Homocyclotirucallane and Two Dihydrophenanthrenes from *Spiranthes sinensis*

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A novel homocyclotirucallane, sinetirucallol (1), and two additional new dihydrophenanthrenes, sinensols G (2) and H (3), were isolated from the aerial parts of *Spiranthes sinensis* (PERS.) AMES. Their structures were determined by various spectral analyses, including MS and two-dimentional nuclear magnetic resonance techniques. The structure of compound 1 was further confirmed by single-crystal X-ray analysis. The absolute configuration of 1 was determined by modified Mosher's method.

Key words *Spiranthes sinensis*; Orchidaceae; aerial part; homocyclotirucallane; dihydrophenanthrene

In a previous paper,[1] we have described the characterization of six new dihydrophenanthrene derivatives (sinensols A—F) together with five known dihydrophenanthrenes from the aerial parts of *Spiranthes sinensis* (PERS.) AMES. (Orchidaceae), which has been used as a folk drug in Taiwan.[2,3] Our continuing chemical studies on this plants has resulted in the isolation of a novel homocyclotirucallane, sinetirucallol (**1**), and two new dihydrophenanthrene derivatives, sinensols G (**2**) and H (**3**), together with spiranthesol,[4] 2-(3′,4′-dihydroxyphenyl)-1,3-benzodioxole-5-aldehyde,[5] ergosterol peroxide,[6] and a series of phenolic compounds, *p*-hydroxybenzaldehyde,[7] 3,4-dihydroxybenzaldehyde,[8] 3,4-dihydroxybenzyl acohol,[9] hydroquinone,[7] 4-hydroxybenzyl ethyl ether,[10] 4-hydroxybenzyl methyl ether,[11] and methyl 3-(4-hydroxyphenyl)propanoate.[12] This paper reports the isolation and the structural elucidation of the novel homocyclotirucallane (**1**) and two new additional dihydrophenanthrene derivatives, sinensol G (**2**) and sinensol H (**3**).

Results and Discussion

The EtOH extract of the aerial parts of *S. sinensis* (PERS.) AMES. was fractionated into EtOAc-soluble, *n*-BuOH-soluble and H_2O-soluble fractions. The cytotoxic EtOAc-soluble fraction was further subjected to repeated column chromatography to afford a novel homocyclotirucallane (**1**) and two additional dihydrophenanthrenes, **2** and **3**.

Compound **1** was obtained as colorless needles. It gave the molecular formula $C_{31}H_{52}O$ from HR-EI-MS. The EI-MS showed fragment ions at *m/z* 425 $[M-CH_3]^+$, 407 $[M-CH_3-H_2O]$, and 313 $[M-\text{side chain}-2H]^+$. Its IR had hydroxyl (3381, 1097 cm^{-1}) and olefinic (3045, 1625 cm^{-1}) absorptions. The ^{1}H-NMR spectrum (see Experimental) revealed two characteristic cyclopropane protons [δ −0.18 (t, J=4.0 Hz), 0.33 (dd, J=8.5, 4.0 Hz)], seven singlet methyl groups (δ 0.67, 0.70, 0.88, 0.98, 1.02, 1.04, 1.06), one doublet methyl group [δ 0.89 (d, J=6.5 Hz)], one methine proton [δ 0.41 (m)], one carbinyl proton [δ 3.22 (dd, J=10.8, 5.5 Hz)], and one olefinic proton [δ 5.29 (br s)]. The ^{13}C-NMR and distortionless enhancement by polarlization transfer (DEPT) spectra indicated that **1** was a tetracyclic triterpenoid with eight methyl, ten methylene, five methine, one oxygenated methine, one trisubstituted olefin, five quaternary carbons, and one cyclopropane ring.

The location of the double bond at C-9, -11 was determined from the methyl group upfield of δ 0.67 (C-18). Such data indicated that the compound was a member of the Δ^9-euphane or Δ^9-tirucallane series of compounds.[13,14] And a strong ion at M^+-15 also supported the assignment of a double bond to C-9 (11) for an allylic cation resulted from this process. The negative optical rotation ($[\alpha]_D^{25}$ −66°) revealed that it belongs to the tirucallane rather than euphane series.[14] The side chain and the cyclopropane of **1** were deduced from 1D total correlation spectroscopy (TOCSY1D), heteronuclear multiple bond correlation (HMBC) and nuclear Overhauser enhancement spectroscopy (NOESY) experiments. From TOCSY1D spectrum, the contiguous protons from cyclopropane H-31 are as follows: H-31, H-24, H-23, H-22, and H-20. In addition, long-range correlations (HMBC) and NOE correlations observed between the cyclopropane protons and H-26, -27 confirmed the two methyl groups (H_3-26, -27) connecting to the terminal carbon of the cyclopropane. The signal at δ 3.22 [(dd, J=10.8, 5.5 Hz)] was assigned as H-3 being on α-axial orientation due to the larger coupling constant and having HMBC correlations with C-4, C-28, and C-29. From the above evidence, the structure of **1** was established as 24,31-homocyclotirucall-9(11)-ene-3β-ol, a novel homocyclotirucallane skeleton. The relative configuration of **1** was determined by NOESY technique (see Experimental) and X-ray single-crystal analysis (Fig. 2). Its absolute configuration was determined by the modified Mosher's method.[15,16] Treatment of **1** with (*S*)- and (*R*)-2-methoxy-2-trifluoromethyl-2-phenylacetyl chloride (MTPACl) afforded (*S*)- and (*R*)-MTPA esters (**1a**, **1b**, respectively). The ^{1}H-NMR signals of the two derivatives were assigned by TOCSY1D. The $\Delta\delta$ values ($\delta_S-\delta_R$ in Hz) of the individual protons of ring A are shown in Fig. 1. The systematic arrangement of positive and negative $\Delta\delta$ values indicated that the configuration of C-3 is *R*.

Compound **2** was isolated as a colorless amorphous powder, and gave the molecular formula $C_{20}H_{22}O_3$ from HR-EI-MS. The IR spectrum indicated hydroxyl (3417, 1158 cm^{-1}), and aromatic ring (1616, 1590, 1494 cm^{-1}) absorptions. Its ^{1}H-NMR showed signals (see Experimental) due to four protons [δ 2.71 (4H, m)] typical H-9 and H-10 signals of 9,10-dihydrophenanthrenes,[1] an isopentenyl group [δ 5.38 (1H, t, J=7.0 Hz), 3.40 (2H, d, J=7.0 Hz), 1.79 and 1.81 (3H each, s)], a methoxyl [δ 3.81 (3H, s)], two *meta*-phenyl protons [δ 6.37, 6.43 (d, J=2.0 Hz)] and two *para*-phenyl protons [δ

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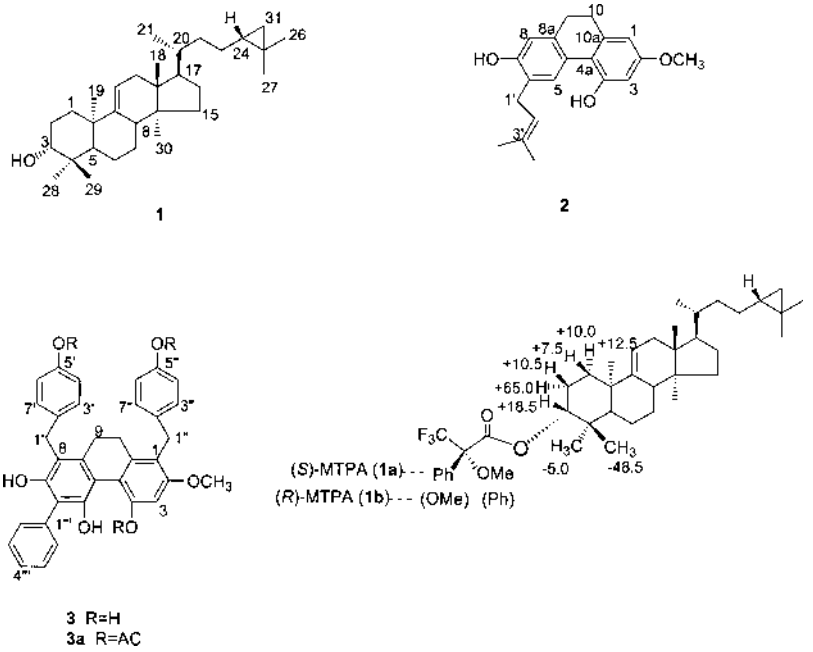

Fig. 1. $\Delta\delta$ Values [$\Delta\delta$ (in Hz)$=\delta_S-\delta_R$] obtained for the (*S*)- and (*R*)-MTPA Esters (**1a**, **b**, Respectively)

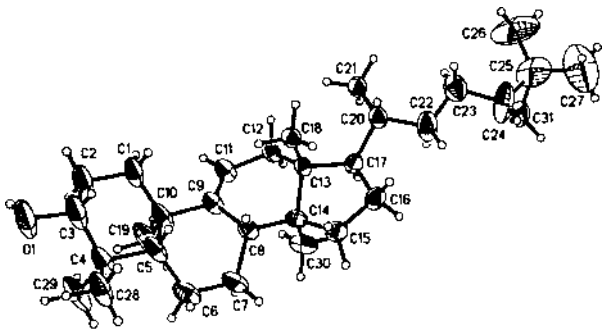

Fig. 2. X-Ray Crystal Structure for **1**

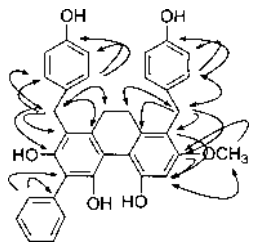

Fig. 3. Key HMBC (→) and NOE (↔) Correlations of **3**

Table 1. Crystal Data and Structure Refinement for IC7156

Identification code	ic7156
Empirical formula	$C_{33}H_{58}O$
Formula weight	470.79
Temperature	150 (2) K
Wavelength	0.71073 Å
Crystal system	Monoclinic
Space group	*C*2
Unit cell dimensions	a=44.2182 (5) Å, alpha=90°, b=9.04440 (10) Å, beta=97.7020 (10)°, c=7.44880 (10) Å, gamma=90°
Volume, *Z*	2952.10 (6) Å^3, 4
Density (Calculated)	1.059 mg/m^3
Absorption coefficient	0.061 mm^{-1}
F(000)	1056
Crystal size	0.40×0.30×0.20 mm
θ range for data collection	0.93 to 27.50°
Limiting indices	$-58\leq h\leq 58$, $-11\leq k\leq 11$, $-9\leq l\leq 9$
Reflections collected	14545
Independent reflections	6758 (R_{int}=0.0235)
Absorption correction	Used SADABS
Max. and min. transmission	0.830 and 0.781
Refinement method	Full-matrix least-squares on F^2
Data/restraints/parameters	6463/1/308
Goodness-of-fit on F^2	1.045
Final *R* indices [$I>2\sigma(I)$]	$R1$=0.0922, $wR2$=0.2400
R indices (all data)	$R1$=0.1136, $wR2$=0.2653
Absolute structure parameter	0 (5)
Extinction coefficient	0.0008 (8)
Largest diff. peak and hole	0.866 and −0.340 e Å^{-3}
Note:	
Solvent: C_2H_6	

6.72, 7.78 (s, 1H each)]. The relatively lower field at δ 7.78 was assigned as H-5 due to the deshielding by the C-4 hydroxyl group on the adjacent aromatic ring. The ^{13}C-NMR indicated three oxygenated aromatic carbons (δ_C 152.8, 153.5, 158.9). The HMBC correlations, C$\underline{H}_3$O (δ 3.81)/C-2; H-1′/C-5, -6, -7, -2′, and -3′; H-9 (-10)/C-1, 4a, -4b, -8, -8a, and -10a; H-1/C-2, -3, and -4a, and H-3/C-1, -2, and -4, determined the situation of the methoxyl, isopentenyl, and hydroxyl groups on the dihydrophen-anthrene. From these spectral data, **2** was identified as 2-methoxy-4,7-dihydroxy-6-isopentenyl-9,10-dihydrophenanthrene. This assignment was further confirmed by the NOE correlations as follows: C$\underline{H}_3$O (δ 3.81)/H-1, -3; H-1′ (δ 3.40)/H-5 (δ 7.78).

Compound **3** had the molecular formula of $C_{35}H_{30}O_6$ from EI-MS and ^{13}C-NMR. It showed IR absorptions at 3365 (OH), 1615, 1599, 1514, and 1497 (aromatic ring) cm^{-1}. The ^{1}H-NMR spectrum had signals arising from two 4-hydroxybenzyl [δ 3.92, 3.95 (2H each, s), 6.63, 6.86 (2H each, d, J=8.5 Hz), and 6.65, 6.93 (2H each, s)], one phenyl [δ 6.98 (2H, d, J=8.5 Hz), 7.11 (1H, dd, J=8.5, 9.0 Hz), and 7.21 (2H, dd, J=8.5, 9.0 Hz)], one aromatic proton (δ 6.50), four

Table 2. Bond Lengths (Å) and Angles (°) for IC7156

O(1)–C(3)	1.449 (5)	C(1)–C(2)	1.536 (6)
C(1)–C(10)	1.566 (7)	C(2)–C(3)	1.499 (6)
C(3)–C(4)	1.531 (8)	C(4)–C(28)	1.540 (5)
C(4)–C(29)	1.546 (7)	C(4)–C(5)	1.574 (5)
C(5)–C(6)	1.509 (6)	C(5)–C(10)	1.554 (4)
C(6)–C(7)	1.535 (6)	C(7)–C(8)	1.539 (5)
C(8)–C(9)	1.522 (5)	C(8)–C(14)	1.529 (5)
C(9)–C(11)	1.333 (4)	C(9)–C(10)	1.543 (5)
C(10)–C(19)	1.529 (6)	C(11)–C(12)	1.512 (4)
C(12)–C(13)	1.535 (4)	C(13)–C(18)	1.541 (4)
C(13)–C(17)	1.548 (4)	C(13)–C(14)	1.562 (4)
C(14)–C(15)	1.537 (5)	C(14)–C(30)	1.558 (5)
C(15)–C(16)	1.537 (5)	C(16)–C(17)	1.557 (4)
C(17)–C(20)	1.544 (5)	C(20)–C(21)	1.529 (5)
C(20)–C(22)	1.576 (6)	C(22)–C(23)	1.438 (7)
C(23)–C(24)	1.544 (6)	C(24)–C(25)	1.446 (9)
C(24)–C(31)	1.522 (7)	C(25)–C(27)	1.505 (11)
C(25)–C(26)	1.534 (11)	C(25)–C(31)	1.537 (9)
C(32)–C(33)	1.389 (12)		
C(2)–C(1)–C(10)	113.5 (4)	C(3)–C(2)–C(1)	111.1 (4)
O(1)–C(3)–C(2)	109.8 (4)	O(1)–C(3)–C(4)	111.8 (4)
C(2)–C(3)–C(4)	114.6 (5)	C(3)–C(4)–C(28)	109.4 (5)
C(3)–C(4)–C(29)	110.3 (4)	C(28)–C(4)–C(29)	105.7 (3)
C(3)–C(4)–C(5)	107.8 (3)	C(28)–C(4)–C(5)	108.4 (3)
C(29)–C(4)–C(5)	115.1 (5)	C(6)–C(5)–C(10)	114.1 (4)
C(6)–C(5)–C(4)	113.5 (3)	C(10)–C(5)–C(4)	116.0 (3)
C(5)–C(6)–C(7)	113.3 (3)	C(6)–C(7)–C(8)	112.2 (4)
C(9)–C(8)–C(14)	112.2 (2)	C(9)–C(8)–C(7)	108.2 (3)
C(14)–C(8)–C(7)	114.2 (3)	C(11)–C(9)–C(8)	121.1 (3)
C(11)–C(9)–C(10)	121.2 (3)	C(8)–C(9)–C(10)	117.7 (3)
C(19)–C(10)–C(9)	109.1 (4)	C(19)–C(10)–C(5)	113.6 (3)
C(9)–C(10)–C(5)	108.3 (3)	C(19)–C(10)–C(1)	110.0 (4)
C(9)–C(10)–C(1)	108.1 (3)	C(5)–C(10)–C(1)	107.5 (4)
C(9)–C(11)–C(12)	125.7 (3)	C(11)–C(12)–C(13)	110.8 (2)
C(12)–C(13)–C(18)	108.0 (3)	C(12)–C(13)–C(17)	118.0 (2)
C(18)–C(13)–C(17)	109.6 (3)	C(12)–C(13)–C(14)	108.0 (2)
C(18)–C(13)–C(14)	111.6 (2)	C(17)–C(13)–C(14)	101.5 (2)
C(8)–C(14)–C(15)	116.0 (3)	C(8)–C(14)–C(30)	109.6 (3)
C(15)–C(14)–C(30)	108.0 (3)	C(8)–C(14)–C(13)	110.2 (3)
C(15)–C(14)–C(13)	102.2 (3)	C(30)–C(14)–C(13)	110.7 (3)
C(16)–C(15)–C(14)	105.0 (2)	C(15)–C(16)–C(17)	107.2 (3)
C(20)–C(17)–C(13)	120.0 (3)	C(20)–C(17)–C(16)	113.1 (3)
C(13)–C(17)–C(16)	102.9 (2)	C(21)–C(20)–C(17)	112.2 (3)
C(21)–C(20)–C(22)	108.9 (3)	C(17)–C(20)–C(22)	107.4 (3)
C(23)–C(22)–C(20)	117.4 (5)	C(22)–C(23)–C(24)	110.5 (5)
C(25)–C(24)–C(31)	62.3 (4)	C(25)–C(24)–C(23)	119.7 (6)
C(31)–C(24)–C(23)	123.0 (5)	C(24)–C(25)–C(27)	118.0 (7)
C(24)–C(25)–C(26)	118.1 (7)	C(27)–C(25)–C(26)	116.1 (8)
C(24)–C(25)–C(31)	61.2 (4)	C(27)–C(25)–C(31)	118.0 (6)
C(26)–C(25–C(31)	114.2 (7)	C(24)–C(31)–C(25)	56.5 (4)

Symmetry transformations used to generate equivalent atoms.

typical H-9, H-10 of dihydrophenanthrene protons [δ 2.35 (2H, m), δ 2.71 (2H, m)], and a methoxyl group [δ 3.78 (3H, s)]. Its NMR spectrum showed six oxygenated carbons (δ_C 155.9, 156.0, 156.0, 156.1, 156.1, 158.4) and five exchangeable phenolic protons [δ 4.59 (br s), exchangeable]. The key HMBC correlations, H-1′/C-7 (δ 155.9), -8, -8a; H-1″/C-1, -2 (δ 158.4), -10a; H-3/C-1, -2, -4 (δ 156.1), -4a, and OC$\underline{H}_3$/C-2, suggested the connection of two 4-hydroxybenzyl and methoxyl groups at C-1, C-8, and C-2, respectively, while two hydroxylated carbons are located at C-4 and C-7. This assignment was further confirmed from the NOE correlations of H-1′/H-9; H-1″/H-10, OC$\underline{H}_3$/H-3, H-3′(7′)/H-9, and H-3″(7″)/H-10 in its NOSEY spectrum.

Acetylation of **3** with Ac_2O/pyridine yielded triacetate (**3a**) (δ 2.17, 2.28, 2.28). The IR spectrum of **3a** showed hydroxyl (3459 cm^{-1}), ester (1763, 1202 cm^{-1}), and aromatic ring (1600, 1515 cm^{-1}) absorptions. Two phenolic hydroxy groups [δ 4.67 (br s), exchangeable] resisted acetylation due to the steric effect from the benzyl and phenyl groups. The chemical shift of the two oxygenated carbons at δ_C 155.9 (C-7) and 156.0 (C-5) excluded a catechol-type composition. Therefore, the structure of **3** can be assigned as 4,5,7-trihydroxy-1,8-bis(4-hydroxybenzyl)-3-methoxy-6-phenyl-9,10-dihydrophenanthrene.

Experimental

General Experimental Procedures Melting points were determined on Yanagimoto micromelting point apparatus and are uncorrected. Optical rotations were recorded on a JASCO DIP-370 polarimeter. IR spectra were recorded on a Nicolet avatar 320 FT-IR spectrophotometer. UV spectra were measured on a Hitachi U-3200 spectrophotometer. NMR were run on a Bruker AC-300 and a Varian unity INOVA-500 spectrometer. Mass spectra (EI-MS and HR-EI-MS) were taken on a JEOL JMS-HX110 and a JEOL SX-102A instrument, respectively.

Plant Material The aerial parts of *Spiranthes sinenesis* (Pers.) Ames. were purchased from a local herbal medicine store, Taipei, Taiwan, in April, 1999, and identified by comparison with the voucher specimens already deposited at the Herbarium of the Department of Botany, National Taiwan University, Taipei, Taiwan (no: TAI. 218182, collected on April 12, 1934).

Extraction and Isolation The aerial parts of *Spiranthes sinenesis* (Pers.) Ames. (3 kg) were extracted with EtOH (50 l) at 50 °C three times (8 h each time). The EtOH extract was evaporated under reduced pressure. The concentrate was taken up in H_2O, and partitioned into EtOAc-soluble, *n*-BuOH-soluble and H_2O fractions. The EtOAc-soluble fraction (35 g) was subjected to column chromatography over silica gel using an *n*-hexane–EtOAc–methanol gradient. The fractions of 25—33% ethyl acetate were further separated on a Si gel column to yield **1** (645 mg), phytosterol (465 mg), and ergosterol peroxide (48 mg). The fraction of 5—10% methanol/ethyl acetate yielding three fractions were further purified by Sephadex LH-20 (EtOAc : MeOH = 1 : 1) and preparative HPLC on Si gel (Merck, Si 60, 7 μm, using *n*-hexane–EtOAC = 2 : 1 or 1 : 1) column chromatography, yielded **2** (32 mg), **3** (18 mg), and a series of phenolic compounds, 4-hydroxybenzaldehyde (112 mg), 3,4-dihydroxybenzaldehyde (345 mg), 3,4-dihydroxybenzyl acohol (48 mg), hydroquinone (65 mg), 4-hydroxybenzyl ethyl ether (59 mg), 4-hydroxybenzyl methyl ether (98 mg), methyl 3-(4-hydroxyphenyl)propanoate (83 mg).

Sinetirucallol (**1**): Colorless needles, mp: 96—97 °C. $[\alpha]_D^{25}$ −66° (c = 0.5, $CHCl_3$). IR ν_{max} (KBr) cm^{-1}: 3381, 3045, 2940, 2869, 1625, 1456, 1375, 1097. ^{1}H-NMR (500 MHz, $CDCl_3$): δ −0.18 (t, J = 4.0 Hz, H-31), 0.33 (dd, J = 8.5, 4.0 Hz, H-31), 0.41 (1H, m, H-24), 0.67, 0.70, 0.88, 0.98, 1.02, 1.04, 1.06 (each 3H, s, H-18, H-30, H-29, H-28, H-26, H-27, H-19), 0.89 (3H, d, J = 6.5 Hz, H-21), 1.95 (2H, br s, H-12), 3.22 (1H, dd, J = 10.8, 5.5 Hz, H-3), 5.29 (1H, br s, H-11). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 14.9 (q, C-30), 15.0 (q, C-29), 17.0 (q, C-18), 18.4 (q, C-21), 19.0 (t, C-6), 19.5 (t, C-7), 19.6 (t, C-31), 20.0 (q, C-26), 25.2 (q, C-19), 25.2 (d, C-24), 26.5 (t, C-23), 27.4 (q, C-28), 27.7 (q, C-27), 27.9 (t, C-22), 28.1 (s, C-25), 28.1 (t, C-2), 33.3 (t, C-15), 36.0 (d, C-20), 36.7 (t, C-16), 37.5 (s, C-10), 37.8 (t, C-12), 39.2 (s, C-4), 39.3 (t, C-1), 40.5 (s, C-8), 44.0 (s, C-13), 44.5 (d, C-5), 46.6 (s, C-14), 50.8 (s, C-17), 79.1 (d, C-3), 116.9 (d, C-11), 150.4 (s, C-9). HMBC correlations: H-3/C-1, -2, -4, -5. -28, -29; H-18/C-12, -13, -14, -17; H-11/C-8, -9, -10, -12, -13; H-19/C-1, -5, -9, -10; H-24/C-22, -23, 25, -26, -27, -31; H-31/C-23, -24, -25, -26, -27. NOE correlations: H-3/H-1, -2, -5, -28, -29; H-8/H-7, -18; H-11/H-12, -19; H-20/H-17, -21, -22; H-24/H-23, -31; H-31/H-24, -26, -27. EI-MS (20 eV) *m/z* (rel. int.): 440 ([M]$^+$, 58), 425 (100), 313 (45), 259 (9), 220 (31), 123 (12), 95 (28), 83 (10), 69 (15). HR-EI-MS *m/z* 440.4013 (Calcd for $C_{31}H_{52}O$: 440.4018).

Sinensol G (**2**): Colorless amorphous powder. IR ν_{max} (KBr) cm^{-1}: 3417, 3040, 1616, 1590, 1494, 1158, 1052, 836, 755. UV λ_{max} (MeOH) nm (log ε): 310sh (4.05), 302 (4.14), 289 (4.38), 270sh (4.30). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.79 and 1.81 (3H each, s, H-4′, -5′), 2.71 (4H, m, H-9, -10), 3.40 (2H, d, J = 7.0 Hz, H-1′), 3.81 (3H, s, OCH_3), 5.14 (2H, br s, OH), 5.38 (1H, t, J = 7.0 Hz, H-2′), 6.37 (1H, d, J = 2.0 Hz, H-3), 6.43 (1H, d, J = 2.0 Hz, H-1), 6.72 (1H, s, H-8), 7.78 (1H, s, H-5). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 18.2 (q, C-5′), 26.0 (q, C-4′), 29.6 (t, C-9), 30.2 (t, C-1′), 30.9 (t, C-10), 55.5 (q, O$\underline{C}H_3$), 101.0 (d, C-3), 106.8 (d, C-1), 115.0 (s, C-4a), 115.9 (d, C-8), 122.3 (d, C-2′), 124.8 (s, C-6), 125.5 (s, C-4b), 127.5 (d, C-5), 135.1 (s, C-3′), 138.4 (s, C-8a), 141.4 (s, C-10a), 152.8 (s, C-7), 153.5 (s, C-

4), 158.9 (s, C-2). HMBC correlations: H-1/C-2, -3, -4a, -10a, -10; H-3/C-1, -2, -4, -4a; H-5/C-4a, -4b, -6, -7, -8a; H-8/C-4b, 6, -7; H-1′/C-5, -6, -7, -2′, -3′; H-9(10)/C-1, -4a, -4b, -8, -8a, -10a; H-4′(5′)/C-2′, -3′. NOE correlations: OC$\underline{H}_3$/H-1, -3; H-9/H-8; H-10/H-1; H-1′/H-5. EI-MS (20 eV) *m/z* 310 ($[M]^+$, 25), 254 (100), 243 (62), 241 (15). HR-EI-MS *m/z* 310.1569 (Calcd for $C_{31}H_{52}O$: 310.1569).

Sinensol H (**3**): Pale yellow amorphous powder. $[\alpha]_D^{25}$ 0° (*c*=0.5, MeOH). IR ν_{max} (KBr) cm^{-1}: 3365, 3028, 1615, 1599, 1514, 1497, 1103, 823, 737, 701. UV λ_{max} (MeOH) nm (log ε): 288 (4.12), 283 (4.10). ^{1}H-NMR (500 MHz, CD_3OD): δ 2.35 and 2.71 (2H each, m, H-9, -10), 3.78 (3H, s, OC$\underline{H}_3$), 3.92 and 3.95 (2H each, s, H-1″, -1′), 4.59 (5H, br s, OH), 6.50 (1H, s, H-3), 6.63 and 6.86 [2H each, d, *J*=8.5 Hz, H-4′ (6′), -3′ (7′)], 6.65 and 6.93 [2H each, d, *J*=8.5 Hz, H-4″ (6″), -3″ (7″)], 6.98 (2H, d, *J*=8.5 Hz, H-2‴, -6‴), 7.11 (1H, dd, *J*=8.5, 9.0 Hz, H-4‴), 7.21 (2H, dd, *J*=8.5, 9.0 Hz, H-3‴, -5‴). ^{13}C-NMR (125 MHz, CD_3OD): δ 31.1 (t, C-1″), 31.2 (t, C-1′), 33.4 (t, C-10), 37.7 (t, C-9), 55.9 (O$\underline{C}H_3$), 98.0 (d, C-3), 115.8 (s, C-6), 115.8 (d, C-4″, -6″), 115.9 (d, C-4′,-6′), 119.5 (s, C-4a), 119.5 (s, C-1), 120.3 (s, C-8), 126.8 (d, C-4‴), 129.1 (s, C-4b), 129.2 (d, C-3‴, -5‴), 129.2 (d, C-2‴, -6‴), 129.9 (d, C-3″, -7″), 130.1 (d, C-3′, -7′), 134.3 (s, C-2″), 134.4 (s, C-2′), 142.7 (s, C-1‴), 142.7 (s, C-10a), 143.6 (s, C-8a), 155.9 (s, C-7), 156.0 (s, C-5), 156.0 (s, C-5″), 156.1 (s, C-4), 156.1 (s, C-5′), 158.4 (s, C-2). Key HMBC correlations: H-3/C-1, -2, -4, -4a; H-1′/C-7, -8, -8a, -2′, -3′ (7′); H-1″/C-1, -2, 10a, -2″, -3″ (7″); H-2‴ (6‴)/C-6, -1‴, -3‴ (5‴), -4‴. Key NOE correlations: H-1′/H-9, -3′ (7′); H-1″/H-10, –OC$\underline{H}_3$, -3″ (7″), H-3/OC$\underline{H}_3$. EI-MS (20 eV) *m/z* (rel. int.): 546 ($[M]^+$, 5), 440 (100), 334 (65), 255 (72), 243 (40), 107 (85), 77 (15). HR-EI-MS *m/z* 546.20441 (Calcd for $C_{35}H_{30}O_6$: 546.20430).

(*S*)- and (*R*)-MTPA Ester of 1 Triethylamine (30 μl) and (*S*)-2-methoxy-2-trifluoromethyl-2-phenylacetyl chloride (MTPACl) (5 μl) were added to a solution of **1** (3 mg) and 4-(dimethylamino)pyridine (100 μg) in dichloromethane solution (dried, 500 μl) at room temperature, and stirring was continued for 2 h. After addition of *N*,*N*-dimethyl-1,3-propanediamine (20 μl) and evaporation of solvent, the residue was passed through a silica gel column (hexane/EtOAc, 4 : 1) to afford the (*S*)-MTPA (**1a**). The (*R*)-MTPA ester (**1b**) was obtained in the same method.

Acetylation of 3 Compound **3** (5 mg) was acetylated with Ac_2O (0.5 ml) in pyridine (0.5 ml) at 60 °C overnight. The solvent and excess reagent were removed using a high-vacuum pump. Purification with Si gel column gave triacetate (**3a**, 4 mg); IR ν_{max} (KBr) cm^{-1}: 3459, 3030, 1763, 1600, 1515, 1506, 1459, 1202, 1167, 1104, 1044, 1018, 904. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.17 (3H, s), 2.28 (6H, s), 2.50 and 2.83 (2H each, m), 3.78 (3H, s, OCH_3), 3.94 (2H, s), 4.10 (2H, s), 6.63 (1H, s), 6.95 and 7.07 (2H each, d, *J*=8.0 Hz), 6.97 and 7.09 (2H each, d, *J*=8.0 Hz), 7.00 (2H, d, *J*=8.5 Hz), 7.18 (1H, t, *J*=8.5 Hz), 7.22 (2H, t, *J*=8.5 Hz).

X-Ray Crystal Structural Analysis of 1 A colorless crystal of **1** with 0.40×0.30×0.20 mm was selected for X-ray analysis. Structure analysis was performed by using the SHELXTL program on PC. Data were collected over a hemisphere of reciprocal space, by a combination of three sets of exposures. The compound crystallized in the monoclinic space group *C*2, *a*=44.2182 (5) Å, *b*=9.04440 (10) Å, *c*=7.44880 (10) Å, β=97.7020 (10)°, *V*=2952.10 (6) Å^3, *Z*=4, D_{calc}=1.059 mg/m^3, λ=0.71073 Å, μ(Mo*K*α)=0.061 mm^{-1}, *F*(000)=1056, and *T*=150 (2) K. The SMART program was used to make data correction. A total of 14545 reflections, collected in the range $0.93<\theta<27.5°$, yielded 6758 unique reflections. The structure was solved using direct methods and refined by full-matrix least-squares on F^2 values for 6463 reflections with $I>2\sigma(I)$. Non-hydrogen atoms were refined anisotropically. Hydrogen atoms were fixed at calculated positions and refined using ariding mode. The final indices were R=0.0922, R_w=0.1136 with goodness-of-fit=1.045. Scattering factors were taken from the *International Tables for X-ray Crystallography.*

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