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POSKEANOLIDE, A SECO-GERMACRANOLIDE AND OTHER SESQUITERPENE LACTONES FROM *VERNONIA* SPECIES

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Key Word Index—*Vernonia cinerea*; *V. poskeana*; *V. flexipappa*; *Critoniopsis huaircajana*; *C. bogotana*; Compositae; sesquiterpene lactones; glaucolides; hirsutinolides; seco-germacranolides.

Abstract—The aerial parts of *Vernonia cinerea*, collected in Costa Rica, gave four new hirsutinolides while a sample from Malawi afforded glaucolide E and two related lactones. From *V. poskeana* a seco-germacranolide biogenetically closely related to a new glaucolide was isolated. The investigation of two *Critoniopsis* species gave in addition to known lactones a further glaucolide and a vernopatensolide. A related species, *V. flexipappa*, only gave glaucolide B. The structures were elucidated by highfield NMR spectroscopy.

INTRODUCTION

In a continuation of our investigations of members of the tribe Vernonieae we have studied two representatives of the recently described genus *Critoniopsis* [1] as so far none of these species have been studied chemically.

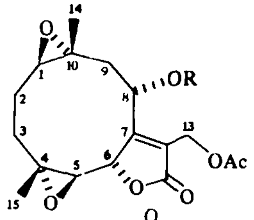
RESULTS AND DISCUSSION

The aerial parts of *Critoniopsis huaircajana* (Hieron.) H. Robinson gave 8α-methacryloyloxyhirsutinolide-13-*O*-acetate (**7**) [2, 3], stilpnotomentolide-8-*O*-methacrylate [3, 4], 17,18-epoxy-vernotaloide (**1**) [5] and a closely related lactone (**2**), and a vernopatensolide derivative (**3**). The structure of **2** followed from the ^{1}H NMR spectrum (Table 1) which was close to that of **1** [5]. The changed nature of the ester group at C-8 followed from the typical signals of a 2-hydroxy-3-chloroisobutyrate. The structure of **3** was deduced by comparison of its ^{1}H NMR spectrum (Table 1) with that of the corresponding angelate [3]. Again at room temperature most signals were broadened. The ^{13}C NMR data (Table 2) also agreed with the structure.

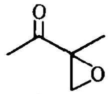
The aerial parts of *C. bogotana* (Cuatr.) H. Robinson gave very similar lactones. However, in addition to the methacrylates, the angelates and tiglates of hirsutinolide-13-*O*-acetate [3, 4], stilpnotomentolide [3, 4] and vernonataloide [3, 6] were present. The aerial parts of *Vernonia flexipappa* Gleason, which is closely related to the *Critoniopsis* species, afforded large amounts of glaucolide B.

Vernonia poskeana Vatke. and Hild. had been investigated previously [7]. As in the case of the two subspecies from Transvaal [7], the main compound in the sample from Malawi was 8α-[5-acetoxysenecioyloxy]-3-oxo-1-desoxy-1,2-dehydrohirsutinolide-13-*O*-acetate [7]. The stereochemistry of this lactone was proven by NOE difference spectroscopy. Clear effects were observed between H-15 and H-5, between H-10 and H-9 as well as between H-14 and H-2. The latter NOE clearly indicated the uncommon 10β-orientation of the methyl group. The ^{13}C NMR data are given in Table 2. In addition to the acetoxy senecioate **6** [8] and the related 8α-[5-acetoxy senecioyloxy]-3β-hydroxy-10αH-hirsutinolide-13-*O*-acetate, which had been prepared from **6** [8], two new lactones, the diketone **5** and the seco-derivative **4** were isolated. The structure of **5** followed from the ^{1}H NMR spectrum (Table 1) which was close to that of **6** [8]. However, the presence of a second keto group was indicated by a pair of doublets ($\delta 3.88$ and 3.58). The chemical shift required a position between two keto groups. Though some of the remaining signals in the spectra of **5** and **6** showed some shift differences, the coupling pattern was nearly identical. NOE difference spectroscopy allowed the assignment of the stereochemistry and the conformation. Thus clear effects were observed between H-14, H-2α and H-9α, between H-15, H-2β, H-6 and H-8 as well as between H-10, H-5 and H-2α. Accordingly, the keto group at C-1 and the 4-methyl group were above the ring, the 10-methyl group quasi equatorial and the 3-keto group below the ring.

The ^{1}H NMR spectrum of **4** (Table 1) indicated the presence of a methyl ester, a methyl ketone, an acetoxy and an acetoxy senecioyloxy group. Some of the remaining signals were close to those of **5** and **6**. However, a singlet at $\delta 5.70$ and the absence of an H-6 signal indicated the presence of an enol lactone. As the chemical shift of H-10 was nearly the same as in **5** a keto group was present at C-1. The only group which could be linked with this group was the methyl group which displayed a singlet at $\delta 2.19$. The chemical shift of H-15 required a neighbouring carbonyl group which had to be the carbomethoxy group. In the mass spectrum the highest fragment was *m/z* 465 ($C_{23}H_{29}O_{10}$) formed by loss of CO_2Me as the next fragment *m/z* 307 was obviously formed as a result of elimination of the acid residue. CIMS also gave no molecular ion, but the ^{13}C NMR clearly showed (Table 2) that the molecular formula was $C_{25}H_{32}O_{12}$. All data therefore agreed with the structure **4** which we have named poskeanolide. Most likely **4** is biogenetically



1 R =



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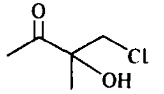

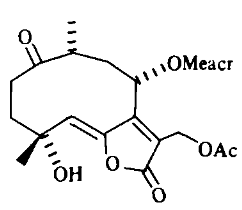

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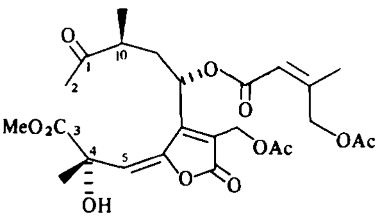
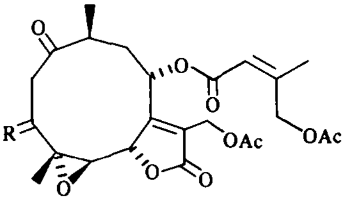
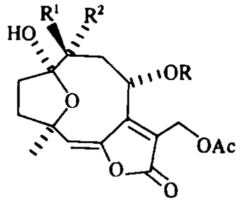


4



5 R = O
6 R = βOH,H



	7	**8**	**9**	**10**	**11**	**12**
R	Meacr	4-OH Meacr	Tigl	4-OH Tigl	4-OH Meacr	4-OH Tigl
R^1	H	H	H	H	Me	Me
R^2	Me	Me	Me	Me	OH	OH

formed starting with **5** by an acid splitting-like process followed by opening of the epoxide and elimination of water which leads to the formation of an enol lactone. Accordingly, the stereochemistry should be the same as in **4**. So far only a few seco-germacranolides have been reported. In addition to pycnolide from a *Liatris* species [9] some seco-derivatives are present in *Trichogonia* species [10, 11]. A further derivative of pycnolide has been isolated from *Mikania vitifolia* [12]. All these species are placed in the tribe Eupatorieae.

Vernonia cinerea (L.) Less. had been reported to contain vernolic acid, several flavones, tridecapentaynene, triterpenes and sterols [13, 14]. A reinvestigation of material from two very different locations gave several typical sesquiterpene lactones. The aerial parts from a collection in Costa Rica gave stilpnotomentolide-8-*O*-tiglate [15], 8α-[hydroxymethacryloyloxy]-hirsutinolide-13-*O*-acetate (**8**) [2, 3] and four further hirsutinolides (**9**–**12**). The structure of **9** was deduced from the ^{1}H NMR spectrum (Table 1) which only differed from that of **8** by the typical signals of the ester residue. Also the spectrum of **10** was very close to those of **8** and **9** (Table 1). Typical signals [7.02 *t* (*br*), 4.23 *d* (*br*) and 1.81 *s* (*br*)] for a 4-hydroxytiglate indicated the structure of this hirsutinolide. The structures of **11** and **12** which again only differed in the nature of the ester residue also could be deduced from the ^{1}H NMR spectra (Table 1) at elevated temperature while at room temperature highly broadened signals did not allow a clear assignment by spin decoupling. But, as in similar cases, even at 57° the signal of H-8 could not be detected. As, however, the spectral data of **11** and **12** only differed by the signals of the ester residue from those of similar hirsutinolides [2, 3] the structures were settled. The stereochemistry of these lactones has been determined by NOE difference spectroscopy [3].

The collection from Malawi gave glaucolide E (**15**) [16] and two new lactones, the corresponding hydroxymethacrylate **14** and the bisepoxide **13**. The structure of **14** was deduced from its ^{1}H NMR spectrum (Table 1) which was close to that of **15**. All signals could be assigned by spin decoupling. The nature of the ester groups followed from the typical ^{1}H NMR signals.

The structure of **13** followed from the molecular formula ($C_{21}H_{24}O_9$) and from the ^{1}H NMR spectrum, especially in deuteriobenzene (Table 1). The presence of a glaucolide derived lactone followed from the pair of H-13 signals, one of them showing a homoallylic coupling with H-6. The latter was coupled with a sharp doublet at δ2.23. The chemical shift indicated the presence of an epoxide proton. This, together with a methyl singlet at δ1.14, suggested the presence of a 4,5-epoxide. A pair of signals for *exo*-methylene protons were due to H-14 and H-14′

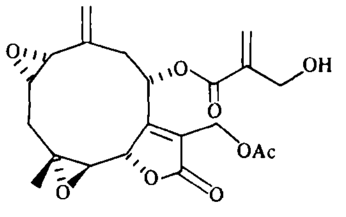
Table 1. ^{1}H NMR spectral data of **2**–**5** and **9**–**14** (400 MHz, CDCl$_3$, TMS as internal standard)

H	**2**	**3**	**4***	**5**	**9**	**10** (CD$_3$OD, 57°)	**11** (CD$_3$OD, 57°)	**12**	**13** (C$_6$D$_6$)	**14**
1	2.68 *br d*	—	—	—	—	—	—	—	2.65 *br d*	5.20 *br d*
2	2.14 *br dd*	2.3–2.5 *m*	2.19 *s*	3.88 *d*	2.0–2.1 *m*	2.0–2.15 *m*	†	†	—	5.58 *ddd*
2′	1.53 *m*			3.58 *d*			†	†	2.68 *ddd*	—
3	2.31 *ddd*		—	—			†	†	2.27 *dd*	2.59 *dd*
3′	1.35 *ddd*	2.05 *m*	—	—			†	†	0.97 *dd*	1.28 *br dd*
5	2.58 *d*	5.40 *br s*	5.70 *s*	2.78 *d*	5.87 *s*	6.00 *s*	6.07 *s*	6.08 *s*	2.23 *d*	2.48 *d*
6	4.92 *br d*	—	—	4.99 *br d*	—	—	—	—	4.72 *br d*	4.83 *br d*
8	5.32 *br d*	5.50 *br d*	5.83 *dd*	4.91 *dd*	6.26 *br d*	6.28 *d*	†	†	5.03 *dd*	5.04 *br d*
9	2.68 *br d*	1.87 *br d*	2.44 *ddd*	2.55 *m*	2.29 *dd*	2.42 *br dd*	2.54 *dd*	2.53 *dd*	2.84 *dd*	3.01 *dd*
9′	2.07 *dd*	2.40 *m*	1.71 *ddd*	2.20 *dd*	1.88 *m*	1.90 *m*	2.21 *br d*	2.23 *dd*	2.34 *br dd*	2.68 *br d*
10	—	2.92 *m*	2.64 *ddq*	2.60 *m*	1.92 *m*		—	—	—	—
13	5.15 *dd*	5.02 *br d*	4.97 *d*	4.96 *br d*	5.09 *d*	5.02 *d*	4.94 *d*	4.95 *d*	5.09 *br d*	5.00 *d*
13′	4.83 *br d*	4.95 *br d*	4.90 *d*	4.1 *dd*	5.00 *d*	4.96 *d*	4.90 *d*	4.88 *d*	4.92 *dd*	4.85 *d*
14	1.50 *s*	1.08 *d*	1.21 *d*	1.23 *d*	0.85 *d*	0.89 *d*	1.21 *s*	1.22 *s*	4.99 *br s* 4.66 *br s*	2.03 *br s*
15	1.48 *s*	1.51 *br s*	1.70 *s*	1.71 *s*	1.48 *s*	1.48 *s*	1.56 *s*	1.56 *s*	1.14 *s*	1.38 *s*
OCOR	3.78*d*	6.17 *br s*	5.73 *ddq*	5.74 *ddq*	7.00 *qq*	7.02 *br t*	6.30 *br s*	6.93 *br t*	6.19 *dt*	6.27 *br s*
	3.59 *d*	5.70 *br s*	5.21 *br d*	5.13 *br s*	1.78 *dq*	4.23 *br d*	5.90 *br s*	4.28 *br d*	5.77 *dt*	5.98 *dt*
	1.53 *s*	1.97 *br s*	5.13 *br d*	1.95 *br s*	1.82 *dq*	1.81 *br s*	4.33 *br d*	1.83 *dt*	4.13 *br s*	4.31 *br s*
	3.44 *s* (OH)		1.95 *br s*				4.23 *br d*			
OAc	2.13 *s*	2.06 *s*	2.10 *s*	2.10 *s*	2.07 *s*	2.04 *s*	2.02 *s*	2.02 *s*	1.73 *s*	2.03 *s*
			2.08 *s*	2.07 *s*						2.08 *s*

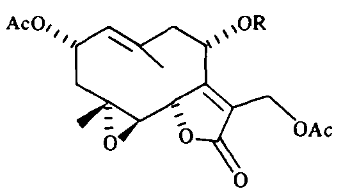
*OMe 3.81 *s*.

†Obscured signals.

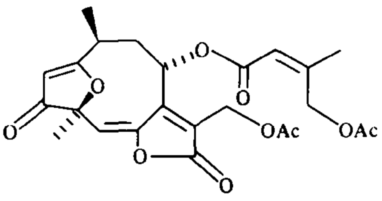
J (Hz): Compound **2**: 1,2′ = 10.5; 2,2′ = 14; 2,3 = 2; 2,3′ = 6; 2′,3 = 5; 2,3′ = 3,3′ = 13.5; 5,6 = 8.5; 6,13 = 1.5; 8,9′ = 9; 9,9′ = 14; 13,13′ = 13; compound **3**: 8,9′ = 11; 9,9′ = 13.5; 13,13′ = 13; compound **4**: 8,9 = 10.5; 8,9′ = 4; 9,9′ = 14; 9,10 = 9′,10 = 10,14 = 7; 13,13′ = 13; compound **5**: 2,2′ = 16; 5,6 = 9; 6,13′ = 1.5; 8,9′ = 9,9′ = 12; 10,14 = 6; 13,13′ = 13; compounds **9** and **10**: 8,9′ = 8; 9,9′ = 16; 10,14 = 7; 13,13′ = 13; compounds **11** and **12**: 8,9 = 7; 8,9′ = 3; 9,9′ = 15; 13,13′ = 13; compound **14**: 1,2 = 11; 2,3 = 6.5; 2,3′ = 12; 3,3′ = 13; 5,6 = 9; 8,9 = 9; 13,13′ = 13; compound **13**: 1,2 = 4; 2,3 = 6; 2,3′ = 8; 3,3′ = 9,9′ = 13,13′ = 13; 5,6 = 10; 6,13′ = 1.5; 8,9 = 12; 8,9′ = 2.5; CH$_2$Cl (*J* = 11.5); AcSen: 2′,4′ = 2′,$5'_1$ = 2′,$5'_2$ = 1.5; Tigl: 3′,4′ = 7; 3′,5′ = 1.5; Hydroxytigl: 3′,4′ = 6; 3′,5′ = 4′,5′ = 1.5; Hydroxymeacr: $3'_1$,$3'_2$ = $3'_1$,4′ = $3'_2$,4′ = 1.5; $4'_1$,$4'_2$ = 15.



13



14 R = 4-OH Meacr
15 R = Meacr



16

while the sequence of H-1 through H-3 and H-8, H-9, H-9′ could be assigned by spin decoupling. The stereochemistry was determined by NOE difference spectroscopy. Thus clear effects were observed between H-15, H-2, H-3, H-6 and H-8, between H-5 and H-3α, between H-1 and H-9β, between H-8 and H-6, as well as between H-6, H-8 and H-15. These data also indicated the favoured conformation with the 4-methyl above and the 10-methylene below the ring. This explained the upfield shifts of H-5 and H-3α by the shielding effect of the 10(14)-double bond. The ^{13}C NMR spectrum (Table 2) also supported the structure. Compound **13** we have named vernocinerolide-8-*O*-hydroxymethacrylate.

Table 2. ^{13}C NMR spectral data of **3–5**, **13** and **16*** (100 MHz, $CDCl_3$)

C	3	4	5	13	16
1	211.1	210.3	206.4	57.2	194.7
2	42.8	28.2	55.1	56.0	99.0
3	38.4	174.3	197.1	44.4	201.8
4	72.9	72.9	63.3	58.1	86.8
5	118.0	116.1	62.2	65.0	117.1
6	152.7	152.9	79.9	80.5	151.2
7	148.2	145.7	162.3	162.7	146.2
8	69.3	66.1	66.1	67.4	65.6
9	37.8	36.6	36.2	35.8	40.1
10	46.2	43.6	42.9	138.4	31.2
11	122.1	124.3	128.3	127.6	131.8
12	166.9	166.7	170.2	165.2	165.9
13	54.9	54.7	55.3	55.1	55.7
14	19.1	16.6	14.8	118.0	15.2
15	26.6	26.3	18.9	18.5	20.9
OR	165.7	163.9	164.3	170.4	163.9
	135.2	115.8	115.6	135.8	116.6
	127.3	157.7	157.7	127.7	156.4
	18.2	21.6	21.5	61.8	21.3
		63.5	63.4		63.4
OAc	170.3	170.5	170.5	170.2	170.9
	20.7	170.3	170.4	20.7	169.8
		21.5	20.6		20.5
		20.7	20.6		20.4
OMe		53.5			

The chemistry of the material from the two localities is clearly different. However, the compounds isolated are all related to the precursors of the glaucolides, though the compounds from the material from Malawi are less common in the genus *Vernonia*.

The chemistry of the genus *Critoniopsis* is not very different from that of most other species in the large genus *Vernonia*. As nearly all the isolated sesquiterpene lactones are biogenetically closely related, the structure variations surely are not sufficient to support any separation of a new genus or subgenus. Further investigations are necessary to get more detailed information.

EXPERIMENTAL

The air dried plant material was extracted at 20° for 24 hr with $MeOH–Et_2O–$petrol (1:1:1). The extracts obtained were defatted by treatment with MeOH and separated first by CC (silica gel) and further by prep. TLC (silica gel, PF 254) and HPLC (RP 8, 100 bar, flow rate *ca* 3 ml/min) as reported previously [17].

Critoniopsis huaircajana (100 g, voucher Keeley 4128-35, collected 16 km S. of Canar, Ecuador) afforded a polar CC fraction (Et_2O and $Et_2O–MeOH$, 9:1) which gave by prep. TLC 20 mg **7**, 100 mg stilpnotomentolide-8-*O*-methacrylate and a mixture which when further separated by prep. TLC ($CH_2Cl_2–Et_2O$, 17:3) afforded 10 mg **1** (R_f 0.52), 5 mg **2** (R_f 0.46) and 2 mg **3** (R_f 0.31).

Critoniopsis bogotana (100 g, voucher Keeley 4228-29, collected 4.4 km W. of turn off to Los Nevados, National Park, Province Caldas, Columbia) gave a polar fraction which afforded by prep. TLC ($CH_2Cl_2–Et_2O$, 17:3) 10 mg **7**, 5 mg of the corresponding angelate and 10 mg of the tiglate, 30 mg stilpnotomentolide-8-*O*-methacrylate, 20 mg of the corresponding angelate and 30 mg of tiglate as well as 20 mg vernonataloide, 10 mg of the corresponding angelate and 20 mg of the tiglate.

Vernonia flexipappa (100 g, voucher Keeley 4104-15, collected 14.8 km from transit control out of Loja, Province Zamora-Chinchipe, Ecuador) gave by CC 1 g glaucolide B.

Vernonia poskeana (100 g, collected in Malawi, voucher deposited in the Herbarium of the Chancelor College, University of

Malawi) gave a polar CC fraction (Et_2O and Et_2O–MeOH, 9:1) which was separated by repeated CC (1, CH_2Cl_2–Et_2O, 9:1; 2, CH_2Cl_2–Et_2O; 3:1 and 3, CH_2Cl_2–MeOH, 4:1). HPLC of fraction 1 (MeOH–H_2O, 7:3) gave 150 mg **5** (R_t 3.0 min) and 500 mg **16** (R_t 4.5 min). Fraction 2 gave by prep. TLC (Et_2O, three developments) 12 mg **4** (R_f 0.22) and prep. TLC of fraction 3 (Et_2O, three developments) gave 5 mg **6** (R_f 0.18) and a mixture which by repeated prep. TLC (C_6H_6–CH_2Cl_2–Et_2O, 4:4:1) afforded 3 mg **4** (R_f 0.42) and 3 mg 8α-[5-acetoxy senecioyloxy]-3β-hydroxy-10α H-hirsutinolide-13-*O*-acetate (R_f 0.38).

Vernonia cinerea (350 g, collected in January 1983 in Puente Rio Barbilla, Costa Rica, voucher CR 92367, deposited in Herbario National de Costa Rica and 100 g, collected in summer 1984 in Malawi, voucher 1760, deposited in the U.S. National Herbarium). The extract of the Costa Rica material gave two polar fractions (1, Et_2O–petrol, 1:1 and 2, Et_2O). Prep. TLC of fraction 1 (Et_2O–petrol, 7:3) gave 15 mg **9** (R_f 0.45) and prep. TLC of fraction 2 (Et_2O) gave 7 mg **8**, 104 mg stilpnotomentolide-8-*O*-tiglate and a mixture which by HPLC (MeOH–H_2O, 3:2) afforded 2.8 mg **11** (R_t 2.2 min), 1.9 mg **12** (R_t 2.5 min) and 2.3 mg **10** (R_t 3.5 min). The extract of the Malawi sample gave by CC (silica gel) two polar fractions (1, Et_2O and 2, Et_2O–MeOH, 4:1). Prep. TLC of fraction 1 (Et_2O–petrol, 4:1) gave 4.5 mg **15** and 3 mg **14** (R_f 0.35). Prep. TLC of fraction 2 (C_6H_6–CH_2Cl_2–Et_2O, 1:1:3) followed by HPLC (RP 18, MeOH–H_2O, 3:2) gave 7.5 mg **13** (R_t 7.0 min). Known compounds were identified by comparing the 400 MHz ^1H NMR spectra with those of authentic material.

17-*Dihydro*-17-*hydroxy*-18-*chlorovernonataloide* (**2**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1780 (γ-lactone), 1750, (OCOR, OAc); MS *m/z* (rel. int.): 458 $[M]^+$ (0.1), 440 $[M-H_2O]^+$ (0.5), 409.150 $[M-CH_2Cl]^+$ (2) (calc. for $C_{20}H_{25}O_9$: 409.1499), 398.113 $[M-AcOH]^+$ (1.5) (calc. for $C_{19}H_{23}ClO_7$: 398.113), 278 $[M-RCO_2H, ketene]^+$ (20), 260 $[M-RCO_2H, AcOH]^+$ (12), 250 $[278-CO]^+$ (25), 231 $[260-CHO]^+$ (30), 97 (100), 93 (95), 69 (90).

Vernopatensolide-8-O-*methacrylate* (**3**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1780 (γ-lactone), 1740–1720 (OCOR, ketone); MS *m/z* (rel. int.): 406.163 $[M]^+$ (1) (calc. for $C_{21}H_{26}O_8$: 406.163), 337 $[M-RCO]^+$ (6), 320 $[M-RCO_2H]^+$ (3), 260 $[320-HOAc]^+$ (5), 69 $[C_3H_5CO]^+$ (100). Stilpnotomentolide-8-*O*-[2-methacrylate] (10 mg) was stirred 1 hr at 40° in 0.5 ml dioxane and 0.1 ml 1 M K_2CO_3. Usual work-up and prep. TLC (Et_2O) gave 8 mg **3**, identical with the natural product.

Poskeanolide (**4**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1780 (γ-lactone), 1740–1720, 1250 (OCOR, ketone); MS *m/z* (rel. int.): 465.176 $[M-CO_2Me]^+$ (20) (calc. for $C_{23}H_{29}O_{10}$: 465.176), 366 $[M-RCO_2H]^+$ (3), 307 $[465-RCO_2H]^+$ (50), 264 $[307-MeCO]^+$ (25), 247 $[307-AcOH]^+$ (50), 99 $[RCO-ketene]^+$ (100);

$$[\alpha]_{24}^{\lambda} = \frac{589 \quad 578 \quad 546 \quad 436\ \text{nm}}{-37 \quad -41 \quad -52 \quad -120}\ (CHCl_3;\ c\ 0.33).$$

3-*Oxo*-10αH-*stilpnotomentolide*-8-O-(5-*acetoxysenecioate*) (**5**). Colourless crystals, mp 131°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1780 (γ-lactone), 1740, 1260 (OCOR, OAc), 1710 (ketone); MS *m/z* (rel. int.): 492.163 $[M]^+$ (1) (calc. for $C_{24}H_{28}O_{11}$: 492.163), 450 $[M-ketene]^+$ (1), 433 $[M-OAc]^+$ (2), 432 $[M-HOAc]^+$ (2), 292 $[450-RCO_2H]^+$ (8), 274 $[432-RCO_2H]^+$ (10), 99 $[RCO-ketene]^+$ (100);

$$[\alpha]_{24}^{\lambda} = \frac{589 \quad 578 \quad 546 \quad 436\ \text{nm}}{-194 \quad -202 \quad -234 \quad -540}\ (CHCl_3;\ c\ 0.46).$$

8α-*Tigloyloxyhirsutinolide*-13-O-*acetate* (**9**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1760 (γ-lactone, OAc), 1710, 1650 (C=CCO$_2$R); MS *m/z* (rel. int.): 420.178 $[M]^+$ (6) (calc. for $C_{22}H_{28}O_8$: 420.178), 403 $[M-OH]^+$ (0.5), 360 $[M-HOAc]^+$ (0.7), 260 $[360-RCO_2H]^+$ (6), 242 $[260-H_2O]^+$ (5), 83 $[C_4H_7CO]^+$ (100), 55 $[83-CO]^+$ (42); $[\alpha]_D = +104$ ($CHCl_3$; *c* 1.46).

8α-[4-*Hydroxytigloyloxy*]-*hirsutinolide*-13-O-*acetate* (**10**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}. 3600 (OH), 1760 (γ-lactone, OAc), 1720, 1600 (C=CCO$_2$R); MS *m/z* (rel. int.): 436.173 $[M]^+$ (6) (calc. for $C_{22}H_{28}O_9$: 436.173), 376 $[M-HOAc]^+$ (0.6), 320 $[M-RCO_2H]^+$ (1), 278 $[320-ketene]^+$ (5), 260 $[320-HOAc]^+$ (11), 99 $[RCO]^+$ (100), 71 $[99-CO]^+$ (68).

8α-[4-*Hydroxymethacryloyloxy*]-10α-*hydroxyhirsutinolide*-13-O-*acetate* (**11**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3440 (OH), 1765 (γ-lactone), 1725 (OAc, C=CCO$_2$R); MS *m/z* (rel. int.): 438.153 $[M]^+$ (8) (calc. for $C_{21}H_{26}O_{10}$: 438.153), 378 $[M-HOAc]^+$ (4), 276 $[378-RCO_2H]^+$ (41), 234 $[276-C_2H_2O]^+$ (100), 216 $[234-H_2O]^+$ (50), 85 $[RCO]^+$ (52), 57 $[85-CO]^+$ (64).

8α-[4-*Hydroxytigloyloxy*]-10α-*hydroxyhirsutinolide*-13-O-*acetate* (**12**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3540 (OH), 1770 (γ-lactone), 1730 (OAc, C=CCO$_2$R); MS *m/z* (rel. int.): 452.168 $[M]^+$ (5) (calc. for $C_{22}H_{28}O_{10}$: 452.168), 392 $[M-HOAc]^+$ (1), 336 $[M-RCO_2H]^+$ (1.3), 321 $[336-Me]^+$ (4), 276 $[336-HOAc]^+$ (21), 234 $[276-C_2H_2O]^+$ (47), 99 $[RCO]^+$ (100), 71 $[99-CO]^+$ (64); $[\alpha]_D = +69$ ($CHCl_3$; *c* 0.19).

Vernocinerolide-8-O-[4-*hydroxymethacrylate*] (**13**). Colourless crystals, mp 184°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1775 (γ-lactone), 1735 (OAc, C=CCO$_2$R); CIMS *m/z* (rel. int.): 421 $[M+H]^+$ (22) ($C_{21}H_{24}O_9+H$), 361 $[421-HOAc]^+$ (4), 319 $[421-RCO_2H]^+$ (4), 259 $[319-HOAc]^+$ (22), 103 $[RCO_2H+1]^+$ (57), 61 $[AcOH+1]^+$ (100); $[\alpha]_D = -3$ ($CHCl_3$; *c* 0.5).

19-*Hydroxyglaucolide E* (**14**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1770 (γ-lactone), 1730 (OAc, C=CCO$_2$R); MS *m/z* (rel. int.): 464.168 $[M]^+$ (1) (calc. for $C_{23}H_{28}O_{10}$: 464.168), 404 $[M-HOAc]^+$ (4), 362 $[M-RCO_2H]^+$ (7), 302 $[362-HOAc]^+$ (3), 260 $[302-ketene]^+$ (8), 242 $[302-HOAc]^+$ (10), 85 $[RCO]^+$ (100); $[\alpha]_D = -13$ ($CHCl_3$; *c* 0.3).

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