Phytochemistry, Vol. 20, No. 7, pp. 1649–1655, 1981.
Printed in Great Britain.

0031-9422/81/071649-07 $02.00/0

TRIXIKINGOLIDES AND GERMACRENE DERIVATIVES FROM *TRIXIS* SPECIES*

FERDINAND BOHLMANN, ANTOINETTE SUWITA, JASMIN JAKUPOVIC, ROBERT M. KING† and HAROLD ROBINSON†

Institute for Organic Chemistry, Technical University of Berlin, D-1000 Berlin 12, West Germany; †Smithsonian Institution, Washington, DC 20560, U.S.A.

(*Received* 18 *November* 1980)

Key Word Index—*Trixis vautheri*; *T. antimenorrhoea*; Compositae; Mutisieae; sesquiterpenes; trixikingolides; germacrene derivatives; rotundene derivative; flavanones.

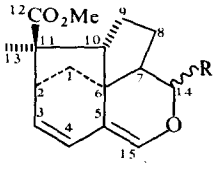
Abstract—The investigation of two further *Trixis* species afforded five new sesquiterpenes related to trixikingolide, six new germacrene derivatives and a sesquiterpene derived from rotundene. Some further known compounds were isolated too, which in part may be of chemotaxonomic significance. The structures were elucidated by spectroscopic methods and a few chemical transformations. The relative position of the ester groups in eight of the new sesquiterpenoids however, could not be established with certainty as partial saponifications were not successful.

INTRODUCTION

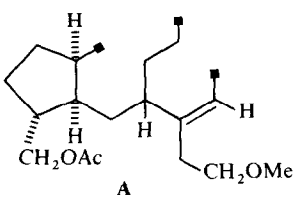
Only a few species of the large genus *Trixis* have so far been investigated chemically. All contained a new type of sesquiterpene skeleton [1–3], also present in a *Proustia* species [3]. As the taxonomy of the tribe seems to be very complicated, we have now investigated two further species to see whether these compounds are typical for the genus or for the subtribe, and whether other constituents may give indications to further relationships in the tribe. Again trixikingolides and similar compounds were present. However, *T. vautheri* also contained a new type of highly oxygenated germacrene derivatives, unusual sesquiterpene lactones and a coumarin, so far only isolated from *Gerbera* species.

RESULTS AND DISCUSSION

The roots of *T. vautheri* DC. afforded caryophyllene, the corresponding 1,10-epoxide, the sesquiterpene lactones **15** [4] and **16** [5], the isovalerate **1** [1], the lactone **3** [2], as well as the methyl ether **2**, which has not been isolated before. Its structure followed from the ^1H NMR data (Table 1), which clearly indicated that the stereochemistry at C-14 was changed if compared with that of **1**. As C-14 epimeric compounds have already been prepared [2], the assignment of the configuration was easy. We have named **2** 14β-methoxytrixic acid methyl ester. Furthermore, a methoxysesquiterpene acetate was present in small amounts. The molecular formula and the ^{13}C NMR data indicated the presence of a tricyclic sesquiterpene with one double bond. The ^1H NMR data (Table 4) showed one broadened olefinic singlet. Its allylic coupling with the signals of a CH_2OMe group allowed the placement of this oxygen function, while a CH_2OAc group had to be placed at a tertiary carbon. Only one methyl group was present (1.04, *s*), indicating that the carbon skeleton must be formed by using one of the methyls normally present in sesquiterpenes. Addition of $Eu(fod)_3$ allowed the assignment of several more signals. The broadened double doublet at 2.48 ppm obviously must be the signal of a tertiary allylic proton. Epoxidation led to only one epoxide, while oxidation of the free alcohol, obtained by saponification, gave an aldehyde. All signals of the epoxide could be assigned by measuring the spectrum in $CDCl_3$ with different amounts of C_6D_6 (10–50%). In each spectrum all signals that were not overlapping were decoupled by double resonance experiments starting with the signals of the CH_2OAc group. This allowed the assignment of the neighbouring proton and further spin decoupling in the usual way led to the sequence **A**:



1 R = α-O-*i*-Val
2 R = β-OMe



A

* Part 346 in the series "Naturally Occurring Terpene Derivatives". For Part 345 see Bohlmann, F., Suwita, A., Robinson, H. and King, R. M. (1981) *Phytochemistry* **20**, (in press).

Table 1. ^{1}H NMR spectral data of compounds **2** and **4–8** (270 MHz, $CDCl_3$, TMS as internal standard)

	2	**4**	**5** + D_2O	**6**	**7**	**8**
H-1α	2.00 *m*	1.44 *dd*	1.44 *dd*	1.45 *dd*	1.43 *dd*	1.4 *m*
H-1β		3.16 *dd*	3.17 *dd*	3.16 *dd*	3.15 *dd*	3.17 *dd*
H-2	2.60 *br dd*	2.38 *ddd*	2.38 *ddd*	2.38 *ddd*	2.39 *ddd*	2.38 *br d*
H-3α	5.75 *dd*	4.95 *dd*	4.95 *dd*	4.95 *dd*	4.96 *dd*	4.94 *dd*
H-3β		—	—	—	—	—
H-4	5.83 *d*	4.87 *dd*	4.87 *dd*	4.86 *dd*	4.83 *dd*	4.87 *dd*
H-7	2.00 *m*	2.62 *ddd*	2.62 *ddd*	2.60 *ddd*	2.62 *ddd*	2.4 *m*
H-8α	1.9–1.4 *m*	2.23 *dd*	2.23 *dd*	2.22 *dd*	2.23 *dd*	2.2 *m*
H-8β		1.87 *ddd*	1.88 *ddd*	1.87 *ddd*	1.89 *ddd*	1.6 *m*
H-9α		—	—	—	—	—
H-9β		4.42 *dd*	4.41 *dd*	4.41 *dd*	4.40 *dd*	4.41 *dd*
H-10	2.85 *dd*	2.18 *br d*	2.17 *br d*	2.18 *br d*	2.18 *br d*	2.1 *m*
H-13	1.28 *s*	1.59 *s*	1.59 *s*	1.59 *s*	1.60 *s*	1.53 *s*
H-14	4.58 *d*	5.47 *d*	5.48 *d*	5.49 *d*	5.44 *d*	4.50 *d*
H-15	6.10 *s*	6.53 *s*	6.53 *s*	6.52 *s*	6.49 *s*	6.51 *s*
OMe	3.67 *s*	—	—	—	—	—
	3.44 *s*	—	—	—	—	—

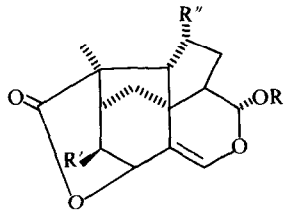
$OCOCH_2C(OAc)Me_2$: 2.95 and 2.85 *d*, J = 14.5 Hz; 1.52 *s*; 2.00 *s*; OCOCH(Me)CH(OH)Me: 2.56 *dq*, J = 7, 7 Hz; 3.94 *dq*, J = 7, 7 Hz; 1.25 *d* and 1.21 *d* (J = 7 Hz) [in **5**: 2.59 *dq*, 4.11 *dq* (J = 7, 4.5 Hz), 1.24 *d*, 1.23 *d*]; $OCOCH_2C(OH)Me_2$: 2.58 *s*, 1.33 *s*, 1.31 *s*; COCH(Me)Et: 2.34 *ddq* (J = 7,7,7 Hz), 1.64 *ddq* and 1.43 *ddq* (J = 14,7,7 Hz), 1,13 *d* and 0.89 *d* (J = 7 Hz); OCOCH(Me)CH(OAc)Me: 2.80 *dq* (J = 7,7 Hz), 5.16 *dq* (J = 7,7 Hz), 1.25 *d* and 1.20 *d* (J = 7 Hz).

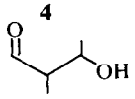
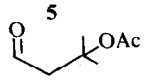
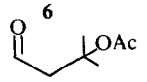
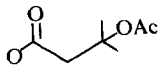
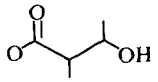
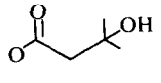
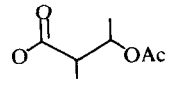
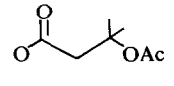
J (Hz): **2**: 1,2 = 4; 2,3 = 6; 3,4 = 9; 7,14 = 3.5; 9,10 = 8; **4**: 1α,1β = 12; 1α,2 = 1.5; 1β,2 = 6; 2,3α = 3α,4 = 2.5; 7,8α = 8.5; 7,8β = 6.5; 7,14 = 9; 8α,8β = 15; 8β,9β = 9β,10 = 5.

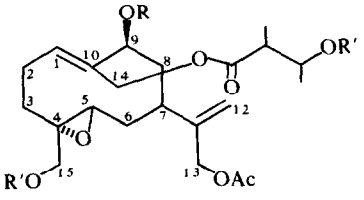
Together with the other data this was in good agreement with structure **29** and consequently the natural compound is **27**. Though a few couplings could not be estimated with certainty, the crucial ones were clear and fully in agreement with those expected from a model. Especially the angles between H-7 and H-6β and H-8α were nearly 90° and those between H-6β and H-5 180° thus explaining the large coupling observed. Irradiation of the H-7 signal sharpened the H-12 signal, thus establishing the position of the olefinic bond. A *W*-coupling was present further between H-2β and H-4, which supported the α-orientation of the CH_2OAc group. Furthermore the observed shifts after addition of $Eu(fod)_3$ in the spectrum of **27** were in agreement with the proposed stereochemistry. Since H-5 showed one large coupling only H-1 and H-5 must be both α-orientated. The ^{13}C NMR data (Table 4) also agreed with the proposed structure, though not all signals could be assigned with certainty. In the mass spectrum of **27** the base peak formed by loss of CH_2OMe is remarkable. Most probably this has to be explained as shown in the Scheme 1 (**27a**), by first splitting the 1,11-bond followed by 5,11-H-shift leading to an allylic methyl ether. The corresponding hydrocarbon probably is rotundene [6], in which structure, however, no stereochemistry is proposed. **27** may be derived from a guaiane like **30** by an acid-catalyzed cyclisation (see Scheme 1).

The aerial parts afforded caryophyllene, **1**, **2**, **3**, the coumarin aldehyde **26** [7], the flavones **23–25** [8] and the flavanones **17–20**. Sakuranetin (**17**) is widespread in Compositae, while padmatin (**19**) [9] and 7-*O*-methyldihydrokaempferol (**20**) [10] seem to be rare. **18** or its 3′,4′-isomer was isolated from a *Eupatorium* species [10].

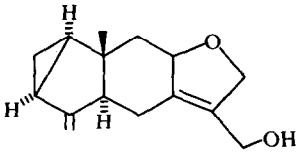
If the ^{1}H NMR data of **18** (Table 3) were compared with those of the acetylation products **21** and **22**, the free hydroxyl most probably must be placed at C-4′. Furthermore, from the most polar fractions a complex mixture of sesquiterpenes was isolated, which could only be separated by HPLC. Two groups of compounds were present, the germacrene derivatives **9–13** (**11** and **12** could not be separated) and the trixikingolides **4–6**. **9** was the main constituent. Acetylation afforded the diacetate **14**. Careful ^{1}H NMR studies (Table 2) and comparison of the data with those of related germacrenes led to the proposed structure. Spin decoupling starting with the H-7 signal allowed the assignment of all signals, though several were overlapped. The stereochemistry at C-5 and C-9 was deduced from the corresponding couplings observed. The presence of a 15-OH group was shown by comparing the NMR data of **9** and **14**, while the position of the three ester groups could be deduced only indirectly. The presence of a β-hydroxy-2-methylbutyrate in all compounds was apparent from the typical ^{1}H NMR signals as was the nature of the other ester groups. As on acetylation of **9** the H-14 signals were shifted slightly, while the chemical shifts of these signals were nearly the same in all compounds, the hydroxymethylbutyrate group was assigned to the 14-position. While the chemical shift of H-12 was not different in the spectra of **8–14**, the position of the H-9 signal depended on the nature of the ester residue. Therefore most probably **9–13** differed in the oxygen function at C-9 only. We have named **9** with a free hydroxyl at C-9 vautheriol. The structures of **4–6** could not be deduced directly from the ^{1}H NMR data (Table 1). However, the data were all very close to those of the known 9α-hydroxykingolide diesters [1]. From the ^{1}H NMR data the nature of the ester



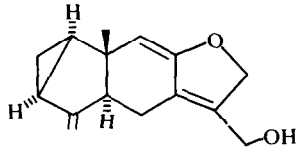
	3	4	5	6	7	8
R	*i*-Val					H
R′	H					
R″	H	OH	OH	OH	OH	OH



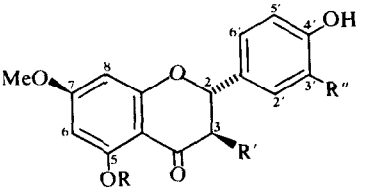
	9	10	11	12	13	14
R	MeBu	Ang	Tigl	Sen	*i*-Bu	MeBu
R′	H	H	H	H	H	Ac



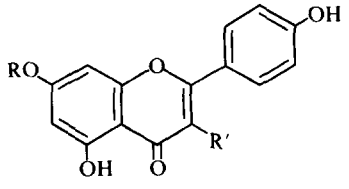
15



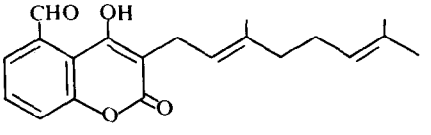
16



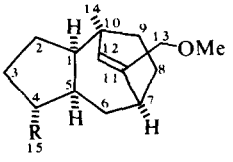
	17	18	19	20	21	22
R	H	H	H	H	Ac	H
R′	H	OH	OH	OH	OAc	OAc
R″	H	OMe	OH	H	OAc	OAc



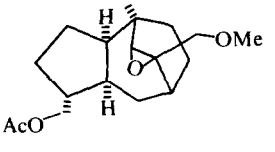
	23	24	25
R	Me	H	Me
R′	OH	OH	H



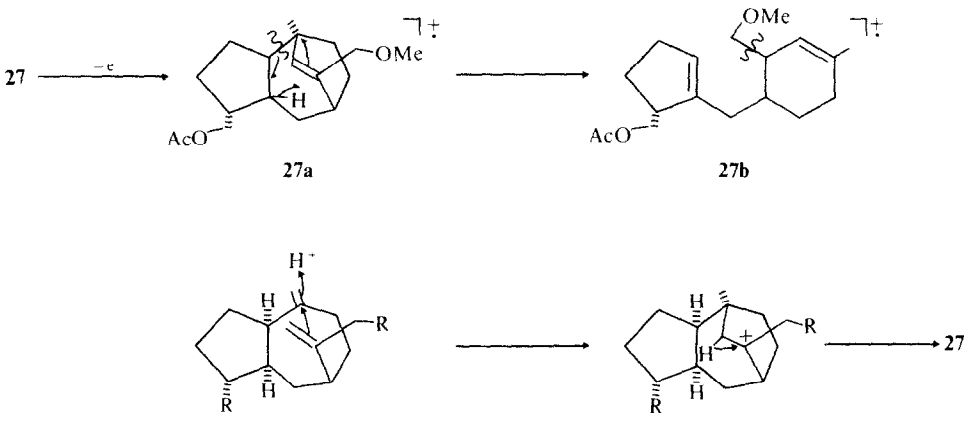
26



27 R = CH_2OAc
28 R = CHO



29



Scheme 1.

Table 2. ^{1}H NMR data of **9**–**14** (270 MHz, $CDCl_3$, TMS as internal standard)

	9(C_6D_6)	**10**	**11**		**12**	**13**	**14**
H-1	5.73 *br dd*	5.81 *br dd*		5.80 *br dd*		5.80 *br dd*	5.80 *m*
H-2α	1.85 *m*	2.15 *m*		2.15 *m*		2.2 *m*	2.1 *m*
H-2β	2.78 *m*	2.82 *m*		2.80 *m*		2.8 *m*	2.8 *m*
H-3α	2.48 *m*	2.5 *m*		2.5 *m*		2.5 *m*	2.5 *m*
H-3β	1.35 *m*	1.5 *m*		1.5 *m*		1.5 *m*	1.5 *m*
H-5	3.03 *dd*	3.35 *br d*		3.34 *br d*		3.32 *br d*	3.33 *br d*
H-6α	1.58 *ddd*	1.7 *m*		1.68 *m*		1.65 *m*	1.65 *m*
H-6β	2.21 *br d*	2.28 *m*		2.28 *m*		2.26 *m*	2.2 *m*
H-7	2.26 *br dd*	2.50 *m*		2.50 *m*		2.5 *m*	2.5 *m*
H-8α	2.21 *m*	2.20 *m*		2.2 *m*		2.2 *m*	2.2 *m*
H-8β	1.93 *m*	2.0 *m*		2.0 *m*		2.0 *m*	2.0 *m*
H-9	6.01 *br d*	5.93 *br d*		5.89 *br d*		5.84 *br d*	5.87 *m*
H-12	5.00 *br s*	5.05 *br s*		5.06 *br s*		5.06 *br s*	5.08 *br s*
H-12′	4.90 *br s*	4.95 *br s*		4.95 *br s*		4.95 *br s*	4.97 *br s*
H-13	4.57 ABq	4.54 *br s*		4.53 *br s*		4.53 *br s*	4.55 *br s*
H-14	4.86 *d*	4.83 *d*	4.82 *d*		4.80 *d*	4.80 *d*	4.63 *d*
H-14′	4.51 *d*	4.48 *d*		4.47 *d*		4.46 *d*	4.53 *d*
H-15	3.89 *br d*	3.79 *br d*		3.78 *br d*		3.78 *br d*	4.37 *br d*
H-15′	3.62 *br d*	3.58 *br d*		3.58 *br d*		3.58 *br d*	3.93 *br d*
OAc	1.81 *s*	2.08 *s*	2.07 *s*		2.08 *s*	2.10 *s*	2.12 *s*
							2.09 *s*
							2.00 *s*
OCOR	2.27 *tq*	6.12 *qq*	6.86 *qq*		5.66 *qq*	2.53 *qq*	2.38 *tq*
	1.67 *ddd*						
	1.37 *ddd*						
	0.89 *t*	1.99 *dq*	1.80 *br d*		2.17 *d*	1.18 *d*	0.92 *t*
	1.07 *d*	1.88 *dq*	1.82 *br s*		1.90 *d*	—	1.14 *d*
	2.48 *dq*	2.50 *dq*		2.48 *dq*		2.48 *dq*	2.77 *dq*
				3.91 *dq*		3.93 *dq*	
	3.97 *dq*	3.92 *dq*		1.23 *d*		1.24 *d*	5.15 *dq*
	1.14 *d*	1.24 *d*		1.17 *d*		1.16 *d*	1.24 *d*
	1.07 *d*	1.19 *d*					1.21 *d*

J(Hz): 1,2α = 7; 1,2β = 10; 5,6α = 11; 5,6β = 2; 6α,7 = 10; 6α,6β = 12; 7,8β ~ 5; 8α,8β ~ 12; 8β,9α ~ 5; 14,14′ = 12.5; 15,15′ = 12; OCOCH(Me)CH(OH)Me: 2′,3′ = 2′,5′ = 3′,4′ = 7; OMebu: 2′,3′ = 2′5′ = 3′4′ = 7: $3'_1,3'_2$ = 14; OAng: 3′,4′ = 7; 3′,5′ = 4′,5′ = 1.5; OTigl: 3′,4′ = 7: OSen: 2′,4′ = 2′,5′ = 1; O-i-Bu: 2′,3′ = 2′,4′ = 7.

Table 3. ^{1}H NMR spectral data of compounds **18**, **21** and **22** (270 MHz, $CDCl_3$, TMS as internal standard)

	18	21	22
H-2	5.02 *d*	5.39 *d*	5.37 *d*
H-3	4.57 *d*	5.73 *d*	5.82 *d*
H-6	6.13 *d*	6.43 *d*	6.14 *d*
H-8	6.07 *d*	6.34 *d*	6.08 *d*
H-2′	7.05 *d*	7.09 *d*	7.10 *d*
H-5′	6.99 *d*	7.08 *d*	7.09 *d*
H-6′	7.07 *dd*	7.02 *dd*	7.03 *dd*
OMe	3.95 *s*	3.87 *s*	3.88 *s*
	3.83 *s*	3.84 *s*	3.84 *s*
OAc	—	2.39 *s*	2.34 *s*
	—	2.33 *s*	—
	—	2.03 *s*	2.08 *s*
OH	11.21 *s*	—	11.46 *s*
	5.74 *s*	—	—

J(Hz): 2,3 = 12; 2′,6′ = 1.5; 5′6′ = 8.

groups was clearly deduced, but the relative position of the different esters caused difficulties. In the case of **4**, partial saponification was successful and thus allowed structural assignment since in the ^{1}H NMR spectrum of the resulting diol **8** the H-14 signal was shifted upfield and the signals of the acetoxyisovalerate still were present. As **5** was an isomer of **4**, its structure was also clear. If the signals of the hydroxymethylbutyrate residues in the spectra of **4** and **5** are compared, slight difference in the chemical shifts can be observed, which surely were caused by the lactone carbonyl. The relative position of the ester residues in **6** could not be established with certainty. As a partial saponification was not possible, the presence of hydroxy acid at C-14 was less likely, as obviously the success in the case of **4** was highly influenced by the lability of such an acid function.

The roots of *T. antimenorrhoea* (Schrank.) Mart. also afforded **1**, **3** and γ-curcumene, while the aerial parts gave germacrene D, **1**, **3** and a further derivative of this type differing in the nature of the ester residues. The ^{1}H NMR data showed the presence of a 2-methylbutyrate and a β-acetoxy-2-methylbutyrate group, while the other signals were more or less the same as those of **4**–**6**. A small upfield shift of the H-14 signal led to the proposed structure **7** as the more likely one. The absence of a β-oxygen function at the ester residue was obviously the reason for this difference in chemical shifts. Again partial saponification was unsuccessful. The results show again the significance of the trixikingolide like compounds for the subgenus *Nassauviinae*. However, the lactones **15** and **16**, present in a *Wunderlichia* [4] and an *Onoseris* species [5], respectively, as well as the coumarin **26**, found in *Gerbera* species [7], show relationships to the subtribes Gochnatiinae and Mutisiinae. Investigations of the fruit anatomy [11] have also led to groupings of genera, which include *Trixis*, *Gerbera*, *Onoseris* and *Wunderlichia*. These genera also show chemical relationships.

EXPERIMENTAL

The air-dried plant material was extracted with Et_2O–petrol (1:2) and the resulting extracts were separated first by column chromatography and further by repeated TLC (Si gel). Only the polar parts were further separated by HPLC (reversed phase, RF 18). Known compounds were identified by comparing the IR and ^{1}H NMR spectra with those of authentic material.

Trixis vautheri (voucher RMK 8040, collected in north-eastern Brazil). The roots (500 mg) afforded 300 mg caryophyllene, 20 mg caryophyllene epoxide, 100 mg **1**, 100 mg **2** (Et_2O–petrol, 1:3), 100 mg **3**, 10 mg **15**, 300 mg **16**, and 10 mg **27** (Et_2O–petrol, 1:3), while the aerial parts (330 g) gave 200 mg caryophyllene, 20 mg **1**, 20 mg **2**, 500 mg **3**, 50 mg **9**, 8 mg **10**, 4 mg **11**, 1 mg **12**, 6 mg **13** (**9**–**13** separated by HPLC) (MeOH–H_2O, 7:3), 200 mg **17**, 50 mg **18** ($CHCl_3$–Et_2O, 4:1), 10 mg **19**, 50 mg **20**, 10 mg **26** and a mixture of **4**–**6**, which after HPLC (MeOH–H_2O, 3:2 and MeCN–H_2O, 2:3) finally afforded 5 mg **4**, 5 mg **5** and 5 mg **6**.

Trixis antimenorrhoea (voucher RMK 8071, collected in north-eastern Brazil). The roots (20 g) afforded 10 mg γ-curcumene, 10 mg **1** and 20 mg **3**, while the aerial parts (200 g) gave germacrene D, 20 mg **1**, 20 mg **3** and 5 mg **7** (Et_2O, 2 ×).

14β-Methoxytrixic acid methyl ester (**2**). Colourless gum, IR $\gamma_{max}^{CCl_4}$ cm^{-1}: 1730 (CO_2R), 1650 (C=COR); MS *m/z* (rel. int.): 290.152 (M^+, 38) ($C_{17}H_{32}O_4$), 259 (M − OMe, 4), 231 (M − CO_2Me, 3), 71 ($C_3H_3O_2$, 100).

9α-Hydroxy-3β-[3′-acetoxy-isovaleryloxy]-trixikingolide-3′-hydroxy-2′-methylbutyrate (**4**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3620 (OH), 1740 (lactone, CO_2R), 1670 (C=COR); MS *m/z* (rel. int.): 536.226 (M^+, 0.8) ($C_{27}H_{36}O_{11}$), 435 (M − H_2C=C(Me)OAc, 3), 419 (M − OCOCH(Me)CH(OH)-Me, 6), 376 (M − $HO_2CCH_2C(Me)_2OAc$, 3), 83 ($C_4H_7CO^+$, 100).

$$[\alpha]_{24°}^{\lambda} = \frac{589 \quad 578 \quad 546 \quad 436\,nm}{-17.5 \quad -18 \quad -21 \quad -32} (c = 0.48, CHCl_3).$$

To 5 mg **4** in 1 ml MeOH was added 10 mg K_2CO_3 in 0.1 ml H_2O. Following the reaction by TLC led to the isolation of **8** (2 mg), colourless gum. MS *m/z* (rel. int.): 436.173 (M^+, 3) ($C_{22}H_{28}O_9$), 376 (M − HOAc, 2), 294 (M − O=C=CH–C(Me)$_2$OAc, 4), 143 (RCO^+, 21), 83 (143 − HOAc, 100).

9α-Hydroxy-3β-[3′-hydroxy-2′-methylbutyryloxy]-trixikingolide-3′-acetoxyisovalerate (**5**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3620 (OH), 1740 (lactone, OAc), 1710 (CO_2R), 1760 (C=COR); MS *m/z* (rel. int.): 536.226 (M^+, 0.3), 435 (M − H_2C–C(Me)OAc, 2), 419 (M–OCOCH(Me)CH(OH)Me, 4), 376 (M − RCO_2H, 2), 143 (RCO^+, 21), 83 (143 − HOAc, 100).

$$[\alpha]_{24°}^{\lambda} = \frac{589 \quad 578 \quad 546 \quad 436\,nm}{-33 \quad -35 \quad -40 \quad -63} (c = 0.2, CHCl_3).$$

9α-Hydroxy-3β-[3′-hydroxy-isovaleryloxy]-trixikingolide-3′-acetoxy-isovalerate (**6**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3620 (OH), 1745 (lactone, CO_2R), 1670 (C=COR); MS *m/z* (rel. int.): 536.226 (M^+, 0.8) ($C_{27}H_{36}O_{11}$), 436 (2), 419 (6), 376 (3), 143 (19), 83 (100).

$$[\alpha]_{24°}^{\lambda} = \frac{589 \quad 578 \quad 546 \quad 436\,nm}{-42 \quad -46 \quad -52 \quad -82} (c = 0.2, CHCl_3).$$

9α-Hydroxy-3β-[3′-acetoxy-2′-methylbutyryloxy]-trixikingolide-2′-methylbutyrate (**7**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3620 (OH), 1750 (lactone, CO_2R), 1670 (C=COR); MS *m/z* (rel. int.): 520.231 (M^+, 5) ($C_{27}H_{36}O_{10}$), 409 (M − RCO_2, 4), 83 ($C_4H_7CO^+$, 100).

Vautheriol-2′-methylbutyrate (**9**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3480 (OH), 1740 (CO_2R), 1660 (C=C); MS *m/z* (rel. int.): 290 (M − HO_2CCH(Me)Et, HO_2CCH(Me)CH(OH)Me, 14), 85 ($C_4H_9CO^+$, 58), 57 (85 − CO, 100); CI (*iso*-butane): 511 (M + 1, 4), 409 (511 − HO_2CCH(Me)Et), 291 (409 − HO_2-CCH(Me)CH(OH)Me, 100); ^{13}C NMR (C_6D_6): 175.7 *s*, 175.6 *s*,

170.1 *s*, 148.8 *s*, 135.5 *s*, 130.3 *d*, 111.5 *t*, 72.3 *d*, 69.8 *d*, 65.6 *t*, 64.7 *s*, 64.2 *t*, 63.7 *t*, 60.9 *d*, 48.3 *d*, 41.3 *d*, 40.4 *t*, 35.1 *t*, 31.7 *t*, 27.0 *t*, 25.4 *t*, 21.0 *q*, 20.51 *q*, 16.6 *q*, 14.1 *q*, 11.7 *q*.

$$[\alpha]_{24°}^{\lambda} = \frac{589 \quad 578 \quad 546 \quad 436\,\text{nm}}{-33.5 \quad -35 \quad -39.5 \quad -64} (c = 4.7, CHCl_3).$$

10 mg **9** were heated for 1 hr with 0.1 ml Ac_2O at 70°. TLC afforded 10 mg **14**, colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1740 (CO_2R), 1655 (C=C); MS *m/z* (rel. int.): 534.283 (M^+, 0.3) ($C_{29}H_{42}O_9$), 474 (M − HOAc, 0.2), 432 (M − RCO_2H, 0.3), 372 (474 − RCO_2H, 0.6), 272 (432 − $HO_2CCH(Me)CH(OAc)Me$, 4), 143 (RCO^+, 21), 83 (143 − HOAc, 100).

Vautheriol angelate (**10**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3500 (OH), 1740 (CO_2R), 1720, 1650 ($C=CCO_2R$); MS (CI, *iso*-butane) *m/z* (rel. int.): 509 (M + 1, 3), 409 (M + 1 − AngOH, 11), 391 (509 − RCO_2H, 10), 291 (391 − AngOH, 100), 231 (391 − HOAc, 85), 213 (231 − H_2O, 47), 101 (AngOH + 1, 42), 83 (101 − H_2O, 10).

$$[\alpha]_{24°}^{\lambda} = \frac{589 \quad 578 \quad 546 \quad 436\,\text{nm}}{-34.5 \quad -36 \quad -40.5 \quad -61} (c = 0.8, CHCl_3).$$

Vautheriol tiglate and senecioate (**11** *and* **12**). Not separated colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3500 (OH), 1740 (CO_2R), 1720, 1655 ($C=CCO_2R$); MS (CI, *iso*-butane) *m/z* (rel. int.): 509 (M + 1, 4), 409 (18), 391 (12), 291 (100), 231 (92), 213 (51), 101 (52), 83 (8).

Vautheriol isobutyrate (**13**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3480 (OH), 1735 (CO_2R); MS (CI, *iso*-butane): 497 (M + 1, 5), 409 (M + 1 − Me_2CCO_2H, 21), 291 (409 − RCO_2H, 100), 231 (291 − HOAc, 72), 119 ($MeCH(OH)CH(Me)CO_2H$ + 1, 11), 101 (119 − H_2O, 11).

$$[\alpha]_{24°}^{\lambda} = \frac{589 \quad 578 \quad 546 \quad 436\,\text{nm}}{-30 \quad -32 \quad -36 \quad -58} (c = 0.58, CHCl_3).$$

3β,5,4′-Trihydroxy-7,3′-dimethoxyflavanone (**18**). Colourless crystals, mp 185–190°, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3540 (OH), 1640 (PhCO); MS *m/z* (rel. int.): 332.090 (M^+, 30), 314 (M − H_2O, 6), 303 (M − CHO, 42), 167 ($C_8H_7O_4$, 100). To 20 mg **18** in 2 ml $CHCl_3$ were added 30 mg 4-pyrrolidinopyridine [12] and 0.1 ml Ac_2O. After 20 hr TLC afforded 10 mg **21** and 6 mg **22**. **21**: IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1760 (PhOAc), 1710 (OAc), 1640 (PhCO); MS *m/z* (rel. int.): 458.121 (M^+, 6) ($C_{21}H_{22}O_{10}$), 416 (M − ketene, 10), 374 (416 − ketene, 8), 332 (374 − ketene, 8), 314 (374 − HOAc, 100), 167 ($C_8H_7O_4$, 95); **22**: IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1770, 1640; MS *m/z* (rel. int.): 416.111 (M^+, 15) ($C_{21}H_{20}O_9$), 374 (12), 332 (12), 314 (100), 167 (95).

15-Acetoxy-13-methoxyrotundene (**27**). Colourless oil, IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1745, 1250 (OAc), 840 (–C=CH–); MS *m/z* (rel. int.): 292.204 (M^+, 21) ($C_{18}H_{28}O_3$), 260 (M − MeOH, 8), 247 (M − CH_2OMe, 100), 200 (260 − HOAc, 30), 187 (247 − HOAc, 89).

2 mg **27** were saponified at room temp. with KOH–MeOH–H_2O. The alcohol obtained on stirring with 20 mg MnO_2 in Et_2O afforded 1.5 mg **28**. For ^1H NMR see Table 4. 8 mg in 1 ml $CHCl_3$ was stirred with 20 mg NaOAc and 20 mg *m*-chloroperbenzoic acid. TLC (Et_2O–petrol, 1:4) afforded 6 mg **29**, colourless oil. For ^1H NMR see Table 4.

Table 4. ^1H NMR spectral data of compounds **27**–**29** (400 MHz, TMS as internal standard)

	27 (C_6D_6)	**27** (+Eu(fod)$_3$)	**28** (C_6D_6)	**29** (C_6D_6–$CDCl_3$, 9:11)		**29** $^{13}C(CDCl_3)$*
H-1				1.73 *ddd*	C-1	51.2 *d*
H-2				1.22 *m*	C-2	23.1 *t*
H-2′				1.37 *dddd*	C-3	27.3 *t*
H-3		1.9 *m*		1.51 *dddd*	C-4	41.4 *d*
H-3′		2.08 *m*		1.11 *dddd*	C-5	40.3 *d*
				2.06 *br dddd*	C-6	29.5 *t*
H-4	2.18 *br dddd*	2.99 *br dddd*	2.40 *br dddd*	2.06 *br dddd*	C-7	32.6 *d*
H-5	1.7 *m*	2.35 *dddd*	2.04 *dddd*	1.95 *dddd*	C-8	29.7 *d*
H-6		2.23 *br ddd*		1.61 *br ddd*	C-9	28.1 *t*
H-6′	0.82 *br dd*	1.23 *br dd*	0.88 *br dd*	0.86 *br dd*	C-10	36.5 *s*
H-7	2.58 *br dd*	2.80 *br dd*	2.43 *br dd*	2.15 *br dd*	C-11	138.5 *s*
					C-12	135.5 *d*
H-8	1.1 *m*			0.93 *dddd*	C-13	65.7 *t*
H-8′	1.7 *m*	2.08 *m*		1.83 *dddd*	C-14	30.1 *q*
H-9				1.30 *m*	C-15	75.5 *t*
H-9′				1.22 *m*	OMe	57.9 *q*
H-12	5.78 *br s*	5.98 *br s*	5.74 *br s*	2.70 *br s*		
H-13	3.81 *dd*	4.23 *dd*	3.75 *dd*	3.48 *d*	Ac	171.1 *s*
H-13′	3.76 *dd*	4.15 *dd*	3.67 *dd*	3.03 *d*		20.9 *q*
H-14	1.04 *s*	1.13 *s*	0.98 *s*	0.87 *s*		
H-15	4.10 *dd*	5.84 *dd*	9.50 *d*	3.88 *dd*		
H-15′	4.00 *dd*	5.64 *dd*		3.80 *dd*		
OMe	3.20 *s*	3.58 *s*	3.18 *s*	3.19 *s*		
OAc	1.75 *s*	3.39 *s*		1.73 *s*		

* Some shifts may be interchangeable.

J(Hz): 1,2α ~ 6.5; 1,2β ~ 9; 1,5 = 6.5; 2α,2β = 3α,3β = 6α,6β = 8α,8β ~ 14; 2α,3α ~ 8; 2α,3β ~ 9; 2β,3α = 8; 2β,3β ~ 7; 3α,4 = 11; 3β,4 ~ 5; 4,5 = 6.5; 4,15 = 6.5; 4,15′ = 8; 5,6α = 6.5; 5.6β = 13; 6α,7 = 7.5; 7,8α = 1.3; 7,8β = 6; 8α,9α ~ 5; 8α,9β ~ 10; 8β,9α ~ 11; 8β,9β = 4; 13,13′ = 11.5; 15,15′ = 10.5.

Acknowledgements—We thank Drs. Scott A. Mori and P. Alvim, Herbario Centro des Pesquisas do Cacau at Itabanu, Bahia, Brazil, for their help in plant collection and the Deutsche Forschungsgemeinschaft for financial support.

REFERENCES

1. Bohlmann, F., Zdero, C., King, R. M. and Robinson, H. (1979) *Photochemistry* **18**, 885.
2. Bohlmann, F. and Zdero, C. (1979) *Chem. Ber.* **112**, 435.
3. Bohlmann, F. and Zdero, C. (1979) *Chem. Ber.* **112**, 427.
4. Bohlmann, F., Zdero, C., Robinson, H. and King, R. M. (1981) *Phytochemistry* **20**, 1631.
5. Bohlmann, F., Zdero, C., King, R. M. and Robinson, J. (1980) *Phytochemistry* **19**, 689.
6. Paknikar, S. K., Moti, O. and Chakravarti, K. K. (1977) *Tetrahedron Letters* 2121.
7. Bohlmann, F. and Grenz, M. (1975) *Chem. Ber.* **108**, 26.
8. Harborne, J. B. (1967) *Comparative Biochemistry of the Flavonoids*. Academic Press, London.
9. Goel, R. N. and Seshadri, T. R. (1959) *Tetrahedron* **5**, 91.
10. Herz, W., Gibaja, S., Bhat, S. V. and Srinivasan, A. (1972) *Phytochemistry* **11**, 2859.
11. Grau, J. (1980) *Mitt. Bot. München* **16**, 269.
12. Höfle, G. and Steglich, W. (1972) *Synthesis* 619.