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DITERPENES AND SESQUITERPENE LACTONES FROM *MIKANIA CONGESTA*

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Key Word Index—*Mikania congesta*; Compositae; Eupatorieae; diterpenes; geranylnerol derivatives; sesquiterpene lactones; elephantopin analogs; melampolide; coumarins.

Abstract—The chloroform extract of the aerial parts of *Mikania congesta*, afforded four new geranylnerol derivatives, new analogs of deoxyelephantopin, a new melampolide and several known compounds. Structures were elucidated by spectroscopic methods and chemical transformations.

INTRODUCTION

Of the twenty representatives of the large genus *Mikania* (Compositae, tribe Eupatorieae) which have so far been studied chemically [1–19], six have furnished characteristic sesquiterpene dilactones of the mikanolide group [1–8]. Various other sesquiterpene lactone types have been encountered in six other taxa [7, 9–13] and diterpenes, mainly *ent*-kaurenes, appear to be relatively common [6, 10, 13, 15–19]. We now report the isolation from the aerial parts of *Mikania congesta* DC. of four new geranylnerol derivatives **1a**, **1c** and **2a**, **2b**, four new sesquiterpene lactones **4a**, **9a**, **9b** and **10**, scopoletin (**3a**), *O*-geranylscopoletin (**3b**) [20, 21] and the fatty acid derivative 9,16-dioxooctadec-10,12,14-trienoic acid (**13**) [22].

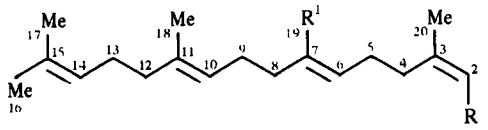
RESULTS AND DISCUSSION

Among the four new diterpenes, the pair **1a** and **1c** were isolated as the corresponding methyl esters **1b** and **1d** in spectroscopically pure form, with **1b** being related to **1d** by acetylation. Detailed analysis of the ^{1}H NMR spectra (Table 1) of **1b**, **1d** and **1c**, the latter obtained by oxidation of **1b**, led to identification of these compounds as derivatives of geranylnerol. Determination of the sequence of protons H-1 to H-6 in **1b** by spin decoupling permitted placement of the carbomethoxy group at C-7. Irradiation at the frequency of H-2 collapsed not only the H-1 signals, but sharpened the vinyl methyl resonance at δ1.75 (H-20) and a two-proton broadened triplet at δ2.9, thus identifying the H-4 signal. Irradiation at the frequency of H-4 identified the H-5 quartet and irradiation at the latter's frequency collapsed a broadened triplet at δ5.87 (H-6) whose chemical shift indicated that it was on the β-carbon of a conjugated system. Hence the carboxyl group was on C-7. The *Z*-configuration of the C-2,C-3 and the C-6,C-7 double bonds clearly followed from the chemical shifts of H-6 in **1b**, **1d** and **1e** and of H-20 in **1e** (δ1.9), the *E*-configuration of the C-10,C-11 double bond from the lack of an NOE involving H-10 and H-18.

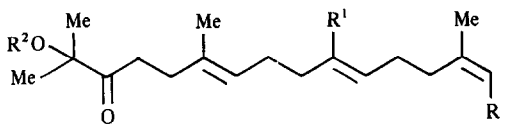
The second set of diterpenes **2a** and **2b** was also identified on spectroscopic evidence. Acetylation of **2a** furnished **2b** and the triacetate **2e**, while oxidation of **2a** afforded the aldehydes **2c** and **2d**. Since the carbonyl group of **2a** and **2b** was not conjugated (IR band at 1700 cm^{-1}, chemical shift of the vinyl protons) and since decoupling experiments established that in the ^{1}H NMR spectra of **2a**–**2e** the triplet near δ2.6 was due to H-13a,b, the carbonyl group could only be placed on C-14. The location of the interior CH_2OH group on C-7 was evident from the decoupling experiments and from the chemical shift of H-6 in the dialdehyde **2c**. The *Z*-configuration of the 2,3- and 6,7-double bonds followed from the chemical shifts of H-19 and H-20 in **2c**; the *E*-configuration of the 10,11-double bond was deduced in the same manner as that of **1a** and **1c**.

The major sesquiterpene lactone constituent of *M. congesta* was **4a**. Comparison of the IR and ^{1}H NMR spectra of **4a** and its derived epoxide **5** with those of deoxyelephantopin (**6a**) [22, 23] and 2′,3′-dihydroelephantopin (**7**) [24, 25] (see Table 2) and those of analogs **6b**–**6e** reported in the recent literature [26, 27] indicated the presence of the same gross structure (except for the nature of the ester side chain), as did the ^{13}C NMR spectrum of **4a** (Table 3). However, small differences in the coupling constants of H-2 (*br d*, J = 5 Hz for **4a** and **5**, *m*, $W_{1/2}$ = 5 Hz for **6a** and **7**) and, more significantly, a reversal in the relative chemical shifts of H-9a and H-9b, one of which exhibits a large (J = 12 Hz) and the other a small (J = 2.5–3.5 Hz) coupling to H-8, suggested that **4a** and **6a**–**6e**, and **5** and **7** might differ in stereochemistry at C-2. Indeed, inspection of models indicated that in **4a** and **5** one of the C-9 protons, namely the one strongly coupled to H-8, would be deshielded by the C-14 lactone carbonyl, whereas, by contrast, in **6a**–**6e** and in **7** the other proton, which displays only small coupling to H-8, would be so deshielded, as actually observed.

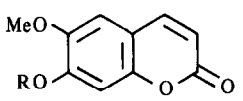
The NOE difference spectrum of **4a** (Table 4) which revealed significant interactions between H-1, H-6, H-9 and H-15 on the one hand and between H-5 and H-8 on the other was also in accord with deductions drawn from the model. The model also shows that in contrast with compounds of type **6** and **7** which are in the $_1D^{14}$, $^{15}D_5$ [28] conformation with the two ring double bonds 'crossed' [25, 29, 30], compound **4a** possesses a $^1D_{14}$, $^{15}D_5$ conformation with the two ring double bonds nearly



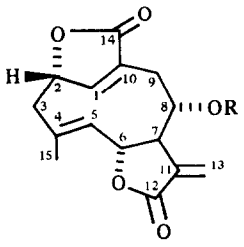
1a R = CH_2OH, R^1 = CO_2H
1b R = CH_2OH, R^1 = CO_2Me
1c R = CH_2OAc, R^1 = CO_2H
1d R = CH_2OAc, R^1 = CO_2Me
1e R = CHO, R^1 = CO_2Me

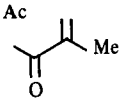


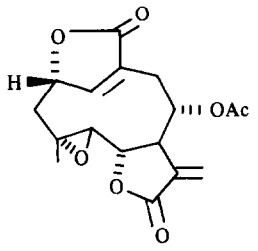
2a R, R^1 = CH_2OH, R^2 = H
2b R, R^1 = CH_2OAc, R^2 = H
2c R, R^1 = CHO, R^2 = H
2d R = CHO, R^1 = CH_2OH, R^2 = H
2e R, R^1 = CH_2OAc, R^2 = Ac



3a R = H
3b R = geranyl



4a R = Ac
4b R = 



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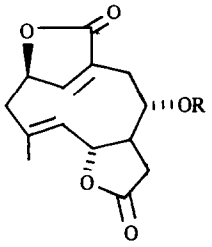
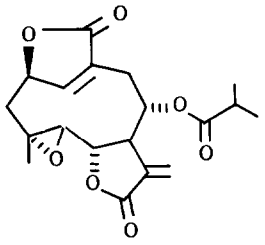


6a R = MeAcr
6b R = Sen
6c R = 2-MeBu
6d R = H
6e R = Ang



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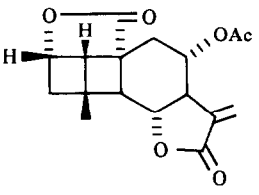

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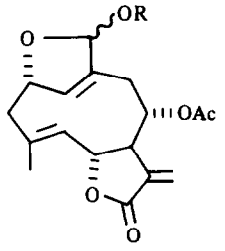


9a,9b R = H
9c,9d R = Ac

parallel. Although in the model the two ring double bonds are relatively far apart, it was hoped to adduce additional evidence fot the proposed stereochemistry by inducing **4a** to undergo a photocyclization in the manner exhibited by the minor conformer of isabelin [31]. In fact, photolysis of **4a** (C_6H_6, 254 nm) afforded in low yield a photocyclization product whose ^1H NMR and ^{13}C NMR spectra (Tables 2 and 3) were fully in accord with structure **8**. Hence **4a** is a C-2 epimer of compounds of the deoxyelephantopin series.* The difference in the conformations of **4a** and **5**, on the one hand, and **6a** and **7**, on the other, is exemplified by the CD spectra (see Experimental): although the curves are relatively complex due to the presence of several chromophores, the intense low wave-

*A dilactone 'isodeoxyelephantopin' has been isolated from *Elephantopus scaber* as a minor constituent and was believed to differ from **6a** in stereochemistry at C-2 and/or C-8 [32]. The same compound has been reported recently from *Elephantopus carolinianus* and assigned formula **4b** on the basis of its ^1H NMR spectrum which was not listed [33].

Table 1. ^{1}H NMR spectra of compounds **1b**–**1d** and **2a**–**2e** (270 MHz, $CDCl_3$)

H	1b	1c	1d	1d*	1e	2a	2b	2c	2d	2e
1	4.12 *br d* (7)	4.58 *br d*	4.58 *br d*	4.65 *br d*	9.47 *d* (7)	4.07 *br d*	4.55 *br d*	9 91 *d* (7)	9.89 *d*	4.55 *br d*
2	5.46 *br t* (7)	5 39 *br t*	5 39 *br t*	5.40 *br t*	5.87 *br d*	5 46 *br t*	5.38 *br t*	5.96 *br d*	5 90 *br d*	5.37 *br t*
4	2.19 *br t* (7)	2.25 *m*	2.24 *m*	2.10 *m*	2 66 *m*	2.25 *m*	2.16 *m*	2.80 *br t* (7)	2.64 *br t*	2.18 *m*
5	2.50 *br q* (7)	2.61 *br q*	2.61 *br q*	2.56 *br q*	2.66 *m*	2.25 *m*	2.16 *m*	2.81 *br q* (7)	2.31 *br q*	2.18 *m*
6	5.87 *br t* (7)	5.99 *br t*	5.85 *br t*	5.71 *br t*	5.84 *br t*	5.30 *br t*	5.38 *br t*	6.38 *br t*	5 29 *br t*	5.38 *br t*
8	2.27 *br t* (7)	2.25 *m*	2.24 *m*	2.39 *br t*	2.26 *br t*	2–2.5 *m*	2.08 *m*	2.21 *br t* (7)	2.11 *m*	obsc.
9	1.95–2.15 *m*	2.05 *m*	2.05 *m*	2.26 *br q*	1.95–2.15 *m*	2–2.5 *m*	2.08 *m*	2.08 *br q* (7)	2.11 *m*	obsc.
10	5 10 *br t* (7)	5 11 *br t*	5.10 *br t*	5.26 *br t*	5 08 *br t*	5.15 *br t*	5.13 *br t*	5.09 *br t*	5.13 *br t*	5.12 *br t*
12	1.95–2.15 *m*	2 05 *m*	2.05 *m*	2.10 *m*	1.95–2.15 *m*	2.28 *br t*	2.28 *br t*	2.28 *br t*	2.28 *br t*	2 24 *br t*
13	1.95–2.15 *m*	2 05 *m*	2.05 *m*	2.10 *m*	1.95–32.15 *m*	2.65 *t* (7)	2 65 *t*	2.64 *t*	2.64 *t*	2.57 *t*
14	5.10 *br t* (7)	5.00 *br t*	5.0 *br t*	5.23 *br t*	5.08 *br t*	—	—	—	—	—
16	1.68 *br*	0.68 *br*	1.68 *br*	1.68	1.67 *br*	1.37	1.38	1 38	1.37	1.47
17	1.60 *br*	0.60 *br*	1.60 *br*	1 60	1 59 *br*	1.37	1.38	1.38	1.37	1.47
18	1.58 *br*	1.60 *br*	1.57 *br*	1.60	1.56 *br*	1.62 *br*	1.62 *br*	1.59 *br*	1.61 *br*	1.60 *br*
19	—	—	—	—	—	4.06 *br*	4.58 *br*	10.08	4.11 *br*	4.58 *br*
20	1.75 *br*	1.77 *br*	1.77 *br*	1.57	1.99 *d* (1 5)	1.75 *br*	1.76 *br*	2.02 *br*	1.99 *br*	1 76 *br*
OAc	—	2 04	2 05	1.71	—	—	2.06, 2.04	—	—	2.08, 2.06, 2.04
OMe	3.74	—	3.75	3.42	3.75	—	—	—	—	—

*In C_6D_6.

Table 2. ^{1}H NMR spectra of compounds **4a**, **5**, **6a**, **7**, **8** and **9a–9c** (270 MHz, $CDCl_3$)

H	4a	4a*	5	6a	7	8	9a†	9c
1	7 12 *br*	7.69 *br*	7.49 *br*	7.07 *br*	7.39 *br*	3.08 *d* (6)	5.84 *br*	5.96 *br*
2	5.36 *br d* (5)	5.50 *br d*	5.36 *br d*	5.46 *m*‡	5.38 *m*	5.05 *ddd* (8, 6, 2)	5.31 *dd* (5, 3.5)	5.37 *dd*
3a	2.92 *br d* (14.5)	2.65–2.85 *m*	2.53 *dd* (14, 4.5)	2.86 *dd*	2.84 *dd* (14.5, 4)	2.60 *dd* (15, 8)	2.67 *br d*	2.72 *br d*
3b	2 37 *dd* (14, 5.5)	2.43 *dd*	2.15 *br d* (14)	2.70 *ddd* (14, 2, 1)	1.65 *dd* (14.5, 2.5)	2.44 *dd* (15, 2)	2.21 *dd* (14.5, 5)	2.22 *dd*
5	5.11‖	4.84 *br d* (10)	2.79 *d* (9.5)	4.77 *br d* (10)	2.57 *d*	2.94 *d*	5.12 *br d*	5.22 *br d*
6	5.07‖	5.08 *dd* (10, 9)	4.21 *t* (9.5)	5.14 *dd* (10, 8)	4.38 *dd*	4.17 *dd* (11.5, 10)	5.19 *dd* (10, 8.5)	5.16 *dd*
7	3.10 *dddd* (9, 4, 3.5, 3)	2.92 *dddd*	3.24 *dddd* (9.5, 4, 3.5, 3)	2.94 *dddd* (8, 4, 3.5, 3)	3.19 *dddd* (9.5, 4, 3.5, 3)	2.84 *dddd* (11.5, 10, 3 5, 3)	2.83 *m*	2.87 *m*
8	4.46 *ddd* (12, 4, 3.5)	4.39 *ddd*	4.50 *ddd* (12, 4, 3)	4.66 *ddd* (12, 4, 2.5)	4.25 *dt* (12, 2.5)	5.17 *ddd* (10, 7, 5.5)	4.56 *ddd* (12, 4, 3.5)	4.56 *ddd*
9a	2.95 *t* (12)	2 85	3.03 *t* (12)	3.02 *br d* (12)	3.08 *br d*	2.32 *dd* (15.5, 7)	2.75 *br dd* (12, 4)	2.75 *br dd*
9b	2.68 *br dd* (12, 3.5)	2.85 *m*	2.82 *br dd* (12, 3)	2.79 *t* (12)	2.75 *t*	2.19 *dd* (15.5, 5.5)	2.57 *t* (12)	2.52 *t*
13a	6.25 *dd* (3.5, 1)	6.10 *dd*	6.34 *d* (3.5)	6.23 *d*	6.36 *d*	6.29 *br d*	6.28 *d*	6.29 *d*
13b	5 70 *dd* (3, 1)	5.76 *dd*	5.77 *d* (3)	5.65 *d*	5.70 *d*	5.75 *d*	5.70 *d*	5.70 *d*
14	—	—	—	—	—	—	5.83 *br d* (3.5)	6.76 *br d*
15§	1.76 *d* (1)	1.74 *d*	1.46	1.85 *d* (1)	1.33	1.32	1.76 *d* (1.5)	1.77 *d*
Ac§	2.05	2.05	2.06	¶	¶	2.16	2.06	2.09, 2.05

*In DMSO-d_6

†Signals of **9b** H-13a, 6.29 *d*, H-13b, 5.71 *d*, H-14, 5.88 *br d*.

‡$W_{1/2}$ = 8 Hz.

§Intensity 3 protons.

‖Signals superimposed.

¶'Ester side chain signals in **6a**, H-3″a, 6.14 *br*, H-3′b, 5.65 *br*, H-4′, 1.93 *br*; in **7**, H-2, 2.51 *sept.* (7), H-3′, H-4′ 1.12 *d* (7).

Table 3. ^{13}C NMR spectra of compounds **4a**, **5**, **8** and **10** (67.89 $CDCl_3$)

C	4a	5	8*	10
1	149.73 *d*	152.60 *d*	50.80†	155.40 *d*
2	79.34 *d*†	80.15 *d*	72.60†	67.82 *d*†
3	39.79 *t*†	40.84 *t*	43.70	46.31 *t*
4	135.69 *s*	56.58 *s*	42.24‡	140.64 *s*
5	124.68 *d*	58.70 *d*	53.91†	126.30 *d*
6	78.60 *d*†	78.36 *d*	77.34†	72.80 *d*†
7	49 47 *d*	45.24 *d*	45.06	47.97 *d*
8	73.39 *d*†	73.13 *d*	71.14†	76.35 *d*†
9	29.72 *t*†	29.85 *t*	33.41	29.26 *t*
10	130.97 *s*	129.60 *s*	40.22‡	138.15 *s*
11	134.36 *s*	133.22 *s*	135.12	136.27 *s*
12	169.17 *s*	168.60 *s*	169 21	169.94 *s*
13	122.51 *t*	124.13 *t*	122.50	123.74 *t*
14	174.30 *s*	174 32 *s*	181.61	193.54 *d*
15	21.20 *s*†	21.74 *q*‡	20.16	18.14 *q*
1′	169.99 *s*	170 33 *s*	170.46	170.67 *s*
2′	20.64 *q*	20.84 *q*‡	20.97†	21.30 *q*

*Multiplicities assigned by DEPT sequence.
†Assignments by selective spin decoupling.
‡Assignments may be interchanged.

Table 4. NOE difference spectrum of compound **4a**

Saturation	Observed NOE (%)
H-1	H-2 (10)
	H-8 (4.3)
	H-15 (4.7)
H-2	H-1 (7.8)
	H-3b (5.6)
H-5 and H-6	H-3a (3.3)
	H-7 (8.9)
	H-8 (6.1)
	H-15 (7.3)
H-7	H-5 and H-6 (11)
	H-8 (2.8)
H-8	H-1 (5)
	H-5 and H-6 (14.5)
	H-7 (5)
	H-9b (6.7)
	H-15 (4)
H-9a and H-3	H-3b (16.6)
	H-5 and H-6 (5.4)
H-15	H-1 (4.3)
	H-3b (3)
	H-5 and H-6 (7.5)
	H-8 (2.5)

length absorptions of **4a** and **6a** which reflect the interaction between the two ring double bonds differ in sign.

Accompanying **4a** was a small amount of a mixture of epimers **9a**, **9b**, further characterized as **9c**, **9d**, whose structure was apparent from the ^1H NMR spectrum (Table 2). The co-occurrence of these hemiacetals suggests that they are intermediates on the biogenetic route to compounds of type **4**.

The gross structure of another non-crystalline lactone **10** was deduced by a combination of IR, mass and ^1H and ^{13}C NMR spectrometry (Tables 3 and 5). Spin decoupling established the entire sequence of protons on the carbon skeleton. The chemical shift (δ9.51) of the H-14 aldehyde proton indicated that the C-1,C-10 double bond was *cis*. This was verified by an 11% enhancement in the strength of the H-14 signal upon irradiation of H-1 in the NOE experiment (Table 6). Absence of a NOE involving H-5 and H-15 showed that the C-4,C-5 double bond was *trans*. On the assumption that the molecule assumes the usual

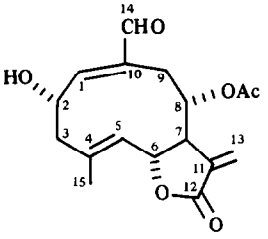
Table 5. ^1H NMR spectra of compounds **10–12** (270 MHz, $CDCl_3$)

H	10	11	12a	12b
1	6.43 *dd* (7.5, 1.5)	7.01 *br*	3.46 *br dd* (7, 4.5)	3.41 *t* (7)
2	4.39 *ddd* (11.5, 7.5, 3.5)	—	—	
3a	2.54 *dd* (11.5, 3.5)	6.26 *m*†	6.09 *quint* (1 5)	6.12 *quint*
3b	2.42 *t* (11.5)	—	—	—
5a	5.20 *br d* (10)	2.83 *dd* (14, 9)	3.23 *br dd* (10, 7)	3.33 *br dd*
5b	—	2.72 *dd* (14, 3.5)	—	—
6	4.62 *t* (10)	4.30 *dt* (9, 3.5)	3.92 *dd* (10, 9)	3.83 *dd*
7	2.82 *dddd* (11, 10, 3.5, 3)	2.82 *dddd* (11, 3.5, 2.5, 2.5)	3.20 *m*	3.10 *m*
8	5.09 *ddd* (11, 4, 2.5)	4.91 *ddd* (11, 6, 2)	5.14 *dt* (10, 4.5)	5.04 *dt* (10, 5)
9a	3.06 *br d* (15.5)	3.17 *dd* (14, 6)	2.41 *br d* (15)	obsc.
9b	1.99 *dd* (15.5)	2.90 *br d* (14)	obsc.	obsc.
10	—	—	2.94 *br dd* (8.5, 4.5)	3.16 *m*
13a	6.25 *d* (3.5)	6.33 *d* (2.5)	6.29 *d* (3.5)	6.28 *d* (3.5)
13b	5.73 *d* (3)	5.68 *d* (2.5)	5.68 *d* (3)	5.65 *d* (3)
14	9.51 *br*	9.58 *d* (1)	9.74 *br*	9.93 *br d* (1.5)
15*	1.95 *br*	2.00 *d* (1.5)	2.36 *br*	2.36 *br*
OAc*	2.22	1.95	2.12	2.15

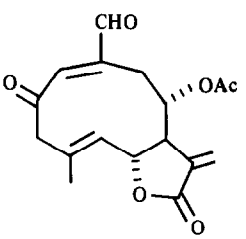
*Intensity three protons.
†$W_{1/2}$ = 3.5 Hz.

Table 6. NOE difference spectrum of compound **10**

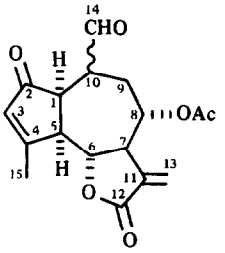
Saturation	Observed NOE (%)
H-1	H-14 (11)
H-2	H-9b and H-15 (6.7)
H-5	H-7 (9.3)
H-7	H-5 (5)
H-14	H-1 (10)
H-9b and H-15	H-2 (3.3)



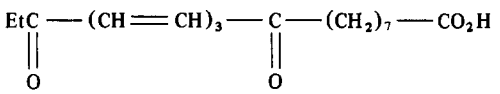
10



11



12a,12b



13

$_1D_{14}$, $^{15}D_5$ conformation of other C-6-*trans*-lactonized melampolides [34–36] and on the basis of an NOE between H-2 on the one hand and H-9b and H-15 on the other, the C-2 hydroxyl was assigned the α-configuration.

Oxidation of **10** with CrO_3–pyridine proceeded only sluggishly, but produced small amounts of **4a**, thus providing further evidence for the C-2 stereochemistry. Most of the starting material was recovered. Oxidation of **10** with pyridinium dichromate afforded **11** and a 3:2 mixture of epimers **12a**, **12b**. Structures of **11**, **12a** and **12b** were established by IR, mass and ^{1}H NMR spectrometry (Table 5). That **12a** and **12b** were *cis*-fused guaianolides was evident from the value of $J_{1,5}$ (7 Hz) which compared with $J_{1,5}$ in similar compounds [37–39]. Their formation from **10** (and that of **4a** as well) requires *cis–trans* isomerization of the C-1, C-10 bond at some stage during the oxidative process, but is otherwise unexceptional.

Dilactones of type **4** have so far been found only in *Elephantopus* species (Vernonieae). Our results suggest the possibility of a wider distribution of such lactones and indicate that the sesquiterpene lactone chemistry of *Mikania* is fairly diverse.

EXPERIMENTAL

Extraction of Mikania congesta. Aerial parts (22 kg) of *M congesta* DC., collected by Manuel Rimachi L. on May 30, 1978, on the inundated margin of a lake by the side of Rio Nanay, Morona Cocha, Dtto. Iquitos, Maynas, Loreto, Peru, and identified by Dr. S. McDaniel (Voucher No. 3608 in herbarium of Mississippi State University) were extracted with $CHCl_3$ and worked up in the usual fashion [40]. The crude extract was taken up in a small amount of $CHCl_3$ and on refrigeration deposited 4.6 g of **4a** in the course of a year. The remaining crude gum (82 g) was adsorbed on 130 g of silicic acid (Mallinckrodt, 100 mesh) and chromatographed over 1 kg of the same adsorbent set in hexane, 500 ml fractions being collected as follows: Fr 1–8 (hexane–EtOAc, 19:1), 9–14 (hexane–EtOAc, 9 1), 15–20 (hexane–EtOAc, 4:1), 21–28 (hexane–EtOAc, 3:2), 29–34 (hexane–EtOAc, 1:1), 35–40 (hexane–EtOAc, 2:3), 41–44 (hexane–EtOAc, 1:4), 45–48 (EtOAc), 49–52 (EtOAc–MeOH, 49:1), 53–56 (EtOAc–MeOH, 19:1) and 57–60 (EtOAc–MeOH, 9:1).

Purification of fr. 16 by TLC (C_6H_6–EtOAc, 9:1) gave mainly 70 mg of **1c** (^{1}H NMR in Table 1) which could not be purified satisfactorily. Esterification with CH_2N_2 and TLC (C_6H_6–EtOAc, 9:1) gave spectroscopically pure **1d** as an oil; IR ν_{max}^{neat} cm^{-1}: 1735, 1715; ^{1}H NMR: Table 1, MS *m/z* (rel. int.): 376 $[M]^+$ (0 1), 376 (2.7), 247 (4.4), 205 (3 2), 187 (9.9) and 69 (95.2).

Fr. 20 upon purification by TLC (C_6H_6–EtOAc, 9:1, two developments) gave from the upper band 5 mg of **3b** which could not be induced to crystallize; ^{1}H NMR ($CHCl_3$): δ6.28 (*d*, *J* = 10 Hz, H-3), 7.61 (*d*, *J* = 10 Hz, H-4), 6.85, 6.83 (*br*, H-5, H-8), 4.70 (*br d*, *J* = 7 Hz, H-1'), 5 48 (*br t*, *J* = 7 Hz, H-2'), 2.09 (*m*, 4p's, H-4' and H-5'), 5.07 (*br t*, *J* = 7 Hz, H-6'), 1.77 (*br*, H-10'), 1.60 (*br*, H-9'), 1.65 (*br*, H-8'), 3 91 (OMe); MS: 328 $[M]^+$* The lower band furnished 35 mg of **2b** as a gum; IR ν_{max}^{neat} cm^{-1}. 3470, 1735, 1710; ^{1}H NMR: Table 1; MS *m/z* (rel. int.): 423 $[M+1]^+$ (0.03), 363 (0.6), 303 (2.6), 285 (0.9), 276 (1.2), 216 (6 3), 169 (3.3), 151 (9), 133 (19.1) and 59 (100).

Fr. 21 after esterification with CH_2N_2 and purification by TLC (C_6H_6–EtOAc, 9:1; developed twice) gave 45 mg of **1b** as a gum, IR ν_{max}^{neat} cm^{-1}: 3400 br, 1710; ^{1}H NMR. Table 1; MS *m/z* (rel. int.): 334 (3.2), 316 (1.7), 247 (3.6), 205 (2.7), 187 (7.4) and 69 (100). [Calc. for $C_{21}H_{34}O_3$: M_r, 334.2506. Found: M_r (MS), 334.2500]. A soln of 15 mg of **1b** in hexane was stirred with 100 mg of MnO_2 for 6 hr at room temp; the usual work-up yielded **1e** as a gum; IR ν_{max}^{neat} cm^{-1}: 1715, 1675; NMR: Table 1. [Calc. for $C_{21}H_{32}O_3$: M_r, 332.2349. Found: M_r (MS), 332.2354]. Acetylation of a small amount of **1b** (Ac_2O–pyridine) gave material identical in all respects with **1d**.

Fr. 24 on standing in hexane–EtOAc deposited 9 mg of **13** [22]. Rechromatography of fr. 28–30 (silica gel, $CHCl_3$–MeOH, 99:1) gave 0.11 g of scopoletin (**3a**). Fr. 31–42 on trituration with hexane–EtOAc gave 18.5 g of **4a**, mp 199–202° (dec) from $CHCl_3$–EtOAc; IR ν_{max}^{KBr} cm^{-1}: 1765, 1745, 1725, 1645 and 1630; ^{1}H NMR and ^{13}C NMR in Tables 2 and 3, CD curve (MeOH) $[\theta]_{268}$ −1700, $[\theta]_{259}$ 0, $[\theta]$ +61300 (fine structure, last reading); (Calc for $C_{17}H_{18}O_6$. M_r 318.1104. Found: M_r (MS) 318.1106). Other significant peaks in the high resolution MS were *m/z* (composition, rel. int.) 276 ($C_{15}H_{16}O_5$, 100) and 258 ($C_{15}H_{14}O_4$, 15.6)

TLC of the crystalline residue from fr. 41 and 42 indicated, in addition to **4a**, the presence of a very minor polar substance.

*The literature [20, 21] contains no reference to the ^{1}H NMR spectrum of **3b**; hence the identification of our substance as **3b** is not unambiguous However, the signals of the coumarin moiety and the side chain were very similar to those of farnesylscopoletin [41].

Purification by TLC ($CHCl_3$–MeOH–EtOAc, 18:1:1) of 0.4 g of the residue from fr. 41 afforded 12 mg of **9a**, which on standing in $CDCl_3$ soln was converted to a 1:1 mixture of **9a** and **9b**. ^1H NMR spectra are listed in Table 2; MS(CI) of the mixture *m/z* (rel. int.). 321 $[M+1]^+$ (67.3), 303 (52.5), 279 (6.5), 261 (100) and 243 (54 7) Acetylation of a small amount of **9a** and **9b** (Ac_2O–pyridine) gave **9c** and **9d**; ^1H NMR spectra in Table 2; MS(CI) *m/z* (rel. int.): 363 $[M+H]^+$ (28.7), 321 (13.1), 303 (90.4), 261 (27.8) and 243 (100).

The mother liquors from fr. 33–35 were combined and rechromatographed over silica gel. Elution with $CHCl_3$–MeOH (97:3) gave, in fr. 6–10, 0.32 g of **10** which could not be induced to crystallize; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3400 br, 1760, 1730 and 1690; ^1H NMR in Table 5; ^{13}C NMR in Table 3; CD curve (MeOH) $[\theta]_{318}$ +8250 (maximum), $[\theta]_{278}$ 0; $[\theta]_{253}$ −5010 (minimum), $[\theta]_{249}$ −4420 (neg. maximum), $[\theta]_{222}$ −34600 (last reading); MS(EI) *m/z* (rel. int.): 278 $[M-42]^+$ (1.9), 260 (8) and 242 (16.8); MS (CI) *m/z* (rel. int): 321 $[M+H]^+$ (23), 303 (19.2), 279 (6.1) and 261 (100). Continuation of the chromatography yielded, in fr 12–15, 0.16 g of **2a** as a gum, IR ν_{max}^{neat} cm^{-1}: 3350 br, 1700, ^1H NMR in Table 1; MS *m/z* (rel int.) 339 $[M+1]^+$ (0.02), 320 (0.2), 302 (0.3), 279 (0.2), 169 (2), 151 (8.8), 133 (14 2) and 59 (100). Acetylation of 20 mg of **2a** with Ac_2O–pyridine and purification by TLC (C_6H_6–EtOAc, 5:1) gave 6 mg of **2e** and 15 mg of **2b** as gums; IR spectrum of **2e** ν_{max}^{neat} cm^{-1}: 1735; ^1H NMR in Table 1, MS *m/z* (rel. int.) 464 $[M]^+$ (0 05), 422 (0.16), 405 (0.3), 404 (0 2), 362 (0.12), 344 (1.3), 285 (1.3), 284 (1.3), 211 (2.7), 151 (16.0), 133 (10.7); 101 (18 8), 59 (20.0) and 43 (100). Oxidation of 20 mg of **2a** by stirring with 0.200 mg of MnO_2 for 6 hr at room temp and purification of the crude product by TLC (C_6H_6–EtOAc, 4:1) yielded 7 mg of **2c** and 15 mg of **2d** whose ^1H NMR spectra are listed in Table 1.

Reactions of compound **4a**. (a) A soln of 0.2 g of **4a** in 10 ml of $CHCl_3$ was stirred with 0.5 g of *m*-chloroperbenzoic acid at room temp. overnight, diluted with 15 ml of EtOAc, and washed with 5% $NaHSO_3$, 5% $NaHCO_3$ and H_2O. Evaporation of the dried organic layer and recrystallization of the residue from EtOAc gave 0.19 g of **5**, mp 231° (dec.); IR ν_{max}^{KBr} cm^{-1}: 1770, 1750, 1730, 1650 and 1635; ^1H NMR and ^{13}C NMR spectra in Tables 2 and 3; CD curve (MeOH) $[\theta]_{266}$ −926, $[\theta]_{254}$ 0, $[\theta]_{232}$ +4100, $[\theta]_{225}$ 0, $[\theta]_{222}$ −3300 (last reading), MS *m/z* (rel. int.): 335 $[M+1]^+$ (10.7), 334 $[M]^+$ (0.5), 293 (4.5), 292 (2.1), 274 (24.7) and 204 (100) [Calc. for $C_{17}H_{18}O_6$: M_r, 334.1051. Found: M_r (MS), 335 1057].

(b) A soln of 1.5 g of **4a** in 500 ml of C_6H_6 was flushed with N_2 for 1 hr and then irradiated with UV light (35 W, 354 nm) in a quartz reactor for 12 hr under N_2. TLC of the soln revealed in addition to starting material the presence of a very minor product **8** with higher R_f which was isolated by TLC ($CHCl_3$–MeOH–EtOAc, 18:1.1) in 23 mg yield as a gum, ^1H NMR and ^{13}C NMR spectra in Tables 2 and 3; MS(CI) *m/z* (rel. int.): 319 $[M+H]^+$ (100), 277 (2.3) and 259 (21.1).

Reactions of compound **10** (a) A soln of 70 mg of **10** in CH_2Cl_2 (5 ml) was stirred with CrO_3–pyridine complex for 12 hr at room temp, filtered through silica gel and separated by TLC ($CHCl_3$–MeOH–EtOAc, 8.1:1) to yield 6 mg of **4a** and 50 mg of starting material.

(b) A soln of 50 mg of **10** in 3 ml of CH_2Cl_2 was stirred with 0 2 g of pyridinium dichromate for 18 hr at room temp. After filtration through silica gel the product mixture was separated by TLC ($CHCl_3$–MeOH–EtOAc, 19:1:1, two developments) to afford 11 mg of **11** and 28 mg of a 3:2 mixture of **12a** and **12b**. Lactone **11** was a gum; IR ν_{max}^{neat} cm^{-1} 1765, 1740, 1690, 1655; ^1H NMR: Table 5; MS *m/z* (rel. int.): 318 $[M]^+$ (0.8), 290 (0.8), 276 (2.3), 258 (1.7), 229 (5.6) and 43 (100). [Calc for $C_{17}H_{18}O_6$: M_r, 318.1102 Found. M_r (MS), 318.1102].

A small amount (2 mg) of the minor component **12b** of the **12a** and **12b** mixture could be obtained in approximately 80% purity by repeated TLC of the mixture; ^1H NMR of both isomers: Table 5; MS *m/z* (rel. int.): 319 $[M+1]^+$ (0.7), 318 (0.1), 290 (7.3), 276 (0.3), 258 (0.8), 230 (14.5) and 43 (100) [Calc. for $C_{17}H_{18}O_6$: M_r, 318.1102 Found: M_r (MS), 318.1104.] CD spectra: Deoxyelephantopin (**6a**) (MeOH): Very weakly negative above 275 nm, $[\theta]_{275}$ 0, $[\theta]_{241}$ +51350, $[\theta]_{227}$ 0, $[\theta]_{212}$ −114500 (last reading). 2′,3′-Dihydroelephantopin (**7**) (MeOH): $[\theta]_{240-250}$ −5000 (sh?), $[\theta]_{221}$ −57350; $[\theta]_{210}$ 0.

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