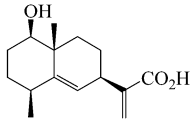
324



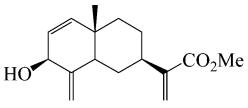
325 $\Delta^{3(4)}$ R = α-OH
326 $\Delta^{4(15)}$ R = α-OH
327 $\Delta^{4(15)}$ R = β-OH



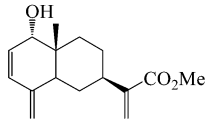
328



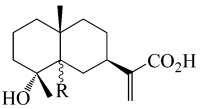
329



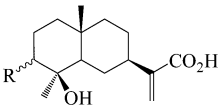
330



331



332 R = α-OH
333 R = β-OH

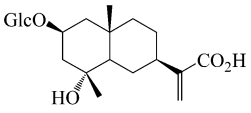


334 R = β-OAc
335 R = α-OAc

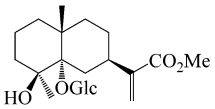
336 R_1 = H, R_2 = OH
337 R_1 = OH, R_2 = H

338

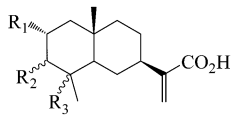
339



340



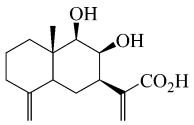
341



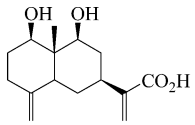
342 R_1 = H, R_2 = β-OH, R_3 = α-OH

343 R_1 = H, R_2 = α-OH, R_3 = β-OH

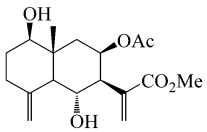
344 R_1 = OH, R_2 = H, R_3 = α-OH



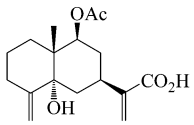
345



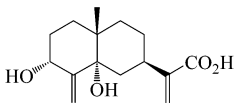
346



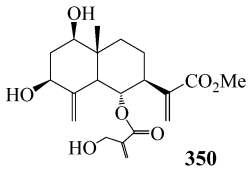
347



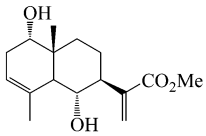
348



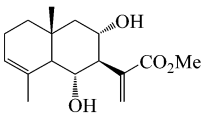
349



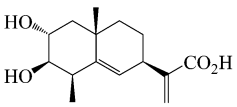
350



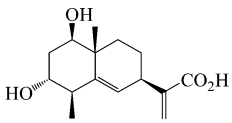
351



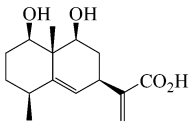
352



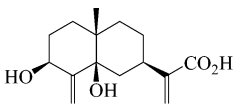
353



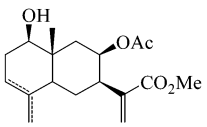
354



355

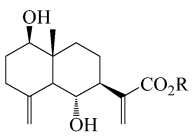


356



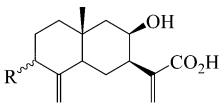
357 $\Delta^{3(4)}$

358 $\Delta^{4(15)}$



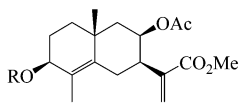
359 R = H

360 R = Et



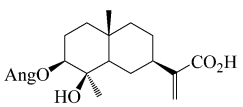
361 R = β-OH

362 R = α-OH

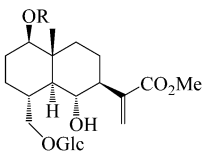


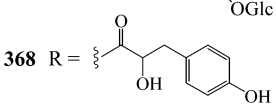
363 R = Ang **365** R = Prop

364 R = iBu **366** R = MeSen

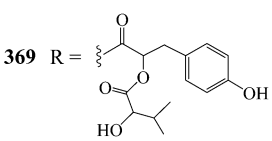


367

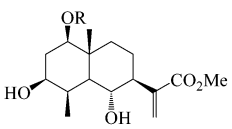




368 R =

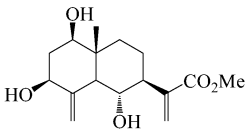


369 R =

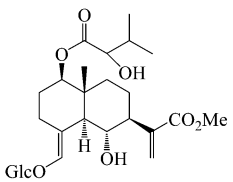


370 R = Glc

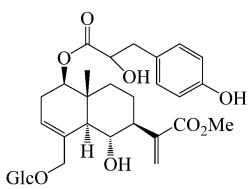
371 R = H



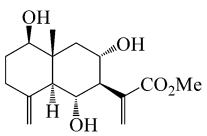
372



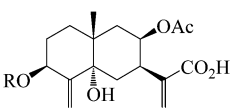
373



374

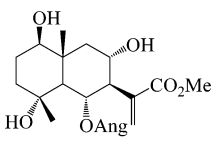


375

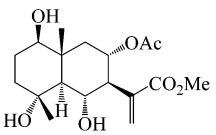


376 R = Ang

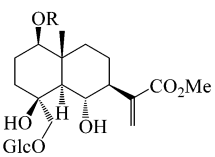
377 R = iBu



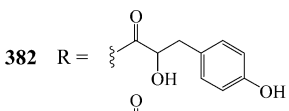
378



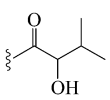
379



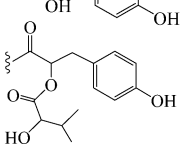
380 R = H



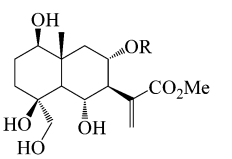
382 R =



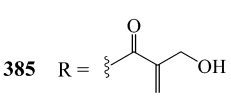
381 R =



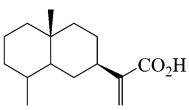
383 R =



384 R = H



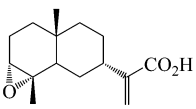
385 R =



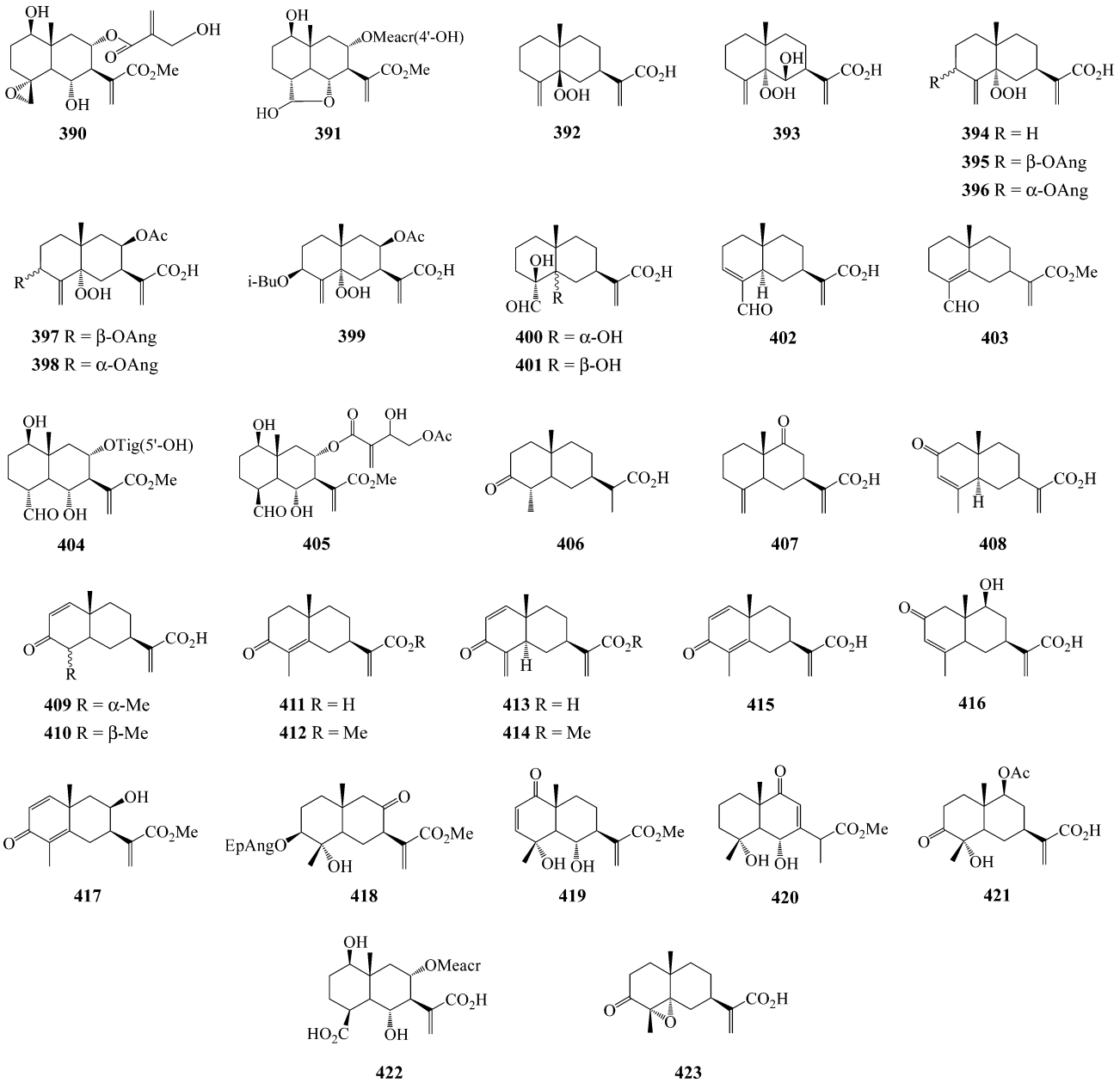
386 4α,15-epoxide

387 4α,5α-epoxide

388 4β,5β-epoxide



389



biotransformation and chemical syntheses studies about those lactones have been completed.

The lactones **424–742** and their corresponding plant sources are outlined in Table 8. Lasolide **506** and isolasolide **507** have been obtained from plants of the genus *Laser*, and the structure of **506** has been revised.[314] The structures of 7α-hydroxycostunolide[338] badkhysinin **443** and oopodin **660** have been determined by X-ray analysis,[395] and the stereochemistry of tauremisin **707** has been determined by single-crystal X-ray diffraction analysis.[201] The structure of torrentin, an eudesmanolide isolated from *Artemisia herba-alba*, has been revised to **487**.[309] The lactone **432**, also obtained from *Artemisia herba-alba*,[279] has had its structure revised, as the original configuration assigned at C-11 was erroneous.[278] Conformational analyses of 6α- and 6β-eudesmanolides, as well as 8α- and 8β-eudesmanolides, have been carried out.[396] The structure of 1-*O*-acetylbritannilactone has been determined by X-ray analysis,[397] whilst the absolute configuratuion of glaucescenolide has been confirmed by chemical synthesis.[398] The known eudesmanolide magnolialide has been obtained from *Cichorium intybus* and shown to be identical to cichoriolide (another eudesmanolide), and cichopumilide (a guaianolide). Consequently, the structures of these last two lactones must be corrected. Moreover, the structures of their natural 11β,13-dihydro derivatives and the glycosides cichorioside and sonchuside C should also be amended.[399] The structures of the alkaline reduction products of santonin have been determined.[400] A straightforward procedure for the introduction of a double bond between C-7 and C-11 in the eudesmanolide skeleton has been described.[401]

Sphaeranthanolide **498** exhibited immunostimulant activity in the jerne plaque assay.[402] The toxicity and antifeedant activity of several eudesmanolides from two *Encelia* species against larvae of

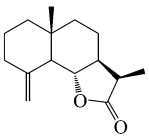
Table 7 Sources of eudesmane carboxylic acids

Sources	Compounds
Achillea schischkinii	**420**[254]
Ambrosia elatior	**293**[37]
Apalochlamys spectabilis	**325**–**327**,[48,197] **280**, **386**–**388**[197]
Arctotis aspera	**413**[247]
Artemisia altaiensis	**412**[246]
Artemisia genus	**406**[242]
Artemisia herba-alba	**281**,[198] **326**[218]
Artemisia mongolica	**352**[229]
Artemisia pectinata	**318**, **319**[213]
Artemisia phaeolepis	**421**[255]
Artemisia rutifolia	**350**,[227] **372**[236]
Artemisia tournefortiana	**316**,[211] **316**, **317**,[212] **348**,[31] **407**[211]
Artemisia vulgaris	**331**, **415**[220]
Brocchia cinerea	**378**[237]
Cassinia uncata	**283**, **290**, **300**–**307**, **375**, **379**, **402**[16]
Centaurea arguta	**330**, **414**[219]
Centaurea attica	**405**[241]
Centaurea chilensis	**291**[201]
Centaurea tweediei	**422**[257]
Cratystylis conocephala	**320**[215]
Dittrichia viscosa	**275**,[192] **309**, **313**[207]
Eriocephalus pauperrimus	**292**, **361**–**367**, **376**, **377**, **392**, **394**–**399**, **423**[202]
Eupatorium quadrangulare	**279**[196]
Ferreyranthus fruticosus	**417**[251]
Flourensia macrophylla	**296**, **297**, **345**, **346**, **407**[204]
Flourensia thurifera	**283**–**285**[199]
Geigeria rigida	**322**, **323**[217]
Haeckeria punctulata	**314**, **315**,[210] **334**, **335**[223]
Helianthus annuus	**276**[193]
Holocarpha virgata	**273**[190]
Hydropectis aquatica	**347**[226]
Hypochoeris radicata	**295**, **324**[52]
Inula japonica	**357**, **358**[231,232]
Inula viscose	**310**,[208] **308**, **311**,[205] **313**,[209] **389**,[209] **416**, **342**–**344**[225]
Ixeris debilis	**368**, **369**, **373**, **374**, **380**[108]
Jasonia candicans	**282**[34]
Jasonia montana	**327**, **349**,[48] **411**[244]
Laggara pterodonota	**338**[31,200]
Laggera alata	**298**, **299**, **340**,[85] **277**, **336**, **341**,[194] **333**,[222] **337**,[224]
Laggera pterodonta	**274**, **312**, **329**, **353**,[191] **286**,[191] **287**,[200] **288**, **289**,[11] **332**,[221] **354**, **355**,[31,200] **412**[245]
Montanoa speciosa	**413**[248]
Onopordon acaulon	**384**, **385**,[238] **390**[239]
Onopordon illyricum	**391**, **404**[240]
Perymenium featherstonei	**409**, **410**[243]
Pluchea arguta	**418**[252]
Pluchea dioscoridis	**294**, **403**,[203] **400**, **401**[49]
Rudbeckia grandiflora	**321**, **339**[216]
Saussurea lappa	**360**[234]
Schistostephium rotundifolium	**309**, **408**[206]
Sphaeranthus indicus	**320**,[214] **370**[131]
Tanacetum praeteritum	**351**,[228] **419**[253]
Taraxacum laevigatum	**371**[235]
Tessaria absinthioides	**356**[230]
Tessaria integrifolia	**316**[138]
Ursinia eckloniana	**392**[3]
Ursinia tenuifolia	**328**, **393**[3]
Verbesina turbacensis	**278**[195]
Warionia saharae	**359**[233]

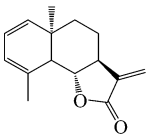
Spodoptera littoralis have been determined.[403] A structure–activity relationship study of the sesquiterpene lactones that stimulate the germination of witchweed *Striga asiatica* has been described. The highest activity was observed with a mixture of santamarin and reynosin.[404] The cytotoxic and antibacterial activities of the sesquiterpene lactones isolated from *Tanacetum praeteritum* has been evaluated.[405] The cytotoxic properties of the known eudesmane lactones from *Artemisia princes* have been examined,[406] and the pharmacological activity of reynosin[407,408] and santamarine[408] has been studied. The *in vitro* activity of compounds **687**, **688**, **689** and **695** against three Gram-positive and three Gram-negative bateria was evaluated using a microdilution method, and their cytotoxic activity was determined against a panel of human tumour cell lines.[374] Preliminary studies using the mycelial growth method indicated that the synthetic eudesmanolides **675**, **676**, **677**, **678** and **702** had inhibitory activities of against pathogenic fungi such as *Pythiumaphami dermatum*, *Phytophthora capsici*, *Fusarium oxysporum*, *Rhizoctonia solani*and *Botrytis cinerea* of 100–200 mg L^{-1}.[409] Antiproliferative sesquiterpene lactones have been obtained from the roots of *Inula helenium.*[410] The effect of yomogin, an eudesmanolide with anti-inflammatory activity, has been investigated in human promyelocytic HL-60 leukaemia cells,[411] whilst the antiplasmodial activity of the lactones isolated from *Eupatorium semialatum* has been studied.[412] The antimicrobial activities of several lactones obtained from *Inula helenium*, *Rudbeckia subtomentosa*[413] and *Hemiteptia lyrata*[414] have been studied. The known lactones magnolialide and artesin have been obtained from *Cichorium intybus*;[415] magnolialide has been shown to inhibit the growth of several tumour cell lines, but artesin was inactive.[416] Studies of the inhibition of nitric oxide production by the lactone yomogin have been carried out.[417]

The biotransformation of α-santonin by the fungus *Botrytis cinerea* afforded its 11β-hydroxy derivatives in very good yield.[418] The microbiological transformation of deoxyvulgarin by *Rhizopus nigricans* and *Aspergillus ochraceus* has been reported,[419] and the microbiological transformation of α-santonin by *Pseudomonas cichorii*[420] and *Aspergillus niger*[421] has also been studied. A biogenetic synthesis of vulgarin and peroxyvulgarin has been devised.[422] During the preparation of 4-*epi*-6β-vulgarin, a biotransformation with the fungus *Rhizopus nigricans* was utilised in one of the synthetic steps.[424] The biomimetic cyclisation of cnicin led to a new lactone, malactanolide **741**.[425] The microbiological transformation of several sesquiterpene lactones by the fungi *Cunninghamella echinulata* and *Rhizopus oryzae* has been reported,[426] and transformations of α-santonin, and α-, β-, and γ-cyclocostunolide with various fungi have been investigated.[427] The microbiological transformations of 7α-hydroxyfrullanolide[428] and 11,13-dehydrosantonin[429] by *Aspergillus niger* have been reported. The microbial transformations of 6α- and 6β-eudesmanolides by cultures of the fungus *Rhizopus nigricans* have been examined,[430] and the microbiological transformation of α-santonin by several fungi has been studied.[431] A biomimetic synthesis of the bisesquiterpene lactones (±)-biatractylolide and (±)-biepiasterolide has been accomplished.[432] A *Pseudomonas* strain has been utilised in the biotransformation of α-santonin to 1,2-dihydrosantonin and the dihydroxy derivative **743**.[433] The high photoreactivity of isoalantolactone with thymine to give photoadducts, involving the 5,6-double bond of thymine and the exomethylene double bond of the lactone, has been studied. This reaction may provide an explanation of the progressive evolution of contact dermatitis into chronic actinic dermatitis as an effect of the action of sesquiterpene lactones on the skin.[434]

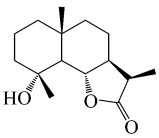
A review of approaches towards the synthesis of *cis*-decalins has been reported. The *cis*-decalin framework is present in various classes of natural products.[435] A review of the conversion of



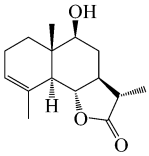
424



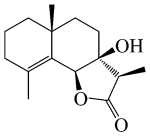
425



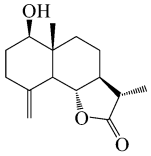
426



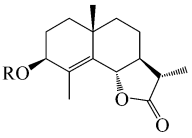
427



428

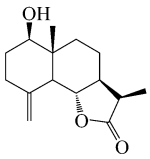


429

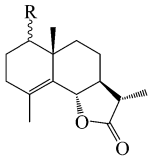


430 R = Glc

431 R = H



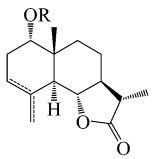
432



433 R = α-OH

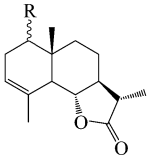
434 R = β-OH

435 R = α-OAc



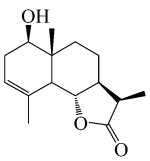
436 $\Delta^{3(4)}$, R = Ac

437 $\Delta^{4(15)}$, R = H

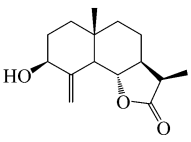


438 R = α-OH

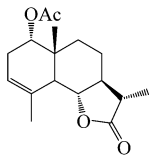
439 R = β-OH



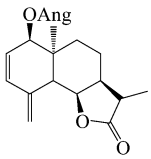
440



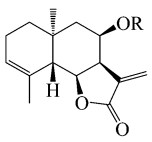
441



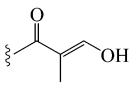
442



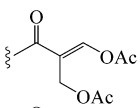
443



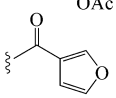
444 R =

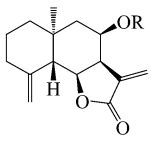


445 R =

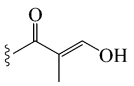


446 R =

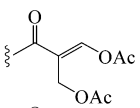




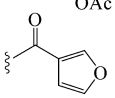
447 R =

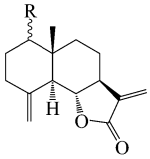


448 R =



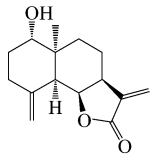
449 R =



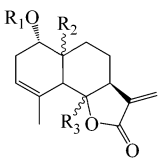


450 R = α-OH

451 R = β-OH

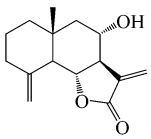


452

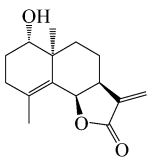


453 R_1 = H, R_2 = α-Me, R_3 = α-H

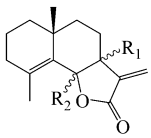
454 R_1 = Ac, R_2 = β-Me, R_3 = β-H



455

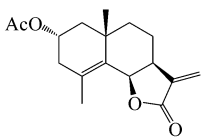


456

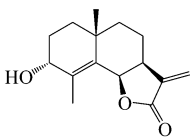


457 R_1 = α-OH, R_2 = α-H

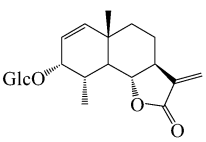
458 R_1 = β-OH, R_2 = β-H



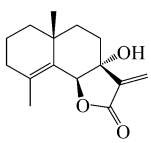
459



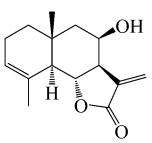
460



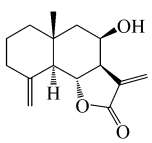
461



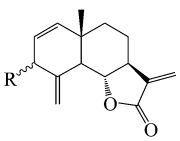
462



463



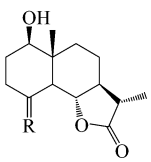
464



465 R = α-OGlc

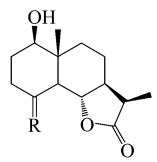
466 R = α-OAc

467 R = β-OGlc



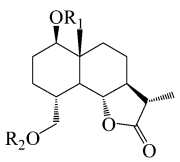
468 R = β-OH, α-Me

469 R = α-OH, β-Me



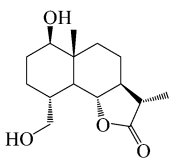
470 R = β-OH, α-Me

471 R = α-OH, β-Me



472 R_1 = Glc, R_2 = H

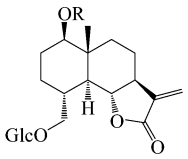
473 R_1 = H, R_2 = Glc

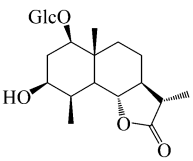


474

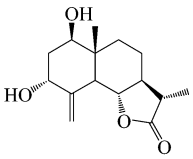
475

476

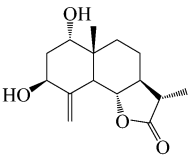




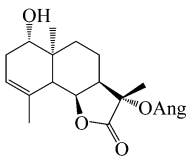
479



480

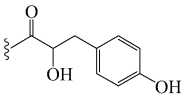


481

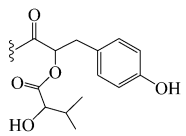


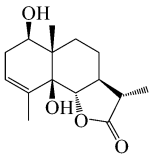
482

477 R =

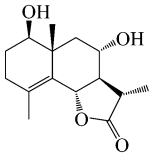


478 R =

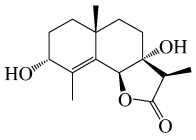




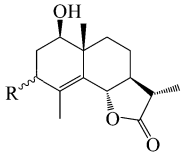
483



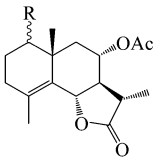
484



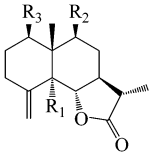
485



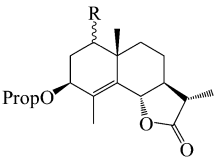
486 R = α-OH
487 R = β-OAc



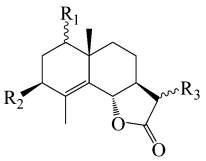
488 R = α-OH
489 R = β-OH



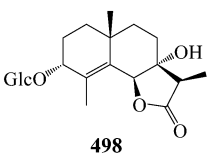
490 R_1 = OH, R_2 = H, R_3 = OAc
491 R_2 = OH, R_1 = R_3 = H



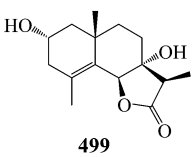
492 R = α-OH
493 R = β-OH



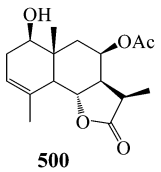
494 R_1 = β-OH, R_2 = OAc, R_3 = β-Me
495 R_1 = α-OH, R_2 = OAc, R_3 = β-Me
496 R_1 = β-OH, R_2 = OH, R_3 = α-Me
497 R_1 = β-OH, R_2 = OH, R_3 = β-Me



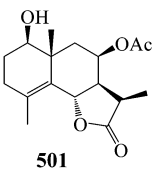
498



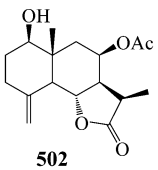
499



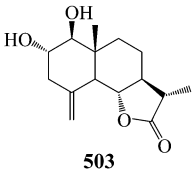
500



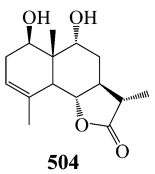
501



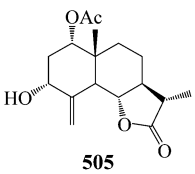
502



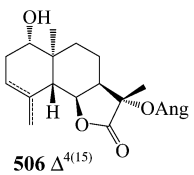
503



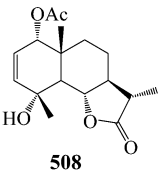
504



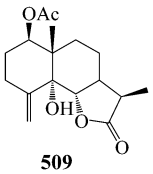
505



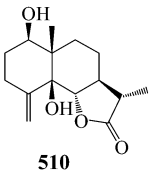
506 $\Delta^{4(15)}$
507 $\Delta^{3(4)}$



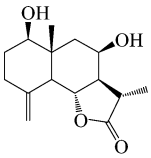
508



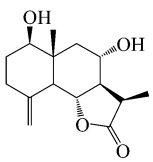
509



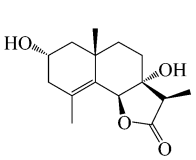
510



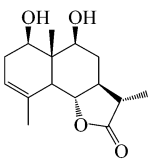
511



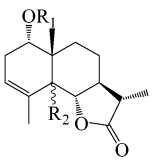
512



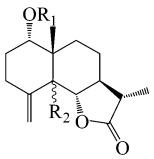
513



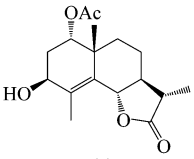
514



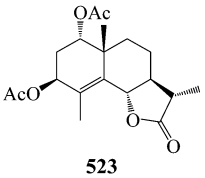
515 R_1 = H, R_2 = α-OH
516 R_1 = H, R_2 = β-OH
517 R_1 = Ac, R_2 = β-OH



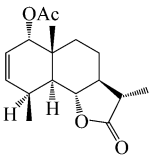
518 R_1 = H, R_2 = α-OH
519 R_1 = H, R_2 = β-OH
520 R_1 = Ac, R_2 = α-OH
521 R_1 = Ac, R_2 = β-OH



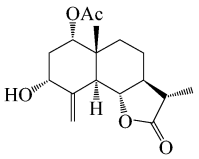
522



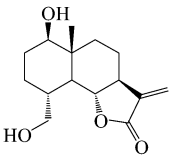
523



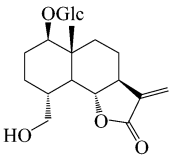
524



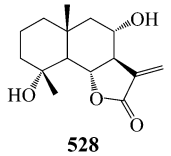
525



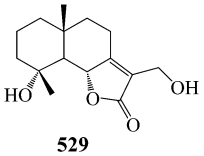
526



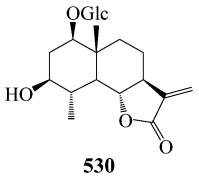
527



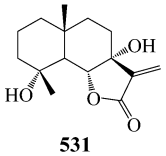
528



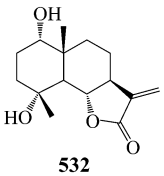
529



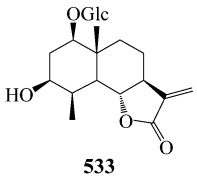
530



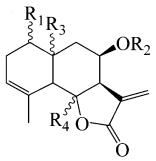
531



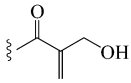
532



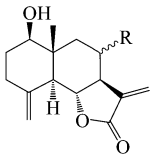
533



534 R_1 = α-OH, R_2 = H, R_3 = α-Me, R_4 = α-H

535 R_1 = β-OH, R_2 =  , R_3 = β-Me, R_4 = β-H

536 R_1 = β-OH, R_2 = C(O)Pr^i, R_3 = β-Me, R_4 = β-H



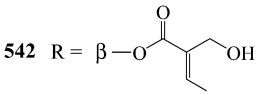
537 R = α-OH

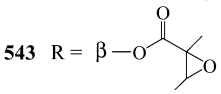
538 R = α-OAc

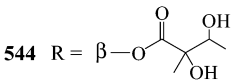
539 R = α-OAng

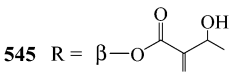
540 R = β-OH

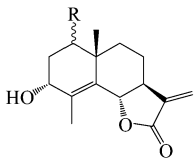
541 R = β-OC(O)Pr^i

542 R = 

543 R = 

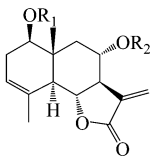
544 R = 

545 R = 



546 R = α-OH

547 R = β-OH



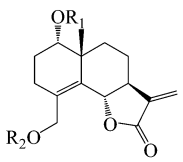
548 R_1 = R_2 = H

549 R_1 = Ang, R_2 = H

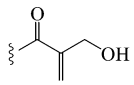
550 R_1 = H, R_2 = Meacr

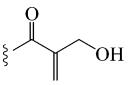
551 R_1 = H, R_2 = C(O)Pr^i

552 R_1 = H, R_2 = Ac

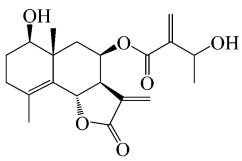


553 R_1 = H, R_2 = Meacr

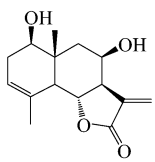
554 R_1 = H, R_2 = 

555 R_1 = Ac, R_2 = 

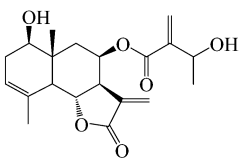
556 R_1 = H, R_2 = 



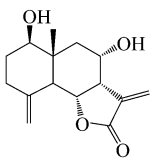
557



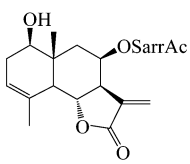
558



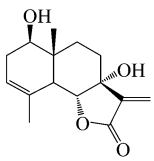
559



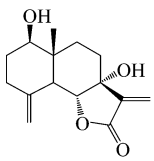
560



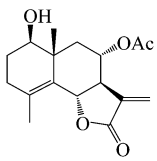
561



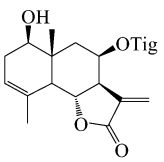
562



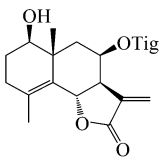
563



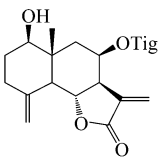
564



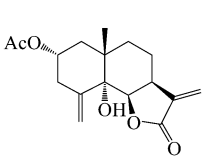
565



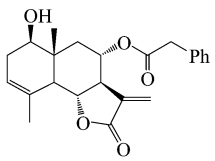
566



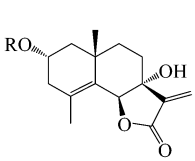
567



568

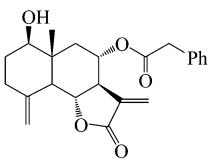


569

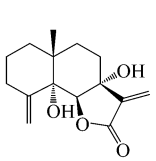


570 R = H

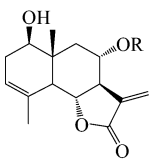
571 R = Ac



572

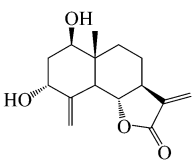


573

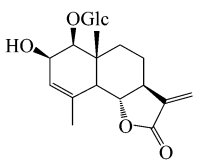


574 R = H

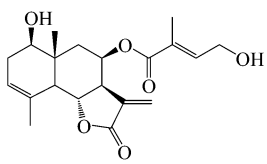
575 R = Ac



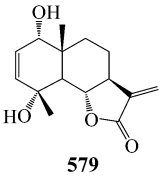
576



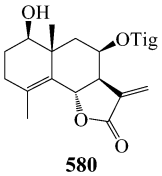
577



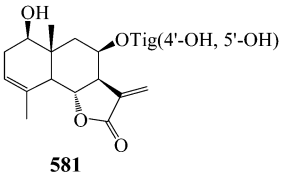
578



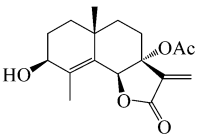
579



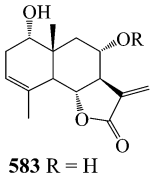
580



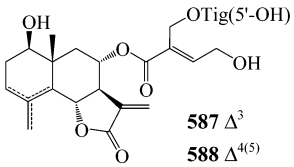
581



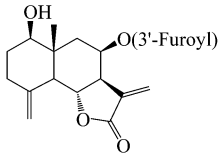
582



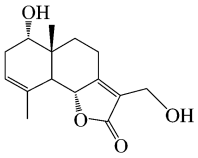
583 R = H
584 R = C(O)Pr^{i}
585 R = Tig
586 R = Ang



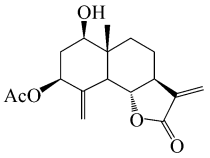
587 Δ^{3}
588 $\Delta^{4(5)}$
589 $\Delta^{4(15)}$



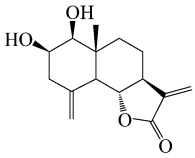
590



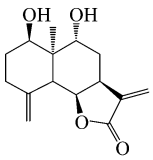
591



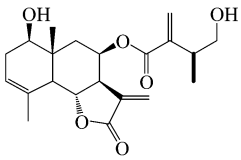
592



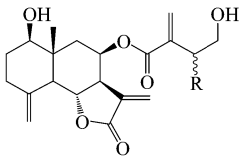
593



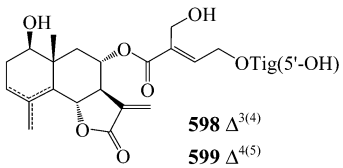
594



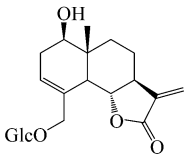
595



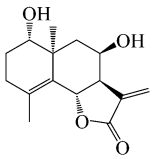
596 R = α-OMe
597 R = β-OMe



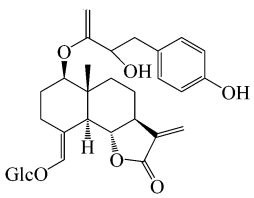
598 $\Delta^{3(4)}$
599 $\Delta^{4(5)}$
600 $\Delta^{4(15)}$



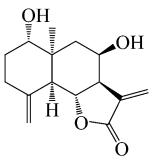
601



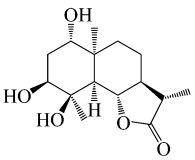
602



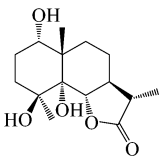
603



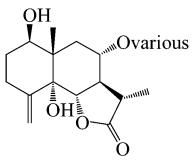
604



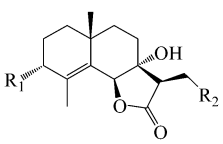
605



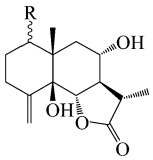
606



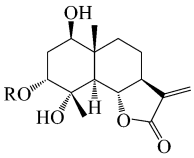
607



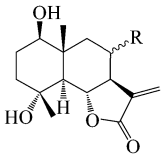
608 R_1 = OH, R_2 = H
609 R_1 = H, R_2 = OH
610 R_1 = H, R_2 = OMe



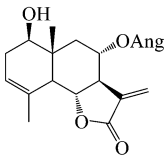
611 R = α-OAc
612 R = α-OVal^{i}
613 R = β-OH



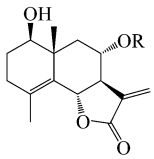
614 R = C(O)Pr^{i}
615 R = Mebu



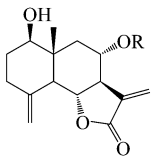
616 R = α-OH
617 R = α-OAc
618 R = β-OH



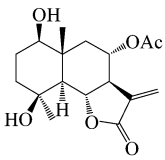
619



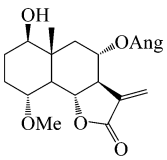
620 R = Ang
621 R = Tig



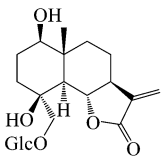
622 R = Ang
623 R = Tig
624 R = C(O)Pr^{i}



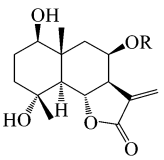
625



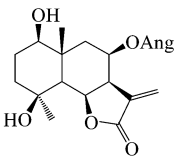
626



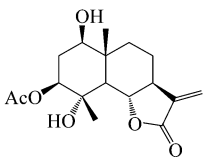
627



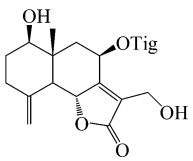
628 R = H
629 R = Tig



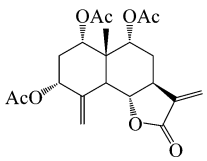
630



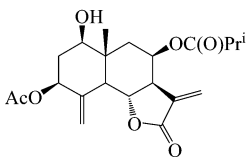
631



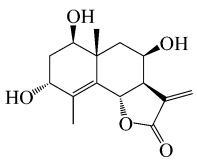
632



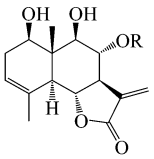
633



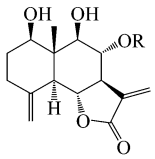
634



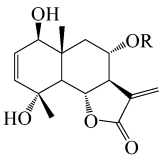
635



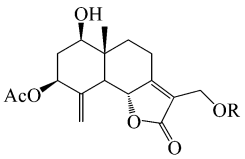
636 R = Ang
637 R = Sen



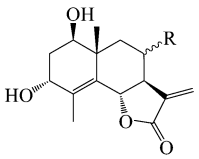
638 R = Ang
639 R = Sen



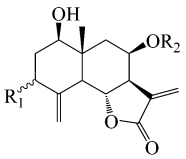
640 R = Meacr
641 R = C(O)Pr^{i}



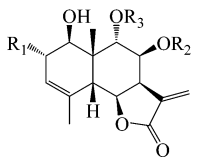
642 R = H
643 R = Ac



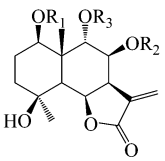
644 R = α-OAc
645 R = α-OMeacr
646 R = α-OC(O)Pr^{i}
647 R = β-OTig



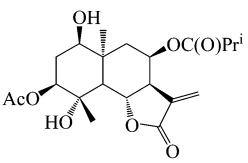
648 R_1 = α-OH, R_2 = Meacr
649 R_1 = α-OH, R_2 = C(O)Pr^{i}
650 R_1 = β-OH, R_2 = Ang
651 R_1 = β-OH, R_2 = C(O)Pr^{i}



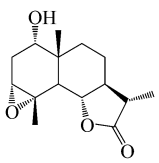
652 R_1 = R_3 = H, R_2 = EpAng
653 R_1, R_2, R_3 (various)



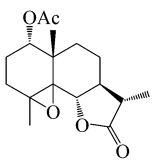
654 R_1, R_2, R_3 (various)



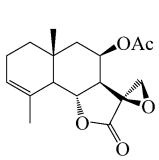
655



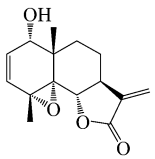
656



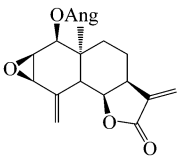
657



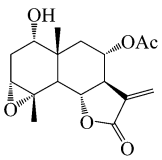
658



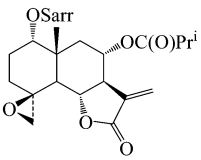
659



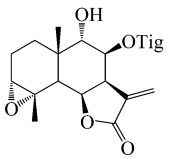
660



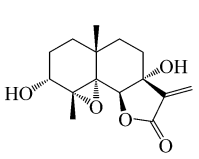
661



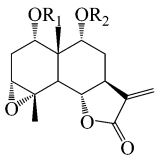
662



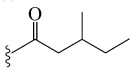
663

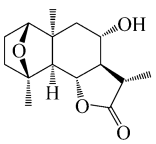


664

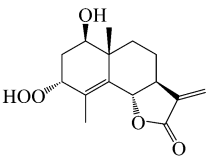


665 R_1 = Ang, R_2 = H
666 R_1 = H, R_2 = Ang
667 R_1 = H, R_2 = Val^{i}
668 R_1 = H, R_2 =

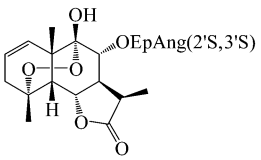




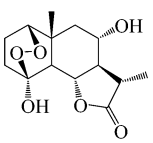
669



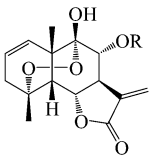
670



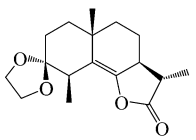
671



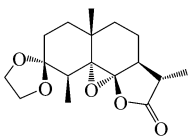
672



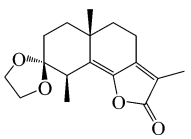
673 R = EpAng(2'R,3'R)
674 R = EpAng(2'S,3'S)



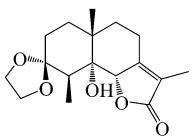
675



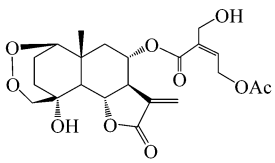
676



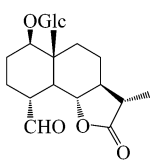
677



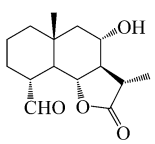
678



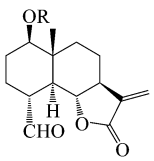
679



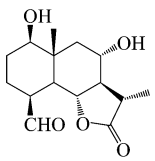
680



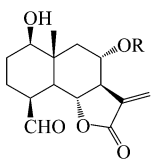
681



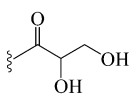
682 R = H
683 R = Glc



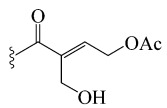
684



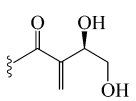
685 R = H



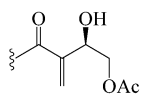
686 R =



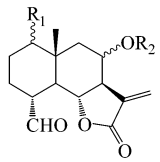
688 R =



687 R =

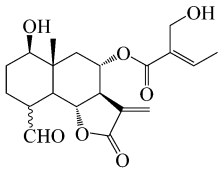


689 R =

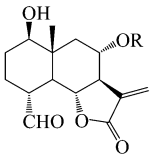


690 R_1 = α-OH, R_2 = α-Meacr(4'-OH)

691 R_1 = β-OH, R_2 = β-Meacr



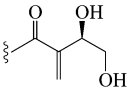
692

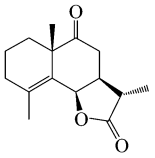


693 R = H

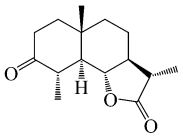
694 R = Meacr(3'-CH_2OAc,3'-OH)

695 R =

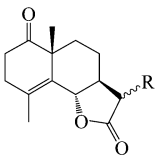




696

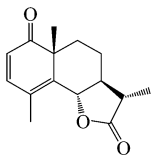


697

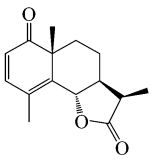


698 R = α-Me

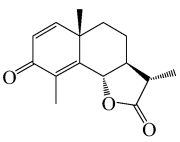
699 R = β-Me



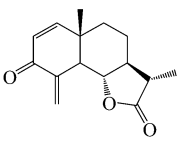
700



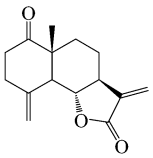
701



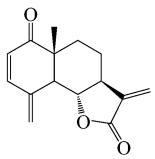
702



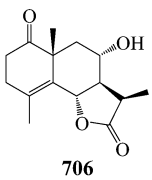
703



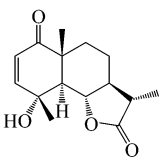
704



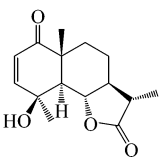
705



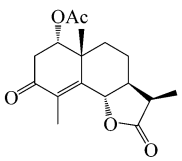
706



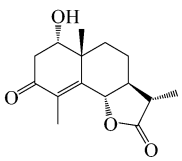
707



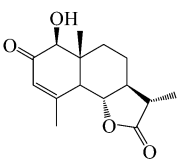
708



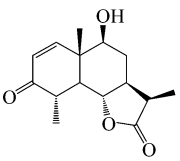
709



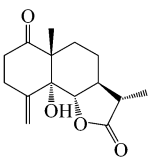
710



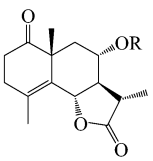
711



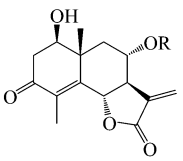
712



713



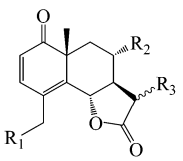
714 R = various



715 R = Ac

716 R = Meacr

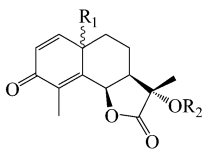
717 R = $C(O)Pr^i$



718 R_1 = OH, R_2 = H, R_3 = β-Me

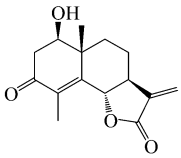
719 R_1 = OH, R_2 = H, R_3 = α-Me

720 R_1 = H, R_2 = OH, R_3 = α-Me

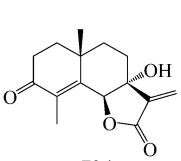


721 R_1 = α-Me, R_2 = Ang

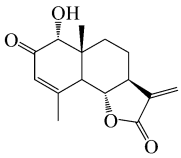
722 R_1 = β-Me, R_2 = H



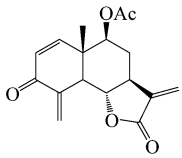
723



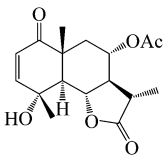
724



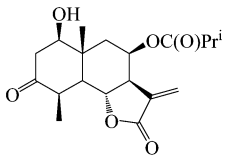
725



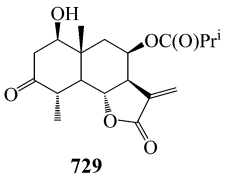
726



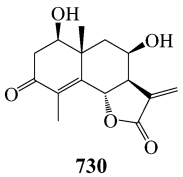
727



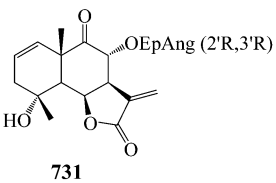
728



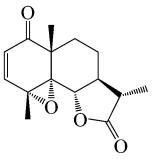
729



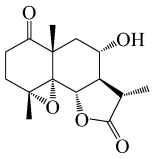
730



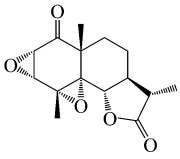
731



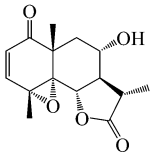
732



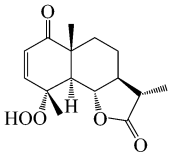
733



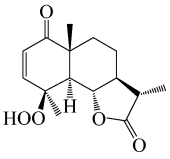
734



735

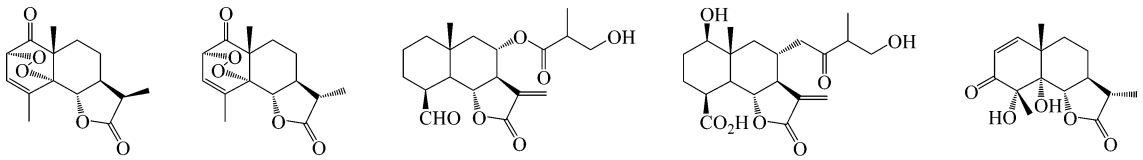


736



737

738



739 740 741 742 743

α-santonin into other sesquiterpene lactones, such as eudesma-12,6-olides and eudesma-12,8-olides, has been published.[436] Chemical, enzymatic and microbiological methods have been used in the transformation of santonin into sivasinolide and yomogin analogues.[437] Ultrasound has been used to enhance the rate of the reductive cleavage of sesquiterpene γ-enone-lactones.[438] An interesting procedure for the SmI_2-catalyzed rearrangement of a 5α,6α-epoxy-11,13-dihydroeudesmanolide to an eudesm-5,7(11)-dienolide has been reported.[439]

The synthesis of deuterium-labelled eudesmanolides, starting from lactones isolated from *Inula helenium*, has been described.[440] The partial syntheses of 7β-hydroxyeudesmanolide,[442] erivanin, and 1-*epi*-erivanin[443] has been reported. The syntheses of artepaulin, tuberin, oopodin, and vulgarin derivatives, starting from α-santonin, has been reported.[444] The sesquiterpene lactone costunolide has been used in an efficient partial synthesis of several eudesmanolides.[445] A synthesis of (+)-colartin and (+)-arbusculin together with their C-4 epimers has been devised, and the plant growth regulating activity of these lactones has been studied.[446] A novel approach towards the stereocontrolled synthesis of eudesmanolides has been developed following a quasi-biomimetic strategy starting from a functionalised oxabicyclic template, by which the first total syntheses of gallicadiol and isogallicadiol were achieved.[447] Another lactone, **722**, has been synthesised as a racemate,[448] which implied a revision of the structure previously assigned.[449] An enantioselective synthesis of (+)-decipienin A has been achieved.[450] The syntheses, using free-radial chemistry, of (+)-3α-hydroxyreynosin, (+)-reynosin and (+)-11β,13-dihydroreynosin, starting from 1,10-epoxy-11β,13-dihydrocostunolide, have been accomplished.[451]

The syntheses of dehydrobrachylaenolide, isodehydrochamaecynone and *trans*-isodehydrochamaecynone, starting from tuberiferine, have been reported. Eudesmanolides possessing an α-methylene-γ-lactone moiety, such as dehydrobrachylaenolide, exhibited significant inhibitory activity toward the induction of the intercellular adhesion molecule-1 (ICAM-1).[452] The total synthesis[453] of (+)-decipienin A **721** has been carried out, confirming the stereochemistry proposed by the Czech authors[454] and correcting the original structure.[455] (+)-Stoebenolide has been prepared starting from (+)-salonitenolide.[456] A short synthesis of the sesquiterpene lactone 1-oxoeudesma-2,4-dien-11β-hydro-12,6α-olide has been achieved,[457] and a synthesis of 11β-angeloyloxy-α-santonin has been devised. In this work, the X-ray structure of 11β-hydroxy-α-santonin was described.[458] The partial synthesis of 6β-eudesmanolides and 6β-guaianolides from 6α-eudesmanolides has been reported,[459] and a synthesis of the reported structure of herbolide I has been devised, showing that the assigned structure is erroneous.[460]

A short synthesis of (+)-colarin and (+)-arbusculin, starting from α-santonin, has been accomplished.[461] The syntheses of the eudesmanolides torrentin and dihydrosantamarine, and the elemanolide saussaurea lactone have been reported,[462] and a synthetic strategy whereby 6β-eudesmanolide isomers are converted into the 6α-analogues in modest yield has been developed.[463] Artemisin has been used as the starting material in the preparation of herbolide E, showing that the previously proposed structure for this compound must be revised.[464] Syntheses of 4α,5α- and 4β,5β-epoxy-eudesmanolides[465] and the bioactive lactones (−)-arbusclin D **529** and (−)-*epi*-arbusclin D have been reported.[323] A formal synthesis of (−)-α-santonin has been achieved using an optically active key intermediate, prepared by asymmetric hydrolysis of its racemate.[466] Santonin and other sesquiterpene lactones react with pyrrolidine at room temperature to afford γ-hydroxyalkylamides,[467] and the unexpected selective formation of a δ-lactone after the ozonolysis of a santonin derivative has been reported.[468]

A first total synthesis of (±)-diplophyllin has been devised,[469] and a highly stereoselective synthesis of ivangulin has been achieved.[470] A modified synthesis of racemic occidentaol has been reported,[471] as well as the synthesis and *in vitro* activity of 3-hydroxyencelin.[425] An easy route to racemic 11-hydroxy-eudesmanolides, such as decipienin A, has been described,[472] and short syntheses of dehydroisoerivanin, isoerivanin, ludovicin C and 1α,3α-dihydroxyarbusculin B have been described.[473] (−)-α-Santonin has been used as starting material in the synthesis of phytuberin,[474] and other studies towards the biomimetic synthesis of these sesquitepene lactones have been described.[475] Syntheses of (−)-isobaimuxinol and (−)-baimuxinol have been reported,[476,477] and cytotoxic α-aminomethyl-substituted eudesmanolides have been prepared by stereoselective Michael-type addition of amines to alantolactone and isoalantolactone.[478]

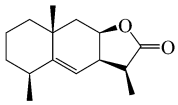
3.7.2 Eudesmane-12,8-olides. The new eudesmane-12,8-olides **744–917** and their plant sources are summarised in Table 9. Single crystal X-ray diffraction analysis has been used to establish the structures of sesquiterpene lactones **849**, **850** and **851**[522] obtained from *Steiractinia*, the telekin epimers **769** and **887**,[538] as well as isogallicadiol,[543] gazanniolide[544] and compound **813**.[508] The structure of eudesmanolide, isolated from *Lasiolanea santosii*[503] and *Mikania goyazensis*,[504] has been revised to **797**,[545] and the stereochemistry of septuplinolide **761** has been revised, correcting the stereochemistry of the 4-OH group from β to α.[490]

Inunal **745** and isoalloalantolactone **897** are biologically active as plant growth regulators, promoting the formation of adventitious roots.[481] The biotransformation of pyrenthrosin by *Rhizopus nigricans* has been investigated to generate eudesmanolide-type metabolites, which exhibited cytotoxic, antifungal, and antiprotozoal activities.[546]

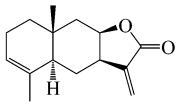
The chemical and microbiological transformation of (−)-α-santonin into 8-*epi*-artemisin has been carried out,[441] and the synthesis of 8-*epi*-ivangustin and 8-*epi*-isoivangustin starting from santonin has been explored.[444] The synthesis of deuterium-labelled eudesmanolides, starting from lactones isolated from *Inula helenium*, has also been described.[547] A partial synthesis

Table 8 Sources of eudesmane-12,6-olides

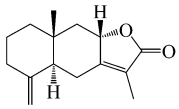
Sources	Compounds
Anthemis carpatica	**583**–**586**[345]
Arctotheca calendula	**703**[247]
Argyranthemum foeniculaceum	**697**[380]
Artemisia afra	**643**[136]
Artemisia caerulescens	**488**, **489**,[134] **669**[211,366]
Artemisia caerulescens subsp. *gallica*	**709**[387]
Artemisia caerulescens var. *cretacea*	**433**[280]
Artemisia canariensis	**532**, **575**, **704**, **705**,[325] **727**[393]
Artemisia cretacea	**698**[381]
Artemisia diffusa	**437**, **710**[283]
Artemisia fragrans	**438**,[285] **475**[304]
Artemisia giraldii	**706**[385]
Artemisia gracilescens	**698**[382]
Artemisia herba-alba	**469**, **481**, **492**, **493**,[218] **424**, **426**, **440**, **470**, **471**, **699**,[198] **490**, **491**,[161] **700**, **701**, **718**–**720**, **732**, **734**, **735**, **738**–**740**,[383] **427**, **476**,[272] **429**, **434**, **436**, **484**,[276] **432**,[279] **487**,[309] **494**–**497**,[310] **514**,[319] **656**[361]
Artemisia hugueti	**435**, **437**, **510**, **515**–**523**, **611**[282]
Artemisia ifranensis	**606**[282]
Artemisia inculta	**512**[317]
Artemisia judaica	**480**, **486**, **642**, **707**,[305] **708**, **736**,[386] **737**[394]
Artemisia lehmanniana	**524**, **525**[321]
Artemisia lehmannianoda	**442**[288]
Artemisia lerchiana	**592**, **631**[348]
Artemisia leucotricha	**514**[320]
Artemisia lucentica	**425**, **593**[273]
Artemisia ludoviciana	**576**[342]
Artemisia maritima	**483**,[307] **547**, **661**, **715**[333]
Artemisia nitrosa	**509**[315]
Artemisia pauciflora	**697**[379]
Artemisia pontica	**607**, **612**, **613**[351]
Artemisia rutifolia	**439**[227]
Artemisia salina	**441**[87]
Artemisia santolinifolia	**713**[390]
Artemisia santonicus	**714**, **733**[391]
Artemisia spicigera	**437**[284]
Artemisia splendens	**434**[281]
Artemisia tenuisecta	**657**[362]
Artemisia tournefortiana	**696**[211]
Athanasia calva	**569**, **572**[340]
Bartlettina karwinskiana	**658**[363]
Bishopanthus soliceps	**614**, **615**[353]
Calea trichomata	**542**, **545**, **632**, **650**,[331] **647**[359]
Calostephane divaricata	**630**, **652**–**654**, **663**[355]
Cassinia subtropica	**558**, **635**[16]
Cassinia uncata	**463**, **464**, **537**, **538**, **540**, **574**, **602**, **604**, **616**–**618**, **625**, **730**[16]
Centaurea aspera	**672**, **679**[368]
Centaurea attica	**687**[241]
Centaurea deusta	**694**[378]
Centaurea granata	**681**[369]
Centaurea malacitana	**686**, **741**[373]
Centaurea ornata	**432**[278]
Centaurea spinosa	**687**, **688**, **689**, **695**[374]
Centaurea thessala	**685**[241,372]
Centaurea tweediei	**691**[257]
Centaurea zuccariniana	**693**[377]
Chamaemelum fuscatum	**550**, **551**, **645**, **646**, **716**, **717**,[335] **640**, **641**, **648**, **649**[358]
Cratystylis conocephala	**633**[215]
Decachaeta ovatifolia	**562**, **563**[338]
Dendroseris neriifolia	**468**[299]
Dicoma macrocephala	**466**[298]
Dimerostemma asperatum	**662**[337]
Dimerostemma bishopii	**553**–**556**[337]
Disynaphia multicrenulata	**590**[347]
Echinops spinosissimus	**440**[286]
Eupatorium semialatum	**587**–**589**, **598**–**600**,[346] **595**–**597**[349]
Geigeria rigida	**452**, **453**, **456**, **534**, **560**[217]
Grangea maderaspatana	**485**[308]
Greenmaniella resinosa	**536**, **541**, **651**, **728**, **729**[328]
Gutenbergia cordifolia	**726**[294]
Helipterum roseum	**619**–**624**, **626**[354]
Hieracium intybaceum	**461**, **467**[295]
Inula graveolens	**460**, **724**[293]
Inula salsoloides	**511**[316]
Ixeris dentata	**465**[297]
Ixeris repens	**477**, **478**, **601**, **603**, **627**[108]
Laser trilobum	**482**,[306] **506**, **507**[314]
Leucanthemopsis actinata	**429**[275]
Liabum floribundum	**712**[389]
Liatris laevigata	**565**–**567**,[339] **629**[239]
Mikania guaco	**552**,[336] **564**, **644**[336]
Montanoa frutescens	**636**–**639**[357]
Montanoa hibiscifolia	**671**, **673**, **674**, **731**[367]
Onopordon myriacanthum	**692**[376]
Onopordum ambiguum	**690**[375]
Onorpordon tauricum	**684**, **742**[371]
Pegolettia oxydonta	**534**, **560**[8]
Pegolettia senegalensis	**444**–**449**, **534**[289]
Perymenium mendezii	**455**[290]
Picris aculeata	**462**, **480**, **486**[296]
Picris spinifera	**711**[388]
Pluchea dioscoridis	**504**, **548**, **666**–**668**,[312] **549**,[334] **594**,[49] **665**[312,365]
Podochaenium eminens	**531**[324]
Pyrethrum santolinoides	**605**[350]
Ratibida latipalearis	**659**[364]
Schistostephium crataegifolium	**538**[206]
Schistostephium heptalobum	**454**, **546**[206]
Schistostephium rotundifolium	**450**[206]
Senecio chrysanthemoides	**505**, **508**[313]
Sonchus asper	**472**, **473**, **527**, **680**, **683**[301]
Sonchus macrocarpus	**474**, **526**,[302] **682**[370]
Sonchus oleraceous	**430**, **431**, **451**[277]
Sphaeranthus indicus	**428**, **458**, **462**,[274] **457**,[291] **498**,[166] **513**,[318] **573**,[341] **582**, **664**,[131] **608**–**610**[352]
Sphaeranthus suaveolens	**459**, **499**, **568**, **570**, **571**[292]
Squmoappus skutchii	**539**[329]
Stevia aff. *tomentosum*	**500**–**502**[311]
Stevia alpina	**580**, **581**[344]
Stevia breviaristata	**578**[343]
Tanacetum ferulaceum	**528**[322]
Tanacetum parthenium	**540**,[330] **579**, **591**, **670**,[228] **725**[253]
Tanacetum vulgare	**723**[392]
Taraxacum hallaisanensis	**479**, **530**[303]
Taraxacum linearisquameum	**533**, **577**[326]
Tithonia diversifolia	**634**,[356] **655**[360]
Tithonia rotundifolia	**543**, **544**, **557**, **559**, **561**[332]
Ursinia abrotanoides	**628**[3]
Vladimiria souliei	**469**, **503**[300]
Zexmenia lantanifolia	**535**[327]



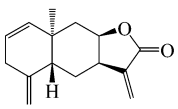
744



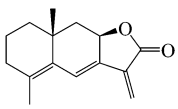
745



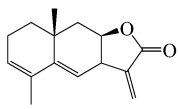
746



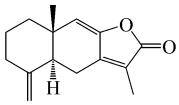
747



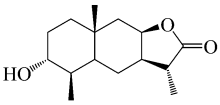
748



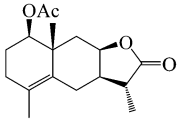
749



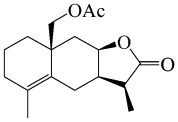
750



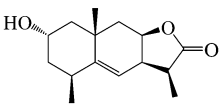
751



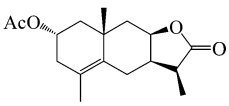
752



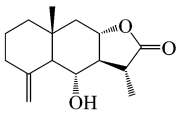
753



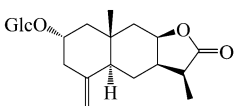
754



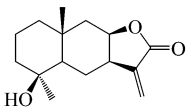
755



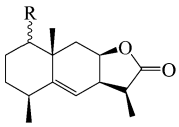
756



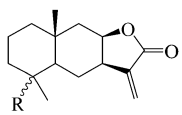
757



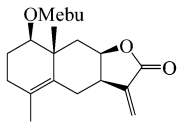
758



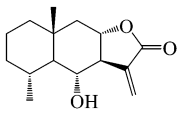
759 R = α-OH
760 R = β-OH



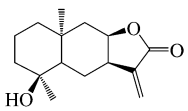
761 R = α-OH
762 R = α-OAc
763 R = β-OAc



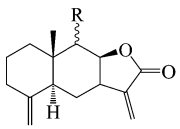
764



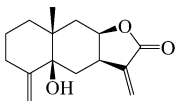
765



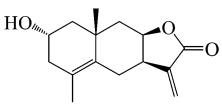
766



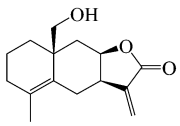
767 R = α-OH
768 R = β-OH



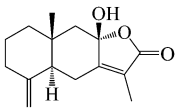
769



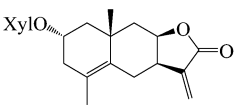
770



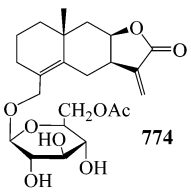
771



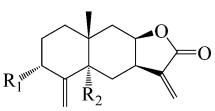
772



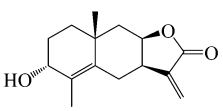
773



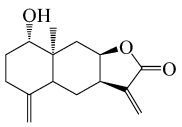
774



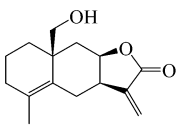
775 R_1 = OH, R_2 = H
776 R_1 = H, R_2 = OH



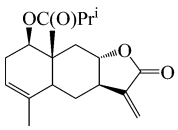
777



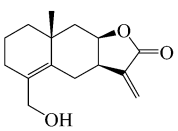
778



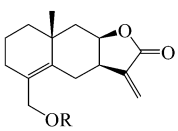
779



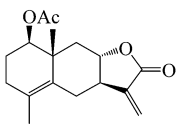
780



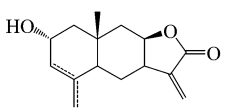
781



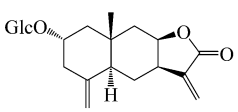
782 R = H
783 R = Ac
784 R = *trans*-Cinn
785 R = *cis*-Cinn



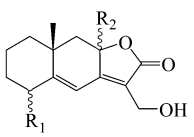
786



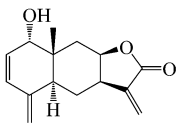
787 $\Delta^{3(4)}$
788 $\Delta^{4(15)}$



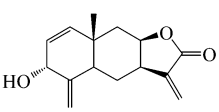
789



790 R_1 = α-Me, R_2 = β-H
791 R_1 = β-Me, R_2 = α-H



792



793

794

795

796

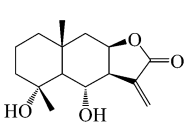
797

798

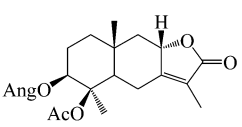
799

800 R = Ac
801 R = H

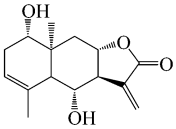
802



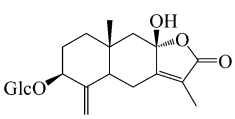
803



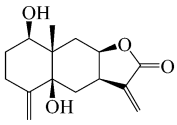
804



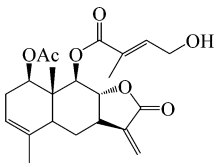
805



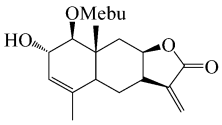
806



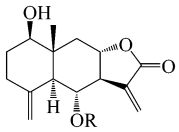
807



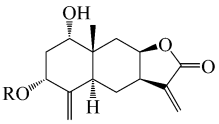
808



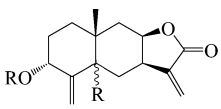
809



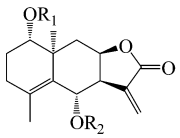
810 R = Sen
811 R = Meacr
812 R = Ang
813 R = C(O)Pr^{i}



814 R = Mebu
815 R = C(O)Pr^{i}

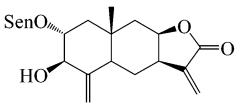


816 R = α-OH
817 R = β-OH

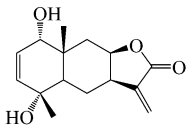


818 R_1 = H, R_2 = Tig
819 R_1 = H, R_2 = Ang

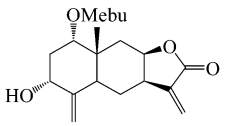
820 R_1 = H, R_2 = Meacr
821 R_1 = Ac, R_2 = Meacr
822 R_1 = Ac, R_2 = Tig
823 R_1 = Ac, R_2 = iBu
824 R_1 = Ac, R_2 = Val^{i}



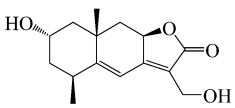
825



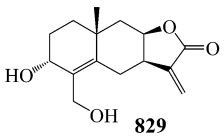
826



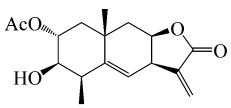
827



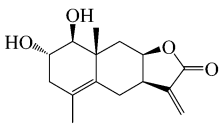
828



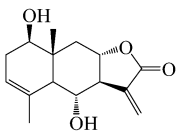
829



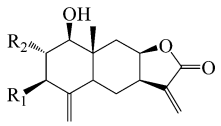
830



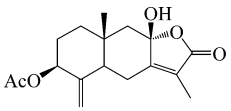
831



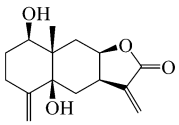
832



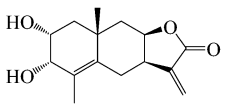
833 R_1 = H, R_2 = OH
834 R_1 = H, R_2 = OGlc (6'-OAc)
835 R_1 = OAc, R_2 = H



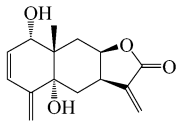
836



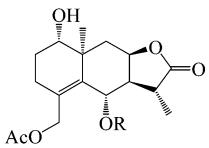
837



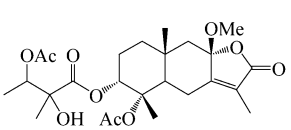
838



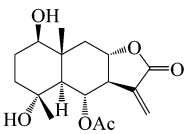
839



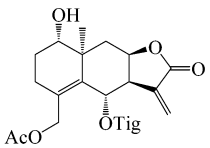
840 R = Tig
841 R = Ang



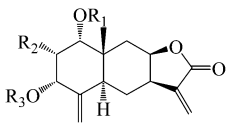
842



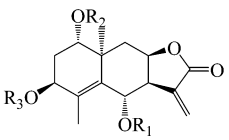
843



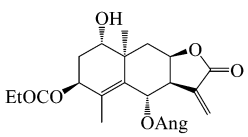
844



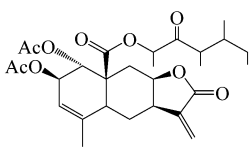
845 R_1 = H, R_2 = OH, R_3 = Mebu
846 R_1 = Ac, R_2 = OH, R_3 = Mebu
847 R_1 = H, R_2 = OMebu, R_3 = H
848 R_1 = Ac, R_2 = OMebu, R_3 = Ac



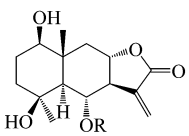
849 R_1 = Tig, R_2 = H, R_3 = Ac
850 R_1 = Tig, R_2 = Ac, R_3 = H
851 R_1 = Tig, R_2 = Ac, R_3 = Ac



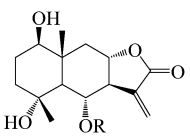
852



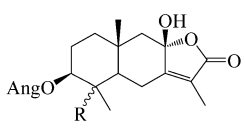
853



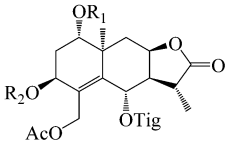
854 R = Ang
855 R = Sen
856 R = Meacr
857 R = Tig



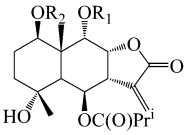
858 R = H
859 R = Tig
860 R = OC(O)Pr^{i}



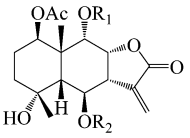
861 R = α-OH
862 R = β-OAc



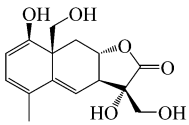
863 R_1 = H, R_2 = Ac
864 R_1 = Ac, R_2 = H



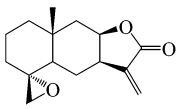
865 R_1 = Ang, R_2 = H
866 R_1 = Tig, R_2 = H



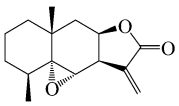
867 R_1 = H, R_2 = C(O)Pr^i
868 R_1 = H, R_2 = Meacr
869 R_1 = Ac, R_2 = C(O)Pr^i
870 R_1 = Ac, R_2 = Meacr
871 R_1 = C(O)Pr^i, R_2 = Ac
872 R_1 = Ac, R_2 = C(O)Pr^i



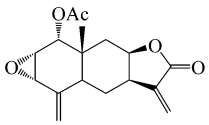
873



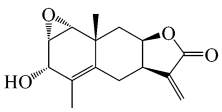
874



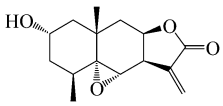
875



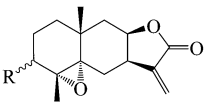
876



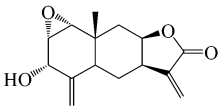
877



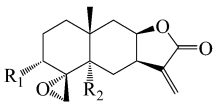
878



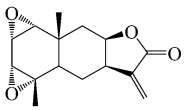
879 R = α-OH
880 R = β-OH



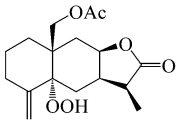
881



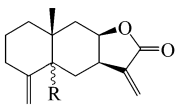
882 R_1 = OH, R_2 = H
883 R_1 = H, R_2 = OH



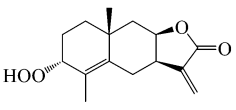
884



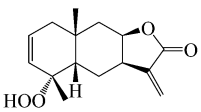
885



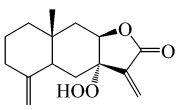
886 R = α-OOH
887 R = β-OOH



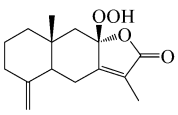
888



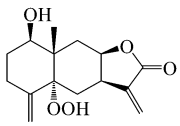
889



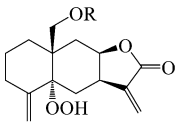
890



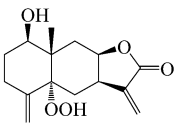
891



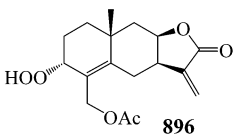
892



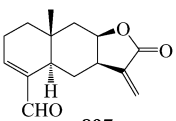
893 R = H
894 R = Ac



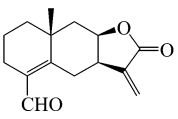
895



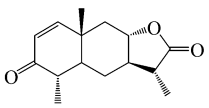
896



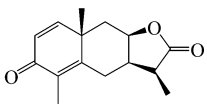
897



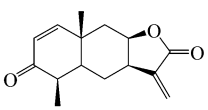
898



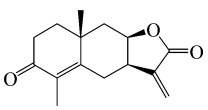
899



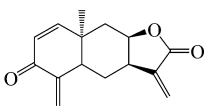
900



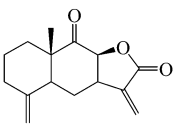
901



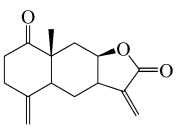
902



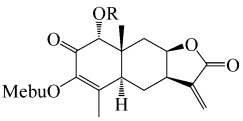
903



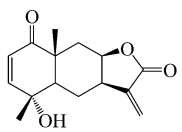
904



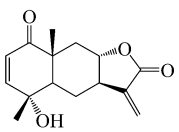
905



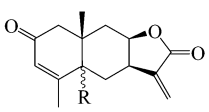
906 R = H
907 R = Ac



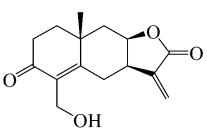
908



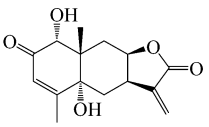
909



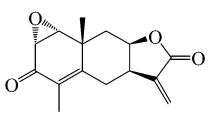
910 R = α-OH
911 R = β-OH



912



913



914

915

916

917

Table 9 Sources of eudesmane-12,8-olides

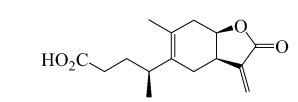
Sources	Compounds
Ambrosia artemisioides	**782**, **783**, **784**, **785**, **829**, **874**, **879**, **896**, **912**[38]
Anthemis altissima	**805**[506]
Artemisia argyi	**762**, **763**[491]
Artemisia feddei	**884**, [536]**915**[542]
Artemisia iwayomogi	**745**, **775**–**777**, **816**, **817**, **879**, **880**, **888**, **889**, **902**[280]
Artemisia umbelliformis	**886**, **887**[537]
Artemisia xerophytica	**826**[512]
Aspilia pluriseta	**849**–**851**[522]
Atractylodes japonica	**746**, **750**, **772**,[107] **806**[507]
Atractylodes macrocephala	**836**,[519] **891**[539]
Bahia absinthifolia	**774**[497]
Blumea afrakiana	**827**[513]
Blumea densiflora	**814**, **815**, **845**–**848**, **906**, **907**[509]
Calea septuplinerva	**761**,[490] **758**[488]
Calea subcordata	**780**,[498] **813**,[508] **909**[541]
Carpesium cernuun	**791**[501,502]
Carpesium macrocephalum	**755**, **800**, **801**,[485] **757**, **789**,[487] **755**, **795**[486]
Cassinia subtropica	**843**[16]
Eriocephalus africanus	**837**, **885**, **892**–**895**[202]
Eriocephalus pauperrimus	**771**, **807**[202]
Eriocephalus scariosus	**752**–**753**, **779**[202]
Ferreyranthus fruticosus	**792**, **793**, **839**, **877**, **881**, **884**, **900**, **908**, **913**, **914**, **916**[251]
Flourensia macrophylla	**767**, **768**, **904**, **905**[204]
Flourensia riparia	**766**[494]
Gnephosis arachnoidea	**786**, **831**[500]
Gochnatia vernonioides	**857**[525]
Greenmaniella resinosa	**910**, **911**[328]
Guizotia scabra	**876**[533]
Hyaloseris salicifolia	**833**, **834**[517]
Inula britannica	**803**[505]
Inula caspica	**825**[511]
Inula japonica	**760**[231]
Inula macrophylla	**744**, **873**,[479] **744**,[480] **790**, **799**[479]
Inula montana	**835**[518]
Inula racemosa	**745**,[481] **748**, **749**,[483] **781**, **874**, **875**, **898**,[499] **882**, **883**, **890**,[535] **897**[481]
Inula thapsoides	**759**, **760**, **798**[489]
Lasiolanea santosii	**797**[503]
Mikania cynanchifolia	**917**[551]
Mikania goyazensis	**797**[504]
Ondetia linearis	**754**, **787**, **788**, **796**[109]
Pegolettia oxydonta	**808**[8]
Perymenium featherstonei	**901**[243]
Pluchea dioscordis	**773**[496]
Pluchea quitoc	**804**, **861**, **862**[101]
Pulicaria crispa	**878**[534]
Pulicaria undulata	**770**, **828**[495]
Schistostephium crataegifolium	**810**–**813**, **854**–**856**[206]
Senecio flammeus	**853**[524]
Spilanthes acmella	**899**[540]
Spilanthes leiocarpa	**747**[482]
Stevia achalensis	**751**, **778**, **903**[484]
Tanacetopsis mucronata	**832**[515]
Tanacetum argenteum	**859**[527]
Tanacetum densum	**832**,[516] **837**,[520] **858**[526]
Tanacetum ferulaceum	**756**, **794**,[322] **765**[493]
Tanacetum parthenium	**859**[529]
Tessaria ambigua	**842**[138]
Vicoa pentanema	**830**, **838**[514]
Wedelia grandiflora	**818**–**824**[510]
Wedelia hispida	**863**, **864**[528]
Wedelia paludosa	**871**, **872**[532]
Wedelia pinetorum	**840**, **841**, **844**[521]
Wedelia prostata	**867**–**870**[531]
Wedelia prostrata	**865**, **866**[530]
Wunderlichia mirabilis	**764**, **802**, **809**[492]
Zexmenia virgulata	**852**[523]

of (+)-ivalin has been achieved,[423] and a general procedure for the synthesis of both 12,6- and 12,8-eudesmanolides has been described.[548] Partial syntheses of (+)-isoalantolactone and (+)-isoalloalantolactone have been devised,[549] and the synthesis of (−)-dehydrobaimuxinol has been reported.[550]

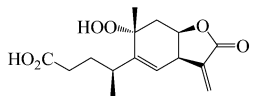
4 Secoeudesmanes

4.1 1,10-Secoeudesmanes

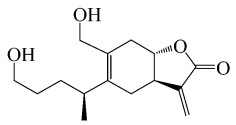
1,10-Secoeudesmanes **918** and **919** have been found in *Gnephosis arachnoidea.*[500] Metabolite **920** has been isolated from *Calostephane divaricata*,[355] **921** and **923** have been identified from *Inula britannica*,[552] and the secoeudesmanes **922**, **925** and **926** have been found in *Inula japonica.*[553] Compound **924** has been isolated from *Artemisia hugueti*,[282] **927**–**929** have been found in *Inula britannica*,[554] and **930** has been isolated from *Solidago gigantea.*[129]



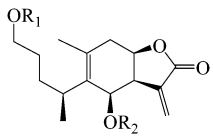
918



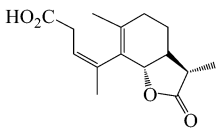
919



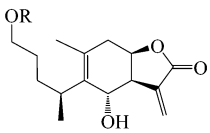
920



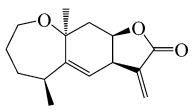
921 $R_1 = R_2 = H$
922 $R_1 = Ac$, $R_2 = H$
923 $R_1 = Ac$, $R_2 = Ac$



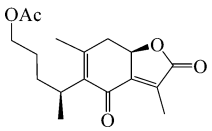
924



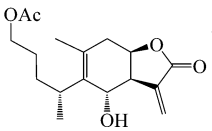
925 R = H
926 R = Ac



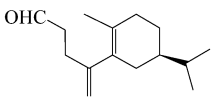
927



928



929

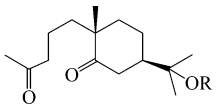


930

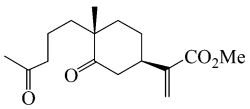
Studies on the semi-synthesis, structure determination and biotransformation of cyclic sulfinated eudesmane derivatives have been described.[555] The structures of deacetylinulicin and inulicin, two secopseudoguaianolides extracted from *Inula japonica*, have been revised to the secoeudesmanolides **921** and **922** repectively.[552,553] An enantioselective synthesis of the 1,10-*seco*-eudesmanolides eriolanin and eriolangin has been achieved.[556]

4.2 4,5-Secoeudesmanes

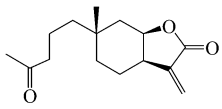
4,5-Secoeudesmanolide **935**[480] has been identified from *Inula macrophylla.* The diketone eudesmanes **931**,[202] **932**,[7] **933**[108] and **934**[3] have been found in *Eriocephalus africanus*, *Iphiona scabra*, *Ixeris repens* and *Ursinia eckloniana*, respectively. 6,7-Secoeudesmane, (−)-α-eudesmol[557] and 7-*epi*-γ-eudesmol[558] have been described, and a racemic synthesis of balanitol has been reported.[69] The enantioselective total syntheses of chrysanthemol,[559,560]



931 R = H
932 R = Xyl
933 R = Xyl(2'-OAc)



934

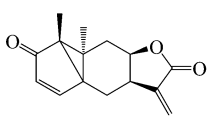


935

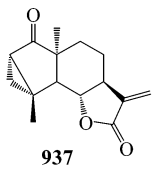
4,5-dioxo-*seco*-γ-eudesmol, 5β,11-dihydroxyiphionan-4-one[561] and the secoeudesmane glutinone,[320,562] have been reported. The total syntheses of 4,5-secoeudesmane-type sesquiterpenes, such as 4,5-dioxo-10-*epi*-4,5-seco-γ-eudesmane and 4,5-dioxo-10-*epi*-4,5-seco-γ-eudesmanol, have also been reported.[563]

5 Cycloeudesmanes and isomeric eudesmanes

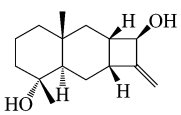
The cycloeudesmanes are few in the Asteraceae family. For example, the methyl-transferred 1,5-cycloeudesmane **936** has been identified from *Ferreyranthus fruticosus*[251] and 2,4-cycloeudesm-12,6-olide **937**, the structure of which was confirmed by X-ray analysis, is a constituent of *Ratibida latipalearis*.[564,565] 8,12-Cycloeudesmene **938** has been isolated from *Jasonia candicans*,[34] 6,8-cycloeudesmene **939** has been identified from *Solidago gigantea*,[129] and 2,4-cycloeudesm-12,8-olide **940** is a constituent of *Ondetia linearis.*[109] The isomeric eudesma-13-acids **941**[566] and **942**[360] have been found in *Tithonia diversifolia*, and **943**–**947** were obtained from *Inula macrophylla.*[480]



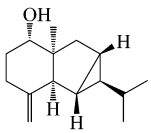
936



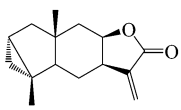
937



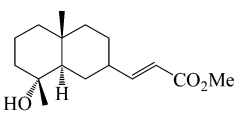
938



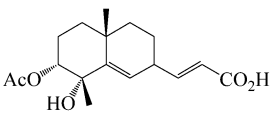
939



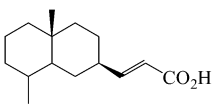
940



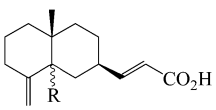
941



942



943 Δ $^{4(5)}$
944 4α,5α-epoxy
945 4β,5β-epoxy

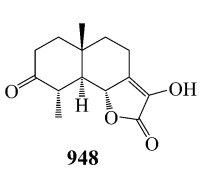


946 R = α-OH
947 R = β-OH

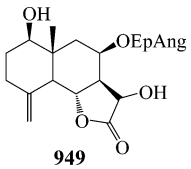
6 Noreudesmanes

15-Noreudesmanes **950** and **951** are elaborated by *Parthenium argentatum*,[137] and eudesmanes **952** and **958** have been isolated from *Apalochlamys spectabilis*[197] and *Microliabum polymniodes*[384] respectively. Sesquiterpene **959** has been elucidated from *Onopordon ambigum,*[256] and compound **957** is a constituent of *Erigeron annuus.*[39] A stereoselective synthesis of the norsesquiterpene platyphyllide has been achieved.[567]

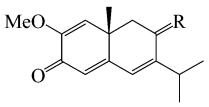
14-Noreudesmanes **953**, **954**[568] and **956**[133] have been identified from *Ligularia dentata*, and **955** has been isolated from *Senecio gilliesianus.*[569] The 13-noreudesmanes **948** and **949** have been found in *Crepis pygmaea*[570] and *Tithonia pedunculata*,[571] respectively. The norsesquiterpenolide **948** has been synthesised from α-santonin.[572] Di-noreudesmane **960** has been isolated from *Jasonia montana*,[48] and trinoreudesmanes **961** and **962** have been found in *Pluchea arguta*[252] and *Rebutia marsoneri*,[573] respectively. A practical synthesis of enantiomerically pure (−)-geosmin has been achieved,[574] and the eudesmane sesquiterpene (+)-dehydrogeosmin **962** has been prepared by synthesis.[575] The biosynthesis of the trinorsesquiterpene geosmin in a *Streptomyces* species and also in the liverwort *Fossombronia pusilla* has been investigated. This work revealed that the bacterium produces geosmin *via* 1-deoxy-D-xylose, whilst the liverwort uses the mevalolactone pathway.[576] An efficient procedure for creating precise gene replacements in *Streptomyces coelicolor* has permitted the identification of a protein domain required for the biosynthesis of the trinorsesquiterpene geosmin,



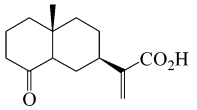
948



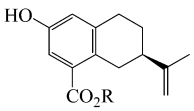
949



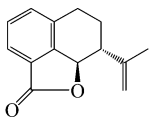
950 R = H_2
951 R = O



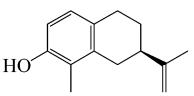
952



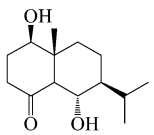
953 R = Me
954 R = Et



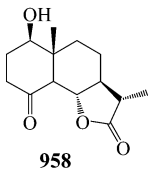
955



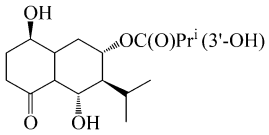
956



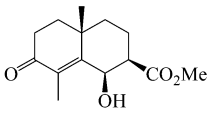
957



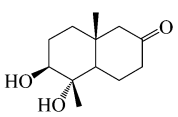
958



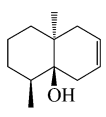
959



960



961



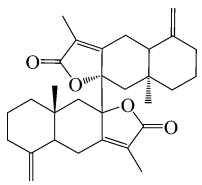
962

the metabolite responsible for the musty-earthy odour of soil.[577] Moreover, the expression and mechanistic analysis of a germacradienol synthase from this *Streptomyces* species, implicated in the biosynthesis of geosmin, has been described.[578] The quantitative determination of this norsesquiterpene in red beets and wheat grain[579] has also been reported.

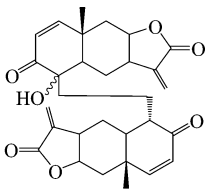
7 Dimers

7.1 Dieudesmanes

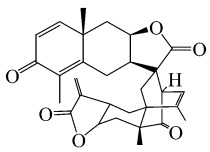
The bis-sesquiterpene biatractylode **963** has been found in an extract of the Chinese medicinal herb *Atractylodes macrocephala.*[580,581] A biomimetic synthesis of the bis-sesquiterpenes biatractylolide and biepiasterolide has been achieved.[582,583] A dimeric eudesmanolide, hydroxyl-bis-dihydroencelin **964**, has been found as a component of the aerial parts of *Montanoa speciosa*,[584] and the structure of 2(11′),5(13′)-dieudesmane **965** from *Ferreyranthus fruticosus* has been elucidated.[251] The structure of the dimeric lactone biatractylolide has been determined by X-ray analysis.[585]



963



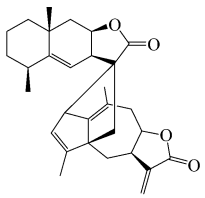
964



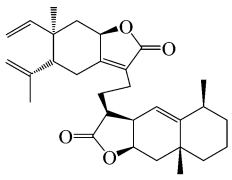
965

7.2 Iso-dimers

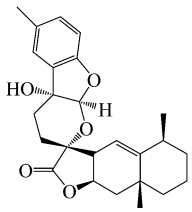
Rudbeckiolide **966**, a new dimeric sesquiterpene lactone with a eudesmane and a guaiane skeleton, has been obtained in low yield from *Rudbeckia laciniata.*[586] Compound **968** and macrophyllidimer A **967** are two novel sesquiterpenes, which have been found in an extract from the bark of *Inula macrophylla.*[587,588] Saussureamines D (**969**) and E (**970**), formed from a eudesmanolide and an alkaloid, have been isolated from *Saussurea lappa.*[589] Two new compounds, **971** and **972**, adducts of a eudesmene lactone with a monoterpene, and of a trinoreudesmane with a monoterpene, have been obtained from *Artemisia herba-alba.*[383]



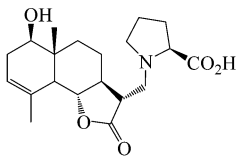
966



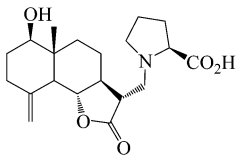
967



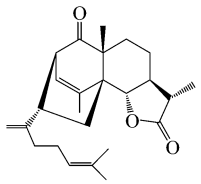
968



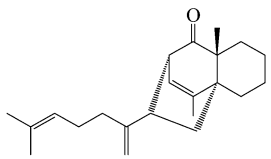
969



970



971



972

8 Conclusions

The Asteraceae family includes many species with a variety of uses, some of which are economically important.[1] The majority of eudesmanolides described in this report were isolated from either the aerial parts or the whole plants, mainly by "traditional' methods, but also by HPLC. The stereochemistry of many compounds was determined conclusively – molecular mechanics methods were also used in a number of cases to calculate conformations and relative stabilities.[590]

The 972 compounds described in this review were isolated from 247 species (of 110 genera), 523 of these compounds belonging to the eudesmanolide group – a field in which Chinese researchers have been very active. The phytochemistry studies were focused on the large genera: *Artemisia*, *Centaurea*, *Inula*, *Pluchea*, *etc.* Our literature search has shown that interest in eudesmanoids from the Asteraceae is decreasing (see Fig. 1), although many researchers are still engaged in this area. For the period 1983–1989, the number of eudesmanes reported from the Asteraceae species was 75% of the number from the other higher plants and marine organisms.

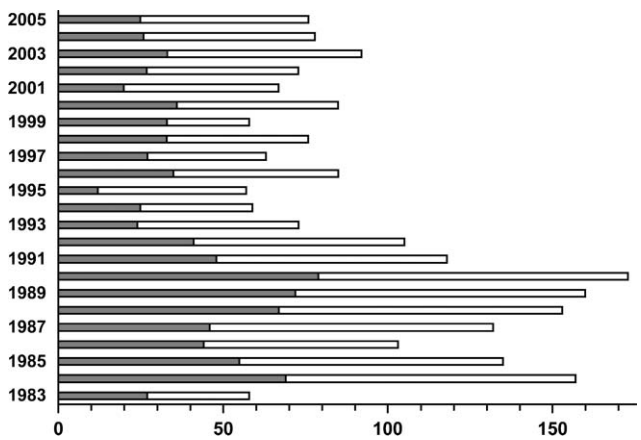


Fig. 1 Distribution of the total number of eudesmanes from 1983 to 2005. The grey part of each bar shows the number of eudesmanes reported from the Asteraceae species. The white part of each bar shows the number of eudesmanes reported from the other higher plants and marine organisms.

For the period 1990–1999, this proportion fell to 65%, and for the period 2000–2005, it fell again to 50%.

In the early years of eudesmanoid research there was less emphasis on biological testing, but increasingly there has been a focus on the biological properties of these compounds. Therefore the starting point for many investigations is the use of plants in traditional medicine, followed by the isolation and biological testing of their active principles. The broad and often very promising biological properties of eudesmanoids are very well known. Studies on the semi-synthesis, total synthesis and biotransformation of eudesmane derivatives have been described and have been increasing in number. Structure–activity relationships of sesquiterpene lactones have also been undertaken.[591] However, systematic structure–activity studies with cell cultures or other biological models, which might give insight into the mechanism of activity of eudesmanoids on the molecular level, seem to be absent. This might be a promising direction in which work in the field of eudesmanoids from the Asteraceae may proceed.

Recently, there has been great interest in the study of chemotaxonomy based on secondary metabolites from the Asteraceae family. In these studies, sesquiterpene lactones, which are used as taxonomic markers, are the most studied class of secondary metabolites. More than 4000 sesquiterpene lactones with around 30 different skeletons have so far been reported from several tribes of Asteraceae,[592] from which it is clear that eudesmanoids are particularly widespread, and have special trends of accumulation in particular Asteraceae tribes and subtribes.[593]

9 Acknowledgements

This work was supported by the Foundation for the "Bairen Jihua" of the Chinese Academy of Sciences (CAS) in 2000, by the National Natural Science Foundation of China (NSFC 20021001, 20372029, and 20475057) and by the Natural Science Foundation of Gansu Province (No. 3ZS051-A25–077).

10 References

1 R. Lin and Y. L. Chen, *Flora Reipublicae Popularis Sinicae*, Science Press, Beijing, 1985, vol. 74, p. 1.
2 X. S. Yao, *Natural Pharmic Chemistry*, Renmin Weisheng, 2001, 222.
3 J. Jakupovic, U. Ganzer, P. Pritschow, L. Lehmann, F. Bohlmann and R. M. King, *Phytochemistry*, 1992, **31**, 863.
4 G. Blay, L. Cardona, B. García, J. R. Pedro and J. J. Sánchez, *Tetrahedron*, 1996, **52**, 10507.
5 G. Blay, R. Schrijvers, J. B. P. A. Wijnberg and Ae. de Groot, *J. Org. Chem.*, 1995, **60**, 2188.
6 A. H. Elmi, M. H. Farah, E. Fattorusso, S. Magno and L. Mayol, *Phytochemistry*, 1987, **26**, 3069.
7 M. G. El-Ghazouly, N. A. El-Sebakhy, A. A. S. El-Din, C. Zedero and F. Bohlmann, *Phytochemistry*, 1987, **26**, 439.
8 C. Zdero and F. Bohlmann, *Phytochemistry*, 1989, **28**, 1949.
9 V. S. P. Chaturvedula, A. Farooq, J. K. Schilling, S. Malone, I. Derveld, M. C. M. Werkhoven, J. H. Wisse, M. Ratsimbason and D. G. I. Kingston, *J. Nat. Prod.*, 2004, **67**, 2053.
10 P. Rharivelomanana, J. P. Bianchini, A. R. P. Ramanoelina, J. R. E. Rasoarahona, R. Faure and A. Cambon, *Phytochemistry*, 1998, **47**, 1085.
11 Y. Zhao, J. Yue, Y. He, Z. Lin and H. Sun, *Phytochemistry*, 1997, **44**, 459.
12 A. San Feliciano, M. Medarde, B. Del Rey, J. M. Miguel del Corral and A. F. Barrero, *Phytochemistry*, 1990, **29**, 3207.
13 J. Jakupovic, M. Grenz, F. Bohlmann, A. Rustaiyan and S. Koussari, *Planta Med.*, 1988, **54**, 254.
14 A. Bianchini, F. Tomi, P. Richomme, A. F. Bernardini and J. Casanova, *Magn. Reson. Chem.*, 2004, **42**, 983.
15 A. A. Ahmed and A. A. S. El-Din, *J. Nat. Prod.*, 1990, **53**, 1031.
16 J. Jakupovic, L. Lehmann, F. Bohlmann, R. M. King and H. Robinson, *Phytochemistry*, 1988, **27**, 3831.
17 A. F. Brrero, M. M. Herrador, J. F. Quilez, R. Alvarez-Manzaneda, D. Portal, J. E. Gabin, D. G. Gravalos, M. S. J. Simmonds and W. M. Blaney, *Phytochemistry*, 1999, **51**, 529.
18 L. K. Sy and G. D. Brown, *Phytochemistry*, 1998, **48**, 1207.
19 P. J. Biju, K. Parmod and G. S. R. S. Rao, *ARKIVOC*, 2003((iii)), 88.
20 J. C. Liao, Q. X. Zhu, X. P. Yang and Z. J. Jia, *J. Chin. Chem. Soc. (Taipei)*, 2002, **49**, 129.
21 Y. Wang, C. S. Yuan, Y. F. Han and Z. J. Jia, *Chin. Chem. Lett.*, 2002, **13**, 1069.
22 Y. Wang, C. S. Yuan, Y. F. Han and Z. J. Jia, *Pharmazie*, 2003, **58**, 349.
23 R. Baker, A. J. Organ, S. A. Walmslley, M. Webster and A. M. R. Galas, *J. Chem. Res. (S)*, 1984, 138.
24 L. Liu, Z. Xiong, F. Nan, T. Li and Y. Li, *Lipids*, 1995, **25**, 1971.
25 D. F. Taber, R. S. Bhamidipati and L. Yet, *J. Org. Chem.*, 1995, **60**, 5537.
26 S. Nagashima, H. Ontsuka, M. Shiro and K. Kanematsu, *Heterocycles*, 1995, **37**, 245.
27 L. Cardona, B. Garcia, J. E. Gimenez and J. R. Pedro, *Tetrahedron*, 1992, **48**, 851.
28 M. Ando, K. Arai, K. Kikuchi and K. Isogai, *J. Nat. Prod.*, 1994, **57**, 1189.
29 S. H. Wu, H. J. Zhang, Z. W. Lin and H. D. Sun, *Phytochemistry*, 1993, **34**, 1176.
30 S. Li and J. Ding, *Yunnan Zhiwu Yanjiu*, 1993, **15**, 303.
31 Y. Zhao, J. Yue, Y. He, Z. Lin and H. Sun, *J. Nat. Prod.*, 1997, **60**, 545.
32 V. U. Ahmad, T. A. Farooqui, A. Sultana, K. Fizza and R. Kharoon, *Phytochemistry*, 1992, **31**, 2888.
33 A. A. Ahmed, H. R. El-Seedi, A. A. Mahmoud, A. E. A. El-Douski, I. F. Zeid and L. Bohlin, *Phytochemistry*, 1998, **49**, 2421.
34 A. A. Ahmed and A. A. Mahmoud, *Tetrahedron*, 1998, **54**, 8141.
35 W. Guo, R. X. Zhu, Y. P. Shi and Z. J. Jia, *Indian J. Chem., Sect. B: Org. Chem. Incl. Med. Chem.*, 1999, **38**, 828.
36 R. Sánchez-Martínez, L. Villaescusa-Castillo, M. Bernabe and A. N. Diaz-Lanza, *Z. Naturforsch., C: Biosci.*, 2000, **55**, 693.
37 T. Ohmoto, K. Ikeda, S. Nomura, M. Shimizu and S. Saito, *Chem. Pharm. Bull.*, 1987, **35**, 2272.
38 J. Jakupovic, M. Jaensch, F. Bohlmann and M. O. Dillon, *Phytochemistry*, 1988, **27**, 3551.
39 X. Li, M. Yang, Y. F. Han and K. Gao, *Planta Med.*, 2005, **71**, 268.
40 F. Bohlmann, N. Ates, R. M. King and H. Robinson, *Phytochemistry*, 1983, **22**, 1675.
41 A. G. González, J. Bermejo-Barrera, A. C. Yanes, J. G. Díaz and E. M. Rodriguez-Pérez, *Phytochemistry*, 1989, **28**, 2520.
42 J. F. Hu, S. P. Bai and Z. J. Jia, *Phytochemistry*, 1996, **43**, 815.
43 V. Castro, J. Jakupovic and F. Bohlmann, *Rev. Latinoam. Quim.*, 1984, **15**, 111.
44 D. Yu and F. Xie, *Yaoxue Xuebao*, 1987, **22**, 837.
45 C. Zdero and F. Bohlmann, *Phytochemistry*, 1989, **28**, 3097.
46 T. Uchiyama, T. Miyase, A. Ueno and K. Usmanghani, *Phytochemistry*, 1991, **30**, 655.
47 S. Yahara, T. Higashi, K. Iwaki, T. Nohara, N. Marubayashi, I. Ueda, H. Kohda, K. Goto and H. Izumi, *Chem. Pharm. Bull.*, 1989, **37**, 2995.
48 A. A. Ahmed and J. Jakupovic, *Phytochemistry*, 1990, **29**, 3658.
49 A. A. Mahmoud, *Phytochemistry*, 1997, **45**, 1633.
50 A. G. Gonzaiez, J. Bermejo-Barrera, J. Triana-Mezzez, M. López-Sánchez and J. L. Eiroa-Martínez, *Phytochemistry*, 1992, **31**, 1816.
51 P. Pritschow, J. Jakupovic, F. Bohlmann, M. Bittner and H. M. Niemeyer, *Phytochemistry*, 1991, **30**, 893.
52 K. Ohmura, T. Miyase and A. Ueno, *Phytochemistry*, 1989, **28**, 1919.
53 M. Yoshikawa, T. Morikawa, T. Murakami, I. Toguchida, S. Harima and H. Matsuda, *Chem. Pharm. Bull.*, 1999, **47**, 340.
54 K. Gao and Z. J. Jia, *Chem. Res. Chin. Univ.*, 1999, **15**, 70.
55 K. Gao and Z. J. Jia, *J. Chin. Chem. Soc. (Taipei)*, 1999, **46**, 619.
56 E. Fattorusso, F. U. Santelia, G. Appendino, M. Ballero and O. Taglialatela-Scafati, *J. Nat. Prod.*, 2004, **67**, 37.
57 B. M. Fraga, M. G. Hernandez, T. Mestrez, T. Mestres, J. M. Arteaga and A. Perales, *Phytochemistry*, 1993, **34**, 1083.
58 C. C. Wang, L. G. Chen and L. L. Yang, *Planta Med.*, 2002, **68**, 204.

59 L. Pous, R. Carrizo, O. Donadel, M. K. Sanz and E. Guerreiro, *Nat. Prod. Lett.*, 1998, **12**, 231.
60 R. Carrizo, C. Tonn and E. Guerreiro, *Nat. Prod. Lett.*, 1998, **12**, 271.
61 A. García-Granados, M. C. Gutiérrez, A. Parra and F. Rivas, *J. Nat. Prod.*, 2002, **65**, 1011.
62 G. Mehta and R. S. Kumaran, *Tetrahedron Lett.*, 2003, **44**, 7055.
63 Z. Xiong, G. Zhou, J. Yang, Y. Chen and Y. Li, *Tetrahedron: Asymmetry*, 1998, **9**, 1525.
64 Y. Chen, Z. Xiong, G. Zhou, L. Liu and Y. Li, *Tetrahedron: Asymmetry*, 1998, **9**, 1923.
65 Y. Chen, Z. Xiong, G. Zhou, J. Yang and Y. Li, *Chem. Lett.*, 1997, 1289.
66 J. Yang, Z. Xiong, Y. Chen and Y. Li, *Synth. Commun.*, 1997, **27**, 2985.
67 J. Chen and J. N. Marx, *Tetrahedron Lett.*, 1997, **38**, 1889.
68 H. J. Liu and D. Sun, *Tetrahedron Lett.*, 1997, **38**, 6159.
69 Z. Zhang, W. D. Z. Li and Y. L. Li, *Org. Lett.*, 2001, **3**, 2555.
70 B. Frey, J. Schnaubelt and H. U. Reiβig, *Eur. J. Org. Chem.*, 1999, 1385.
71 R. B. Mane and A. J. Kadam, *Collect. Czech. Chem. Commun.*, 1999, **64**, 533.
72 T. L. Ho and Y. J. Lin, *J. Chem. Soc., Perkin Trans. 1*, 1999, 1207.
73 H. J. Liu and D. Sun, *Heterocycles*, 2000, **52**, 1251.
74 J. C. Chen, G. J. Zheng, C. Zhang, L. J. Fang and Y. L. Li, *Chin. J. Chem.*, 2003, **21**, 904.
75 H. B. Wang, H. P. Zhang, Y. Zhou, J. P. Zuo and G. W. Qin, *J. Nat. Prod.*, 2005, **68**, 762.
76 M. Martinez, A. Romo de Vivar, A. Ortega, M. de Lourdes Quintero, C. García and F. R. Fronczek, *Phytochemistry*, 1983, **22**, 979.
77 M. Ono, C. Masuoka, Y. Odake, Y. Ito and T. Nohara, *Phytochemistry*, 2000, **54**, 479.
78 A. A. Ahmed, B. A. A. Balboul, A. 1. Scott, H. H. Williams, B. Miao and T. J. Mabry, *Phytochemistry*, 1998, **47**, 411.
79 M. B. Izbosarov, I. M. Yusopova, B. K. Abduazimov, B. Tashkhodzhaev, A. Vdovin and N. D. Abdullaev, *Chem. Nat. Compd.*, 1998, **34**, 289.
80 S. Li, J. Ding and B. Na, *Phytochemistry*, 1998, **49**, 2035.
81 A. A. Ahmed, J. Jakupovic and F. Bohlmann, *Phytochemistry*, 1990, **29**, 3355.
82 T. Miyase, H. Ozaki and A. Ueno, *Chem. Pharm. Bull.*, 1991, **39**, 937.
83 A. F. Barrero, R. Alvarez-Manzaneda, J. F. Quilez and M. M. Herrador, *Phytochemistry*, 1998, **48**, 807.
84 J. Yue, Z. Lin, D. Wang and H. Sun, *Phytochemistry*, 1994, **36**, 717.
85 Q. X. Zheng, Z. J. Xu, X. F. Sun, F. Guéritte, M. Cesario, H. D. Sun, C. H. K. Cheng, X. J. Hao and Y. Zhao, *J. Nat. Prod.*, 2003, **66**, 1078.
86 J. Kitajima, A. Kamoshita, T. Ishikawa, A. Takano, T. Fukuda, S. Isoda and Y. Ida, *Chem. Pharm. Bull.*, 2003, **51**, 673.
87 M. N. Todorova, M. L. Krasteva, M. M. Markova, E. T. Tsankova, R. M. Taskova and D. R. Peev, *Phytochemistry*, 1998, **49**, 2371.
88 M. Stavri, K. T. Mathew, T. Gibson, R. T. Williamson and S. Gibbons, *J. Nat. Prod.*, 2004, **67**, 892.
89 H. X. Wei, W. Y. Gao, Y. J. Tian, Y. K. Guan, M. H. Huang and D. L. Cheng, *Pharmazie*, 1997, **52**, 245.
90 C. Zdero, F. Bohlmann and H. M. Niemeyer, *Phytochemistry*, 1988, **27**, 2165.
91 M. Miyazawa, Y. Honjo and H. Kameoka, *Phytochemistry*, 1997, **44**, 433.
92 G. Zhou, X. L. Gao, Z. Zhang, Y. L. Li, Z. Z. Shang and R. A. Liao, *Chin. Chem. Lett.*, 2000, **11**, 111.
93 G. Zhou, X. L. Gao, Z. Zhang and Y. L. Li, *J. Chem. Res. (S)*, 2000, 174.
94 G. Zhou, X. L. Gao, Z. Zhang, W. Z. Li and Y. L. Li, *Tetrahedron: Asymmetry*, 2000, **11**, 1819.
95 J. F. Hu, S. P. Bai and Z. J. Jia, *Chin. Chem. Lett.*, 1996, **7**, 913.
96 J. F. Hu, S. P. Bai, Q. X. Zhu and Z. J. Jia, *Indian J. Chem., Sect. B: Org. Chem. Incl. Med. Chem.*, 1998, **37**, 607.
97 S. Banerjee, J. Jakupovic, F. Bohlmann, R. M. King and H. Robinson, *Phytochemistry*, 1985, **24**, 1106.
98 A. A. Ahmed, J. Jakupovic and T. Mabry, *J. Nat. Prod.*, 1993, **56**, 1821.
99 A. García-Granados, M. C. Gutiérrez, A. Martínez and F. Rivas, *J. Org. Chem.*, 2005, **70**, 338.
100 A. García-Granados, E. Melguizo, A. Parra, F. L. Pérez, Y. Simeó, B. Viseras and J. M. Arias, *Tetrahedron*, 2000, **56**, 6517.
101 G. M. S. P. Guilhon and A. H. Müller, *Phytochemistry*, 1998, **49**, 1347.
102 F. Bohlmann, K. Umemoto, J. Jakupovic, R. M. King and H. Robinson, *Phytochemistry*, 1984, **23**, 1800.
103 P. Weyerstahl, C. Christiansen and H. Marschall, *Liebigs Ann. Chem.*, 1995, 1039.
104 N. Li, J. J. Chem and J. Zhou, *J. Asian Nat. Prod. Res.*, 2005, **7**, 279.
105 T. Iijima, Y. Yaoita and M. Kituchi, *Chem. Pharm. Bull.*, 2003, **51**, 545.
106 D. Q. Yu and F. Z. Xie, *Chin. Chem. Lett.*, 1993, **4**, 893.
107 K. Hatano, Y. Shoyama and I. Nishiota, *Planta Med.*, 1990, **56**, 131.
108 T. Warashima, M. Ishino, T. Miyase and A. Ueno, *Phytochemistry*, 1990, **29**, 3217.
109 C. Zdero and F. Bohlmann, *Phytochemistry*, 1989, **28**, 1653.
110 G. M. S. P. Gulhon and A. H. Müller, *Phytochemistry*, 1996, **41**, 417.
111 G. F. Chernenko, Y. V. Gamilov and E. N. Schmidt, *Chem. Nat. Compd.*, 1994, **30**, 328.
112 M. Resch, A. Steigel, Z. L. Chen and R. Bauer, *J. Nat. Prod.*, 1998, **61**, 347.
113 Z. M. Xiong, G. Zhou, Y. G. Chen and Y. L. Li, *J. Chem. Res. (S)*, 1998, 450.
114 L. Cardona, B. García, J. R. Pedro and D. Ruiz, *Tetrahedron*, 1994, **50**, 5527.
115 A. Chakiaborty, G. K. Kar and J. K. Ray, *Tetrahedron*, 1997, **53**, 2989.
116 E. P. Kundig, R. Cannas, M. Laxmisha, I. Ronggang and S. Tchertchian, *J. Am. Chem. Soc.*, 2003, **125**, 5642.
117 S. Z. Choi, S. O. Lee, S. U Choi and K. R. Lee, *Arch. Pharmacal Res.*, 2003, **26**, 521.
118 J. Jakupovic, T. V. Chau-Thi, U. Warning, F. Bohlmann and H. Greg, *Phytochemistry*, 1986, **25**, 1663.
119 V. Castro, G. Tamayo-Castillo and J. Jakupovic, *Phytochemistry*, 1989, **28**, 2415.
120 T. Lu, D. Vargas and N. H. Fisher, *Phytochemistry*, 1993, **34**, 737.
121 M. N. Todorova and E. T. Tsankova, *Phytochemistry*, 1999, **52**, 1515.
122 X. A. Dominguez, J. Verde, S. N. E. Guerra, R. E. Ellenmaurer and J. Jakupovic, *Phytochemistry*, 1986, **25**, 2893.
123 M. Grande, I. S. Bellido, P. Torres and F. Piera, *J. Nat. Prod.*, 1992, **55**, 1074.
124 F. Bohlmann, N. Ates and J. Jakupovic, *Phytochemistry*, 1983, **22**, 1159.
125 J. Jakupovic, S. Hafez, F. Bohlmann and X. A. Dominguez, *Phytochemistry*, 1988, **27**, 3881.
126 M. B. Izbosarov, B. K. Abduazimov and V. M. Malikov, *Chem. Nat. Compd.*, 1999, **35**, 471.
127 O. J. Donadel, E. Guerreiro, A. Q. María, G. Wendel, R. D. Enriz, O. S. Giordano and C. E. Tonn, *Bioorg. Med. Chem. Lett.*, 2005, **15**, 3547.
128 I. Fernández, J. R. Pedro and R. de la Salud, *Tetrahedron*, 1996, **52**, 12031.
129 D. Kalemba, H. Marschall and P. Brades, *Flavour Fragrance J.*, 2001, **16**, 19.
130 J. C. Coll, B. F. Bowden, D. M. Tapiolas, R. H. Willis, P. Djura, M. Streamer and L. Trott, *Tetrahedron*, 1985, **41**, 1085.
131 P. P. Pujar, D. D. Sawaikar, S. R. Rojatkar and B. A. Nagasampagi, *Fitoterapia*, 2000, **71**, 264.
132 F. Bohlmann, J. Jakupovic, U. Warning, M. Grenz, T. V. Chau-Thi, R. M. King and H. Robinson, *Bull. Soc. Chim. Belg.*, 1986, **95**, 707.
133 K. Naya, T. Okayama, M. Fujiwara, M. Nakata, T. Ohtsuka and S. Kurio, *Bull. Chem. Soc. Jpn.*, 1990, **63**, 2239.
134 J. F. Sanz and J. A. Marco, *Phytochemistry*, 1990, **29**, 2913.
135 Y. Maruta, Y. Fukushi, K. Ohkawa, Y. Nakanishi, S. Tahara and J. Mizutani, *Phytochemistry*, 1995, **38**, 1169.
136 J. Jakupovic, H. Klemeyer, F. Bohlmann and E. H. Graven, *Phytochemistry*, 1988, **27**, 1129.
137 G. T. Maatooq, D. K. Stumpf, J. J. Hoffmann, L. K. Hutter and B. T. Timmermann, *Phytochemistry*, 1996, **41**, 519.
138 E. Guerreiro, M. J. Pestchanker, L. del Vitto and O. S. Glordano, *Phytochemistry*, 1990, **29**, 877.
139 F. Bohlmann, M. Wallmeyer, J. Jakupovic, T. Gerke, R. M. King and H. Robinson, *Phytochemistry*, 1985, **24**, 505.
140 S. Mukhopadhyay, G. A. Cordell, N. Ruangrungsi, S. Rodkird, P. Tantivatana and P. J. Hylands, *J. Nat. Prod.*, 1983, **46**, 671.
141 V. A. Ahmad and K. Fizza, *Planta Med.*, 1988, **54**, 462.
142 J. Jakupovic, L. N. Misra, T. V. Chau Thi, F. Bohlmann and V. Castro, *Phytochemistry*, 1985, **24**, 3053.
143 S. R. Rojatkar, V. G. Puranik, S. S. Tavale, T. N. G. Row and B. A. Nagasampagi, *Phytochemistry*, 1987, **26**, 569.

144 E. Maldonado, *Phytochemisty*, 1989, **28**, 1973.
145 V. U. Ahmad, R. Khatoon, T. A. Farooqui, N. Ismail and K. Fizza, *Nat. Prod. Lett.*, 1992, **1**, 225.
146 G. M. S. P. Guilhon and A. H. Müller, *Phytochemistry*, 1998, **47**, 227.
147 V. U. Ahmad, K. Fizza, M. A. Khan and T. A. Farooqui, *Phytochemistry*, 1991, **30**, 689.
148 F. J. Arriaga and J. Borges del Castillo, *Planta Med.*, 1985, 290.
149 V. U. Ahmad and K. Fizza, *Liebigs Ann. Chem.*, 1987, 643.
150 F. J. Arriaga-Giner, J. Borges-del-Castillo, M. T. Manresa-Ferrero, P. Vazquez-Bueno, F. Rodriguez-Luis and S. Valdes-Iraheta, *Phytochemistry*, 1983, **22**, 1767.
151 V. U. Ahmad, T. A. Farooqui, K. Fizza, A. Suhana and R. Kharoon, *J. Nat. Prod.*, 1992, **55**, 730.
152 V. U. Ahmad and R. Khatoon, *Sci. Pharm.*, 1995, **63**, 231.
153 V. A. Ahmad and K. Fizza, *Phytochemistry*, 1988, **27**, 1861.
154 V. A. Ahmad, M. Zahid, R. Khatoon, Z. Ali, M. Abbas and M. Z. Iqbal, *Nat. Prod. Sci.*, 1999, **5**, 85.
155 A. A. Ahmed, A. A. Mahmoud, E. T. Ali, O. Tzakou, M. Couladis, T. J. Mabry, T. Gáti and G. Tóth, *Phytochemistry*, 2002, **59**, 851.
156 Z. D. Yang, S. Li, C. S. Yuan and Z. J. Jia, *Chin. Chem. Lett.*, 2002, **13**, 752.
157 Z. D. Yang, K. Gao and Z. J. Jia, *Phytochemistry*, 2003, **62**, 1195.
158 V. U. Ahmad, K. Fizza and A. Amber, *J. Nat. Prod.*, 1989, **52**, 861.
159 T. Kato, B. Frei, M. Heinrich and O. Sticher, *Planta Med.*, 1996, **62**, 67.
160 V. A. Ahmad and K. Fizza, *Z. Naturforsch., B: Chem. Sci.*, 1988, **43**, 911.
161 A. A. Ahmed, M. Abou-El-Ela, J. Jakupovic, A. A. Seif El-Din and N. Sabri, *Phytochemistry*, 1990, **29**, 3661.
162 C. Zdero, F. Bohlmann, J. C. Solomon, R. M. King and H. Robinson, *Phytochemistry*, 1989, **28**, 531.
163 A. A. Ahmed, B. A. Ali, M. Krawiec and W. H. Watson, 235, *Acta Crvstallogr., Sect. C: Cryst. Struct. Commun.*, 1996, **52**.
164 F. Bohlmann, J. Ziesche, R. M. King and H. Robinson, *Phytochemistry*, 1980, **19**, 969.
165 F. Bohlmann, N. Borthakur, H. Robinson and R. M. King, *Phytochemistry*, 1982, **21**, 1795.
166 J. Reisch, R. A. Hussain, B. Krebs and M. Dartmann, *Monatsh. Chem.*, 1990, **121**, 941.
167 J. M. Torres-Valencia, D. L. Quintero-Mogica, G. I. Leon, O. R. Suárez-Castillo, J. R. Villagómez-Ibarra, E. Maldonado, C. M. Cerda-García-Rojas and P. Joseph-Nathan, *Tetrahedron: Asymmetry*, 2003, **14**, 543.
168 M. Gasquet, F. Delmas, E. Ollivier, M. Bernabe, R. Faure, R. Elias and G. Balansard, *Pharm. Biol.*, 2000, **38**, 176.
169 E. Burgeño-Tapia, M. A. Bucio, A. Rivera and P. Joseph-Nathan, *J. Nat. Prod.*, 2001, **64**, 518.
170 V. M. Dirsch, H. Stuppner and A. M. Vollmar, *Planta Med.*, 2001, **67**, 557.
171 A. García-Granados, A. Martínez, A. Parra, F. Rivas, M. E. Onorato and J. M. Arias, *Tetrahedron*, 1993, **49**, 1091.
172 A. García-Granados, A. Martínez, F. Rivas, M. E. Onorato and J. M. Arias, *J. Nat. Prod.*, 1990, **53**, 436.
173 M. García, M. S. Sosa, O. J. Donadel, O. S. Giordano and C. E. Tonn, *J. Chem. Ecol.*, 2003, **29**, 175.
174 A. Tanaka, S. Watanabe and K. Yamashita, *Biosci., Biotechnol., Biochem.*, 1992, **56**, 104.
175 A. A. Haaksma, B. J. M. Jansen and A. De Groot, *Tetrahedron*, 1992, **48**, 3121.
176 Y. K. Guan, P. Li, G. Zhou, X. L. Gao and Y. L. Li, *Chem. J. Chin. Univ.*, 2005, **7**, 1281.
177 J. W. de Kraker, M. Schurink, M. C. R. Franssen, W. A. König, A. de Groot and H. J. Bouwmeester, *Tetrahedron*, 2003, **59**, 409.
178 E. Muri, A. Kanazawa, E. Barreiro and A. E. Greene, *J. Chem. Soc., Perkin Trans. 1*, 2000, 731.
179 G. M. S. P. Guilhon and A. H. Muller, *Phytochemistry*, 1998, **47**, 227.
180 B. S. M. Tenius, A. R. Rhode, M. M. Victor and C. Viegas, *Synth. Commun.*, 1996, **26**, 197.
181 V. Barges, G. Blay, B. García, C. L. García and J. R. Pedro, *Tetrahedron*, 1995, **51**, 5609.
182 A. K. Banerjee and M. Laya-Mimo, *Synth. Commun.*, 1995, **25**, 1035.
183 P. M. Imamura and R. T. Nogueira, *Synth. Commun.*, 1995, **25**, 405.
184 L. Cardona, B. García, C. L. García and J. R. Pedro, *Tetrahedron*, 1993, **49**, 7829.
185 W. J. Xia, D. R. Li, Y. Q. Tu and A. C. Cao, *Chin. Chem. Lett.*, 2001, **12**, 21.
186 O. Cherkaoul, P. Nebois and H. Fillion, *Chem. Pharm. Bull.*, 1997, **45**, 457.
187 G. A. Kraus and X. Wang, *Synlett*, 1999, 1395.
188 L. Liu, G. Zhou, J. Li, Y. Chen, Z. Xiong and Y. Li, *Synth. Commun.*, 1999, **29**, 3379.
189 A. Kanazawa, A. Patin and A. E. Greene, *J. Nat. Prod.*, 2000, **63**, 1292.
190 D. L. Dreyer, *Biochem. Syst. Ecol.*, 1987, **15**, 661.
191 S. Lin and J. Ding, *Yunnan Zhiwu Yanjiu*, 1996, **18**, 349.
192 P. Barbetti, I. Chiappini, G. Fardella and A. Menghini, *Planta Med.*, 1985, 471.
193 A. A. Alfatafta and C. Mulin, *Phytochemistry*, 1992, **31**, 4109.
194 Q. X. Zheng, Z. J. Xu, X. F. Sun, F. Guéntte, M. Cesario, C. H. K. Cheng, H. D. Sun and Y. Zhao, *Chin. Chem. Lett.*, 2003, **14**, 393.
195 J. M. Amaro Luis, I. Ramirez, P. Delgado-Méndez and Z. D. Jorge, *J. Braz. Chem. Soc.*, 2002, **13**, 352.
196 A. G. Gonzalez, J. Bermejo Barrera, A. Yanes Hernandez, F. Estevez Rosas and X. A. Dominguez, *Phytochemistry*, 1985, **24**, 1847.
197 C. Zdero, F. Bohlmann and R. M. King, *Phytochemistry*, 1990, **29**, 3201.
198 J. F. Sanz, G. Castellano and M. J. Alberto, *Phytochemistry*, 1990, **29**, 541.
199 F. Faini, C. Labbe, R. Torres, G. del le Monache, F. del le Monache and J. Coll, *Nat. Prod. Lett.*, 1997, **11**, 1.
200 Y. Zhao, J. Yue, Y. He, Z. Lin and H. Sun, *Yunnan Zhiwu Yanjiu*, 1997, **19**, 207.
201 S. Sepulveda-Boza and E. Breitmaier, *Chem. Ztg.*, 1987, **111**, 187.
202 C. Zdero, F. Bohlmann and M. Mueller, *Phytochemistry*, 1987, **26**, 2763.
203 A. Z. Dawidar and M. Metwally, *Chem. Pharm. Bull.*, 1985, **33**, 5068.
204 F. Bohlmann, J. Jakupovic, A. Schuster, R. M. King and H. Robinson, *Phytochemistry*, 1984, **23**, 1445.
205 J. F. Sanz, C. Ferrando and J. A. Marco, *Phytochemistry*, 1991, **30**, 3653.
206 F. Bohlmann, J. Jakupovic, M. Ahmed and A. Schuster, *Phytochemistry*, 1983, **22**, 1623.
207 P. Ceccherelli, M. Curini, M. C. Marcotullio and A. Menghini, *Phytochemistry*, 1985, **24**, 2987.
208 A. Rustaiyan, J. Jakupovic, T. V. Char-Thi, F. Bohlmann and A. Sadjadi, *Phytochemistry*, 1987, **26**, 2603.
209 A. Ulubelen, S. Oksuz and N. Geron, *Phytochemistry*, 1987, **26**, 1223.
210 C. Zdero, F. Bohlmann, A. Anderberg and R. M. King, *Phytochemistry*, 1991, **30**, 2643.
211 J. F. Sanz and J. A. Marco, *Liebigs Ann. Chem.*, 1990, 541.
212 A. Rustaiyan, A. Bamonieri, M. Raffatrad, J. Jakupovic and F. Bohlmann, *Phytochemistry*, 1987, **26**, 2307.
213 F. Bohlmann, C. Trinks, J. Jakupovic and S. Huneck, *Phytochemistry*, 1985, **24**, 995.
214 J. S. Sohoni, S. R. Rojatkar, M. M. Kulkarni, N. N. Dhaneshwar, N. Narayandatta, S. S. Tavale, T. N. Gururow and B. A. Nagasampagi, *J. Chem. Soc., Perkin Trans. 1*, 1988, 157.
215 C. Zdero, F. Bohlmann, I. Haegi and R. M. King, *Phytochemistry*, 1988, **27**, 865.
216 M. Vasquez, F. A. Macias, L. E. Urbatsch and N. H. Fischer, *Phytochemistry*, 1988, **27**, 2195.
217 C. Zdero and F. Bohlmann, *Phytochemistry*, 1989, **28**, 3105.
218 J. F. Sanz, E. Falco and J. A. Marco, *J. Nat. Prod.*, 1990, **53**, 940.
219 E. Gadeschi, Z. D. Jorge, G. M. Massanet and F. R. Luis, *Phytochemistry*, 1989, **28**, 2204.
220 J. A. Marco, J. F. Sanz and P. Del Hierro, *Phytochemistry*, 1991, **30**, 2403.
221 Y. Xiao, Q. Zheng, Q. Zhang, H. Sun, F. Guéritte and Y. Zhao, *Fitoterapia*, 2003, **74**, 459.
222 Q. Zheng, Z Hu, X. Sun, W. Yao, H. Sun, C. H. K. Cheng and Y. Zhao, *Phytochemistry*, 2003, **63**, 835.
223 Z. J. Jia and H. M. Chen, *Phytochemistry*, 1991, **30**, 3132.
224 M. H. A. Zarga, S. S. Sabri, E. M. Ahmed, M. A. Khanfar, K. P. Zeller and Atta-Ur-Rahman, *Nat. Prod. Lett.*, 2003, **17**, 99.
225 M. H. Abu-Zarga, E. M. Hamed, S. S. Sabri, W. Voelter and K. P. Zeller, *J. Nat. Prod.*, 1998, **61**, 798.
226 J. Jakupovic, A. Schuster, F. Bohlmann, V. H. Sanchez, S. E. del Rio and X. A. Dominguez, *Rev. Latinoam. Quim.*, 1986, **17**, 210.
227 R. X. Tan and Z. J. Jia, *Phytochemistry*, 1992, **31**, 2534.

228 N. Goren, *Phytochemistry*, 1995, **38**, 1261.
229 J. F. Hu, Q. X. Zhu, S. P. Bai and Z. J. Jia, *Planta Med.*, 1996, **62**, 477.
230 M. B. K. Sanz, O. J. Donadel, P. C. Rossomando, C. E. Tonn and E. Guerreiro, *Phytochemistry*, 1997, **44**, 897.
231 C. Yang, C. M. Wang and Z. J. Jia, *Planta Med.*, 2003, **69**, 662.
232 C. Yang, P. F. Wang and Z. J. Jia, *Chin. Chem. Lett.*, 2003, **14**, 485.
233 F. Hilmi, O. Sticher and J. Heilmann, *Planta Med.*, 2003, **69**, 462.
234 C. M. Sun, W. J. Syu, M. J. Don, J. J. Lu and G. H. Lee, *J. Nat. Prod.*, 2003, **66**, 1175.
235 K. Zielinska and W. Kisiel, *Phytochemistry*, 2000, **54**, 791.
236 J. Jakupovic, R. X. Tan, F. Bohlmann, Z. J. Jia and S. Huneck, *Phytochemistry*, 1991, **30**, 1714.
237 M. M. Abd El-Aal, *Zagazig J. Pharm. Sci.*, 1993, **2**, 104.
238 L. Cardona, R. A. Alemán, B. García and J. R. Pedro, *Phytochemistry*, 1992, **31**, 3630.
239 L. Cardona, A. Bardon, B. García and J. R. Pedro, *Phytochemistry*, 1993, **33**, 1453.
240 A. Braca, N. de Tommasi, I. Morelli and C. Pizza, *J. Nat. Prod.*, 1999, **62**, 1371.
241 H. Skaltsa, D. Lazari, C. Panagouleas, E. Georgiadou, B. García and M. Sokovic, *Phytochemistry*, 2000, **55**, 903.
242 H. W. Thompson and R. A. Lalancette, *Acta Crystallogr., Sect. C: Biosci.*, 2003, **59**, o580.
243 F. Bohlmann, C. Zdero, R. M. King and H. Robinson, *Phytochemistry*, 1984, **23**, 1185.
244 F. Eid, S. El-Dahmy and P. K. Gupta, *Pharmazie*, 1987, **47**, 423.
245 A. H. Zhao and J. X. Wei, *Huaxue Xuebao*, 1994, **52**, 517.
246 M. A. Khanina, A. T. Kulyyasov, I. Y. Bagryanskaya, Y. V. Gatilov, S. M. Adekenov and V. A. Raldugin, *Chem. Nat. Compd.*, 1998, **34**, 145.
247 F. Tsichritzis, J. Jakupovic and F. Bohlmann, *Phytochemistry*, 1990, **29**, 195.
248 F. C. Seaman and A. Bencsath, *Phytochemistry*, 1985, **24**, 607.
249 Y. Li, X. Chen, S. Shao and T. Li, *Synth. Commun.*, 1993, **23**, 2457.
250 Y. Li, X. Chen, S. Shao and T. Li, *Chin. Chem. Lett.*, 1993, **4**, 105.
251 J. Jakupovic, A. Schuster, F. Bohlmann and M. O. Dillon, *Phytochemistry*, 1988, **27**, 1113.
252 V. U. Ahmad, K. Fizza and A. Sultana, *Phytochemistry*, 1989, **28**, 3081.
253 N. Gören, *Phytochemistry*, 1996, **42**, 747.
254 A. Ulubelen, S. Oksuz and E. Tuzlaci, *Planta Med.*, 1988, **54**, 473.
255 R. X. Tan, W. Z. Wang, L. Yang and J. H. Wey, *J. Nat. Prod.*, 1995, **58**, 288.
256 S. A. El-Moghazy, A. A. Ahmed, H. E. Abdel-Ghani and M. A. El-Shanawany, *Fitoterapia*, 2002, **73**, 97.
257 A. M. Fortuna, E. C. de Riscala, C. A. N. Catalán, T. E. Gedris and W. Herz, *Biochem. Syst. Ecol.*, 2001, **29**, 967.
258 W. M. Daniewski, W. Kroszeynski, E. Bloszyk, B. Drozdz, J. Nawrot, U. Rychlewska, M. Budesinsky and M. Holub, *Collect. Czech. Chem. Commun.*, 1986, **51**, 1710.
259 A. P. J. Brunskill, H. W. Thompson and R. A. Lalancette, *Acta Crystallogr., Sect. C: Biosci.*, 2002, **58**, o251.
260 M. M. Al-Dabbas, F. Hashinaga, S. A. M. Abdelgaleil, T. Suganuma, K. Akiyama and H. Hayashi, *J. Ethnopharmacol.*, 2005, **97**, 237.
261 R. Lanzetta, G. Lama, G. Mauriello, M. Parrilli, R Racioppi and G. Sodano, *Phytochemistry*, 1991, **30**, 1121.
262 V. Hernández, M. C. Recio, S. Máñez, J. M. Prieto, R. M. Giner and J. L. Ríos, *Planta Med.*, 2001, **67**, 726.
263 P. Bermejo-Benito, M. J. Abad, A. M. Diaz, L. Villaescusa, M. A. González and A. M. Silván, *Biol. Pharm. Bull.*, 2002, **25**, 1.
264 A. García-Granados, A. Martinez, F. Rivas, M. E. Onorato and J. M. Arias, *Tetrahedron Lett.*, 1991, **32**, 5383.
265 A. García-Granados, A. Martinez, M. E. Onorato, F. Rivas and J. M. Arias, *Tetrahedron*, 1991, **47**, 91.
266 L. Pous, R. Carrizo, M. Kurina-Sanz, J. C. Gianello and E. Guerreiro, *Molecules*, 2000, **5**, 325.
267 K. Y. Orabi, *J. Nat. Prod.*, 2000, **63**, 1709.
268 Z. Xiong, J. Yang and Y. Li, *Tetrahedron: Asymmetry*, 1996, **7**, 2607.
269 G. Blay, L. Cardona, B. García, C. L. García and J. R. Pedro, *J. Org. Chem.*, 1996, **61**, 3815.
270 Y. G. Chen, G. Zhou, L. J. Liu, Z. M. Xiong and Y. L. Li, *Synthesis*, 2001, 1305.
271 D. B. Little and R. B. Croteau, *Arch. Biochem. Biophys.*, 2002, **402**, 120.
272 R. Segal, L. Eden, A. Danin, M. Kaiser and H. Duddeck, *Phytochemistry*, 1985, **24**, 1381.
273 J. A. Marco, J. F. Saenz-Cervera, V. García-Lliso and N. Batlle, *Phytochemistry*, 1997, **45**, 755.
274 M. G. Gogte, L. Ananthasubramanian, K. S. Nargund and S. C. Bhattacharyya, *Indian J. Chem., Sect. B: Org. Chem. Incl. Med. Chem.*, 1986, **25**, 233.
275 I. S. Bellido, M. Medarde, E. Caballero, A. R. Feijoo and M. Gordaliza, *Planta Med.*, 1988, **54**, 180.
276 J. A. Marco, *Phytochemistry*, 1989, **28**, 3121.
277 T. Miyase and S. Fukushima, *Chem. Pharm. Bull.*, 1987, **35**, 69.
278 J. J. Navarro, M. C. Caballero, J. R. Moran, M. Medarde, M. Grande and J. Anaya, *J. Nat. Prod.*, 1990, **53**, 573.
279 J. D. Gomis, J. A. Marco, J. R. P. Llinares, J. S. Parareda, J. M. Sendra and E. Seoane, *Phytochemistry*, 1979, **18**, 1523.
280 H. Greger, C. Zdero and F. Bohlmann, *Phytochemistry*, 1986, **25**, 891.
281 S. V. Serkerov and A. N. Aleskerova, *Khim. Prir. Soedin.*, 1991, 203.
282 J. A. Marco, J. F. Sanz-Cervera, J. M. Pareja, F. Sancenon and J. Valles-Xirau, *Phytochemistry*, 1994, **37**, 477.
283 A. Rustaiyan, H. Sigari, J. Jakupovic and M. Grenz, *Phytochemistry*, 1989, **28**, 2723.
284 J. A. Marco, J. F. Sanz, F. Sancenon, A. Rustaiyan and M. Saberi, *Phytochemistry*, 1993, **32**, 460.
285 S. V. Serkerov and A. N. Aleskerova, *Khim. Prir. Soedin.*, 1990, 632.
286 A. M. Dawidar, M. A. Metwally, M. Abou-Elzahab and M. Abdel-Mogib, *Pharmazie*, 1990, **45**, 70.
287 M. Djermanovic, M. Stefanovia, V. Djermanovia and M. Milovanovie, *Fitoterapia*, 1997, **68**, 81.
288 I. D. Sham'yanov, B. Tashkhodzhaev, R. F. Mukhamatkhanova and M. Y. Antipin, *Chem. Nat. Compd.*, 2000, **36**, 369.
289 F. Bohlmann, J. Jakupovic and A. Schuster, *Phytochemistry*, 1983, **22**, 1637.
290 E. Maldonado, J. Vaughan and A. Ortega, *Phytochemistry*, 1984, **23**, 813.
291 M. S. Atta-ur-Rahman, S. Perveen, A. Habib-ur-Rehman, A. Zia-ul-Haque and D. Shaikh, *J. Chem. Res. (S)*, 1989, 68.
292 J. Jakupovic, M. Grenz, F. Bohlmann and G. M. Mungai, *Phytochemistry*, 1990, **29**, 1213.
293 S. Oksuz and G. Topcu, *Phytochemistry*, 1992, **31**, 195.
294 Y. Fujimoto, T. Kinoshita, N. Ikekawa and J. Mungarulire, *Phytochemistry*, 1987, **26**, 2593.
295 S. Grass, C. Zidorn, E. P. Ellmerer and H. Stuppner, *Chem. Biodiversity*, 2004, **1**, 353.
296 M. Bruno and W. Herz, *Phytochemistry*, 1988, **27**, 1201.
297 M. Seto, T. Miyase and S. Fukushima, *Chem. Pharm. Bull.*, 1986, **34**, 4170.
298 C. Zdero and F. Bohlmann, *Phytochemistry*, 1990, **29**, 183.
299 V. Campos, J. Jakupovic, M. Bittner, M. Silva and T. Stuessy, *Heterocycles*, 1989, **28**, 779.
300 R. X. Tan, J. Jakupovic, F. Bohlmann, Z. J. Jia and A. Schuster, *Phytochemistry*, 1990, **29**, 1209.
301 S. Shimizu, T. Miyase, A. Ueno and K. Usmanghani, *Phytochemistry*, 1989, **28**, 3399.
302 Z. Mahmoud, S. El-Masry, M. Amer, J. Ziesche and M. Grenz, *Phytochemistry*, 1984, **23**, 1105.
303 D. S. Yang, W. K. Whang and I. H. Kim, *Arch. Pharmacal Res.*, 1996, **19**, 507.
304 S. V. Serkerov and A. N. Aleskerova, *Khim. Prir. Soedin.*, 1983, 578.
305 S. M. Khafagy, A. A. S. El-Din, J. Jakupovic, C. Zdero and F. Bohlmann, *Phytochemistry*, 1988, **27**, 1125.
306 Z. Smitalova, M. Budesinsky, D. Saman and M. Holub, *Collect. Czech. Chem. Commun.*, 1986, **51**, 1323.
307 A. G. González, A. Galindo, H. Mancilla, V. H. Kesternich, J. A. Palenzuela and M. López, *Tetrahedron*, 1988, **44**, 6750.
308 N. Ruangrungsi, S. Kasiwong, K. Likhitwitayawuid, G. L. Lange and C. P. Decicco, *J. Nat. Prod.*, 1989, **52**, 130.
309 J. A. Marco, J. F. Sanz and M. Carda, *Phytochemistry*, 1989, **28**, 2505.
310 J. F. Sanz and J. A. Marco, *Planta Med.*, 1991, **57**, 74.
311 M. Martínez-Vazquez, R. E. Gallego and P. Joseph-Nathan, *Phytochemistry*, 1990, **29**, 1689.
312 F. Bohlmann, M. A. Metwally and J. Jakupovic, *Phytochemistry*, 1984, **23**, 1975.
313 N. Mengi, S. C. Taneja, V. P. Mahajan and C. S. Mathela, *Phytochemistry*, 1991, **30**, 2329.

314 M. Holub, M. Budesinsky, Z. Smitalova, D. Saman and U. Rychlewska, *Tetrahedron Lett.*, 1984, **25**, 3755.
315 S. M. Adekenov, A. Z. Turmukhambetov and K. M. Trudybekov, *Izv. Nats. Akad. Nauk. Resp. Kaz., Ser. Khim.*, 1992, 79.
316 F. Jeske, S. Huneck and J. Jakupovic, *Phytochemistry*, 1996, **41**, 1539.
317 J. A. Marco, J. F. Saenz-Cervera, V. García-Lliso, M. Guara and J. Vallés-Xirau, *Phytochemistry*, 1997, **45**, 751.
318 R. B. Jadhav, K. B. Sonawane, G. T. Panse and S. R. Rojatkar, *Indian J. Chem., Sect. B: Org. Chem. Incl. Med. Chem.*, 2004, **43**, 2I7.
319 J. A. Marco, J. F. Sanz-Cervea and G. Ocete, *J. Nat. Prod.*, 1994, **57**, 939.
320 I. D. Sham'yanov, B. Tashkhodzhaev, R. F. Mukhamatkhanova and M. Y. Antipin, *Chem. Nat. Compd.*, 2000, **36**, 284.
321 R. F. Mukhamatkhanova, K. K. Turgunov, B. Tashkhodzhaev, I. D. Sham'yanov and A. I. Saidkhodzhaev, *Chem. Nat. Prod.*, 2004, **40**, 557.
322 A. G. González, J. Bermejo-Barrera, J. Triana-Méndez, M. López-Sánchez and J. L. Eiroa-Martinez, *Phytochemistry*, 1992, **31**, 1821.
323 M. Ando, K. Isogai, H. Azami, N. Hirata, H. Yamasaki and Y. Yanagi, *J. Nat. Prod.*, 1992, **55**, 1620.
324 A. Ortega, R. A. Toscano and E. Maldonado, *Phytochemistry*, 1998, **49**, 1085.
325 H. Mansilla and J. A. Palenzuela, *Phytochemistry*, 1999, **51**, 995.
326 C. Zidorn, E. P. Ellmerer-Müller and H. Stuppner, *Phytochemistry*, 1999, **51**, 991.
327 C. Guerrrero, A. L. Nava and L. Obregon, *Rev. Latinoam. Quim.*, 1987, **18**, 57.
328 C. Zdero, F. Bohlmann and R. Scott, *Phytochemistry*, 1987, **26**, 1999.
329 D. Vargas, L. E. Urbatsch and N. H. Fischer, *Phytochemistry*, 1988, **27**, 1413.
330 M. Stefanovic, S. Mladenovic, M. Dermanovic and N. Ristic, *J. Serb. Chem. Soc.*, 1985, **50**, 435.
331 A. G. Ober, L. Quijano and N. H. Fischer, *Phytochemistry*, 1984, **23**, 1439.
332 A. L. C. Perez, M. V. del C. Colin, R. Carlos Guerrero, M. R. de la Luz Cruz and A. Romo de Vivar, *Phytochemistry*, 1984, **23**, 823.
333 R. Mata, G. Delgado and A. Romo de Vivar, *Phytochemistry*, 1984, **23**, 1665.
334 A. A. Omar, T. M. Sarg, S. M. Khafagy, Y. E. Ibrahim, C. Zdero and F. Bohlmann, *Phytochemistry*, 1983, **22**, 779.
335 J. de Pascual Teresa, E. Caballero, J. Anaya, C. Caballero and M. S. Gonzalez, *Phytochemistry*, 1986, **25**, 1365.
336 V. Castro, J. Jakupovic and F. Bohlmann, *Phytochemistry*, 1986, **25**, 1750.
337 F. Bohlmann, L. N. Misra, J. Jakupovic, R. M. King and H. Robinson, *Phytochemistry*, 1984, **23**, 1802.
338 D. H. de Luengo, M. Miski, D. A. Gage and T. J. Mabry, *Phytochemistry*, 1986, **25**, 1971.
339 W. Herz and P. Kulanthaivel, *Phytochemistry*, 1983, **22**, 715.
340 C. Zdero, L. Lehmann and F. Bohlmann, *Phytochemistry*, 1991, **30**, 1161.
341 S. R. Rojatkar and B. A. Nagasampagi, *Phytochemistry*, 1992, **31**, 3270.
342 A. Ruiz-Cancino, A. E. Cano and G. Delgado, *Phytochemistry*, 1993, **33**, 1113.
343 L. R. Hernández, C. A. N. Catalan, C. M. Cerda-García-Rojas and P. Joseph-Nathan, *Phytochemistry*, 1994, **37**, 1331.
344 Z. N. J. de Hernandez, C. A. N. Catalan, L. R. Hernandez, D. Guerra-Ramirez and P. Joseph-Nathan, *Phytochemistry*, 1999, **51**, 79.
345 J. Staneva, M. Todorova and L. Evatatieva, *Z. Naturforsch., C: Biosci.*, 2002, **57**, 769.
346 G. Lang, C. M. Passreiler, B. E. Medinilla and J. J. Castillo, *Pharm. Biol.*, 2001, **39**, 332.
347 A. N. de Gutierrez, A. Bardón, C. A. N. Catalan, T. B. Gedris and W. Herz, *Biochem. Syst. Ecol.*, 2001, **29**, 633.
348 M. N. Todorova and M. L. Krasteva, *Phytochemistry*, 1996, **42**, 1231.
349 G. Lang, C. M. Passreiter, B. E. Medinilla and J. J. Castillo, *Z. Naturforsch., C: Biosci.*, 2000, **55**, 511.
350 G. Appendino, G. Cravotto, P. Gariboldi, F. Claudi and V. Picci, *Phytochemistry*, 1989, **28**, 849.
351 A. B. Trendafilova, M. N. Todorova and C. V. Gussev, *Phytochemistry*, 1996, **42**, 469.
352 M. S. Shekhani, P. M. Shah, K. M. Khan and Atta-Ur-Rahman, *J. Nat. Prod.*, 1991, **54**, 882.
353 P. Singh, J. Jakupovic, F. Bohlmann, R. M. King and H. Robinson, *Phytochemistry*, 1985, **24**, 2110.
354 C. Zdero, F. Bohlmann, R. M. King and H. Robinson, *Phytochemistry*, 1989, **28**, 517.
355 C. Zdero and F. Bohlmann, *Phytochemistry*, 1989, **28**, 1433.
356 A. Shuster, S. Stokes, F. Papastergiou, V. Castro, L. Proveda and J. Jakupovic, *Phytochemistry*, 1992, **31**, 3139.
357 L. Quijano, J. S. Calderon, F. Gomez, S. Bautista and T. Rios, *Phytochemistry*, 1985, **24**, 861.
358 J. De Pascual-Teresa, J. Anaya, E. Caballero and M. C. Caballero, *Phytochemistry*, 1988, **27**, 855.
359 A. G. Ober, L. Quijano, L. E. Urbatsch and N. H. Fischer, *Phytochemistry*, 1984, **23**, 910.
360 J. Q. Gu, J. J. Gills, E. J. Park, E. Mata-Greenwood, M. E. Hawthorne, F. Axelrod, P. I. Chavez, H. H. S. Fong, R. G. Mehta, J. M. Pezzuto and A. D. Kinghorn, *J. Nat. Prod.*, 2002, **65**, 532.
361 D. Boriky, M. Berrada, M. Talbi, G. Keravis and F. Rouessac, *Phytochemistry*, 1996, **43**, 309.
362 K. Kawazoe, N. Morishita, A. Nagao, Y. Takaishi, G. Honda, M. Ito, Y. Takeda, O. K. Kodzhimatov and O. Ashurmetov, *Nat. Med.*, 2003, **57**, 114.
363 F. Gao, M. Miski and T. J. Mabry, *Phytochemistry*, 1986, **25**, 1231.
364 A. Rojas, R. Villena, A. Jimenez and R. Mata, *J. Nat. Prod.*, 1991, **54**, 1279.
365 F. Bohlmann and M. Grenz, *Tetrahedron Lett.*, 1969, 111.
366 J. F. Sanz and J. A. Marco, *Planta Med.*, 1990, **56**, 236.
367 S. Müller, R. Murillo, V. Castro, V. Brecht and I. Merfort, *J. Nat. Prod.*, 2004, **67**, 622.
368 M. L Cardona, I. Fernandez, J. R. Pedro and B. Perez, *Phytochemistry*, 1991, **30**, 2331.
369 K. Medjroubi, F. Benayache, S. Benayaehe, S. Akkal, M. Kaabeche, F. Tillequin and E. Seguin, *Phytochemistry*, 1998, **49**, 2425.
370 Z. Mahmoud, S. El-Masry, M. Amer, J. Ziesche and F. Bohlmann, *Phytochemistry*, 1983, **22**, 1290.
371 M. Miski, A. H. Miricli and T. J. Mabry, *Phytochemistry*, 1988, **27**, 1417.
372 E. Georgiadou, H. Skaltsa, D. Lazari, B. Garcia and C. Harvala, *Nat. Prod. Lett.*, 2000, **14**, 167.
373 A. F. Barrero, J. E. Oltra, V. Morales and M. Alvarez, *J. Nat. Prod.*, 1997, **60**, 1034.
374 V. Saroglou, A. Karioti, C. Demetzos, K. Dimas and H. Skaltsa, *J. Nat. Prod.*, 2005, **68**, 1404.
375 K. Y. Orabi, K. A. El-Sayed, M. S. Al-Said and F. S. EI-Feraly, *Saudi Pharm. J.*, 2000, **8**, 101.
376 B. García, H. Skalta, F. I. Navarro, J. R. Pedro and D. Lazart, *Phytochemistry*, 1996, **41**, 1113.
377 H. Koukoulitsa, H. Skaltsa, A. Karloti, C. Demetzos and K. Dimas, *Planta Med.*, 2002, **68**, 649.
378 A. Karioti, H. Skalta, D. Lazari, M. Sokovic, B. Garcia and C. harvala, *Z. Naturforsch., C: Biosci.*, 2002, **57**, 75.
379 S. M. Adekenov, A. D. Kagarlitskii, M. N. Mukhametzhanov and A. N. Kapriyanov, *Khim. Prir. Soedin.*, 1983, 238.
380 A. G. González, J. Bermejo, J. G. Díaz, T. Zaragoza and P. P. de Paz, *Biochem. Syst. Ecol.*, 1988, **16**, 17.
381 M. Calleri, G. Chiari and D. Viterbo, *Acta Crystallogr., Sect. C: Cryst. Struct. Commun.*, 1983, **39**, 1115.
382 A. Z. Turmukhambetov, S. M. Adekenov, K. M. Turdybekov and Y. V. Gatilov, *Khim. Prir. Soedin.*, 1991, 339.
383 J. A. Marco, J. F. Sanz, E. Falco, J. Jakupovic and J. Lex, *Tetrahedron*, 1990, **46**, 7941.
384 O. J. Diaz, R. Gil, L. J. Novara, V. E. Sosa and J. R. de la Fuente, *Phytochemistry*, 2004, **65**, 2557.
385 W. G. Zheng, R. X. Tan, L. Yang and Z. L. Liu, *Spectrosc. Lett.*, 1996, **29**, 1589.
386 M. A. Metwally, J. Jakupovic, M. I. Youns and F. Bohlmann, *Phytochemistry*, 1985, **24**, 1103.
387 A. S. Feliciano, M. Medarde, M. T. Poza and J. M. Miguel del Corral, *Phytochemistry*, 1986, **25**, 1757.
388 K. Anake, L. M. M. Vieira, J. M. Cardoso and W. Hen, *Phytochemistry*, 1992, **31**, 3635.
389 J. Jakupovic, A. Schuster, F. Bohlmann and M. O. Dillon, *Phytochemistry*, 1988, **27**, 1771.
390 J. Jakupovic, R. X. Tan, F. Bohlmann, Z. J. Jia and S. Huneck, *Phytochemistry*, 1991, **30**, 1941.

391 A. H. Mericli, J. Jakupovic, F. Bohlmann, B. Damadyan, N. Ozhatay and B. Cubukcu, *Planta Med.*, 1988, **54**, 447.
392 I. Ognyanov and M. Todorova, *Planta Med.*, 1983, **48**, 181.
393 A. G. González, J. Bermejo and T. Zaragoza, *Phytochemistry*, 1983, **22**, 1509.
394 F. A. Eid, *Pharmazie*, 1986, **41**, 674.
395 U. Rychelwska, B. Szczepanska and S. V. Serkerov, *Acta Crystallogr., Sect. C: Cryst. Struct. Commun.*, 1992, **48**, 1543.
396 J. M. Molina, A. P. Sanchez and M. D. P. Olea, *J. Mol. Struct.*, 1994, **318**, 203.
397 S. Liu, H. Liu, W. Yan, L. Zhang, N. Bai and C. T. Ho, *Bioorg. Med. Chem. Lett.*, 2004, **14**, 1101.
398 H. Takikawa, K. Ueda and M. Sasaki, *Tetrahedron Lett.*, 2004, **45**, 5569.
399 W. Kisiel and K. Zielinska, *Phytochemistry*, 2001, **57**, 523.
400 A. Karube and M. Murayama, *Nippon Kagaku Kaishi*, 1998, 465.
401 L. Sun and Y. Tu, *Indian J. Chem., Sect. B: Org. Chem. Incl. Med. Chem.*, 1997, **36**, 723.
402 M. S. Shekhani, P. M. Shah, A. Yasmin, R. Siddiqui, S. Perveen, K. M. Khan, S. U. Kazmi and Atta-ur-Rahman, *Phytochemistry*, 1990, **29**, 2573.
403 R. P. Srivastava, P. Proksch and V. Wray, *Phytochemistry*, 1990, **29**, 3445.
404 N. H. Fischer, J. D. Weidenhamer, J. L Riopèl, L. Quijano and M. A. Menelaou, *Phytochemistry*, 1990, **29**, 2479.
405 N. Gören, H. J. Woerdenbaa and C. Bozok-Johansson, *Planta Med.*, 1996, **62**, 419.
406 S. Y. Ryu, J. O. Kim and S. U. Choi, *Plant Med.*, 1997, **63**, 385.
407 J. H. Jung, J. Y. Ha, K. R. Min, F. Shibata, H. Nakagawa, S. S. Kang, I. M. Chang and Y. Kim, *Planta Med.*, 1998, **64**, 488.
408 J. Y. Cho, J. Park, E. S. Yoo, K. U. Baik, J. H. Jung, J. Lee and M. H. Park, *Planta Med.*, 1998, **64**, 594.
409 A. C. Cao, X. C. Zhang, M. X. Guo, M. Wang, L. Shi and Y. Q. Tu, *Chin. J. Pestic.*, 2005, **44**, 37.
410 T. Konishi, Y. Shimada, T. Nagao, H. Okabe and T. Konoshima, *Biol. Pharm. Bull.*, 2002, **25**, 1370.
411 S. H. Kim and T. S. Kim, *Planta Med.*, 2002, **68**, 886.
412 G. Lang, C. M. Passreiter, C. W. Wright, N. H. Filipowicz, J. Addae-Kyereme, B. E. Medinilla and J. J. Castillo, *Z. Naturforsch., C: Biosci.*, 2001, **57**, 282.
413 C. L. Cantrell, L. Abate, F. R. Fronczek, S. G. Franzblau, L. Quijano and N. H. Fischer, *Planta Med.*, 1999, **65**, 351.
414 D. S. Jang, K. H. Park, J. R. Lee, T. J. Ha, Y. B. Park, S. H. Nam and M. S. Yang, *Han'guk Nonghwa Hakhoechi*, 1999, **42**, 176.
415 H. J. Park, S. Y. Kwon, K. O. Yoo, W. T. Jung, K. T. Lee, J. Kim and Y. N. Han, *Nat. Prod. Sci.*, 2000, **6**, 86.
416 K. T. Lee, J. Kim, H. J. Park, K. O. Yoo, Y. N. Han and K. I. Miyamoto, *Biol. Pharm. Bull.*, 2000, **23**, 1005.
417 S. Y. Ryu, M. H. Oak and K. M. Kim, *Planta Med.*, 2000, **66**, l71.
418 A. Farooq and S. Tahara, *Z. Naturforsch., C: Biosci.*, 2000, **55**, 713.
419 J. M. Arias, J. L. Breton, J. A. Gavin, A. Garcia-Granados, A. Martinez and M. E. Onorato, *J. Chem. Soc., Perkin Trans. 1*, 1978, 471.
420 U. P. Naik, S. Mavinkurve, U. S. Naik and S. K. Paknikar, *Indian J. Chem., Sect. B: Org. Chem. Incl. Med. Chem.*, 1988, **27**, 381.
421 M. Iida, A. Mikami, K. Yamakawa and K. Nishitani, *J. Ferment. Technol.*, 1988, **66**, 51.
422 M. S. Al-Sais, S. I. Khalifa, F. S. El-Feraly and C. D. Huford, *Phytochemistry*, 1989, **28**, 107.
423 K. Tomioka, F. Masumi, T. Yamashita and K. Koga, *Tetrahedron*, 1989, **45**, 643.
424 Y. Amate, J. L Breton, A. Garcia-Granados, A. Martínez, M. E. Onorato and A. Saenz de Buruaga, *Tetrahedron*, 1990, **46**, 6939.
425 R. Trejo, A. Gaytan, D. Mendoza and M. Sabanero, *Microbios*, 1996, **88**, 97.
426 A. F. Barrero, J. E. Oltra, D. S. Raslan and D. A. Saude, *J. Nat. Prod.*, 1999, **62**, 726.
427 T. Hashimoto, Y. Noma and Y. Asakawa, *Heterocycles*, 2001, **54**, 529.
428 Atta-ur-Rahman, M. I. Choudhary, A. Ata, M. Alam, A. Farooq, S. Perveen, M. S. Shekhani and N. Ahmed, *J. Nat. Prod.*, 1994, **57**, 1251.
429 M. Lida, S. Wakuri, S. Mineki, K. Nishitani and K. Yamakawa, *J. Ferment. Bioeng.*, 1993, **76**, 296.
430 Y. García, A. García-Granados, A. Martínez, A. Parra, F. Rivas and J. M. Arias, *J. Nat. Prod.*, 1995, **58**, 1498.
431 A. Ata and J. A. Nachtigall, *Z. Naturforsch., C: Biosci.*, 2004, **59**, 209.
432 S. K. Bagal, R. M. Adlington, J. E. Baldwin and R. Marquez, *J. Org. Chem.*, 2004, **69**, 9100.
433 D. Colaco, I. Furtado, U. P. Naik, S. Mavinkurve and S. K. Paknikar, *Lett. Appl. Microbiol.*, 1993, **17**, 212.
434 V. Beri and J. P. Lepoittevin, *Photochem. Photobiol.*, 1999, **69**, 653.
435 V. Singh, S. R. Iyer and S. Pal, *Tetrahedron*, 2005, **61**, 9197.
436 A. K. Banerjee, W. J. Vera and N. Canudas González, *Tetrahedron*, 1993, **49**, 4761.
437 A. García-Granados, A. Parra, Y. Simeó and A. L. Extremera, *Tetrahedron*, 1998, **54**, 14421.
438 V. Barges, G. Blay, L. Cardona, B. García and J. R. Pedro, *Tetrahedron Lett.*, 1995, **36**, 8469.
439 W. J. Xia, D. R. Li, L. Shi, A. C. Cao and Y. Q. Tu, *Chin. Chem. Lett.*, 2002, **13**, 101.
440 Z. Rozsa and I. Pelczer, *J. Chem. Soc., Perkin Trans. 1*, 1989, 1089.
441 K. Yamakawa, K. Nishitani, M. Iida and A. Mikami, *Chem. Pharm. Bull.*, 1986, **34**, 1319.
442 I. G. Collado, J. G. Madero, G. M. Massanet, F. R. Luis and F. R. Fronczek, *Tetrahedron Lett.*, 1990, **31**, 5795.
443 R. S. Harapanhalli, *J. Chem. Soc., Perkin Trans. 1*, 1990, 2633.
444 G. Blay, M. L. Cardona, B. Garcia and J. R. Pedro, *J. Org. Chem.*, 1991, **56**, 6172.
445 I. Gonzalez-Collado, J. Gomez-Madero, G. Martinez-Massanet and F. Rodriguez-Luis, *J. Org. Chem.*, 1991, **56**, 3587.
446 M. Ando, K. Isogai, H. Azami, N. Hirata and Y. Yanagi, *J. Nat. Prod.*, 1991, **54**, 1017.
447 W. D. Z. Li and Z. H. Gao, *Org. Lett.*, 2005, **7**, 2917.
448 F. J. Moreno-Dorado, F. M. Guerra, F. J. Aladro, J. M. Bustamante, Z. D. Jorge and G. M. Massanet, *J. Nat. Prod.*, 2000, **63**, 934.
449 G. M. Massanet, F. M. Guerra, Z. D. Jorge and C. Astorga, *Phytochemistry*, 1997, **45**, 1645.
450 F. J. Aladro, F. M. Guerra, F. J. Moreno-Dorado, J. M. Bustamante, Z. D. Jorge and G. M. Massanet, *Tetrahedron*, 2001, **57**, 2171.
451 A. F. Barrero, J. E. Oltra, J. M. Cuerva and A. Rosales, *J. Org. Chem.*, 2002, **67**, 2566.
452 Y. Higuchi, F. Shimoma, R. Koyanagi, K. Suda, T. Mitsui, T. Kataoka, K. Nagai and M. Ando, *J. Nat. Prod.*, 2003, **66**, 588.
453 F. A. Macías, J. M. Aguilar, J. M. G. Molinillo, F. Rodríguez-Luis, I. G. Collado, G. M. Massanet and F. R. Fronczek, *Tetrahedron*, 2000, **56**, 3409.
454 M. Holub and M. Budesinsky, *Phytochemistry*, 1986, **25**, 2015.
455 A. G. González, J. L. Bretón, A. Galindo and F. Rodríguez-Luis, *An. Quim.*, 1973, **69**, 1339.
456 A. F. Barrero, J. E. Oltra and M. Alvarez, *Tetrahedron Lett.*, 1998, **39**, 1401.
457 T. Kawamata, N. Nagashima, R. Nakai and T. Tsuji, *Synth. Commun.*, 1996, **26**, 139.
458 F. A. Macías, J. M. Aguiar, J. M. G. Molinillo, G. M. Massanet and F. R. Fronczek, *Tetrahedron*, 1994, **50**, 5439.
459 J. L. Bretón, J. J. Cejudo, A. García-Granados, A. Parra and F. Rivas, *Tetrahedron*, 1994, **50**, 2917.
460 G. Blay, L. Cardona, B. García and J. R. Pedro, *J. Org. Chem.*, 1993, **58**, 7204.
461 G. Blay, L. Cardona, B. García and J. R. Pedro, *J. Nat. Prod.*, 1993, **56**, 1723.
462 G. Blay, L. Cardona, B. García and J. R. Pedro, *Can. J. Chem.*, 1992, **70**, 817.
463 J. L. Bretón, J. J. Cejudo, A. García-Granados, A. Parra and F. Rivas, *Tetrahedron Lett.*, 1992, **33**, 3935.
464 G. Baly, L. Cardona, B. García and J. R. Pedro, *Tetrahedron Lett.*, 1992, **33**, 5253.
465 M. Carda, J. F. Sanz and J. A. Marco, *J. Org. Chem.*, 1992, **57**, 804.
466 N. Simizu, H. Akita, T. Oishi and S. Inayama, *Chem. Pharm. Bull.*, 1994, **42**, 1160.
467 G. Blay, L. Cardona, B. García, C. L. García and J. R. Pedro, *Tetrahedron Lett.*, 1994, **35**, 931.
468 M. Watanabe and N. Harada, *J. Org. Chem.*, 1995, **60**, 7372.
469 K. Nishitani, J. Suzuki, H. Ishibashi, Y. Saitoh, S. Kariya and K. Yamakawa, *Heterocycles*, 1994, **39**, 43.
470 P. Metz, J. Stolting, M. Lage and B. Krebs, *Angew. Chem., Int. Ed. Engl.*, 1994, **31**, 2195.
471 A. K. Banerjee and J. A. Azocar, *Monatsh. Chem.*, 1996, **127**, 1031.

472 F. J. Moreno-Dorado, F. M. Guerra, F. J. Aladro, J. M. Bustamante, Z. D. Jorge and G. M. Massanet, *Tetrahedron*, 1999, **55**, 6997.
473 T. Suzuki and M. Miyashita, *Heterocycles*, 2001, **54**, 865.
474 T. Prangé, M. S. Rodríguez and E. Suárez, *J. Org. Chem.*, 2003, **68**, 4422.
475 S. K. Bagal, R. M. Adlington, R. Marquez, A. Cowley and J. E. Baldwin, *Tetrahedron Lett.*, 2003, **44**, 4993.
476 T. Masuda, A. Jitoe and N. Nakatani, *Chem. Lett.*, 1991, 1625.
477 O. A. Konovalova, V. I. Sheichenko and K. S. Rybalko, *Khim. Prir. Soedin.*, 1991, 141.
478 N. J. Lawrence, A. T. Mcgown, J. Nduka, J. A. Hadfield and R. G. Pritchard, *Bioorg. Med. Chem. Lett.*, 2001, **11**, 429.
479 B. Fu, B. N. Su, Y. Takaishi, G. Honda, M. Ito, Y. Takeda, O. K. Kodzhimatov and O. Ashurmetov, *Phytochemistry*, 2001, **57**, 1121.
480 B. N. Su, Y. Takaishi, T. Yabuuchi, T. Kusumi, M. Tori, S. Takaoka, G. Honda, M. Ito, Y. Takeda, O. K. Kodzhimatov and O. Ashurmetov, *J. Nat. Prod.*, 2001, **64**, 466.
481 B. Kaur and P. S. Kalsi, *Phytochemistry*, 1985, **24**, 2007.
482 F. Bohlmann, J. Jakupovic, L. Hartono, R. M. King and H. Robinson, *Phytochemistry*, 1985, **24**, 1100.
483 P. S. Kalsi, R. Goyal, K. K. Talwar and B. R. Chhabra, *Phytochemistry*, 1989, **28**, 2093.
484 F. Bohlmann, C. Zdero, R. M. King and H. Robinson, *Liebigs Ann. Chem.*, 1986, 799.
485 C. Yang, Y. P. Shi and Z. J. Jia, *Planta Med.*, 2002, **68**, 626.
486 C. Yang, Y. Zhu and Z. J. Jia, *Aust. J. Chem.*, 2003, **56**, 621.
487 C. Yang, Y. P. Shi, X. Wang and Z. J. Jia, *Chin. Chem. Lett.*, 2002, **13**, 247.
488 A. G. Over and N. H. Fischer, *Phytochemistry*, 1987, **26**, 848.
489 S. Őksüz, G. Topeu, M. Krawiec and W. H. Watson, *Phytochemistry*, 1997, **46**, 1131.
490 D. Vargas, F. R. Fronczek, A. G. Ober and N. H. Fisher, *Spectrosc. Lett.*, 1991, **24**, 1353.
491 R. X. Tan and Z. J. Jia, *Planta Med.*, 1992, **58**, 370.
492 F. Bohlmann, G. W. Ludwig, J. Jakupovic, R. M. King and H. Robinson, *Liebigs Ann. Chem.*, 1984, 228.
493 A. G. Gonzalez, J. Bermejo-Barrera, J. Triana-Mendez, M. Lopez-Sanchez and J. L. Eiroa-Martínez, *Phytochemistry*, 1990, **29**, 2339.
494 M. L. Uriburu, J. R. de la Fuente, J. Palermo, R. R. Gil and V. E. Sosa, *Phytochemistry*, 2004, **65**, 2039.
495 A. Rustaiyan, Z. Habibi, M. Saberi and J. Jakupovic, *Phytochemistry*, 1991, **30**, 2405.
496 O. M. Abdallah and Z. Z. Ibraheim, *Phytochemistry*, 1995, **50**, 277.
497 A. L. Perez, L. Nava and A. Romo deVivar, *Phytochemistry*, 1987, **26**, 765.
498 A. B. Gutierrez, J. C. Oberti, V. E. Sosa and W. Herz, *Phytochemistry*, 1987, **26**, 2315.
499 P. S. Kalsi, R. Goyal, K. K. Talwar and B. R. Chhabra, *Phytochemistry*, 1988, **27**, 2079.
500 J. Jakupovic, A. Schuster, F. Bohlmann, R. M. King and N. S. Lander, *Phytochemistry*, 1988, **27**, 3181.
501 C. Yang, Q. X. Zhu, W. Yong and Z. J. Jia, *Chin. Chem. Lett.*, 2001, **12**, 597.
502 C. Yang, Q. X. Zhu, Q. Zhang, Q. Wang and Z. J. Jia, *Pharmazie*, 2001, **56**, 825.
503 F. Bohlmann, J. Jakupovic, R. M. King and H. Robinson, *Phytochemistry*, 1981, **20**, 1613.
504 F. Bohlmann, A. Adler, J. Jakupovic, R. M. King and H. Robinson, *Phytochemistry*, 1982, **21**, 1349.
505 E. J. Park and J. Kim, *Planta Med.*, 1998, **64**, 752.
506 M. Kostantinopoulou, A. Karioti, S. Skaltsa and H. Skaltsa, *J. Nat. Prod.*, 2003, **66**, 699.
507 J. Kitajima, A. Kamoshita, T. Ishikawa, A. Takano, T. Fukuda, S. Isoda and Y. Ida, *Chem. Pharm. Bull.*, 2003, **51**, 152.
508 A. G. Ober, F. R. Fronczek and N. H. Fischer, *J. Nat. Prod.*, 1984, **47**, 920.
509 U. C. Pandey, R. P. Sharma, P. Kulanthaivel and W. Herz, *Phytochemistry*, 1985, **24**, 1509.
510 F. Bohlmann, W. Ang, R. M. King and H. Robinson, *Phytochemistry*, 1984, **23**, 2069.
511 S. M. Adekenov, M. Budesinsky, M. A. Abdikalikov, C. M. Turdybekov, D. Saman, E. Bloszyk, B. Drozdz and M. Holub, *Collect. Czech. Chem. Commun.*, 1990, **55**, 1568.
512 R. X. Tan, J. Jakupovic, F. Bohlmann, Z. J. Jia and S. Huneck, *Phytochemistry*, 1991, **30**, 583.
513 G. Ruecker, G. Paulini, H Sakulas, B. Lawong and F. Geoltenboth, *Planta Med.*, 1991, **57**, 278.
514 J. S. Mossa, F. S. El-Feraly, I. Muhammad, K. Zaw, Z. H. Mbwamho, J. M. Pezzuto and H. H. S. Fong, *J. Nat. Prod.*, 1997, **60**, 550.
515 B. K. Abduazimov, B. Tashkhodzhaev, S. Nasirov, I. D. Sham'yanov, R. M. Yagudaev, V. M. Malikov and S. N. Aminov, *Khim. Prir. Soedin.*, 1991, 19.
516 N. Goren, C. Bozok-Johansson, J. Jakupovic, L. J. Lin, H. L. Shieh, G. A. Cordell and N. Celik, *Phytochemistry*, 1992, **31**, 101.
517 E. C. de Riscala, S. Turbay, C. A. N. Catalán, L. R. Hernández and P. Joseph-Nathan, *Phytochemistry*, 2000, **53**, 873.
518 M. A. González-Romero, L. Villaescusa-Castillo and A. M. Diaz-Lanza, *Z. Naturforsch., C: Biosci.*, 2000, **55**, 697.
519 B. Huang, J. Sun and Z. Chen, *Zhiwu Xuebao*, 1992, **34**, 61.
520 N. Goeren and E. Tahtasakal, *Phytochemistry*, 1994, **36**, 1281.
521 W. Herz and V. E. Sosa, *Phytochemistry*, 1986, **25**, 1481.
522 F. Bohlmann, J. Jakupovic, N. Ates, A. Schuster, J. Pickardt, R. M. King and H. Robinson, *Liebigs Ann. Chem.*, 1983, 962.
523 V. Castro and U. Warning, *Ing. Cienc. Quim.*, 1987, **11**, 5.
524 J. F. Hu and Z. J. Jia, *Planta Med.*, 1999, **65**, 386.
525 F. Bohlmann, G. Schmeda-Hirschmann, J. Jakupovic, R. M. King and H. Robinson, *Phytochemistry*, 1984, **23**, 1989.
526 N. Goren, A. Ulubelen, C. Bozok-Johansson and T. Gebze-Kocaeli, *Phytochemistry*, 1993, **33**, 1157.
527 N. Gören and E. Tahtasakal, *Phytochemistry*, 1997, **45**, 107.
528 W. Herz and P. Kulanthaivel, *Phytochemistry*, 1984, **23**, 2271.
529 M. N. Todorova and L. N. Evstatieva, *Z. Naturforsch., C: Biosci.*, 2001, **56**, 506.
530 S. F. Farag, N. A. El-Emary and M. Niwa, *Chem. Pharm. Bull.*, 1996, **44**, 661.
531 C. Y. Ragasa, W. G. Padolina, B. F. Bowden, S. Li, D. M. Tapiolas and J. C. Coll, *J. Nat. Prod.*, 1993, **56**, 386.
532 D. T. Ferreira, A. R. Levoraro, T. De J. Faria, M. G. De Carvalho and R. Braz-Filho, *Nat. Prod. Lett.*, 1994, **4**, 1.
533 S. K. Panikar and L. G. Sardesai, *Planta Med.*, 1988, **54**, 186.
534 M. A. Al-Yahya, A. M. El-Sayed, J. S. Mossa, J. F. Kozlowski, M. D. Antoun, M. Ferin, W. M. Baird and J. M. Cassady, *J. Nat. Prod.*, 1988, **51**, 621.
535 R. Goyal, B. R. Chhabra and P. S. Kalsi, *Phytochemistry*, 1990, **29**, 2341.
536 S. Matsueda, M. Nagaki and M. Koreeda, *Tennen Yuki Kagobutsu Toronkai Koen Yoshishu*, 1986, **28**, 248.
537 G. Appendino, P. Gariboldi and G. M. Nano, *Phytochemistry*, 1983, **22**, 2767.
538 G. Appendino, M. Calleri, C. Chiari and D. Viterbo, *J. Chem. Soc., Perkin Trans. 2*, 1984, 903.
539 Q. F. Zhang, S. D. Luo and H. Y. Wang, *Chin. Chem. Lett.*, 1998, **9**, 1097.
540 M. Nagashima and N. Nakatani, *Chem. Express*, 1991, **6**, 993.
541 A. G. Ober, F. R. Fronczek and N. H. Fischer, *J. Nat. Prod.*, 1984, **47**, 626.
542 M. Nagaki, *Phytochemistry*, 1984, **23**, 462.
543 A. G. Gonzalez, A. Galindo, H. Mansilla, V. H. Kesternich, J. A. Palenzuela and M. L. Rodriguez, *J. Nat. Prod.*, 1990, **53**, 462.
544 M. A. Janusa, M. S. Jeansoone, F. R. Fronczek and S. F. Watkins, *Acta Crystallogr., Sect. C: Cryst. Struct. Commun.*, 1990, **46**, 2474.
545 M. L. Cardona, I. Fernandez, B. Gracia and J. R. Pedro, *J. Nat. Prod.*, 1990, **53**, 1042.
546 A. M. Galal, *J. Nat. Prod.*, 2001, **64**, 1098.
547 M. Schaeffer, J. Stampf and C. Benezra, *J. Org. Chem.*, 1989, **54**, 6106.
548 A. F. Barrero, A. Rosales, J. M. Cuerva and J. E. Oltra, *Org. Lett.*, 2003, **5**, 1935.
549 G. Blay, L. Cardona, B. García, J. R. Pedro and A. Serrano, *Tetrahedron*, 1992, **48**, 5265.
550 M. Ishihara, T. Tsuneya and K. Uneyama, *Phytochemistry*, 1991, **30**, 3343.
551 F. Bohlmann, E. Tsankova, R. M. King and H. Robinson, *Phytochemistry*, 1984, **23**, 1099.
552 B. Zhou, N. Bai, L. Lin and G. A. Cordell, *Phytochemistry*, 1993, **34**, 249.
553 F. Jeske, S. Huneck and J. Jakupovic, *Phytochemistry*, 1993, **34**, 1647.
554 N. Bai, B. N. Zhou, L. Zhang, S. Sang, K. He and Q. Y. Zheng, *ACS Symp. Ser.*, 2003, **859**, 271.
555 A. García-Granados, M. C. Gutiérrez and F. Rivas, *Org. Biomol. Chem.*, 2003, **1**, 2314.

556 J. Merten, R. Frohlich and P. Metz, *Angew. Chem., Int. Ed.*, 2004, **43**, 5991.
557 Z. Zhang, G. Zhou, X. L. Gao, Y. L. Li and R. Liao, *Synth. Conmmun.*, 2001, **31**, 847.
558 Y. G. Chen, G. Zhou, Z. M. Xiong, L. J. Liu and Y. L. Li, *J. Chin. Chem. Soc. (Taipei)*, 2001, **48**, 261.
559 L. Y. Mou, L. Y. Zhu, Z. Y. Lin and X. T. Liang, *J. Asian Nat. Prod. Res.*, 2001, **3**, 103.
560 Z. M. Xiong, G. Zhou, X. L. Gao, Y. G. Chen and Y. L. Li, *Chin. Chem. Lett.*, 2000, **11**, 113.
561 Z. Zhang, Z. M. Xiong, G. J. Zheng and Y. L. Li, *Tetrahedron: Asymmetry*, 2001, **12**, 2137.
562 Z. Zhang, Z. M. Xiong, Y. K. Guan, G. J. Zheng and Y. L. Li, *Chin. Chem. Lett.*, 2001, **12**, 881.
563 L. J. Fang, J. C. Chen, G. J. Zheng, C. Zhang and Y. L. Li, *Chirality*, 2005, **17**, 163.
564 R. Mata, A Rojas, M. Soriano, R. Villena, R. Bye and E. Linares, *Heterocycles*, 1990, **31**, 1111.
565 M. García-Soriano, R. V. Iribe, R. Mata and A. Rojas, *Acta Crystallogr., Sect. C: Biosci.*, 1990, **46**, 1966.
566 Y. H. Kuo and C. H. Chen, *Chem. Pharm. Bull.*, 1997, **45**, 1223.
567 T. L. Ho and M. F. Ho, *J. Chem. Soc., Perkin Trans. 1*, 1999, 1823.
568 K. Gao and Z. J. Jia, *Phytochemistry*, 1998, **49**, 167.
569 F. H. Guidugli, M. J. Pestchanker, M. S. A. de Salmeron and O. S. Giordano, *Phytochemistry*, 1986, **25**, 1923.
570 C. Rossi, A. Evidente and A. Menghini, *Phytochemistry*, 1985, **24**, 603.
571 A. L. Perez, A. Ortega and A. Romo deVivar, *Phytochemistry*, 1988, **27**, 3897.
572 C. Rossi, G. Grandolini and F. Menichini, *J. Chem. Res. (S)*, 1985, 160.
573 R. Kaiser and C. Nussbaumer, *Helv. Chim. Acta*, 1990, **73**, 133.
574 A. Saito, A. Tanaka and T. Oritani, *Tetrahedron: Asymmetry*, 1996, **7**, 2923.
575 U. Huber, W. Boland, W. A. König and B. Gehrcke, *Helv. Chim. Acta*, 1993, **76**, 1949.
576 D. Spiteller, A. Jux, J. Piel and W. Boland, *Phytochemistry*, 2002, **61**, 827.
577 B. Gust, G. L. Challis, K. Fowler, T. Kieser and K. F. Chater, *Proc. Natl. Acad. Sci. U. S. A.*, 2003, **100**, 1541.
578 D. E. Cane and R. M. Watt, *Proc. Natl. Acad. Sci. U. S. A.*, 2003, **100**, 1547.
579 H. H. Jelen, M. Majcher, R. Zawirska-Wojtasiak, M. Wiewiórowska and E. Wasowicz, *J. Agric. Food Chem.*, 2003, **51**, 7079.
580 Y. Lin, T. Lin, Z. Yuan, Z. Wu, J. Fang and Z. Huang, *Zhongshan Daxue Xuebao, Ziran Kexueban*, 1996, **35**, 75.
581 Y. Lin, T. Jin, X. Wu, Z. Huang and J. Fan, *J. Nat. Prod.*, 1997, **60**, 27.
582 K. B. Iken and B. J. Baker, *J. Nat. Prod.*, 2003, **66**, 888.
583 S. K. Bagal, R. M. Adlington, J. E. Baldwin, R. Marquez and A. Cowley, *Org. Lett.*, 2003, **5**, 3049.
584 L Quijano, F. Gomez-Gomez-Garibay, R. I. Trejo and T. Ríos, *Phytochemistry*, 1991, **30**, 3293.
585 Z. Huang, Y. Lin, S. Liu and W. Chan, *Indian J. Chem., Sect. B: Org. Chem. Incl. Med. Chem.*, 1999, **38**, 106.
586 J. Jakupovic, Y. Y. Jia, R. M. King and F. Bohlmann, *Liebigs Ann. Chem.*, 1986, 1474.
587 B. N. Su, Y. Takaishi, M. Tori, S. Takaoka, G. Honda, M. Itoh, Y. Takeda, O. K. Kodzhimatov and O. Ashurmetov, *Tetrahedron*, 2000, **41**, 1475.
588 B. N. Su, Y. Takaishi, M. Tori, S. Takaoka, G. Honda, M. Itoh, Y. Takeda, O. K. Kodzhimatov and O. Ashurmetov, *Org. Lett.*, 2000, **2**, 493.
589 H. Matsuda, T. Kageura, Y. Inoue, T. Morikawa and M. Yoshikawa, *Tetrahedron*, 2000, **56**, 7763.
590 K. M. Turdybekov, S. V. lindeman, T. V. Timofeeva and Y. T. Struchkov, *Khim. Prir. Soedin.*, 1990, 344.
591 N. H. Fischer, J. D. Weidenhamer, J. L. Riopèl, L. Quijano and M. A. Menelaou, *Phytochemistry*, 1990, **29**, 2479.
592 V. P. Emerenciano, M. J. P. Ferreira, M. D. Branco and J. E. Dubois, *Chemom. Intell. Lab. Syst.*, 1998, **40**, 83.
593 F. B. Da Costa, L. Terfloth and J. Gasteiger, *Phytochemistry*, 2005, **66**, 345.

