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^{1}H- AND ^{13}C-NMR ASSIGNMENTS FOR THE *STEMODIA* DITERPENES, STEMODIN, STEMODINONE, AND MARITIMOL

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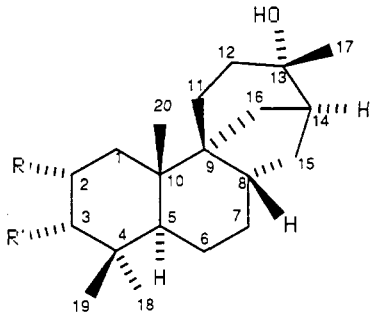
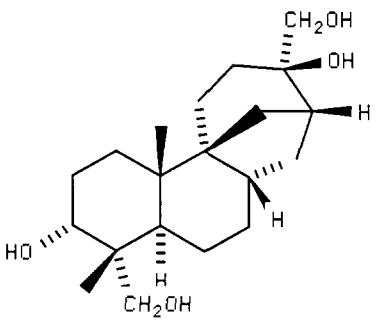
Stemodia maritima L. (Scrophulariaceae) has yielded a number of interesting diterpenes (1–3). The stemodane type, stemodin [**1**], maritimol [**2**], and stemodinone [**3**], are the diterpenes isolated from collections from Curaçao (2). The *Stemodia* diterpenes bear a close resemblance to aphidicolin [**4**], an antiviral diterpene isolated from *Cephalosporium aphidicola* (4,5). In anticipating further studies of related *Stemodia* diterpenes and their metabolites, the complete nmr assignments were necessary. Because there are no previous reports and because these diterpenes were originally isolated and characterized before 2D-nmr techniques were available, applications of these new techniques have now led to the complete ^{1}H- and ^{13}C-nmr assignments for **1**, **2**, and **3**.



1 R=OH, R′=H
2 R=H, R′=OH
3 R==O, R′=H



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The ^{13}C-nmr spectrum of stemodin [**1**], the major diterpene, showed 20 carbon signals whose multiplicities were confirmed by the DEPTGL pulse sequence (Table 1). The carbon assignments were established by utilizing a carbon-carbon connectivity experiment (2D-INADEQUATE) that unambiguously confirmed 19 of the 23 C-C bonds present. Of the remaining four bonds, one bond (C-18, C-4) would not show cross peaks because the chemical shifts are nearly coincidental, two bonds were detected as AB systems (C-7, C-8; C-8, C-15), and, therefore, only one bond (C-9, C-10) did not show any cross peaks. Because C-2 and C-13 could be assigned easily, the remaining connectivities could be established in a straightforward analysis even though two pairs of cross peaks were lacking as noted above. C-4 and C-10 could also be assigned independently by comparing the data for **1** and **2** and by noting the change of shift for C-4 when the hydroxyl group is at C-3 in **2**.

With the ^{13}C-nmr assignments firmly established, the one-bond heteronuclear correlation (HETCOR) and the proton-proton connectivities (COSY) experiments allowed assignments of all of the ^{1}H-nmr assignments (Table 2).

Stemodinone [**3**], an oxidation production of stemodin [**1**] as well as a naturally occurring diterpene, had ^{13}C- and ^{1}H-nmr data similar to those of **1**. The assignments are listed in Tables 1 and 2. The ^{13}C-nmr assignments for C-1 and C-3 follow from expected changes in chemical shifts and by also noting long-range couplings between the C-20 methyl protons with H-1 (and hence C-1

TABLE 1. ^{13}C-nmr Shifts (75 MHz, C_5D_5N) for Stemodin [**1**], Maritimol [**2**], and Stemodinone [**3**].[a]

Carbon atom	Compound		
	1	**2**	**3**
1	46.5 (2)	28.1 (2)[b]	51.5 (2)
2	64.1 (1)	34.7 (2)	210.4 (0)
3	51.5 (2)	71.2 (1)	55.7 (2)
4	34.7 (0)	39.4 (0)[c]	38.7 (0)
5	47.0 (1)	47.4 (1)	47.1 (1)
6	22.4 (2)	22.5 (2)	22.6 (2)
7	36.8 (2)	37.1 (2)	36.0 (2)
8	37.4 (1)	37.6 (1)	37.5 (1)
9	50.5 (0)	50.5 (0)	50.2 (0)
10	40.2 (0)	38.6 (0)[c]	44.6 (0)
11	28.3 (2)	28.2 (2)[b]	28.2 (2)
12	33.3 (2)	33.3 (2)	33.0 (2)
13	71.1 (0)	71.2 (0)	70.6 (0)
14	46.9 (1)	46.8 (1)	46.5 (1)
15	38.3 (2)	38.2 (2)	38.2 (2)
16	30.4 (2)	30.2 (2)	30.5 (2)
17	28.6 (3)	28.6 (3)	28.3 (3)
18	34.8 (3)	30.0 (3)	34.0 (3)
19	23.8 (3)	17.2 (3)	23.7 (3)
20	19.8 (3)	19.0 (3)	18.7 (3)

[a]The numbers in parentheses represent the number of attached hydrogens as determined by the DEPTGL pulse sequence. One-bond HETCOR experiments were performed on all compounds.

[b,c]Signals bearing the same letter superscript may have interchangeable assignments.

TABLE 2. ^{1}H-nmr Shifts (300 MHz, C_5D_5N) for Stemodin [**1**], Maritimol [**2**], and Stemodinone [**3**].[a]

H at C	Compound		
	1	**2**	**3**
1	2.35 ddd (12.0,2.7, 2.7), 1.6 m	1.9 m, 1.7 m	2.51 d (12.0) 2.39 dd (12.0, 2.4)
2	4.05 m	1.9 m, 1.5 m	—
3	2.0 m, 1.35 m	3.5 dd (7.2,7.2)	2.32 d (13.0)
5	1.4 m	1.35 m	1.8 m
6	1.4 m, 1.2 m	1.4 m, 1.2 m	1.4 m, 1.15 m
7	1.9 m, 1.1 m	1.9 m, 1.1 m	1.75 m, 1.1 m
8	1.75 m	1.7 m	1.65 m
11	2.0 m, 1.4 m	1.9 m, 1.4 m	1.70 m, 1.1 m
12	1.6 m	1.6 m	1.55 m
14	2.16 dd (6.9,6.9)	2.18 dd (6.6,6.6)	2.17 dd (6.9,6.9)
15	1.70 m, 1.2 m	1.7 m, 1.2 m	1.65 m, 1.3 m
16	2.41 d (10.8), 1.75 m	2.35 d (11.4), 1.7 m	2.28 d (13.2), 1.7 m
17	1.30 s	1.32 s	1.30 s
18	0.98 s	1.29 s	1.02 s
19	0.94 s	1.12 s	0.88 s
20	1.02 s	1.00 s	0.96 s

[a]Values in parentheses are J in Hz. The chemical shifts reported were obtained from the 1D spectrum after assessment of the 2D COSY and HETCOR plots. The ^{1}H-nmr assignments were based primarily on HETCOR data because the ^{13}C-nmr assignments were established.

by heteronuclear correlation) and the C-19 methyl group protons with H-3 (and hence C-3). The ^{1}H-nmr assignments were based primarily on the data from the HETCOR experiments.

Maritimol [**2**], an isomer of stemodin, had ^{13}C-nmr data that were readily assignable by comparison with those of **1**. The methyl signals C-17 and C-20 would not be expected to change much between **1** and **2**, but, as expected, changes in shifts were noted for C-18 and C-19. The ^{1}H-nmr assignments were made primarily from the HETCOR experiments.

EXPERIMENTAL

GENERAL EXPERIMENTAL PROCEDURES.—Samples of stemodin [**1**], stemodinone [**3**], and maritimol [**2**] were previously obtained from *S. maritima* as reported (2). ^{1}H- and ^{13}C-nmr spectra were recorded in C_5D_5N on a Varian VXR-300 FT spectrometer operating at 300 MHz and 75 MHz, respectively. The chemical shift values are reported in ppm and the coupling constants in Hz. Standard pulse sequences were used for COSY (6), HETCOR (7), and DEPTGL (8). Carbon-carbon connectivities were verified with the CCC2DQ 2D-INADEQUATE pulse sequence as reported (9). A spectral width of 4518.8 Hz in both F2 (the carbon chemical shift axis) and F1 (the double quantum frequency axis) was employed with an acquisition time of 113 msec and 64 increments. The sample was prepared by adding 300 mg of **1** in 0.5 ml of C_5D_5N in a 5-mm tube and maintaining the temperature at 95° (VT unit). The repetition rate of 7.0 sec and 512 repetitions per increment resulted in a total data acquisition time of 65 h. Contour plotting revealed carbon-carbon connectivities as pairs of doublets with the same double quantum frequency appearing opposite the chemical shift positions of carbons joined by a chemical bond. A value of $J_{CC}=40$ Hz was used to determine the pulse sequence timing.

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