Seco-Prezizaane-Type Sesquiterpenes and an Abietane-Type Diterpene from *Illicium minwanense*

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A methanol extract of the pericarps of *Illicium minwanense* afforded seven new *seco*-prezizaane-type sesquiterpenes (**2**−**8**) and a new abietane-type diterpene (**9**), together with six previously known compounds (**1** and **10**−**14**). The structures of the new compounds, (1*S**)- and (1*R**)-minwanenone (**2** and **3**), 1α-hydroxy-6-deoxypseudoanisatin (**4**), (2*S*)-hydroxy-6-deoxypseudoanisatin (**5**), 3-oxopseudoanisatin (**6**), (3*S**,6*R**)-4,7-epoxy-6-deoxypseudoanisatin (**7**), 7-*O*-methylpseudomajucin (**8**), and (+)-8,11,13,15-abietatetraene (**9**), were elucidated by spectroscopic data analysis and chemical transformations. The absolute configurations of **1** and **5** were established by X-ray crystallographic analysis of their *p*-bromobenzoyl derivatives.

Illicium species, which belong to the only genus of the family Illiciaceae, are widely distributed in southern regions of the People's Republic of China.[1] The cortex and root bark of *Illicium* species such as *I. merrillianum*, *I. jiadifengpi*, and *I. miwanense* occurring in China have been used in folk medicine for the treatment of rheumatoid arthritis. Their neurotoxicity, presumably due to anisatin,[2] however, sometimes limits their use in traditional medicine. *Illicium* species are rich in biosynthetically unique *seco*-prezizaane-type sesquiterpenes and prenylated C_6−C_3 compounds. Some *seco*-prezizaanne-type sesquiterpenes have been found not to be neurotoxic, but to have an intriguing neurotrophic property unlike anisatin.[3−6] In a preceding paper,[7] we reported the structure and neurotrophic activity of jiadifenin, a new majucin-subtype of *seco*-prezizaane sesquiterpene isolated from *I. jiadifengpi*. As part of our ongoing studies on biologically active substances of the genus *Illicium*, we have investigated chemical components of the methanol extract of the pericarps of *I. minwanense*, which is indigenous to China, thereby resulting in the isolation of seven new *seco*-prezizaane-type sesquiterpenes (**2**−**8**) and a new abietane-type diterpene (**9**) along with the previously known compounds (**1** and **10**−**14**). In this paper, we report the structure elucidation of these new compounds and revise the previously proposed structure of miwanensin (**1**).[8]

Results and Discussion

A combination of silica gel and reversed-phase RP-8 column chromatography and preparative HPLC on the methanol extract of the pericarps of *I. minwanense* gave seven new *seco*-prezizaane-type sesquiterpenes and an abietane-type diterpene, (1*S**)- and (1*R**)-minwanenone (**2** and **3**), 1α-hydroxy-6-deoxypseudoanisatin (**4**), (2*S*)-hydroxy-6-deoxypseudoanisatin (**5**), 3-oxopseudoanisatin (**6**), (3*S**,6*R**)-4,7-epoxy-6-deoxypseudoanisatin (**7**), 7-*O*-methylpseudoanisatin (**8**), and (+)-8,11,13,15-abietatetraene (**9**), along with the previously known compounds, minwanensin (**1**),[8] 6-deoxypseudoanisatin (**10**),[9] pseudomajucin (**11**),[10] pseudoanisatin (**12**),[11] 1α-hydroxy-3-deoxypseudoanisatin (**13**),[12] and 1α-hydroxypseudoanisatin (**14**).[13]

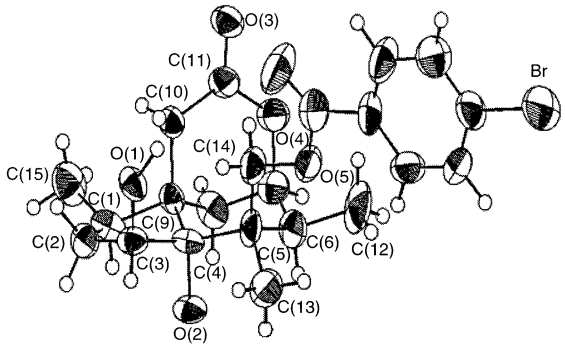

Figure 1. ORTEP drawing for **1a**.

Miwanensin (**1**), a major component of *I. miwanense*, was reported with an α-oriented relative configuration of the hydroxyl group at the C-3 position, on the basis of comparing its NMR data with those of pseudoanisatin.[10] However, the analysis of the NOESY data of **1** indicated that H-3 had no NOE interaction with H-10*β*. Hence, we have decided to re-examine the absolute configuration of **1** by X-ray crystallography. Compound **1** was converted to its *p*-bromobenzoyl derivative **1a**, which gave a single crystal suitable for X-ray crystallographic analysis. Its ORTEP[14] diagram is depicted in Figure 1 and indicates the absolute configuration for **1a**, in which the 3*R* configuration in **1** should be revised to 3*S*.

Compound **2** had a $[M + H]^+$ ion peak at *m*/*z* 265.1411 in the high-resolution CIMS, corresponding to the molecular formula $C_{15}H_{20}O_4$, and its IR spectrum displayed absorptions due to a hydroxyl group at 3440 cm^{-1}, a lactone moiety at 1730 cm^{-1}, and a carbonyl group at 1705 cm^{-1}. The NMR spectral data (Table 1) of **2** contained signals corresponding to a minwanensin-type sesquiterpene except for signals due to H-10*β* at δ_H 2.44 (q, J = 18.9, 2.6 Hz) and H-1 at δ_H 2.41 (q, J = 7.4 Hz) and the presence of an α,*β*-unsaturated ketone due to signals at δ_H 6.01 (s, H-3), δ_C 210.6 (C-2, CO), δ_C 131.3 (C-3), and δ_C 187.5 (C-4). The presence of an α,*β*-unsaturated ketone at the C-2, C-3, and

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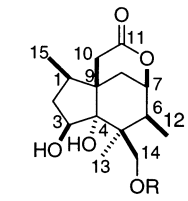
Table 1. ^{13}C and ^{1}H NMR Spectral Data (δ) of Compounds **2**−**4**[a]

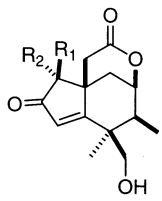
	2		**3**		**4**	
position	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
1	53.8	2.41 q (7.4)	53.0	2.81 q (7.4)	82.9	
2α	210.6		211.1		52.3	2.70 dd (15.5 8.0)
2β						1.93 dd (15.5 8.0)
3	131.3	6.01 s	130.9	6.01 s	79.3	4.51 dd (8.0, 2.7)
4	187.5		188.2		83.8	
5	44.6		45.4		48.6	
6	46.1	1.94 qd (7.4, 2.4)	46.8	1.85 qd (7.4, 2.8)	49.4	2.95 q (6.9)
7	81.1	4.65 ddd (4.4,2.4,2.2)	81.3	4.68 ddd (3.8, 2.8, 2.2)	213.6	
8α	37.5	1.87 ddd (13.7, 2.4, 2.2)	35.1	1.80 ddd (13.5, 2.2, 2.2)	42.4	3.00 dd (16.8, 1.8)
8β		2.45 dd (13.7, 7.4)		2.31 dd (13.5, 3.8)		2.22 d (16.8)
9	45.8		46.2		51.5	
10α	39.0	2.88 d (18.9)	41.7	2.89 d (19.0)	38.8	2.51 d (14.3)
10β		2.44 dd (18.9, 2.6)		2.81 dd (19.0, 2.2)		3.57 dd (14.3, 1.8)
11	173.5		173.5		176.2	
12	12.4	1.20 d (7.4)	12.2	1.22 d (7.4)	8.2	1.10 d (6.9)
13	24.9	1.34 s	24.9	1.36 s	17.3	1.23 s
14α	65.6	3.46 d (11.5)	65.4	3.48 d (11.5)	70.6	5.46 d (13.4)
14β		3.54 d (11.5)		3.63 d (11.5)		3.78 d (13.4)
15	10.1	1.09 d (7.4)	10.1	1.10 d (7.7)	24.4	1.25 s

[a] In CD_3OD at 600 MHz. *J* values (Hz) in parentheses.

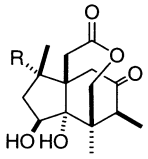
C-4 positions was confirmed by HMBC correlations of H_3-15 at δ_H 1.09 to C-1 at δ_C 53.8 and the C-2 carbonyl signal (δ_C 210.6) and from H-3 at δ_H 6.10 to C-9 at δ_C 45.8. The relative stereochemistry on C-1 of **2** was elucidated by a NOESY experiment, in which CH_3-15 and H-1 showed cross-peaks to H_2-10 and H-8α, respectively, indicating the H-1β configuration. Thus, compound **2** was assigned as 2-oxo-3,4-dehydromiwanensin with a 1*S**-configuration and has been named (1*S**)-miwanenone.



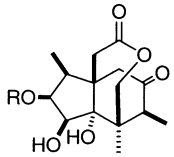
1: R = H
1a: R = *p*-BrBz



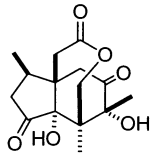
2: R_1 = Me, R_2 = H
3: R_1 = H, R_2 = Me



4: R = OH
10: R = H



5: R = H
5a: R = *p*-BrBz



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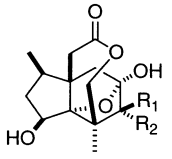
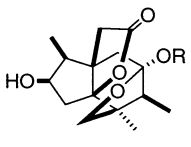
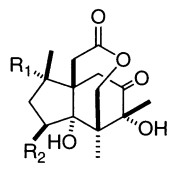


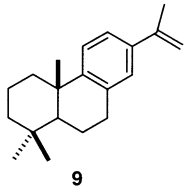
7: R_1 = H, R_2 =Me



8: R= CH_3
11: R = H



12: R_1 = H, R_2 = OH
13: R_1 = OH, R_2 = H
14: R_1 = R_2 = OH



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Compound **3** was assigned the same molecular formula $C_{15}H_{26}O_4$ as **2**, obtained from high-resolution CIMS, and exhibited spectral data very similar to those of compound **2**. Additionally, the analysis of the 2D NMR data of **3** gave the same planar structure as **2**. This meant that **3** is a stereoisomer with respect to one of the chiral centers. In the NOESY experiment CH_3-15 at δ_H 1.10 and H-1 at δ_H 2.81 showed NOE correlations to H-8α and H_2-10, respectively, but otherwise gave the same NOE enhancements as in **2**. Thus, the structure of **3** was assigned as (1*R**)-miwanenone.

Compound **4** gave the molecular formula $C_{15}H_{22}O_6$, as determined by high-resolution FABMS at *m*/*z* 321 $[M + Na]^+$, and its IR spectrum displayed absorptions due to a hydroxyl group at 3418 cm^{-1} and carbonyl groups at 1732 and 1716 cm^{-1}. The NMR spectral data of **4** (Table 1) were found to be similar to those of 6-deoxypseudoanisatin (**10**)[9] except for the presence of the oxygenated quaternary carbon signal which resonated at δ_C 82.9 and the absence of any H-1 signal. The aforementioned spectral observations indicated that **4** has a hydroxyl group that replaces the proton on the C-1 position in **10**. Combined analysis of the $^{1}H-^{1}H$ COSY, HMQC, and HMBC spectra of **4** led to the structure, 1-hydroxy-6-deoxypseudoanisatin. The relative configuration of the C-15 methyl group was assigned as β on the basis of the NOESY interaction between CH_3-15 and H_2-10. Thus, the structure of **4** was determined to be 1α-hydroxy-6-deoxypseudoanisatin.

Compound **5** showed a molecular ion peak at *m*/*z* 298.1398 in the high-resolution EIMS, corresponding to the molecular formula $C_{15}H_{22}O_6$. The IR spectrum displayed the absorption attributable to a hydroxyl group at 3488 cm^{-1} and two carbonyl groups at 1735 and 1705 cm^{-1}. The ^{1}H and ^{13}C NMR spectral data (Table 2) of **5** showed signals similar to those of **10** except for the presence of two oxymethine signals at δ_H 4.32 (dd, J = 7.4 and 6.9 Hz) and δ_C 72.6 and at δ_H 4.25 (d, J = 6.9 Hz) and δ_C 78.5, which were assignable to C-2 and C-3 from the $^{1}H-^{1}H$ COSY and

Table 2. ^{13}C and ^{1}H NMR Spectral Data (δ) of Compounds **5**[a] and **6**[b]

	5		**6**	
position	δ_C	δ_H	δ_C	δ_H
1	46.1	2.56 qd (7.4, 7.4)	35.9	3.01 qdd (19.0, 12.3, 7.1)
2α	72.6	4.32 dd (7.4, 6.9)	41.5	2.82 dd (12.3, 9.3)
2*β*				1.89 dd (19.0, 9.3)
3	78.5	4.25 d (6.9)	210.2	
4	82.4			78.8
5	48.6			46.4
6	49.7	2.88 q (6.9)	83.5	
7	213.3		205.2	
8α	48.0	2.59 dd (16.2, 1.6)	40.8	2.83 d (15.8)
8*β*		2.27 d (16.2)		3.38 dd (15.8, 2.2)
9	48.3		47.8	
10α	36.7	2.31 d (14.8)	35.2	2.78d (14.9)
10*β*		3.29 dd (14.8, 1.6)		2.84 dd (14.9, 2.2)
11	177.0		172.2	
12	8.1	1.10 d (6.9)	17.1	1.70 s
13	18.0	1.26 s	13.2	1.65 s
14α	70.6	5.39 d (13.2)	69.7	4.60 d (14.0)
14*β*		3.80 d (13.2)		4.08 d (14.0)
15	8.3	0.92 d (7.4)	13.0	0.82 d (7.1)

[a] In CD_3OD at 600 MHz. [b] In C_5D_5N at 600 MHz; *J* values (Hz) in parentheses.

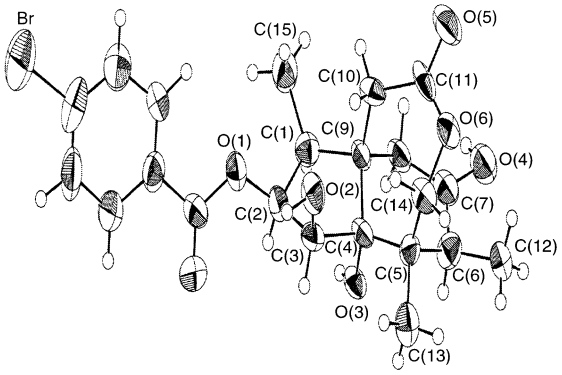

Figure 2. ORTEP drawing for **5a**.

HMQC NMR spectra. These spectral data disclosed that **5** is 3-hydroxy-6-deoxypseudoanisatin. Treatment of **5** with *p*-bromobenzoyl chloride in pyridine and DMAP gave a single crystal of the *p*-bromobenzoyl derivative **5a**, for which X-ray crystallographic analysis was carried out. As a result, the absolute configuration on C-2 was determined to be *S*, as shown in the ORTEP[15] diagram of **5a** (Figure 2). Thus, the structure of **5** was assigned as (2*S*)-hydroxy-6-deoxypseudoanisatin.

Compound **6** gave the molecular formula $C_{15}H_{20}O_6$, as determined by the high-resolution EIMS at *m/z* 296.1235, and its IR spectrum displayed absorptions due to a hydroxyl group at 3380 cm^{-1} and three carbonyl groups at 1737, 1726, and 1719 cm^{-1}. The NMR spectral data (Table 2) of **6** were similar to those of pseudanisatin (**12**)[11] except for the absence of an oxymethine signal at C-3 existing in **12** and the appearance of a carbonyl signal that resonated at δ_C 210.2. These spectral data disclosed that the hydroxyl group on the C-3 position in **12** was oxidized to a ketone in **6**. The presence of the carbonyl group at this position was confirmed not only by the HMBC correlation of H-1 to the C-3 carbonyl signal but also a C-3 hydroxy group in pseudoanisatin (**12**) to **6** with Dess−Martin reagent. Thus, the structure of **6** was determined to be 3-oxopseudoanisatin.

Compound **7** was assigned the molecular formula $C_{15}H_{20}O_6$, as determined by the high-resolution EIMS at *m/z* 282.1436, and its IR spectrum displayed absorptions due to a hydroxyl group at 3420 cm^{-1} and a carbonyl group at 1705 cm^{-1}. The NMR spectral data (Table 3) of **7** showed the presence of a tertiary methyl group (δ_H 1.13), two secondary methyl groups [δ_H 0.92 (d, J = 7.4 Hz), δ_H 0.94 (d, J = 7.1 Hz)], an oxymethylene [δ_H 3.79 and 4.83 (each d, J = 7.1 Hz)], and an oxymethine [δ_H 4.24 (dd, J = 7.4, 3.6 Hz); δ_C 73.8 (C-3)], which was coupled to a methylene [δ_H 2.53 (ddd, J = 13.8, 12.6, 7.4 Hz) and 1.36 (ddd, J = 13.8, 10.2, 3.6 Hz); δ_C 45.0 (C-2)]. The aforementioned spectral data indicated that **7** belongs to the 6-deoxypseudoanisatin-type sesquiterpenes as exemplified by **10**, but the presence of an acetal carbon signal at δ_C 109.3 instead of a carbonyl group on C-7 in **10** was the main difference in **7**. This acetal carbon showed HMBC correlations with both CH_3-12 and H-8, and the chemical shift for C-4 in **7** appeared at δ_C 93.3. These spectral data, in addition to six degrees of unsaturation, indicated that **7** is a 4,7-acetal form of 6-deoxypseudoanisatin (**10**). However, compound **10** did not occur as an equilibrated mixture in $CDCl_3$ solution, whereas **7** was present as an acetal form in the same solution. The relative stereochemistry for **7** was elucidated on the basis of *J* values of vicinal coupling and NOESY data as shown in Figure 3. Thus, the large vicinal *J* value (7.4 Hz) between H-2 and H-3 indicated that

Table 3. ^{13}C and ^{1}H NMR Spectral Data (δ) of Compounds **7**[a] and **8**[b]

	7		**8**	
position	δ_C	δ_H	δ_C	δ_H
1	45.1	2.33 qdd (12.6, 10.2, 7.1)	55.1	1.89 qd (7.2, 3.6)
2α	45.0	2.53 ddd (13.8, 12.6, 7.4)	73.6	4.36 ddd (4.2, 3.6, 1.2)
2*β*		1.36 ddd (13.8, 10.2, 3.6)		
3α	73.8	4.24 dd (7.4, 3.6)	43.9	2.07 dd (15.0, 4.2)
3*β*				2.33 dd (15.0, 1.2)
4	93.3		100.4	
5	40.5		50.9	
6	43.2	2.17 q (7.4)	44.1	1.86 q (7.2)
7	109.3		108.8	
8α	47.9	1.56 d (12.5)	49.4	1.62 d (13.2)
8*β*		1.73 d (12.5)		2.54 d (13.2)
9	52.9		48.6	
10α	34.5	2.54 d (14.3)	41.6	2.78 d (18.6)
10*β*		3.12 d (14.3)		3.20 d (18.6)
11	177.7		176.7	
12	10.4	0.92 d (7.4)	8.7	1.03 d (7.2)
13	16.1	1.13 s	14.0	0.91 s
14α	72.2	4.83 d (13.1)	71.8	4.10 d (9.0)
14*β*		3.79 d (13.1)		3.66 d (9.0)
15	14.1	0.94 d (7.1)	10.1	1.16 d (7.2)
OCH_3			50.7	3.40 s

[a] In CD_3OD at 600 MHz. [b] In C_5D_5N at 600 MHz; *J* values (Hz) in parentheses.

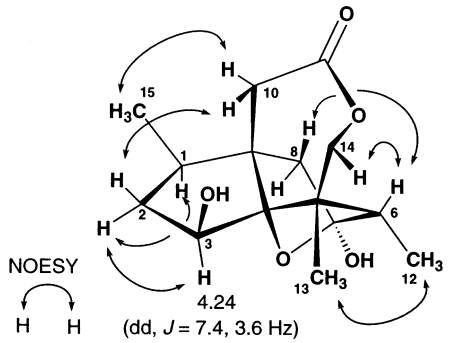

Figure 3. Representative NOESY correlations of **7**.

H-3 occurred in an α-configuration, and it was evident from the NOESY correlation of CH_3-15 to H_2-10 that the CH_3-15 was in a β-orientation. Additionally, the CH_3-12 signal showed a NOESY correlation with CH_3-13, and the H-6 signal showed NOESY correlations with both H-8β and H-14, thereby indicating that CH_3-12 was in an α-configuration. Thus, compound **7** was eluidated as (3*S**,6*R**)-4,7-epoxy-6-deoxypseudoanisatin. It was not possible to determine why the stereochemistry on C-6 plays such a key role in eliciting a favorable equilibrium between the keto and acetal forms of pseudoanisatin on the basis of the global minimum energy calculated for **7** and **10** by MM2 molecular modeling.[16]

Compound **8** showed a protonated molecular ion peak at *m*/*z* 297.1714 $[M + H]^+$ in the high-resolution FABMS, corresponding to a molecular formula of $C_{16}H_{24}O_5$. The IR spectrum displayed absorptions ascribable to a hydroxyl group (3441 cm^{-1}) and two carbonyl groups (1759 cm^{-1}). The ^1H and ^{13}C NMR spectral data (Table 3) of **8** were identical to those of pseudomajucin (**11**)[10] except for the presence of a methoxy group (δ_H 3.40; δ_C 50.7), and the chemical values of C-7 and C-8 were shifted to a lower field (δ_C 108.8) and a higher field (δ_C 49.4), respectively, compared with the corresponding data for **11**. This was taken as evidence that the C-7 hydroxy group in **11** is methylated. In fact, the methoxy signal showed a HMBC correlation to the C-7 acetal carbon at δ_C 108.8. Additionally, the NOESY experiment indicated that the relative stereochemistry for **8** was the same as that of **11**. To confirm the proposed structure of **8**, compound **11** was treated with orthotrimethylformate in the presence of Amberlyst-15 to give 7-*O*-methylpseudomajucin in 91% yield. Thus, the structure of **8** was established as 7-*O*-methylpseudomajucin.

Compound **9** showed in its high-resolution FABMS a peak at *m*/*z* 268.2198, corresponding to an elemental composition of $C_{20}H_{28}$. The IR spectrum displayed only the presence of a hydrocarbon. The ^1H and ^{13}C NMR spectra of **9** were similar to those of (+)-8,11,13-abietatriene[17] except for the presence of an olefin methyl group (δ_H 2.12, δ_C 21.8) and an *exo*-methylene [δ_H 5.01, 5.32 (each br s), δ_C 111.4 and 138.0]. The HMBC experiment displayed both the CH_3-16 and CH_2-17 signals correlated to C-13 at δ_C 143.1 and C-15 at δ_C 138.0; therefore the position of the *exo*-methylene group could be assigned to C-13. Thus, the structure of **9** was determined as (+)-8,11,13,15-abietatetraene.

In conclusion, we have isolated three miwanesin-type sesquiterpenes (**1**−**3**), eight pseudoanisatin-type sesquiterpenes (**4**−**7**, **10**, **12**−**14**), and two pseudomajucin-type sesquiterpenes (**8** and **11**) from *I. miwanense*. This plant is rich in pseudoanisatin-type sesquiterpenes, most of which have been isolated primarily from *I. ansitaum*.[2] According to the occurrence of these sesquiterpenes, *I. miwanense* is likely to be taxonpomically close to the Japanese "Shikimi" (*I. ansitaum*). It is noted that none of the compounds isolated in the present study exhibited neurite outgrowth promoting activity on primary cultures of rat cortical neurons at 10 μM.[18]

Experimental Section

General Experimental Procedures. Optical rotations were measured on a JASCO DIP-1000 digital polarimeter. IR spectra were measured on a JASCO FT-IR 5300 infrared spectrophotometer. 1D- and 2D-NMR spectra were recorded on a Varian Unity 600 or 400 instrument. Chemical shifts are given as δ (ppm) with TMS as internal standard. MS were recorded on a JEOL AX-500 instrument. X-ray crystallography was conducted on an MXC18 (MacScience Co.) instrument. Column chromatography was carried out on Keiselgel 60 (70−230 mesh and 230−400 mesh).

Plant Material. The ripe fruits of *Illicium minwanense* were collected in Wenshang town, Yunnan, People's Republic of China, in September 1989, and a voucher specimen (No. 94041) is deposited at the Beijing University of Chinese Medicine.

Extraction and Isolation. The dried pericarps of *Illicium minwanense* (5 kg) were powdered and extracted with MeOH at room temperature to give 1.2 kg of a pale yellow extract. An aliquot of the MeOH extract (593.6 g) was divided into methanol-soluble (396.2 g) and methanol-insoluble portions (197.4 g). The methanol-soluble portion was chromatographed on a Celite column (515 g) eluting with a step gradient of *n*-hexane (100%), CH_2Cl_2 (100%), CH_2Cl_2−EtOAc (3:1 and 1:3), EtOAc (100%), and MeOH (100%) to yield six fractions (A−F).

Fraction A (15.2 g) was first subjected to Si gel chromatography eluting with *n*-hexane to give fractions 1−12. Fraction 2 (1.67 g) was further chromatographed on a Si gel column eluting with *n*-hexane giving fractions 13−19. Fraction 18 (7.5 mg) was separated by HPLC (Cosmosil Si 60, ϕ 10 × 250 mm) using *n*-hexane as a solvent to give (+)-8,11,13,15-abietatetraene (**9**) (2.8 mg).

Fraction B (52 g) was chromatographed on a Si gel column eluting with a gradient of $CHCl_3$−EtOAc to give fractions 20−31. 6-Deoxypseudoanisatin (**10**) (134.8 mg), which was the major component, was obtained as crystals from fraction 25 (5.7 g). This fraction was chromatographed on Sephadex LH-20, with EtOH as the solvent, to give fractions 32−42. Fraction 36 (1.0 g) was further chromatographed eluting with CH_2Cl_2−MeOH (19:1) to give fractions 43−51. Finally, fraction 46 (13.7 mg) was purified by TLC (RP-18) with MeOH−H_2O−CH_3CN (1:6:3) to give 7-*O*-methylpseudomajucin (**8**) (5.3 mg). Fraction 25 (3.1 g) was chromatographed on a Lobar (RP-18) column eluting with MeOH−H_2O−CH_3CN (2:5:2) to give fractions 62−67. Fraction 62 (16.8 mg) was chromatographed on Sephadex LH-20, with EtOH as the solvent, to give pseudoanisatin (**12**) (11.5 mg). Fraction 64 (20.0 mg) was separated by reversed-phase HPLC (Cosmosil 5C_{18}-AR-II, ϕ 10 × 250 mm) using MeOH−H_2O (3:2) to give (3*S**,6*R**)-4,7-epoxy-6-deoxypseudoanisatin (**7**) (2.8 mg). Fraction 30 (1.31 g) was chromatographed on a Si gel column eluting with CH_2Cl_2−EtOAc (1:5) and was purified by TLC with MeOH−H_2O (2:3) to give pseudomajucin (**11**) (179.9 mg).

Fraction 31 (1.41 g) was chromatographed on a Si gel column eluting with $CHCl_3$−EtOAc (1:5) to give fractions 68−75. Fraction 70 (171.2 mg) was chromatographed on a Lobar (RP-18) column eluting with MeOH−H_2O (1:1) to give minwanensin (**1**) (21.8 mg). Fraction 71 (187 mg) was further chromatographed on a Si gel column eluting with $CHCl_3$−MeOH (10:1) to give (1*R**)-minwanenone (**3**) (6.2 mg). Fraction 72 (142 mg) was further chromatographed on a Si gel column eluting with $CHCl_3$−MeOH (9:1) to give (1*S**)-minwanenone (**2**) (5.5 mg) and (2*S*)-hydroxy-6-deoxypseudoanisatin (**5**) (37.1 mg). Further TLC (RP-18) with MeOH−H_2O (2:3) of this fraction gave 1α-hydroxy-6-deoxypseudoanisatin (**4**) (23.5 mg), 1α-hydroxy-3-deoxypseudoanisatin (**13**) (13.7 mg), and 1α-hydroxypseudoanisatin (**14**) (16.0 mg).

Fraction 49 (169.7 mg) was chromatographed on a Lobar (RP-18) column eluting with H_2O−CH_3CN (7:3) to give fractions 52−61. Fraction 56 (91.4 mg) was separated by reversed-phase HPLC (Cosmosil 5C_{18}-AR-II, ϕ 10 × 250 mm) using MeOH−H_2O−CH_3CN (2:1:1) to give 3-oxopseudoanisatin (**6**) (1.0 mg).

***p*-Bromobenzoylation of Minwanensin (1).** To a solution of **1** (5.4 mg, 0.019 mmol) in pyridine (2 mL) was added *p*-bromobenzoyl chloride (41 mg) and 4-(dimethylamino)-pyridine (4.2 mg). The reaction mixture was stirred at room temperature for 24 h and then condensed in vacuo to give a residue, which was purified by TLC with $CHCl_3$−MeOH (9:1) to afford **1a** (3.0 mg, 56%) as colorless plates; mp 229−230 °C. X-ray crystallographic analysis confirmed the structure of **1a** (absolute stereochemistry; ORTEP diagram, Figure 1).

Single-Crystal X-ray Crystallography of 1a.[14] Suitable colorless plates of **1a** were obtained from a solution in CH_2Cl_2; $C_{22}H_{28}O_6Br$. The crystal belongs to the monoclinic system, space group $P2_12_12_1$ with $a = 8.440(3)$ Å, $b = 11.265(6)$ Å, $c = 27.668(2)$ Å, $V = 2630.6(2)$ Å^3, $Z = 4$, $D_x = 1.468$ Mg m^{-3}, λ(Mo Kα) = 0.71073 Å. Intensity data were measured on a DIP image plate, $\theta_{max} = 25.73°$. A total of 4004 reflections were collected. The structure was solved and refined by the *SHELXS*-97 program.[19] The non-hydrogen atoms were given anisotropic thermal parameters. The refinement converged to a final $R = 0.0689$, $R_w = 0.1870$ for 3297 observed reflections [$I > 2.00\sigma(I)$] and 293 variable parameters. The Flack parameter was 0.015(18). Values of the neutral atom scattering factors and real and imaginary dispersion corrections were taken from the *International Tables for X-ray Crystallography*.[20]

(1*S)-Minwanenone (2):** $[\alpha]^{19}_D$ −19.9° (*c* 1.25, MeOH); IR (film) ν_{max} 3440 (OH), 1730, and 1705 (C=O) cm^{-1}; ^{1}H and ^{13}C NMR, see Table 1; HRCIMS *m*/*z* 265.1411 (calcd for $C_{15}H_{21}O_4$, 265.1440).

(1*R)-Minwanenone (3):** $[\alpha]^{21}_D$ −17.9° (*c* 1.50, EtOH); IR (film) ν_{max} 3420 (OH), 1735, and 1683 (C=O) cm^{-1}; ^{1}H and ^{13}C NMR, see Table 1; HRCIMS *m*/*z* 265.1434 (calcd for $C_{15}H_{21}O_4$, 265.1440).

1α-Hydroxy-6-deoxypseudoanisatin (4): $[\alpha]^{21}_D$ 7.6° (*c* 1.50, MeOH); IR (film) ν_{max} 3418 (OH), 1732, and 1716 (C=O) cm^{-1}; ^{1}H and ^{13}C NMR, see Table 1; HRFABMS *m*/*z* 321.1343 (calcd for $C_{15}H_{22}O_6Na$, 321.1314).

(2*S*)-Hydroxy-6-deoxypseudoanisatin (5): mp 223−224 °C; $[\alpha]^{20}_D$ −23.3° (*c* 0.38, MeOH); IR (film) ν_{max} 3488 (OH), 1735, and 1705 (C=O) cm^{-1}; ^{1}H and ^{13}C NMR, see Table 2; HREIMS *m*/*z* 298.1398 (calcd for $C_{15}H_{22}O_6$, 298.1416).

***p*-Bromobenzoylation of (2*S*)-Hydroxy-6-deoxypseudoanisatin (5).** To a solution of **5** (2.3 mg, 0.0077 mmol) in pyridine (2 mL) was added *p*-bromobenzoyl chloride (16.9 mg) and 4-(dimethylamino)pyridine (3.8 mg). The reaction mixture was stirred at room temperature for 25 h and then condensed in vacuo to give a residue, which was purified by TLC with $CHCl_3$−MeOH (9:1) to afford **5a** (1.8 mg, 78%) as colorless plates; mp 214−215 °C. X-ray crystallographic analysis confirmed the structure of **5a** (absolute stereochemistry; ORTEP diagram, Figure 2).

Single-Crystal X-ray Crystallography of 5a.[15] Suitable colorless plates of **5a** were obtained from a solution in CH_2Cl_2; $C_{22}H_{26}O_7Br$. The crystal belongs to the monoclinic system, space group $P2_12_12_1$ with $a = 6.72$ Å, $b = 13.04$ Å, $c = 28.07$ Å, $V = 2458.58$ Å^3, $Z = 4$, $D_x = 1.530$ Mg m^{-3}, λ(Mo Kα) = 0.71073Å. Intensity data were measured on a DIP image plate, $\theta_{max} = 25.67°$. A total of 2145 reflections were collected. The structure was solved by the *maXus* program[21] and refined by the *SHELXS*-97 program.[19] The non-hydrogen atoms were given anisotropic thermal parameters. The refinement converged to a final $R = 0.063$, $R_w = 0.1590$ for 1369 observed reflections [$I > 2.00\sigma(I)$] and 299 variable parameters. The Rogers η parameter was 1.044. Values of the neutral atom scattering factors and real and imaginary dispersion corrections were taken from the *International Tables for X-ray Crystallography*.[20]

3-Oxopseudoanisatin (6): $[\alpha]^{23}_D$ −181.2° (*c* 0.17, EtOH); IR (film) ν_{max} 3380 (OH), 1737, 1726, and 1711 (C=O) cm^{-1}; ^{1}H and ^{13}C NMR, see Table 2; HREIMS *m*/*z* 296.1235 (calcd for $C_{15}H_{20}O_6$, 296.1260).

Dess−Martin Oxidation of Pseudoanisatin (12). To a solution of **12** (50.0 mg, 0.17 mmol) in CH_2Cl_2 (5 mL) was added Dess−Martin reagent ([1,1,1-triacetoxy-1,1-dihydro-1,2-benzodioxyl-3(1*H*)-one] periodinane) (62.2 mg). After being stirred at room temperature for 5 min, the solvent was evaporated in vacuo to give a residue, which was purified by TLC (RP-18) with MeOH−H_2O−CH_3CN (2:5:2) to afford 3-oxopseudoanisatin (**6**) (16.5 mg, 33%). This product was identical in all respects with natural 3-oxopseudoanisatin (**6**).

(3*S,6*R**)-4,7-Epoxy-6-deoxypseudoanisatin (7):** $[\alpha]^{23}_D$ +42.6° (*c* 0.96, MeOH); IR (film) ν_{max} 3420 (OH), and 1705 (C=O) cm^{-1}; ^{1}H and ^{13}C NMR, see Table 3; HREIMS *m*/*z* 282.1436 (calcd for $C_{15}H_{22}O_5$, 282.1467).

7-*O*-Methylpseudomajucin (8): $[\alpha]^{23}_D$ −35.6° (*c* 1.08, MeOH); IR (film) ν_{max} 3441 (OH), and 1759 (C=O) cm^{-1}; ^{1}H and ^{13}C NMR, see Table 3; HRFABMS *m*/*z* 297.1714 (calcd for $C_{15}H_{22}O_5$, 297.1702).

Methylation of Pseudomajucin (11). To a solution of **11** (2.0 mg, 0.007 mmol) was added orthotrimethylformate (250 μL) and Amberlyst-15 (three pieces). After being stirred at room temperature for 1 day, the solvent was evaporated in vacuo to give a residue, which was purified by TLC with CH_2Cl_2−EtOAc (1:2) to afford 7-*O*-methylpseudomajucin (**8**) (2.0 mg, 91%). This product was identical in all respects with natural 7-*O*-methylpseudomajucin.

(+)-8,11,13,15-Abietatetraene (9): $[\alpha]^{24}_D$ +48.2° (*c* 0.22, MeOH); IR (film) ν_{max} 1483 (C=C) cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 0.93 (3H, s), 0.97 (3H, s), 1.19 (3H, s), 1.46 (1H, br s), 1.75 (1H, m), 1.89 (1H, m), 2.12 (3H, s), 2.28 (1H, br s), 2.88 (1H, ddd, $J = 16.4$, 7.2, 1.7 Hz), 2.94 (1H, ddd, $J = 16.4$, 7.2, 1.7 Hz), 5.01 (1H, br s), 5.32 (1H, br s), 7.14 (1H, d, $J = 1.7$ Hz), 7.21 (1H, d, $J = 8.0$ Hz), 7.23 (1H, dd, $J = 1.7$, 8.0 Hz); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 38.8 (C-1), 19.1 (C-2), 41.7 (C-3), 33.5 (C-4), 50.4 (C-5), 19.3 (C-6), 30.5 (C-7), 135.0 (C-8), 149.6 (C-9), 37.7 (C-10), 124.3 (C-11), 122.9 (C-12), 143.1 (C-13), 126.1 (C-14), 138.0 (C-15), 21.8 (C-16), 111.4 (C-17), 33.3 (C-18), 21.7 (C-19), 24.8 (C-20); HREIMS *m*/*z* 268.2198 (calcd for $C_{20}H_{28}$, 268.2191).

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