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Three Novel 5(6→7)Abeoabietane-Type Diterpenes from the Bark of *Taiwania cryptomerioides*

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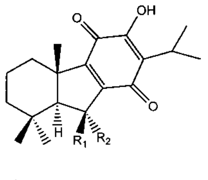
Three new 5(6→7)abeoabietane diterpenes with the uncommon skeleton of fused 6–5–6 rings were isolated from the bark of *Taiwania cryptomerioides* designated as taiwaniaquinone F (8), taiwaniaquinol C (9) and taiwaniaquinol D (10). Meanwhile, two known compounds, taiwaniaquinones A (1) and D (4), were also obtained. Their structures were determined principally from spectral evidence.

Key words *Taiwania cryptomerioides*; Taxodiaceae; diterpene; taiwaniaquinone F; taiwaniaquinol C; taiwaniaquinol D

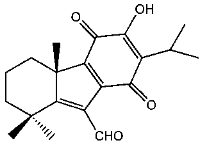
Taiwania cryptomerioides HAYATA (Taxodiaceae), a decay-resistant tree, is an endemic plant growing at elevations from 1800 to 2600 m in the central mountains of Taiwan. Previous phytochemical investigations on the heartwood,[1—3] bark[4—10] and leaves[11—14] of this plant led to the isolation of various sesquiterpenes, lignans, diterpenes, and bisflavones.

Recently, many interesting novel skeletal compounds including seven diterpenes with the novel skeleton six–five–six fused-rings have been isolated from the leaves by Lin *et al.*[11,12] They named the skeletons of these compounds taiwaniaquinone [A (**1**), B (**2**), C (**3**), D (**4**), E (**5**)] and taiwaniaquinol [A (**6**) and B (**7**)]. Based on the different functionalities (quinone and phenol), the nomenclatures of these compounds are not suitable. More suitable nomenclatures are 5(6→7)abeoabietane type (taiwaniaquinones A, B, C, D, E, and taiwaniaquinol A) and 6-*nor*-5(6→7)abeoabietane type (taiwaniaquinol B). These novel skeletons were first isolated from the leaves of *T. cryptomerioides*. Because the early studies on its bark did not yield good results,[4,5] we reinvestigated the components of its bark again, and discovered twenty-three new podocapane-type derivatives.[6—10] In a continuation of our work on the same extract from the bark of the plant, we also obtained three new 5(6→7)abeoabietane-type diterpenes. In this article, we describe the isolation and structural elucidation of three new 5(6→7)abeoabietane-type diterpenes, taiwaniaquinone F (**8**), taiwaniaquinol C (**9**) and taiwaniaquinol D (**10**), as well as two known taiwaniaquinones A (**1**)[11] and D (**4**).[12]

Taiwaniaquinone F (**8**) was isolated as an orange amorphous solid. The high resolution electron impact mass spectrum (HR-EI-MS) showed a molecular ion at *m/z* 344.1986, consistent with the molecular $C_{21}H_{28}O_4$ and indicated eight degrees of unsaturation. Two absorption bands at 1660 and 1650 cm^{-1} in the IR spectrum and the maximum absorption at λ_{max} 279 nm in the UV spectrum indicated the presence of a *para*-benzoquinone moiety. Further evidence included the observation of signals at δ 136.9, 146.2, 155.0, 156.3, 181.4 and 185.7 in the ^{13}C-NMR spectrum (Table 1). The ^{1}H- and ^{13}C-NMR (Table 1) spectra exhibited three methyl singlets [δ_H 0.77, 1.02, 1.13 (3H each, s)], an isopropyl group [δ_H 3.13 (1H, sep, J=6.8 Hz, H-15) and 1.15 (6H, d, J=6.8 Hz, H-16, -17), a phenolic methyl group [δ_H 3.89 (3H, s) and δ_C 61.4] and the consecutive protons of an AMX system, an aldehyde [δ_H 9.80 (1H, d, J=4.0 Hz, H-6) and δ_C 200.5] and two methine protons [δ_H 2.03 (1H, d, J=11.3 Hz, H-5) and δ_H 3.71 (1H, dd, J=4.0, 11.3 Hz, H-7)]. An obvious signal at δ_H 2.27 (1H, br d, J=12.9 Hz) was assigned as a H_β-1 signal. By comparison of the ^{13}C- and ^{1}H-NMR signals between **8** and **1**, the difference is an enol methyl ether in **8** instead of an enol in **1**. It was considered to be a taiwaniaquinone A methyl ether derivative with the skeleton of 6–5–6 fused rings. Full characterization of the structure was accomplished by examination of the correlated spectroscopy (COSY), heteronuclear multiple-quantum coherence (HMQC), heteronuclear multiple-bond correlation spectroscopy (HMBC), and nuclear Overhauser enhancement exchange spectroscopy (NOESY) spectral data. In the HMBC spectrum, the methine proton at δ_H 2.03 (H-5) showed cross-peaks with a quaternary carbon at δ_C 33.6 (C-4) and methyl group C-18 (δ_C 34.9); methine proton H-15 (δ_H 3.13) exhibited coupling with C-12 (δ_C 155.0), C-13 (δ_C 136.9) and C-14 (δ_C 185.7) supported C ring was a *para*-benzoquinone unit. HMBC correlations between H-7 (δ_H 3.71) and olefinic carbons C-8 (δ_C 146.2), C-9 (δ_C 156.3) and aldehyde carbon C-6 (δ_C 200.5) were also observed. The NOESY spectrum lead us to the assignment of its relative stereochemistry. The NOESY correlations (H-5/H_3-18, H-5/H-6, H-7/H_3-20, and H_β-1/H_3-20) indicated a *trans*-junction for the A and B rings and a *trans* ori-



1 R_1=H, R_2=CHO
2 R_1=OH, R_2=CHO
3 R_1=CHO, R_2=OH
5 R_1=H, R_2=COOMe



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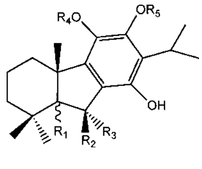
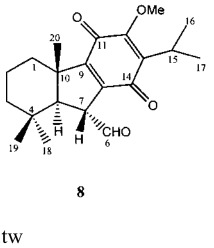


6 R_1=α–H, R_2=H, R_3=CHO
R_4+R_5=CH_2
7 R_1=β–H, R_2+R_3=O
R_4=H, R_5=Me



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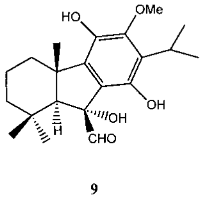

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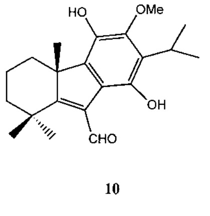

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Table 1. ^{1}H- and ^{13}C-NMR Spectral Data of Compounds **8**—**10** (300 MHz and 75 MHz in $CDCl_3$)

No.	**8**		**9**		**10**	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
1	34.3	1.50 m, 2.27 br d (12.9)	38.3	1.63 m, 2.45[a)]	32.3	1.48 m, 2.64 br d (12.8)
2	19.2	1.58 m, 1.72 m	19.8	1.62 m, 1.82 m	18.0	1.64 m, 1.90 m
3	41.0	1.18 m, 1.42 m	43.3	1.21 m, 1.40 m	42.5	1.45 m, 1.85 m
4	33.6		34.4		38.5	
5	61.4	2.03 d (11.3)	72.2	2.49 s	185.8	
6	200.5	9.80 d (4.0)	200.7	9.96 s	192.4	10.38 s
7	53.9	3.71 dd (4.0, 11.3)	90.9		119.3	
8	146.2		119.4		135.8	
9	156.3		135.5		134.9	
10	49.0		45.4		53.8	
11	181.4		138.2		136.8	
12	155.0		146.6		145.1	
13	136.9		126.9		126.2	
14	185.7		147.4		144.6	
15	24.6	3.13 sep (6.8)	26.0	3.25 sep (7.0)	26.4	3.34 sep (7.0)
16	20.0	1.15 d (6.8)	20.6	1.31 d (7.0)	20.6	1.40 d (7.0)
17	20.0	1.15 d (6.8)	20.6	1.31 d (7.0)	20.6	1.40 d (7.0)
18	34.9	0.77 s	32.4	1.00 s	35.6	1.51 s
19	21.7	1.02 s	23.5	1.01 s	23.4	1.51 s
20	20.4	1.13 s	25.3	1.47 s	29.1	1.49 s
7-O$\underline{H}$				4.23 s		
11-O$\underline{H}$				5.18 s		5.15 br s
14-O$\underline{H}$				6.26 s		10.38 s
–O$\underline{CH_3}$	61.4	3.89 s	62.1	3.73 s	62.1	3.73 s

a) Obscured by another signal.

entation between H-5 and H-7 (with a large coupling constant J=11.3 Hz). Taiwaniaquinone F (**8**) was assigned to have a (5*S*,7*R*,10*S*)-configuration because the $[\alpha]_D$ of **8** showed the same negative values as **1**.

Taiwaniaquinol C (**9**) was obtained as a yellowish amorphous solid. Its molecular formula, $C_{21}H_{30}O_5$, was determined from an $[M]^+$ ion at 362.2097 in the HR-EI-MS and indicated seven degrees of unsaturation. Analysis of the IR spectrum of **9** suggested that it contained a hydroxyl group (3363 cm^{-1}) and an aldehyde group (1712 cm^{-1}). The ^{1}H- and ^{13}C-NMR (Table 1) signals included three methyl groups [δ_H 1.00, 1.01, 1.47 (each 3H, s)], an isopropyl group [δ_H 3.25 (1H, sep, J=7.0 Hz, H-15) and 1.31 (6H, d, J=7.0 Hz, H-16, -17)], a methoxy group [δ_H 3.73 (3H, s) and δ_C 62.1], and an aldehyde group [δ_H 9.96 (1H, s, H-6) and δ_C 200.7]. The ^{1}H- and ^{13}C-NMR data (Table 1) of the A and B rings of **9** were similar to those of **3**. The skeleton of the 6–5–6 fused ring was established by means of the COSY and HMBC experiments. Six quaternary aromatic carbons suggested the presence of a benzene ring with three alkylated carbons and three oxygenated carbons discernible from the signals of one phenolic methyl group at δ 3.76 (3H, s) and two exchangeable phenolic protons at δ 5.18 and 6.26. The placements of the aldehyde and hydroxyl groups at C-7 were confirmed by the HMBC spectrum, in which the H-6 (δ_H 9.96) and 7-OH (δ_H 4.23) showed long-range correlations with C-7 (δ_C 90.9). In the NOESY spectrum, the correlation 12-OMe (δ_H 3.73)/H-16 (δ_H 1.31); δ_H 6.26(OH)/H-16 (δ_H 1.31), H-6 (δ_H 9.96) and H_3-20 (δ_H 1.47); δ_H 5.18 (OH)/H_3-20 (δ_H 1.47) supported the relative position of six substituents of the aromatic ring and β-oriented aldehyde group.

Taiwaniaquinol D (**10**) was obtained as a red-orange gum. The HR-EI-MS gave an $[M]^+$ ion at *m*/*z* 344.1989 corresponding to the molecular formula $C_{21}H_{28}O_4$ and indicated eight degrees of unsaturation. Compound **10** displayed an NMR spectrum similar to that of **4**, in which the difference was observed in signals for *para*-benzoquinone moiety in **4**. The IR spectrum exhibited a broad hydroxyl absorption band at 3377 cm^{-1} and a conjugated carbonyl at 1633 cm^{-1}. The ^{1}H-NMR (Table 1) spectrum showed three tertiary methyl groups [δ_H 1.49 (3H, s), 1.51 (6H, s)], an isopropyl group attached on aromatic [δ_H 3.34 (1H, sep, J=7.0 Hz, H-15) and 1.40 (6H, d, J=7.0 Hz, H-16, -17)], a phenolic methyl group [δ_H 3.73 (3H, s)], a lower field aldehyde group [δ_H 10.38 (1H, s, H-6)], and an H_β-1 signal [δ_H 2.64 (1H, br d, J=12.8 Hz, H-1)]. The ^{13}C-NMR (Table 1) spectrum showed 21 carbons including an aldehyde (δ_C 192.4) and a methoxyl signal (δ_C 62.1). Comparison of the NMR data among **4**, **9** and **10** as well as the molecular formula, **10** was proposed to be a dehydrated product from **9**. A distinguishable ^{13}C spectral feature of **10** from **9** was the presence of two signals for a conjugated double bond (δ_C 119.3, 185.8), which was suggested to locate between C-5 and C-7 ascribing to the presence of conjugated UV absorption and disappearance of the H-5 signal. Its structure was finally elucidated by means of HMBC and HMQC techniques. Treatment of taiwaniaquinol C (**9**) with $AlCl_3$ in CH_2Cl_2 yields a dehydration product, which was identified as taiwaniaquinol D (**10**).

Experimental

General Experimental Procedures IR spectra were recorded on a Perkin-Elmer 781 spectrophotometer. ^{1}H- and ^{13}C-NMR spectra were recorded on a Bruker AM-300 at 300 and 75 MHz in $CDCl_3$, with tetramethylsilane as an internal standard. EI-MS, FAB-MS, UV, and specific rotations were recorded on a JEOL JMS-HX 300, a JOEL JMS-HX 110, a Hitachi S-3200 spectrometer, and a JASCO DIP-180 digital polarimeter, respectively. Extracts were chromatographed on silica gel (Merck 70—230 mesh, 230—400 mesh, ASTM).

Plant Material The bark of *T. cryptomerioides* was collected in Tai-Chun, Taiwan, in 1996. The plant material was identified by Mr. Muh-Tsuen Gun, formerly a technician of the Department of Botany, National Taiwan University. A voucher specimen (no. 013542) has been deposited at the Herbarium of the Department of Botany of the National Taiwan University, Taipei, Taiwan.

Extraction and Isolation Air-dried pieces of *T. cryptomerioides* bark (12 kg) were extracted three times with acetone (60 l) at room temperature (7 d each time). The acetone extract was evaporated *in vacuo* to leave a black residue, which was suspended in H_2O (8 l), and then partitioned (3×) with 1 l of ethyl acetate. The EtOAc fraction (360 g) was chromatographed on Si gel using *n*-hexane and EtOAc of increasing polarity as eluent and further purified by HPLC eluted with *n*-hexane : EtOAc (65 : 35). Three components, taiwaniaquinone F (**8**) (12 mg), taiwaniaquinol C (**9**) (12 mg), and taiwaniaquinol D (**10**) (4 mg), as well as taiwaniaquinones A (**1**, 10 mg) and (**4**, 15 mg) were obtained in pure form.

Taiwaniaquinone F (**8**): Orange amorphous; $[\alpha]_D^{23}=-166.2°$ (c=0.29, $CHCl_3$); UV λ_{max}^{MeOH} nm ($\log \varepsilon$) 279 (3.6); IR (dry film) ν_{max} 1739, 1660, 1650, 1573, 1460, 1255, 1009, 844 cm^{-1}; ^1H- and ^{13}C-NMR, see Table 1; EI-MS (70 eV) (rel. int. %) *m/z* 344 $[M]^+$ (60), 315 (100), 247 (65), 233 (41); HR-EI-MS *m/z* 344.1986 (M^+ Calcd for $C_{21}H_{28}O_4$, 314.1988).

Taiwaniaquinol C (**9**): Yellowish amorphous; $[\alpha]_D^{23}=-10.5°$ (c=0.32, $CHCl_3$); UV λ_{max}^{MeOH} nm ($\log \varepsilon$) 205 (4.1), 293 (3.8); IR (dry film) ν_{max} 3363, 1712, 1639, 1447, 1310, 1288, 1222, 1129, 877 cm^{-1}; ^1H- and ^{13}C-NMR, see Table 1; EI-MS (70 eV) (rel. int. %) *m/z* 362 $[M]^+$ (30), 344 (100), 333 (40), 316 (37), 274 (55), 247 (63), 233 (20); HR-EI-MS *m/z* 362.2097 (M^+ Calcd for $C_{21}H_{30}O_5$, 362.2094).

Taiwaniaquinol D (**10**): Red-orange gum; $[\alpha]_D^{23}=-80.2°$ (c=0.32, $CHCl_3$); UV λ_{max}^{MeOH} nm ($\log \varepsilon$) 217 (4.1), 248 (3.5, sh), 301 (3.3); IR (dry film) ν_{max} 3377, 1633, 1446, 1427, 1348, 1268, 1195, 1029, 903 cm^{-1}; ^1H- and ^{13}C-NMR, see Table 1; EI-MS (70 eV) (rel. int. %) *m/z* 344 $[M]^+$ (100), 316 (37), 274 (55), 247 (63), 233 (20); HR-EI-MS *m/z* 344.1989 (M^+ Calcd for $C_{21}H_{28}O_4$, 344.1988).

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