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DITERPENES AND TETRANORDITERPENES FROM *ACRITOPAPPUS* SPECIES*

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Key Word Index *Acritopappus hagei*; *A. confertus*; *A. morii*; *A. teixeirae*; Compositae; Eupatorieae; new diterpenes; kolavanes; labdanes; tetranorditerpenes; new bicyclogermacrene alcohol; new benzofurans.

Abstract—The investigation of four *Acritopappus* species afforded twenty-three new diterpenes of the labdane or kolavane type and three tetranorditerpenes as well as two new benzofuran derivatives and a hydroxybicyclogermacrene. The structures were elucidated by spectroscopic methods and by some chemical transformations. Though the absolute configuration were not established in all cases, most probably all diterpenes were *ent*-labdanes or kolavanes (≡clerodanes). The chemotaxonomic importance of this investigation is discussed briefly.

INTRODUCTION

Acritopappus (tribe Eupatorieae, family Compositae) is a small Brazilian genus, which together with *Radlkoferotoma* belongs to a group closely related to the *Gyptis* group [1]. Two of the species were placed in the genus *Ageratum*, which, however, differs most significantly from *Acritopappus* by having a conical receptacle and glandular punctate leaves. So far nothing is known about the chemistry of any species of this genus. We have now investigated four species, *A. hagei* K. et R., *A. confertus* (Gardn.) K. et R., *A. morii* K. et R. and *A. teixeirae* K. et R., in order to see whether the chemistry gives an indication of relationships to other genera or groups in the Eupatorieae. Along with known compounds, more than 20 new diterpenes were isolated all being *ent*-labdane or kolavane derivatives. However, a few were degraded tetranorditerpenes. In addition a new sesquiterpene and two new dihydrobenzofurans derivatives were also present.

RESULTS AND DISCUSSION

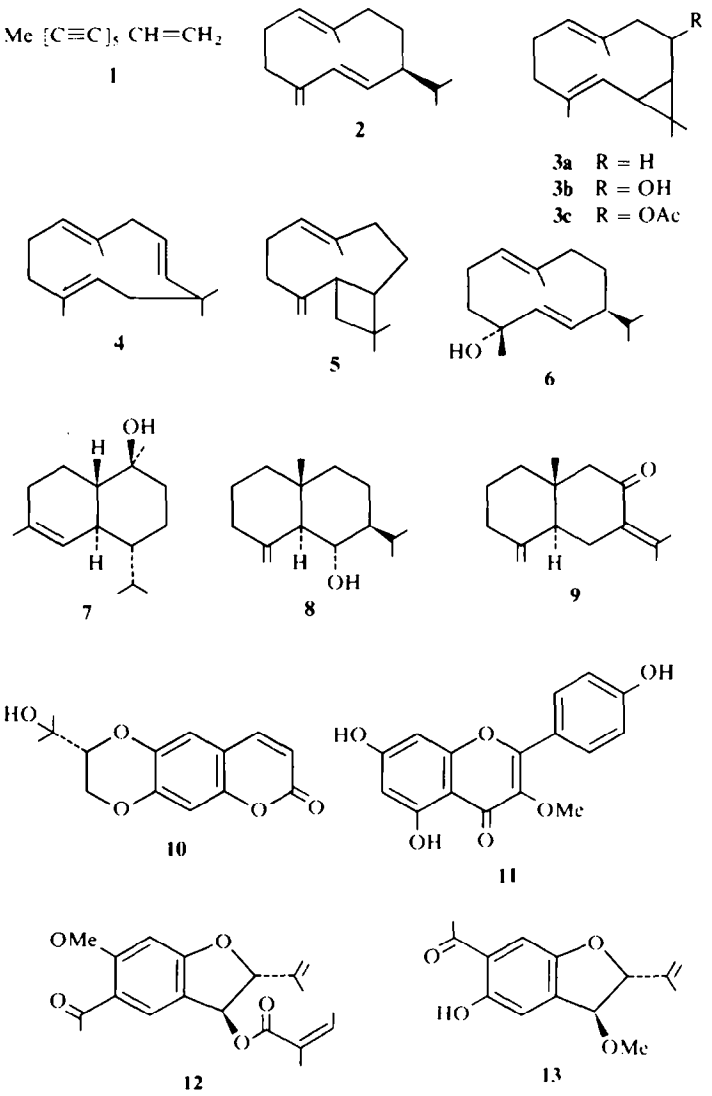
The aerial parts of *A. hagei* K. et R. afforded in addition to **1**, **2** and **3a**, *epi*-friedelinol, the obliquine derivative **10** [2], the flavone **11** and a complex mixture of diterpenes, which were separated after esterification of the acidic part. Finally, five methyl esters were obtained, four being derivatives of methylkolavenate (**22**) [3] oxidized at C-16 and C-18. ^{1}H NMR studies (Table 1) and chemical transformations led to the identification of structures **14b**, **15b**, **16b** and **17b** for the esters and consequently the natural products were **14a**, **15a**, **16a** and **17a**, respectively. The main compound was the diol **15a**. Its methyl ester **15b** on acetylation afforded the diacetate **21** and on MnO_2 oxidation gave a mixture of the two isomeric aldehydes **17b** and **19** and the dialdehyde **18**. All ^{1}H NMR spectra (Table 1) were very similar to that of **22**. The second ester was the hydroxyacetate **14b**, which on acetylation afforded the same diacetate as the diol **15b**, while MnO_2 oxidation gave the aldehyde **16b**, identical with the ester of the third natural compound. The observed differences of the chemical shifts in the spectra of **14b** and **16b** clearly indicated that the acetate group in **14b** was positioned at C-16, while decoupling experiments with **16b** showed that the second double bond must be between C-3 and C-4. Irradiation of the signal of the olefinic proton (δ 6.04 *dd* in C_6D_6) changed the multiplets at 2.28 and 2.14. These signals can be assigned only to 2-H since if a 7,8-double bond was present these signals should be simple double doublets. A three-fold doublet must be assigned to 6α-H as this signal was shifted downfield in the aldehyde when compared with the chemical shift in the diacetate **21**. The addition of Eu(fod)$_3$ allowed further decouplings which clearly showed that 2-H had a neighbouring CH_2 group, although the signals of the latter were partly overlapped by other peaks. Furthermore, the observed Eu(fod)$_3$-induced shifts were in good agreement with the proposed structures. In particular the shifts of the methyl signals could be explained only by a structure related to a kolavenic acid derivative and not by that of an isomeric 7,8-unsaturated labdane. The *E*-configuration of the 13,14-double bond also followed from the ^{1}H NMR data, as the shift difference for 14-H in **15b** and **18** was 0.5 ppm and the chemical shift of the aldehyde proton was also that of an *E*-configuration unsaturated aldehyde. The absolute configuration of **22** is established [4] and most probably all the diterpenes have the same configuration as their optical rotations are similar.

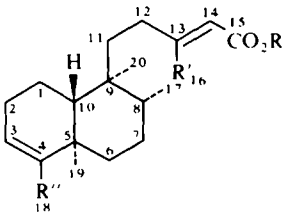
A further ester **17b** could not be separated completely from **14b**. The ^{1}H NMR spectral data (Table 1) clearly show that this compound had a free 16-hydroxy group, while the aldehyde was located at C-4 (δ 6.61, *br. t*, 3-H). However, the ^{1}H NMR data were identical with those of one of the hydroxyaldehydes obtained by MnO_2 oxidation of **15b**.

* Part 281 in the series 'Naturally Occurring Terpene Derivatives'; for Part 280 see: Bohlmann, F. and Bohlmann, R. (1980) *Phytochemistry* **19**, 2045.

	14b	15b	16b*	Δ*	C_6D_6	17b	18	19	20	21	Δ†
2-H			} 2.50 *m*	} 0.36	2.28 *m*		} 2.57 *m*			2.19 *m*	0.46
2'-H					2.14 *m*						
3-H	5.57 *t*(*br*)	5.58 *t*(*br*)	6.61 *t*(*br*)	0.45	6.04 *dd*(*br*)	6.61 *t*(*br*)	6.63 *t*(*br*)		5.60 *t*(*br*)	5.60 *t*(*br*)	1.28
8-H			1.50 *m*							1.58 *m*	0.54
11-H			1.50 *m*	~0.1						1.68 *m*	
12-H	} 2.45 *m*	2.43 *ddd*	2.54 *m*	0.26	2.64 *ddd*		2.6 *m*		2.45 *m*	2.48 *ddd*	} 0.7
12'-H		2.34 *ddd*	2.32 *ddd*	0.30	2.42 *ddd*		2.47 *ddd*			2.41 *ddd*	
14-H	5.81 *t*	5.95 *t*	5.84 *t*	0.17	5.98 *t*	5.96 *t*	6.45 *s*	6.45 *s*	5.81 *t*	5.82 *t*	1.02
16-H	4.59 *d*	4.17 *d*	4.61 *d*	0.23	4.46 *d*	4.15 *d*	9.52 *s*	0.51 *s*	4.62 *d*	4.59 *d*	1.28
17-H	0.86 *d*	0.86 *d*	0.87 *d*	0.09	0.89 *d*	0.85 *d*	0.88 *d*	0.86 *d*	0.87 *d*	0.87 *d*	0.28
18-H	4.08 *s*(*br*)	4.09 *s*(*br*)	9.31 *s*	1.34	9.30 *s*	9.29 *s*	9.32 *s*	4.13 *s*(*br*)	4.52 *s*(*br*)	4.52 *s*(*br*)	3.30
19-H	1.07 *s*	1.08 *s*	1.16 *s*	0.66	1.27 *s*	1.16 *s*	1.17 *s*	1.08 *s*	1.08 *s*	1.08 *s*	0.63
20-H	0.73 *s*	0.73 *s*	0.75 *s*	0.19	0.68 *s*	0.79 *s*	0.71 *s*	0.71 *s*	0.74 *s*	0.74 *s*	0.28
OAc	2.13 *s*		2.13 *s*	0.17	1.70 *s*				2.15 *s*	2.13 *s*	0.19
									2.07 *s*	2.07 *s*	2.98
CO_2Me	3.70 *s*	3.71 *s*	3.71 *s*	0.09	3.43 *s*	3.71 *s*	3.83 *s*	3.69 *s*		3.71 *s*	0.54

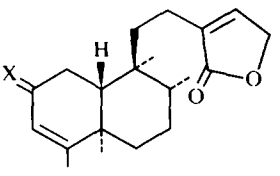
*6α-H 2.64 (*ddd*, *J* = 13,3,3 Hz) Δ 1.24; †Δ-values after addition $Eu(fod)_3$.
J(Hz): 2,3 = 3,5; 7,17 = 7; 14,16 = 1.5; 11,12 = 4; 11'12 = 13; 11,12' = 12; 11',12' = 5; 12,12' = 13.



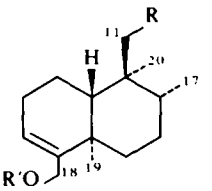


	14a	14b	15a	15b	16a	16b
R	H	Me	H	Me	H	Me
R′	CH_2OAc	CH_2OAc	CH_2OH	CH_2OH	CH_2OAc	CH_2OAc
R″	CH_2OH	CH_2OH	CH_2OH	CH_2OH	CHO	CHO

	17a	17b	18	19	20	21	22
R	H	Me	Me	Me	H	Me	Me
R′	CH_2OH	CH_2OH	CHO	CHO	CH_2OAc	CH_2OAc	Me
R″	CHO	CHO	CHO	CH_2OH	CH_2OAc	CH_2OAc	Me

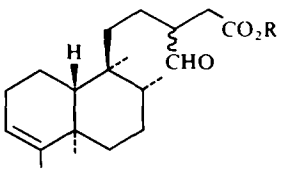


23a X = β-OH, α-H
23b X = β-OAc, α-H
24 X = O

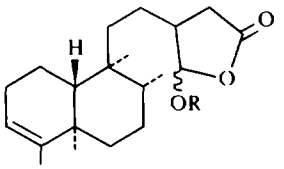


	25a	25b
R	CO_2H	CO_2Me
R′	H	H

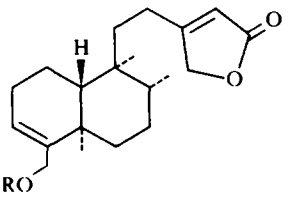
	25c	26a	26b*
R′	CO_2Me	CH_2OH	CH_2OAc
R′	Ac	H	Ac



27a R = H
27b R = Me



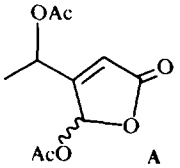
28a R = H
28b R = Ac



29a R = H
29b R = Ac

The last methyl ester could only be purified after acetylation. The acetate had the molecular formula $C_{19}H_{30}O_4$ and therefore this ester must be formed from the acid $C_{16}H_{26}O_3$ clearly indicating, together with the ^{1}H NMR spectrum (Table 2), that it was the tetranorditerpene **25a**. While most of the ^{1}H NMR chemical shifts were very similar to those of **21**, the signals for the C-9 side chain were missing. Only a pair of doublets at δ 2.44 and 2.32 (J = 13 Hz) were new and they could only be assigned to 11-H. In the mass spectrum of **25c** loss of HOAc gave a peak at m/e 262. Further elimination of MeOH and CH_2CO_2Me produced prominent fragments at m/e 230 and 189 which were in good agreement with the proposed structure. We have named compound **25a** acritopappus acid.

The neutral part of the extract afforded four more diterpenes. The main constituents were isolated in a pure state only after acetylation. However, the resulting mixture of epimers could not be separated. In the EI mass spectrum no molecular ion could be detected but the CI spectrum displayed a weak $M^+ + 1$ ion (m/e 419). The spectral data showed that we were dealing with lactones which had two acetoxy groups. The ^{1}H NMR spectrum (Table 3) displayed typical signals for a five-membered unsaturated lactone. The substitution pattern was established by decoupling experiments, which led to the partial structure **A**, where the ring acetoxy group is either α- or β-orientated.



The other signals were very similar to those of labdane derivatives with a 7,8-double bond. Therefore the structures of the epimers were most probably **31a** and **31b** and consequently those of the natural products were **30a** and **30b** respectively. The absolute configuration could not be assigned with certainty. However, as discussed later, they were most probably *ent*-labdanes.

Two further lactones isolated in minute amounts probably had the structures **23a** and **24**. They showed typical ^{1}H NMR signals (Table 2) similar to those of

* Carbon numbering is the same as in the diterpenes.

Table 2. ^{1}H NMR spectral data of compounds **23a**, **23b**, **24**, **25c**, **26b**, **27b**, **28a** and **29b** (270 MHz, $CDCl_3$)

	23a*	**23b***	**24†**	**25c**	**26b**	**27b**	+ Eu(fod)$_3$‡	**28a**	**29b**
2-H	4.25 *m*	5.33 *m*			2.15 *m*				2.18 *m*
2'-H									
3-H	5.23 *s(br)*	5.16 *s(br)*	5.74 *s*	5.58 *t(br)*	5.59 *t(br)*	5.18 *s(br)*	5.18 *s(br)*	5.19 *s(br)*	5.59 *t(br)*
8-H				2.44 *d*					
11-H				2.32 *d*					
12-H				2.15 *m*	4.07 *ddd*				2.28 *m*
12'-H					3.99 *ddd*				
13-H				—					
14-H	7.10 *t*	7.14 *t*	7.09 *t*	—		2.72 *m*	2.71 *dddd*	5.84 *t*	2.3–2.5 *m*
14'-H						2.42 *m*	3.05 *m*		
16-H	-			—	—	9.70 *s(br)*	9.91 *s(br)*	5.52 *s(br)*	4.74 *d*
17-H	0.84 *d*	0.85 *d*	0.88 *d*	0.92 *d*	0.87 *d*	0.78 *d(br)*	0.80 *d(br)*	0.83 *m*	0.83 *d*
18-H	1.63 *s(br)*	1.64 *s(br)*	1.90 *d*	4.51 *s(br)*	4.51 *s(br)*	1.58 *s(br)*	1.58 *s(br)*	1.60 *s(br)*	4.52 *s(br)*
19-H	1.06 *s*	1.08 *s*	1.13 *s*	1.08 *s*	1.07 *s*	0.99 *s*	1.00 *s*	1.02 *s*	1.09 *s*
20-H	0.78 *s*	0.77 *s*	0.85 *s*	0.79 *s*	0.77 *s*	0.71 *s*	0.73 *s*	0.75 *s*	0.79 *s*
OAc		2.06 *s*		2.06 *s*	2.08 *s*				2.07 *s*
					2.04 *s*				
CO_2Me				3.65 *s*	—	OMe 3.68 *s*	5.89 *s*		

* 15-H 4.77 *dt* (J = 2,2 Hz).

† (C_6D_6) 1-H 2.41 *dd*, (J = 17,4 Hz); 1'-H 2.25 *dd*, (J = 17,14 Hz).

‡ Δ-values after addition of Eu(fod)$_3$.

J(Hz): 2,3 = 3.5; 7,17 = 7; 14,16 = 1.5; 11,12 = 4; 11',12 = 13; 11,12' = 12; 11',12 = 5; 11',12 = 5; 12,12' = 13; **25c**: 11,11' = 13; **26b**: 11,12 = 6; 12,12' = 11.

kovalenic acid (Table 2). However, an oxygen function at C-2 was indicated by an additional signal at δ 4.25 in the spectrum of one of the compounds, which could only be purified after acetylation. In the ^{1}H NMR spectrum of the acetate the signal at 4.25 was shifted to 5.33. Decoupling experiments showed that this signal must be assigned to 2-H. The data of the second lactone showed that we were dealing with the corresponding 2-ketone (Table 2), because the signals for the olefinic proton and the olefinic methyl group were shifted downfield. The observed couplings for $J_{1,2}$ supported the *trans*-annelation of the decalin system.

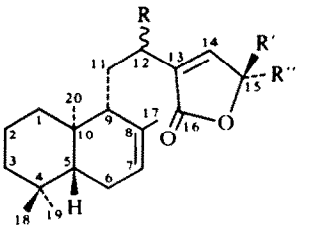
Two further diterpenes, less polar that **30b**, could only be isolated as their acetates. The spectral data showed that they were the acetates **26b** and **29b**. The ^{1}H NMR spectral data of **29b** showed that a labdane derivative was present, with the lactone carbonyl now at C-15 and the acetate group located at C-18. The other signals were very similar to those of the other labdanes isolated. Compound **26b** was a tetranorditerpene closely related to **29a**. From the ^{1}H NMR data (Table 2) it was apparent that the C-11 carbomethoxy group was replaced by an acetoxymethylene group. The structures of the natural products therefore are **26a** and **29a**. Compound **26a** has been named acritopappusol.

The roots afforded, in addition to polyisoprene, compounds **1**, **3a**, **6**, **7**, and the alcohol **3b** which was purified as its acetate. The corresponding angelate has been isolated previously [5] and the ^{1}H NMR spectral

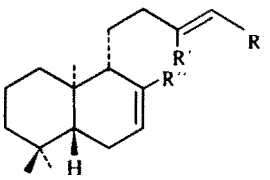
Table 3. ^{1}H NMR spectral data of compounds **31a**, **31b**, **37a**, **37b**, **38a** and **38b** (270 MHz, TMS as internal standard, $CDCl_3$)

	31a	**31b**	**31a** (C_6D_6)	**31b** (C_6D_6)	**37a**	**37b**	**38a**	**38b**
6-H						2.61 *dd*		
6'-H						2.31 *dd*		
7-H	5.49 *s(br)*	5.49 *s(br)*	5.52 *s(br)*	5.52 *s(br)*	4.39 *s(br)*		5.78 *d(br)*	6.83 *ddd*
12-H	5.71 *dt*	5.70 *dt*	5.76 *dt*	5.64 *dt*	2.54 *ddd*	2.58 *ddd*	2.72 *ddd*	2.90 *ddd*
12'-H					2.26 *ddd*	2.30 *m*	2.45 *ddd*	2.40 *m*
14-H	7.00 *d*	7.06 *d*	7.00 *d*	7.09 *d*	6.28 *dd*	6.27 *s(br)*	6.30 *s(br)*	6.34 *s(br)*
15-H	6.09 *t*	6.18 *t*	5.64 *t*	5.68 *t*	7.35 *dd*	7.36 *dd*	7.36 *dd*	7.34 *dd*
16-H					7.21 *dd*	7.22 *s(br)*	7.24 *s(br)*	7.23 *s(br)*
17-H	1.71 *s(br)*	1.71 *s(br)*	1.75 *s(br)*	1.75 *s(br)*	5.01 *dd*	5.87 *dd*	4.20 *d(br)*	9.42 *s*
17'-H					4.70 *dd*	5.16 *dd*	4.02 *d(br)*	
18-H	0.89 *s*	0.89 *s*	0.88 *s*	0.88 *s*	0.89 *s*	0.88 *s*	0.89 *s*	0.94 *s*
19-H	0.87 *s*	0.87 *s*	0.83 *s*	0.82 *s*	0.89 *s*	0.88 *s*	0.87 *s*	0.90 *s*
20-H	0.78 *s*	0.80 *s*	0.79 *s*	0.78 *s*	0.68 *s*	0.84 *s*	0.76 *s*	0.81 *s*
OAc	2.19 *s*	2.16 *s*	1.66 *s*	1.65 *s*				
	2.13 *s*	2.08 *s*	1.60 *s*	1.63 *s*				

J (Hz). 11,12 = 7; 12,14 = 14,15 = 1; **37a**/**37b**: 7,17 = 9,17 ~ 1; 11,12 = 10; 11,12 = 5; 11,12' = 10; 11',12' = 7; 12,12' = 15; 14,15 = 15,15 = 1.5; **38a**/**38b**: 6,7 = 5; 6',7 = 2; 11',12 = 4.5.

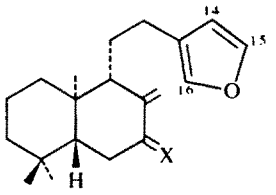


	30a	30b	31a	31b
R	OH	OH	OAc	OAc
R′	OH	H	OAc	H
R″	H	OH	H	OAc

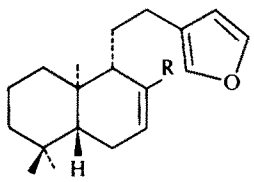


	32a	32b	32c	33a	33b	33c
R	CO_2H	CO_2Me	CO_2Me	CO_2H	CO_2Me	CO_2Me
R′	CH_2OH	CH_2OH	CH_2OAc	CH_2OH	CH_2OH	CH_2OAc
R″	Me	Me	Me	CH_2OH	CH_2OH	CH_2OAc

	34a	34b	34c	35a	35b	36a	36b
R	CO_2H	CO_3Me	CO_2Me	CO_2H	CO_2Me	CO_2H	CO_2Me
R′	CH_2OH	CH_2OH	CH_2OAc	CH_2OAc	CH_2OAc	CH_2OH	CH_2OAc
R″	CHO	CHO	CHO	CH_2OH	CH_2OH	CH_2OMe	CH_2OMe



37a X = β-OH, α-H
37b X = O



38a R = CH_2OH
38b R = CHO

Table 4. ^{1}H NMR spectral data compounds of **32b**, **32c**, **33b**, **33c**, **34b**, **34c**, **35b** and **36b** (270 MHz $CDCl_3$)

	32b	32c	33b	33c	34b	34c	35b	36b	36b (C_6D_6)
6-H 6′-H	1.93 *m*	1.9 *m*	1.92 *m*	2.0 *m*	2.41 *m* 2.28 *m*	2.38 *m* 2.28 *m*	1.95 *m*		
7-H	5.42 *s(br)*	5.42 *s(br)*	5.75 *d(br)*	5.82 *d(br)*	6.88 *ddt*	6.83 *ddt*	5.70 *d(br)*	5.77 *d(br)*	5.73 *d(br)*
9-H	1.93 *m*	1.9 *m*	2.08 *m*	2.0 *m*	2.1 *m*	2.05 *m*	1.95 *m*		
12-H	2.69 *ddd*	2.73 *ddd*	2.94 *ddd*	2.71 *ddd*	3.01 *ddd*	2.93 *ddd*	3.09 *ddd*		
12′-H	2.54 *ddd*	2.58 *ddd*	2.43 *ddd*	2.56 *ddd*	2.61 *ddd*	2.67 *ddd*	2.32 *ddd*		
14-H	5.97 *t*	5.83 *t*	5.94 *t*	5.82 *t*	5.86 *t*	5.79 *t*	5.84 *t*	5.82 *s(br)*	6.04 *s(br)*
16-H 16′-H	4.23 *d*	4.64 *d*	4.26 *dd* 4.13 *dd*	4.62 *s(br)*	4.29 *d(br)* 4.21 *d(br)*	4.78 *d* 4.69 *d*	4.65 *d*	4.64 *t*	4.63 *dd*
17-H 17′-H	1.78 *s(br)*	1.76 *s(br)*	4.32 *d(br)* 4.02 *d(br)*	4.68 *d(br)* 4.54 *d(br)*	9.37 *s*	9.40 *s*	4.34 *d(br)* 4.01 *d(br)*	4.06 *d(br)* 3.70 *d(br)*	4.17 *d(br)* 3.74 *d(br)*
18-H	0.88 *s*	0.87 *s*	0.89 *s*	0.89 *s*	0.94 *s*	0.94 *s*	0.89 *s*	0.90 *s*	0.90 *s*
19-H	0.86 *s*	0.85 *s*	0.87 *s*	0.87 *s*	0.90 *s*	0.89 *s*	0.87 *s*	0.88 *s*	0.88 *s*
20-H	0.74 *s*	0.79 *s*	0.79 *s*	0.76 *s*	0.81 *s*	0.82 *s*	0.75 *s*	0.76 *s*	0.85 *s*
OAc	—	2.12 *s*	—	2.13 *s*		2.13 *s*	2.13 *s*	2.13 *s*	1.70 *s*
OMe	3.72 *s*	3.72 *s*	3.72 *s*	3.71 *s*	3.72 *s*	3.72 *s*	3.72 *s*	3.72 *s*	3.44 *s*
								3.30 *s*	3.26 *s*

J(Hz): 11,12 = 11′,12 = 12,12′ = 12; 11′,12 = 11,12′ = 5; 14,16 = 1.5; **33b**: 6,7 = 5; **34b**: 6,7 = 5; 6′7 = 2.5.

Table 5. ^{1}H NMR spectral data of compounds **39b**, **39c**, **39d**, **40**, **42b**, **43b**, **44** and **45b** (270 MHz, $CDCl_3$)

	39b	C_6D_6	+Eu(fod)$_3$	**39c**	**39d**	**40**	**42b**	**43b**	C_6D_6	+Eu(fod)$_3$	**44**	**45b**
1α-H								1.20 *ddd*	1.03 *ddd*	1.10 *ddd*		
1β-H								1.74 *d(br)*	1.33 *m*	1.63 *d(br)*		
2-H								1.6 *m*		1.38 *m*		
3α-H								1.00 *ddd*	0.55 *ddd*	0.80 *ddd*		
3β-H								1.50 *d(br)*	1.33 *m*	1.49 *d(br)*		
5-H								1.35 *dd*	0.95 *dd*	1.21 *dd*		
6α-H								2.23 *d(br)*	1.87 *d(br)*	2.04 *d(br)*		
6β-H								1.96 *dd*	1.60 *dd(br)*	1.80 *dd(br)*		
7-H		2.38 *ddd*	2.41 *d(br)*	2.38 *d(br)*	2.38 *d(br)*	2.39 *ddd*	5.42 *t*	5.73 *s(br)*	5.17 *s(br)*	5.43 *s(br)*	2.40 *ddd*	5.41 *t*
7'-H		1.94 *ddd*	1.98 *dd(br)*	1.98 *m*	1.98 *ddd*	1.98 *ddd*					1.99 *ddd*	
9-H		2.20 *m*	2.24 *m*					2.35 *m*	1.84 *m*	2.47 *m*		
11-H								2.56 *dd*	2.21 *dd*	3.51 *dd*		
11'-H								2.4 *m*	1.99 *dd*	3.23 *dd*		
13-H	2.80 *dddd**	2.62 *m**	3.63 *m*	1.98 *m*	2.19 *dddd*						5.81 *ddt*	
14-H	2.70 *ddd**	2.57 *ddd**		2.38 *m*	2.34 *m*	3.68 *m*	7.09 *t*	0.91 *s*	0.84 *s*	0.84 *s*	4.98 *ddt*	5.52 *t(br)*
15-H	2.38 *ddd*	2.18 *ddd*					4.78 *dt*	0.89 *s*	0.84 *s*	0.84 *s*	4.93 *ddt*	4.68 *d(br)*
16-H	9.70 *s(br)*			3.52 *m*	4.12 *dd* / 3.97 *dd*	3.80 *dd* / 3.51 *dd*		0.78 *s*	0.94 *s*	0.94 *s*		4.67 *d* / 4.62 *d*
17-H	4.83 *ddd*	4.93 *ddd*	5.00 *s(br)*	4.82 *s(br)*	4.82 *s(br)*	4.83 *ddd*	5.27 *s(br)*	4.70 *d(br)*	4.76 *d(br)*	4.76 *d(br)*	4.83 *s(br)*	5.19 *s(br)*
17'-H	4.45 *s(br)*	4.56 *s(br)*	4.74 *s(br)*	4.47 *s(br)*	4.44 *s(br)*	4.49 *ddd*	4.84 *s(br)*	4.59 *d(br)*	4.65 *d(br)*	4.65 *d(br)*	4.51 *s(br)*	4.76 *s(br)*
18-H	0.88 *s*	0.89 *s*	0.89 *s*	0.88 *s*	0.88 *s*	0.89 *s*	0.84 *s*	0.91 *s*	0.77 *s*	0.84 *s*	0.89 *s*	0.84 *s*
19-H	0.80 *s*	0.83 *s*	0.83 *s*	0.80 *s*	0.80 *s*	0.81 *s*	0.80 *s*	0.89 *s*	0.76 *s*	0.76 *s*	0.81 *s*	0.81 *s*
20-H	0.67 *s*	0.69 *s*	0.73 *s*	0.67 *s*	0.68 *s*	0.69 *s*	0.69 *s*	0.78 *s*	0.54 *s*	0.94 *s*	0.69 *s*	0.68 *s*
OMe	3.67 *s*	3.37 *s*	4.02 *s*	3.68 *s*	3.68 *s*							
OAc	-	-		-	2.05 *s*	-	2.04 *s*					2.07 *s* / 2.06 *s* / 2.05 *s*

* Not first order.

J(Hz): 6α,7α = 4.5; 6α,7β = 2.5; 6β,7α = 12; 6β,7β = 4; 7α,7β = 13; 12,13 = 13,15 = 8; 7,17 = 9,17 = 1.5; **40**: 6α,7α = 4; 6β,7α = 4.5; 13,16 = 4.5; 13,16' = 6.5; 16,16' = 10.5; **42b**: 6,7 = 13; 12,14 = 14,15 = 1.5; **43b**: 1α,1β = 13; 1α,2α = 4; 1α,2β = 13; 2α,3α = 4; 2β,3α = 3α,3β = 13; 5,6α = 5; 5,6β = 11; 6α,6β = 17; 9,11 = 6.5,9,11 = 9; 11,11' = 17,17' = 14; **45b**: 6,7 = 2.5; 14,15 = 7; 16,16' = 14.

data were nearly identical. Together with **6** and **7** other sesquiterpene alcohols were present, all bearing a tertiary hydroxy group, but their structures could not be established. Most probably one of the alcohols was a hydroxy derivative of 4,5-dihydrobicyclogermacrene.

The aerial parts of *A. confertus* (Gardn.) K. et R. afforded **1**, **2**, **6**, **8** and **9**. Furthermore a complex mixture of acids was isolated, which could only be separated as their methyl esters. The main constituent was a diol which on acetylation afforded a diacetate. The ^{1}H NMR data (Table 4) were in agreement with the structures **33a** and **33b** respectively, which were also supported by the mass spectra in which were observed a typical loss of the side chain after elimination of water and acetic acid respectively (*m/e* 189). Therefore the natural compound was the acid **33a**. Three further compounds were obviously closely related to **33a**. Compound **32a** was the 17-desoxy derivative as shown by the absence of the second CH_2OH signal in the ^{1}H NMR spectrum of the methyl ester **32b** and which was replaced by a signal for an olefinic methyl group. As the signals of 14- and 16-H were almost identical with those of **33b**, the methyl group must be positioned at C-8 and not at C-13. Also the data of the acetate **32c** supported the structure. The two further compounds were the corresponding aldehyde alcohol **34a** and the hydroxy acetate **35a** as indicated by the ^{1}H NMR data of the methyl esters (Table 4). The position of the aldehyde group in **34b**, which on reduction afforded **33b**, followed from the observed shift of the 7-H signal when compared with that seen in the spectra of **32b** and **33b**, while the position of the acetoxy group in **35b** was established by sodium borohydride reduction of the acetate **34c**, which led to **35b**. The esters **15b** and **25b** were also isolated and therefore the natural acids **15a** and **25a** were present. Furthermore, the lactone **43b** was isolated. The structure of this tetranorditerpene followed from ^{1}H NMR studies (Table 5). In C_6D_6 the 11-H signals could be assigned (δ 2.21, *dd* and 1.99 *dd*). Irradiation at 1.84 collapsed these signals to doublets. Decoupling experiments further showed that the signals at 1.87 and 1.60 must be assigned to 6-H and that at 5.17 to 7-H, while the two broadened doublets at 4.21 and 4.08 were due to the 13-H protons. The mass spectrum was also in good agreement with the proposed structure and the base peak (*m/e* 124) must be the result of a *retro*-Diels–Alder fragmentation. As **43b** was isolated after acidification of the acid fraction the natural product must be **43a**, a tetranorlabdane derivative, which we have named acriconfertic acid. The roots afforded only germacrene D (**2**) and humulene (**4**).

The aerial parts of *A. morii* K. et R. afforded the hydrocarbons **2**, **3a**, and **4**. The more polar fractions again contained diterpenes. The structures of the two labdane derivatives **37a** and **38a** followed from the ^{1}H NMR spectra of the compounds and the corresponding oxidation products **37b** and **38b**, obtained by MnO_2-oxidation of the alcohols (Table 3). From the spectrum of **37b** the position of the oxygen function was determined as the chemical shifts of the vinylic protons were only in

Table 6. ^{1}H NMR spectral data of compounds **41a** and **41b** (270 MHz, $CDCl_3$)

	41a (C_6D_6)	Δ†	**41b** (C_6D_6)	**41a** $CDCl_3$	**41b** $CDCl_3$
7-H	4.38 *dd*	0.47	4.54 *dd*	4.35 *dd*	4.25 *dd*
12_1-H	2.58 *ddd*	0.14			2.57 *m*
12_2-H	2.28 *ddd*				2.3 *m*
14-H	6.21 *s(br)*	0.07	6.31 *s(br)*	6.27 *s(br)*	6.30 *s(br)*
15-H	7.24 *dd*	0.05	7.24 *dd*	7.36 *s(br)*	7.33 *s(br)*
16-H	7.20 *s(br)*	0.08	7.20 *s(br)*	7.19 *s(br)*	7.23 *s(br)*
17_1-H	5.13 *s(br)*	0.25	5.09 *s(br)*	5.21 *s(br)*	5.11 *s(br)*
17_2-H	4.84 *s(br)*	0.16	4.81 *s(br)*	4.94 *s(br)*	4.77 *s(br)*
18-H*	0.89 *s*	0.01	0.89 *s*	0.88 *s*	0.88 *s*
19-H*	0.82 *s*	0.01	0.85 *s*	0.82 *s*	0.82 *s*
20-H*	0.76 *s*	0.01	0.73 *s*	0.72 *s*	0.72 *s*
7β'-H	2.39 *ddd*	0.02	2.39 *ddd*	2.42 *d(br)*	2.42 *d(br)*
7α'-H	1.9 *m*		1.9 *m*		1.95 *m*
14'-H	2.05 *d*	1.39		2.40 *m*	2.80 *dd* 2.14 *dd*
16_1'-H 16_2'-H	5.20 *d*	0.58	5.05 *d*	5.40 *d*	5.25 *d*
17_1'-H	5.00 *s(br)*	0.05	4.94 *s(br)*	4.84 *s(br)*	4.84 *s(br)*
17_2'-H	4.65 *s(br)*	0.12	4.50 *s(br)*	4.54 *s(br)*	4.44 *s(br)*
18'-H*	0.95 *s*	0.06	0.91 *s*	0.91 *s*	0.91 *s*
19'-H*	0.76 *s*	0.05	0.83 *s*	0.83 *s*	0.83 *s*
20'-H*	0.65 *s*	0.07	0.70 *s*	0.72 *s*	0.72 *s*

* Assignment not certain.

† Δ-values after addition of $Eu(fod)_3$.

J(Hz): 6,7 = 2.5; $11,12_1$ = 11; $11,12_2$ = 4; $11_1,12$ = 7; $11_1,12_1$ = 10; $12,12_1$ = 15; 14,15 = 15,16 = 1.5; 6β',7β' = 4; 6α',7β' = 3; 7α',7β' = 12.5; 13',16' = 5 (**41b**: 3.5).

agreement with a 7-oxo-derivative. The presence of a β-substituted furan afforded the typical ^{1}H NMR signals (Table 3). To establish the proposed *trans*-annelation of the decalin system we also measured the ^{13}C NMR spectrum. The signals were again in very good agreement with those of other *trans*-fused labdanes (Table 7). The structure of the isomeric alcohol **38a** also followed from the ^{1}H NMR data of the alcohol and the corresponding aldehyde **38b**, where the 7-H signal was shifted downfield (6.83 *ddd*). The presence of a labdane derivative was demonstrated by comparison of the other NMR data with those of similar diterpenes. For **37a**, without a hydroxyl at C-7, we propose the name polyalthine, the precursor of polyalthic acid [6], with a carboxyl group at C-4. Compound **38a** has been named 17-hydroxy-isopolyalthine. Somewhat less polar than **37a** was an epimeric mixture of two dimeric diterpenes, which must possess the structures **41a** and **41b**. Reduction with $LiAlH_4$ afforded **37a** and the diol **40**, as was seen from the ^{1}H NMR spectrum. The ^{1}H NMR spectra of the natural compounds (Table 6) showed that **37a** was connected with a hemiacetal of a labdane derivative, which must contain a five-membered lactone ring (IR: 1795 cm^{-1}). The ^{1}H NMR spectrum of one of the epimers displayed typical signals indicating a partial structure $OCOCH_2CH$-. Double resonance experiments further established the nature of the lactone moiety, while the stereochemistry at C-16' could not be assigned with certainty as the vicinal couplings $J_{13,16}$ were very similar in both epimers.

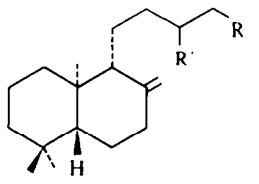
Table 7. ^{13}C NMR spectral signals of compound **37a** ($CDCl_3$, TMS as internal standard, δ-values in ppm)

C-1	38.9 *t*	C-11	23.5 *t**
C-2	19.4 *t*	C-12	23.9 *t**
C-3	42.2 *t*	C-13	109.4 *s*
C-4	33.2 *s*	C-14	110.9 *d*
C-5	47.7 *d*	C-15	138.7 *d*
C-6	31.2 *t*	C-16	142.6 *d*
C-7	74.1 *d*	C-17	109.4 *t*
C-8	149.9 *s*	C-18	33.3 *q*
C-9	50.5 *d*	C-19	21.6 *q*
C-10	39.9 *s*	C-20	13.5 *q*

* Interchangeable.

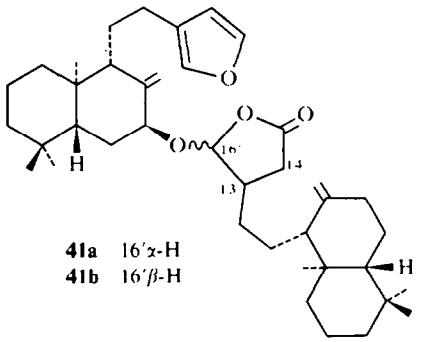
Finally, from the acetates of the polar fraction a triacetate was isolated. The ^{1}H NMR spectral data (Table 5) showed that it was with the labdane **45b**, the natural compound therefore must be **45a**.

A compound which could only be isolated after acetylation was the methyl ether **36b**. The chemical shifts of 16- and 17-H indicated the relative position of the acetate to the methoxy group (Table 4). The neutral extract, again after acetylation, afforded the lactone **42b**. The structure followed from the observed ^{1}H NMR spectral data (Table 5), especially when compared with **37a** (see below). The downfield shift of the 14-H showed the position of the lactone carbonyl. The main constituent was an aldehyde acid. The ^{1}H NMR spectral data (Table 5) showed that it was the diterpene **39a**, which easily epimerized at C-13 on treatment with base, while direct esterification afforded the methyl ester **39b**, which on reduction with sodium borohydride afforded the alcohol **39c**, which was purified as its acetate **39d**. To eliminate the chiral centre at C-13, **39a**

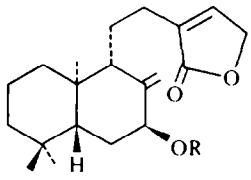


	39a	39b	39c
R	CO_2H	CO_2Me	CO_2Me
R'	CHO	CHO	CH_2OH

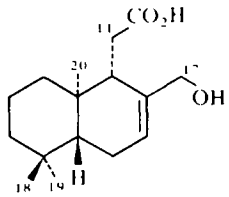
	39d	40	41
R'	CO_2Me	CH_2OH	CO_2H
R'	CH_2OAc	CH_2OH	CO_2H



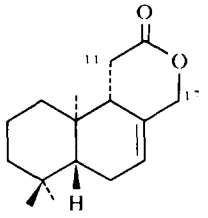
41a 16'α-H
41b 16'β-H



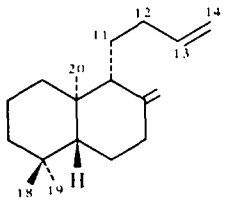
42a R = H
42b R = Ac



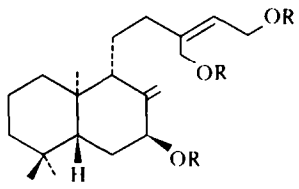
43a*



43b*



44*



45a R = H
45b R = Ac

was degraded to **44** by oxidation with silver oxide followed by lead tetraacetate treatment. Its structure was elucidated from the observed ^{1}H NMR spectral data (Table 5). Compound **44** showed a positive Cotton effect below 210 nm as in *ent*-manool, which again supports the assumption that the diterpenes isolated belong to the *ent*-labdane series. The roots afforded only **2**, **3a** and **12**.

The aerial parts of *A. teixeirae* K. et R. contained the hydrocarbons **2**, **3a**, **4** and **5**, and an aldehyde, which was identified as **27a** by the ^{1}H NMR spectral data of the corresponding methyl ester **27b** (Table 2). The presence of a kolavane-type diterpene followed from the observed ^{1}H NMR signals, especially from those of the methyl and olefinic signals. Furthermore, the corresponding hemiacetal **28a** was present, but this may be an artefact formed from **27a**. Acetylation afforded the acetate **28b**. The ^{1}H NMR data again indicated the presence of the hemiacetal.

The roots also contained **28a** and **2** and an aromatic compound, **13**. The couplings in the ^{1}H NMR spectrum of **13** clearly showed that the substituents at C-2 and C-3 were *trans*-orientated, while the substitution pattern of the aromatic ring followed from the observed chemical shifts for 5- and 7-H, which were characteristically different from those in tremetone derivatives (see Experimental).

The overall picture of the genus *Acritopappus* is very uniform, *ent*-labdane and kolavane derivatives being present in all species investigated. Though these compounds are also found in other genera of the tribe Eupatorieae [7–20], the absence of larger amounts of other types of natural products is unusual. The only link to *Radlkoferotoma* is the isolation of **12**, the *cis* isomer being present in *R. cistifolia* [21], while **10** has been isolated from a member of the *Gyptis* group, which could support the proposed relationship of the *Acritopappus* group to the latter.

* Carbon numbering is the same as in the diterpenes.

EXPERIMENTAL

IR: CCl_4; ^{1}H NMR: 270 MHz, TMS as internal standard; MS: 70 eV, CI: *iso*-butane; optical rotation: $CHCl_3$. The air-dried plant material, collected in north-eastern Brazil, was cut and extracted with Et_2O–petrol (1:2). The resulting extracts were first separated by CC (Si gel, act. grade II) and further by TLC (Si gel, GF 254). The acid portions were separated by addition of equivalent amounts of NaOH to a MeOH soln of the polar fractions. After addition of H_2O the neutral part was extracted with Et_2O and the acid part was also extracted after addition of dil H_2SO_4. The acids were esterified by addition of an Et_2O soln of CH_2N_2. The resulting methyl esters were separated by TLC. Acetylations were carried out by heating the compounds for 1 hr at 70° in excess of Ac_2O, evapn *in vacuo* and purification by TLC.

Acritopappus hagei (*voucher RMK* 8154, 8156, 8165). Roots (50 g) afforded 1 mg **1**, 100 mg polyisoprene, 1 g **3a**, 10 mg **3b** (isolated as its acetate **3c**, Et_2O petrol, 1:10), 50 mg **6**, 200 mg **7** and 100 mg of a mixture of three further sesquiterpene alcohols, which have not been identified. 500 g of aerial parts afforded 1 mg **1**, 100 mg **2**, 150 mg **3a**, 10 mg **10**, 30 mg *epi*-friedelinol, 60 mg **30a** and **30b** (2:1) (Et_2O–petrol, 2:1), 100 mg **14a** (Et_2O), 100 mg **15a** (Et_2O), 10 mg **16a** (Et_2O), 10 mg **17a** (Et_2O), 5 mg **23a** (Et_2O petrol, 1:1), 5 mg **24** (Et_2O petrol, 1:1), 20 mg **25a** (Et_2O) (isolated as acetate methyl ester (**25**)), 15 mg **11**, 5 mg **26a** and 5 mg **29a** (the last three isolated as their acetates, Et_2O petrol, 1:1).

Acritopappus confertus (*voucher RMK* 8153). Roots (100 g) afforded 60 mg **2** and 30 mg **4**, while 320 g aerial parts yielded 0.5 mg **1**, 700 mg **2**, 10 mg **6**, 100 mg **8**, 80 mg **9** and a mixture of acids, which were separated by addition of NaOH to the methanolic soln of the polar CC fraction. After addition of H_2O the neutral part was extracted with Et_2O. The acids were isolated after addition of dil H_2SO_4 by extraction with Et_2O. The acid mixture then was esterified with CH_2N_2. CC and TLC afforded 15 mg **15b**, 15 mg **25c**, 20 mg **32b** (Et_2O petrol, 1:3), 50 mg **33b** (Et_2O), 10 mg **34b** (Et_2O–petrol, 1:1), 15 mg **35b** (Et_2O petrol,

1:1), 10 mg **36a** [isolated as **36b** (Et_2O–petrol, 1:1)], and 15 mg **43b** (Et_2O–petrol, 1:3).

Acritopappus morii (*voucher RMK* 8172). Roots (40 g) afforded 5 mg **2**, 5 mg **3a** and 10 mg **12** (Et_2O petrol, 1:3), while 145 g aerial parts yielded 50 mg **2**, 10 mg **3a**, 10 mg **4**, 5 mg **42a** [isolated as **42b** (Et_2O–petrol, 1:1)], 140 mg **37a** (Et_2O–petrol, 1:3), 5 mg **38a** (Et_2O–petrol, 1:3), 300 mg **39a** (Et_2O–petrol, 1:1), 50 mg **41a** and **41b** (1:1) (Et_2O–petrol, 1:3), and 10 mg **45a** [isolated as **45b** (Et_2O–petrol, 1:1)].

Acritopappus teixeirae (*voucher RMK* 8043). Roots (50 g) afforded 5 mg **2**, 10 mg **13**, and 15 mg **28a**, while 350 g aerial parts yielded 30 mg **2**, 30 mg **3a**, 20 mg **4**, 10 mg **5**, 10 mg **27a** (isolated as its methyl ester **27b**, Et_2O–petrol, 1:3) and 20 mg **28** (Et_2O–petrol, 1:1).

8α-Acetoxybicyclogermacrene (**3c**). Formed after acetylation of the sesquiterpene alcohol mixture, colourless oil, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1755, 1250 (OAc). MS *m/e* (rel. int.): 262.193 (M^+, 5) ($C_{17}H_{26}O_2$), 202 (M − HOAc, 12), 187 (202 − Me, 10), 43 ($MeCO^+$, 100). ^1H NMR ($CDCl_3$): δ 5.09 (*br. dd*, *J* = 9.4 Hz, 1-H), 4.50 (*br. d*, *J* = 11 Hz, 5-H), 4.80 (*ddd*, *J* = 10.5, 10.5, 5 Hz, 8-H), 1.81 (*dd*, *J* = 13, 10.5 Hz, 9α-H), 2.73 (*br. dd*, *J* = 13, 5 Hz, 9β-H), 1.14 (*s*, 12-H), 1.08 (*s*, 13-H), 1.54 (*br. s*, 14-H), 1.68 (*d*, *J* = 1 Hz, 15-H).

3β-Angeloyloxy-6-methoxytrametone (**12**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1720, 1650 C=CCO_2R, 1680 PhCO. MS *m/e* (rel. int.): 330.147 (M^+, 20 ($C_{19}H_{22}O_5$), 231 (M − $OCOC_4H_7$, 35), 83 ($C_4H_7CO^+$, 100). ^1H NMR ($CDCl_3$): δ 5.11 (*d*, 2-H), 6.14 (*d*, *J* = 3 Hz, 3-H), 7.93 (*s*, 4-H), 6.51 (*s*, 7-H), 2.56 (*s*, 9-H), 5.08 (*br. s*, 11-H), 4.97 (*br. s*, 11′-H), 1.80 (*br. s*, 12-H), 3.92 (*s*, OMe), 6.12 (*qq*), 2.00 (*dq*), 1.88 (*dq*) (OAng).

6-Acetyl-5-hydroxy-2-isopropenyl-3β-methoxy-2,3-dihydrobenzofuran (**13**). Colourless oil, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3500–2700 (OH), 1655, 1630, 1600 (PhCO). MS *m/e* (rel. int.): 248.105 (M^+, 100) ($C_{14}H_{16}O_4$), 233 (M − Me, 45), 201 (233 − MeOH, 4). ^1H NMR ($CDCl_3$): δ 4.97 (*br. d*, $J_{2,3}$ = 3 Hz, 2-H), 4.76 (*d*, 3-H), 6.84 (*s*, 4-H), 7.21 (*s*, 7-H), 2.63 (*s*, 8-H), 5.09 (*br. s*, 11-H), 4.94 (*br. s*, 11′-H), 1.74 (*br. s*, 12-H), 12.02 (*s*, OH).

16-Acetoxy-18-hydroxykolavenic acid (**14a**). Colourless gum, MS *m/e* (rel. int.): 358.214 (M-H_2O, 12) ($C_{22}H_{30}O_4$), 298 (358-AcOH; 35), 189 ($C_{14}H_{21}^+$, 100). Methylation afforded **14b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3610 (OH), 1747, 1230 (OAc), 1720, 1655 (C=CCO_2R). MS *m/e* (rel. int.): 392.356 (M^+, 0.4) ($C_{23}H_{36}O_5$) 374 (M − H_2O, 12), 300 (M − HOAc, − MeOH, 14), 189 ($C_{14}H_{21}^-$, 100). Compound **14b** (20 mg) in 3 ml Et_2O was stirred for 2 hr with 200 mg MnO_2. TLC (Et_2O petrol, 1:3) afforded 15 mg **16a**, identical with the aldehyde obtained from the natural acid by esterification. Compound **14b** (10 mg) on acetylation yielded 10 mg **21**, identical with the diacetate obtained from the methyl ester of **15a**.

16,18-Dihydroxykolavenic acid (**15a**). Colourless gum, which was purified as its methyl ester **15b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3610 (OH), 1720, 1660 (C=CCO_2R). MS *m/e* (rel. int.): 332.235 (M − H_2O, 31) ($C_{21}H_{32}O_3$), 317 (332 − Me, 30), 189 ($C_{14}H_{21}^+$, 100).

$$[\alpha]_{24}^{\lambda} = \frac{589 \quad 578 \quad 546 \quad 436\,nm}{-48.4 \quad -50.3 \quad -57.2 \quad -97.9} \qquad (c = 2.6)$$

Compound **15b** (20 mg) on acetylation afforded 21 mg **21**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1750, 1235 (OAc), 1730, 1665 (C=CCO_2R). MS *m/e* (rel. int.): 434.267 (M^+, 0.3) $C_{25}H_{38}O_6$), 374 (M − HOAc, 5), 314 (374 − HOAc, 7), 299 (314 − Me, 11), 189 ($C_{14}H_{21}^-$, 100).

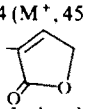
20 mg **15b** were stirred for 4 hr with 200 mg MnO_2. TLC (Et_2O petrol, 1:1) afforded 3 mg **17b**, identical with the methyl ester of **17a**, and 10 mg **18**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 2710, 1700 (CHO), 1725 (CO_2R), 1660, 1625 (C=C). MS *m/e* (rel. int.): 346.211 (M^+, 28) ($C_{21}H_{30}O_4$), 331 (M − Me, 4), 328 (M − H_2O, 5), 314 (M − MeOH, 6), 299 (314 − Me, 45), 205 (M − $CH_2CH_2C(CHO)$=$(CHCO_2Me$, 63), 187 (205 − H_2O, 100); and 3 mg **23**, colourless gum, ^1H NMR see Table 1. **15a** on acetylation afforded the diacetate **20**, ^1H NMR see Table 1.

16-Acetoxy-18-oxo-kolavenic acid (**16a**). Not isolated in pure state, esterification afforded **16b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 2700, 1690 (C=CCHO), 1750, 1225 (OAc), 1720, 1660 (C=CCO_2R). MS *m/e* (rel. int.): 390.241 (M^+, 5) ($C_{23}H_{34}O_5$), 189 ($C_{14}H_{21}^+$, 28), 43 ($MeCO^-$, 100).

16-Hydroxy-18-oxo-kolavenic acid (**17a**). Isolated as methyl ester **17b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3610 (OH), 2700, 1690 (C=CCHO), 1720, 1660 (C=CCO_2R), acetylation afforded **16b**, identical with the acetate obtained from **16a**.

2β,15-Dihydrokolavenic-16-oic acid lactone (**23a**). Colourless gum, which was purified as its acetate (**23b**), colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1770 (lactone), 1735, 1250 (OAc). MS *m/e* (rel. int.): 360.230 (M^+, 10) ($C_{22}H_{32}O_4$), 317 (M − MeCO, 56), 189 ($C_{14}H_{21}^+$, 41), 43 ($MeCO^+$, 100).

$$[\alpha]_{24}^{\lambda} = \frac{589 \quad 578 \quad 546 \quad 436\,nm}{-5.6 \quad -6.5 \quad -7.3 \quad -13.5} \qquad (c = 0.4).$$

15-Hydroxy-2-oxo-kolavenic-16-oic acid lactone (**24**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1765 (lactone), 1670 (C=CCO). MS *m/e* (rel. int.): 316.204 (M^+, 45) ($C_{20}H_{28}O_3$), 301 (M − Me, 20), 205 (M − CH_2CH_2  , 31), 121 (C_8H_9O, 100).

Acritopappusacid (**25a**). Isolated as its methyl ester acetate **25c**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1740 (CO_2R), 1740, 1240 (OAc). MS *m/e* (rel. int.): 322.214 (M^+, 0.2) ($C_{19}H_{30}O_4$), 280 (M − ketene, 2), 262 (M − HOAc, 15), 230 (262 − MeOH, 12), 189 (262 − CH_2CO_2Me, 92), 188 (262 − $MeCO_2Me$, 55), 173 (188 − Me, 100).

$$[\alpha]_{24}^{\lambda} = \frac{589 \quad 578 \quad 546 \quad 436\,nm}{-24.3 \quad -25.3 \quad -28.7 \quad -48.0} \qquad (c = 1.7).$$

Acritopappusol (**26a**). Only isolated as its diacetate **26b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1745, 1240 (OAc). MS *m/e* (rel. int.): 276.142 (M^+, 51) ($C_{18}H_{28}O_2$), 216 (276 − HOAc, 41), 201 (216 − Me, 63), 189 (M − CH_2CH_2OAc; 80), 43 ($MeCO^+$, 100).

16-Oxo-koval-3-ene-15-oic acid (**27a**). Isolated as its methyl ester **27b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 2725, 1735 (CHO), 1735 (CO_2R). MS *m/e* (rel. int.): 334.251 (M^+, 5) ($C_{21}H_{34}O_3$), 319 (M − Me, 23), 191 (M − $CH_2CH_2CH(CHO)CH_2CO_2R$, 47), 95 ($C_7H_{11}^+$, 100).

16,16-Dihydroxykoval-3-ene-15-oic acid lactone (**28a**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3610 (OH), 1795 (lactone). MS *m/e* (rel. int.): 320.235 (M^+, 11) ($C_{20}H_{32}O_3$), 305 (M − Me, 6), 191 (M − CH_2CH_2  , 100). Acetylation afforded the acetate **28b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1795 (lactone), 1760 (OAc). MS *m/e* (rel. int.): 362.246 (M^+, 4) ($C_{22}H_{34}O_4$), 302 (M − HOAc, 36), 95 ($C_7H_{11}^+$, 100. ^1H NMR ($CDCl_3$): δ 0.73 (*s*, 3 H), 0.99 (*s*, 3 H), 0.80 (*m*, 3 H), 1.58 (*br. s*, 3 H), 2.12 (*s*, 3 H), 5.20 (*br. s*, 1 H), 6.29 (*d*, *J* = 1.5 Hz, 16-H).

16,18-Dihydroxykolavenic acid lactone (**29a**). Only isolated as its acetate **29b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1790 (lactones), 1750, 1245 (OAc). MS *m/e* (rel. int.): 318.220 (M^+ − ketene, 8) ($C_{20}H_{30}O_3$), 300 (M − HOAc, 6), 303 (318 − Me, 7), 285 (300 − Me, 27), 189 ($C_{14}H_{21}^+$, 100).

12,15,16-Trihydroxy-ent-labda-7,13-diene-15-oic acid lactone (**30a** and **30b**). Inseparable colourless gum, which was acetylated, yielding the acetates **31a** snd **31b**, which also could not be separated, colourless gum IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1805, 1780 (lactone), 1752, 1250 (OAc), 1660 (conj. C=C). MS *m/e* (rel. int.) (CI): 419

($M^+ + 1$, 2), 359 ($M^+ - HOAc$, 17), 299 (359 − HOAc, 14), 274 (299 − Me, 100).

$$[\alpha]_{24}^{\lambda} = \underset{-10.7}{589} \quad \underset{-11.7}{578} \quad \underset{-12.9}{546\,nm} \quad (c = 5.7).$$

16-*Hydroxy*-ent-*labda*-7,13 E-*diene*-15-*oic acid* (**32a**). Isolated as its methyl ester **32b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3610 (OH), 1720, 1655 (C=CO_2R), MS *m/e* (rel. int.): 334.251 (M^+, 4) ($C_{21}H_{34}O_3$), 319 (M − Me, 8), 316 (M − H_2O, 19), 205 (M − $CH_2C(CH_2OH)$=$CHCO_2Me$, 100), 191 (M − $CH_2CH_2C(CH_2OH)$=$CHCO_2$Me, 52).

$$[\alpha]_{24}^{\lambda} = \underset{-2.3}{589} \quad \underset{-2.5}{578} \quad \underset{-3.1}{546} \quad \underset{-7.0}{436\,nm} \quad (c = 1.22).$$

Compound **32b** (10 mg) was acetylated with Ac_2O (1 hr, 70°). TLC (Et_2O–petrol, 1:3) afforded 11 mg **32c**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1755, 1230 (OAc), 1730, 1660 (C=CCO_2R). MS *m/e* (rel. int.): 376.261 (M^+, 12) ($C_{23}H_{36}O_4$), 361 (M − Me, 14), 316 (M − HOAc, 12), 205 (M − $CH_2C(CH_2OAc)$=$CHCO_2Me$, 100), 189 (M − $CH_2CH_2C(CH_2OAc)$=$CHCO_2Me$, 27).

16,17-*Dihydroxy*-ent-*labda*-7,13E-*diene*-15-*oic acid* (**33a**). Isolated as its methyl ester **33b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3620 (OH), 1715, 1655 (C=CCO_2R). MS *m/e* (rel. int.): 350.246 (M^+, 0.5) ($C_{21}H_{34}O_4$), 332 (M − H_2O, 3), 301 (332 − OMe, 25), 189 (332 − $CH_2CH_2C(CH_2OH)$=$CHCO_2Me$, 71), 109 (C_8H_{13}, 100).

$$[\alpha]_{24}^{\lambda} = \underset{+4.9}{589} \quad \underset{+5.6}{578} \quad \underset{+6.4}{546} \quad \underset{+12.3}{436\,nm} \quad (c = 2.17).$$

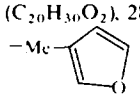
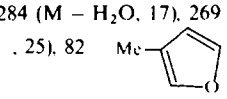
Compound **33b** (10 mg) was heated in 0.5 ml Ac_2O at 70° for 2 hr. TLC (Et_2O–petrol, 1:1) afforded 12 mg **33c**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1745, 1230 (OAc), 1725, 1660 (C=CCO_2R). MS *m/e* (rel. int.): 434.267 (M^+, 0.5) ($C_{25}H_{38}O_6$), 392 (M − ketene, 9), 374 (M − HOAc, 6), 314 (374 − HOAc, 43), 189 ($C_{14}H_{21}^+$, 77), 109 ($C_8H_{13}^+$, 100), 43 ($MeCO^+$, 83).

16-*Hydroxy*-17-*oxo*-ent-*labda*-7,13E-*diene*-15-*oic acid* (**34a**). Isolated as its methyl ester **34b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3630 (OH), 2730, 1690 (CHO), 1725, 1655 (C=CCO_2R). MS *m/e* (rel. int.): 348.230 (M^+, 5) ($C_{21}H_{32}O_4$), 331 (M − OH, 45), 317 (M − OMe, 28), 55 ($C_4H_7^+$, 100). 5 mg **34b** were acetylated with Ac_2O (1 hr, 70°). TLC Et_2O–petrol) 1:1) afforded 5 mg **34c**, colourless gum, ^{1}H NMR see Table 4. 5 mg **34c** were reduced with $NaBH_4$. TLC afforded 4 mg **35b** identical with the ester from the natural acetate. 5 mg **34b** in 1 ml MeOH was reduced with 10 mg $NaBH_4$. TLC (Et_2O) afforded 4 mg **33b**, identical with the ester from the natural product.

17-*Hydroxy*-16-*acetoxy*-ent-*labda*-7,13E-*diene*-15-*oic acid* (**35a**). Isolated as its methyl ester **35b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3620 (OH), 1750, 1230 (OAc), 1720 (C=CCO_2R). MS *m/e* (rel. int.): 392.256 (M^+, 2) ($C_{23}H_{36}O_5$), 375 (M − OH, 3), 315 (375 − HOAc, 32), 109 (C_8H_{13}, 100).

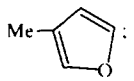
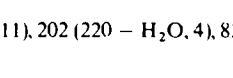
7,15,16-*Trihydroxy*-ent-*labda*-7,12(14)-*diene* (**45a**). Isolated as its triacetate (**45**), colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1735, 1230 (OAc), MS *m/e* (rel. int.): 448.282 (M^+, 1) ($C_{26}H_{40}O_6$), 389 (M − OAc, 12), 388 (M − HOAc 4), 328 (388 − HOAc, 21), 268 (328 − HOAc, 37), 43 ($MeCO^+$, 100).

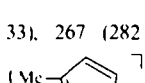
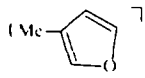
$$[\alpha]_{24}^{\lambda} = \underset{+1.5}{589} \quad \underset{+1.7}{578} \quad \underset{+1.9}{546} \quad \underset{+6.6}{436\,nm} \quad (c = 1.34).$$

7β-*Hydroxypolyalthine* (**37a**). Colourless oil, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3620 (OH), 880 (furan). MS *m/e* (rel. int.): 302.224 (M^+, 30%) ($C_{20}H_{30}O_2$), 284 (M − H_2O, 17), 269 (284 − Me, 9), 220 (M  , 25), 82  , 100).

$$[\alpha]_{24}^{\lambda} = \underset{+8.5}{589} \quad \underset{+9.0}{578} \quad \underset{+10.6}{546} \quad (c = 6.11).$$

Compound **37a** (20 mg) was stirred in 3 ml Et_2O for 2 hr with 200 mg MnO_2. TLC (Et_2O–petrol, 1:13) afforded 15 mg **37b**, colourless oil.

17-*Hydroxyisopolyalthine* (**38a**). Colourless oil, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3620 (OH), 880 (furan). MS *m/e* (rel. int.): 302.224 (M^+, 5) ($C_{20}H_{30}O_2$), 284 (M − H_2O, 13), 269 (284 − Me, 3), 220 (M  ; 11), 202 (220 − H_2O, 4), 82  , 100).

Compound **38a** (5 mg) was stirred in 2 ml Et_2O for 2 hr with 50 mg MnO_2. TLC (Et_2O–petrol, 1:10) afforded 3 mg **38b**, colourless oil, MS *m/e* (rel. int.): 300.209 (M^+, 17) ($C_{20}H_{28}O_2$), 282 (M − H_2O, 33), 267 (282 − Me, 4), 218 (M −  , 4), 82 ( , 100).

16-*Oxo*-ent-*labda*-7(17)*ene*-15-*oic acid* (**39a**). Colourless oil, purified as its methyl ester **39b**, colourless oil, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 2720, 1740 (CHO) 1740 (CO_2R), 3090, 1614, 100 (C=CH_2). MS *m/e* (rel. int.): 334.251 (M^+, 7), ($C_{21}H_{34}O_3$), 319 (M − Me, 2), 316 (M − H_2O, 14), 301 (316 − Me, 6), 218 (M − CH(CHO) CH_2(OH)OMe (McLafferty), 19), 137 ($C_{10}H_{17}^+$, 100).

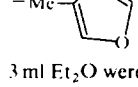
$$[\alpha]_{24}^{\lambda} = \underset{-44.3}{589} \quad \underset{-46.2}{578} \quad \underset{-52.7}{546} \quad \underset{-94.7}{436} \quad (c = 1.64).$$

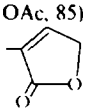
Compound **39b** (10 mg) in 2 ml MeOH was reduced with 10 mg $NaBH_4$. The resulting alcohol **39c** was acetylated by heating with 0.1 ml Ac_2O at 70°. TLC (Et_2O petrol, 1:1) afforded 5 mg **39d**, colourless oil, ^{1}H NMR see Table 6. 100 mg **39a** were added to a suspension of AgOH in 3 ml H_2O containing one equivalent of NaOH. After stirring for 15 min the resulting acid **41** was isolated after addition of dil H_2SO_4. 50 mg **41** and 80 mg $Pb(OAc)_4$ were refluxed in 5 ml C_6H_6 and 0.05 ml pyridine for 1 hr. Filtration over Si gel afforded 15 mg **44**, colourless oil, ^{1}H NMR see Table 5. MS *m/e* (rel. int.): 246.235 (M^+, 4) ($C_{18}H_{30}$), 231 (M − Me, 28), 177 (231 − C_4H_6, 21), 137 ($C_{10}H_{17}^+$, 100).

$$[\alpha]_{24}^{\lambda} = \underset{-20.4}{589} \quad \underset{-20.5}{578} \quad \underset{-23.0}{546\,nm} \quad (c = 1.39).$$

CD MeCN): < 210 nm positive.

Acritopappuslactone A (**41a**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1795 (lactone), 3090, 1650 (C=CH_2), MS *m/e* (rel. int.): 604.449 (M^+, 1) ($C_{40}H_{60}O_4$), 302 ($C_{20}H_{30}O_2^{\cdot+}$, 5), 285.222 ($C_{20}H_{29}O^+$, 76), 284.214 ($C_{20}H_{28}O^{\cdot+}$, 100).

Acritopappuslactone B (**41b**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1795 (lactone), 3090, 1650 (C=CH_2). MS *m/e* (rel. int.): 604.449 (M^+, 0.5) ($C_{40}H_{60}O_4$), 301 (5), 301 (3), 300 (5), 220 (302  , 100). Compound **41a** (10 mg) and **41b** (10 mg) in 3 ml Et_2O were reduced with 20 mg $LiAlH_4$ (5 min room temp.). After addition of dil H_2SO_4 the reaction products were extracted with Et_2O. TLC afforded 4 mg **37a** and 4 mg **40**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3620 (OH), 2090, 1645 (C=CH_2). MS *m/e* (rel. int.): 308 272 (M^+, 7) ($C_{20}H_{36}O_2$), 293 (M − Me, 6), 275 (293 − H_2O, 6), 257 (275 − H_2O, 2), 137 ($C_{10}H_{17}^+$, 100).

7β,15-*Dihydroxy*-ent-*labda*-8(17),13(14)-*dien*-16-*oic acid lactone* (**42a**). Isolated as its acetate (**42b**), colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1765 (lactone), 1735, 1245 (OAc). MS *m/e* (rel. int.): 360 (M^+, 0.5), 318 (M − ketene, 48), 300.209 (M − HOAc, 85) ($C_{20}H_{28}O_2$), 285 (300 − Me, 61), 189 (300 − CH_2CH_2  , 100).

Acritoconfertic acid (**43a**). Isolated as its lactone **43b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1750 (δ-lactone), 1625 (C=C). MS *m/e* (rel. int.): 248.177 (M^+, 4) ($C_{16}H_{24}O_2$), 124 ( , 89), 109 (124 − Me, 100).

16-*Hydroxy*-17-*methoxy*-ent-*labda*-7,13(14)-*diene*-15-*oic acid* (**36a**). Isolated as acetate **36b**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1750, 1230 (OAc), 1725, 1665 (C=CCO$_2$R). MS *m/e* (rel. int.): 406.272 (M^+, 10) ($C_{24}H_{38}O_5$), 391 (M − Me, 3), 374 (M − MeOH, 12), 359 (374 − Me, 6) 346 (374 − CO, 7), 314 (374 − HOAc, 100), 299 (314 − Me, 60).

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