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DITERPENES FROM *TAXUS MAIREI*

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Key Word Index—*Taxus mairei*; isopimaranes; abietanes; 9(10 → 20)*abeo*-abietanes; twigs.

Abstract—Eleven new diterpenes including one isopimarane, five abietanes and five 9(10 → 20)*abeo*-abietanes were isolated from the twigs of *Taxus mairei*. Their structures were determined by chemical and spectroscopic methods. © 1998 Elsevier Science Ltd. All rights reserved

INTRODUCTION

Taxus mairei is the only endemic species belonging to the genus *Taxus* found in Taiwan [1]. The chemical constituents of the plant [2–7] have been shown to contain a number of taxane-type diterpenes including the antitumor agent taxol. As the continuation of our chemical investigation on *T. mairei*, we now report other diterpenoidal constituents.

RESULTS AND DISCUSSION

A concentrated acetone extract of the twigs of *T. mairei* was taken in ethyl acetate, the soluble part was concentrated and chromatographed to give two isopimaranes (**1**–**2**), six abietanes (**3**–**8**) and seven *abeo*-abietanes (**11**–**17**). The fraction of high polarity was subjected to acetylation to give compounds **9** and **10**. By analysis of their physical and spectroscopic properties (mp, [α], IR, MS, ^{1}H and ^{13}C NMR), the known compounds were identified as sandaracopimaric acid (**1**) [8], hinokiol (**3**) [9], sugiol (**4**) [10], 3β-hydroxysugiol (**5**) [11], taxamairin A (**11**) [2] and taxamairin B (**12**) [2]. The 9(10 → 20)*abeo*-abietanes taxamairin A (**11**) and taxamairin B (**12**) have been shown to exhibit inhibitory activity against hepatoma cell [2].

The molecular formula $C_{20}H_{30}O_2$ for compound **2** was deduced from its molecular ion at *m*/*z* 302.2102 in the HR-MS spectrum. The IR absorptions at 3380, 1688 and 1630 cm^{-1} were attributable to hydroxyl, conjugated carbonyl and 1,1-disubstituted alkenyl groups, respectively. The proton and carbon resonances at δ_H 3.49 (*d*, *J* = 10.8 Hz), δ_H 3.80 (*d*, *J* = 10.8 Hz) and δ_C 64.5 corresponded to a CH_2OH group. Along with the analyses of the HMBC and HMQC spectra, the structure of **2** was assigned as 19-(hydroxy)sandaracopimara-8(14),15-dien-7-one. The structure with 13β-methyl group was deduced by analogy to that in sandaracopimaric acid (**1**), and partially supported by its chemical shift at δ_C 25.8. Accordingly [12], the chemical shift of 13β-methyl group in isopimaranes is near δ_C 26, whereas that of 13α-methyl group in pimaranes is beyond δ_C 29. Due to the deshielding effect of the carbonyl group at C-7, the protons at C-6 displayed at low fields of δ_H 2.33 (*dd*, *J* = 14.1, 18.3 Hz) and 2.56 (*dd*, *J* = 4.8, 18.3 Hz). The NOESY spectrum showed a correlation between H-20 (at δ 0.81) and one of H-19 (at δ 3.80), supporting the assigned stereochemistry.

Compound **6** showed the molecular ion at *m*/*z* 344.1980 consistent with a molecular formula $C_{21}H_{28}O_4$. The IR absorptions at 1713 and 1691 cm^{-1} were attributable, respectively, to a carbonyl group and a conjugated carbonyl group. The ^{1}H NMR spectrum exhibited an aromatic proton at δ 7.60 (*s*) and an isopropyl group appearing at δ 1.23 (*d*, *J* = 6.9 Hz) and 3.19 (*sept*, *J* = 6.9 Hz) as the characteristics of abietane-type diterpenes. The structure of **6** was determined to be 11-hydroxy-12-methoxyabieta-8,11,13-triene-3,7-dione (named taxusabietane A). Individual protons and carbons were assigned by the assistance of HMBC and HMQC spectra. The conjugated carbonyl group appearing at δ_C 197.5 was ascribed to C-7, which exerted a deshielding effect to cause the adjacent aromatic proton (H-14) to occur at a low field of δ 7.60. The C-3 carbonyl group (at δ_C 215.9) exhibited ^3J-couplings with H-18 and H-19 (at δ_H 1.15). The singlet at δ_H 3.80 was ascribed to a methoxy group on the phenyl ring. The NOESY spectrum showed

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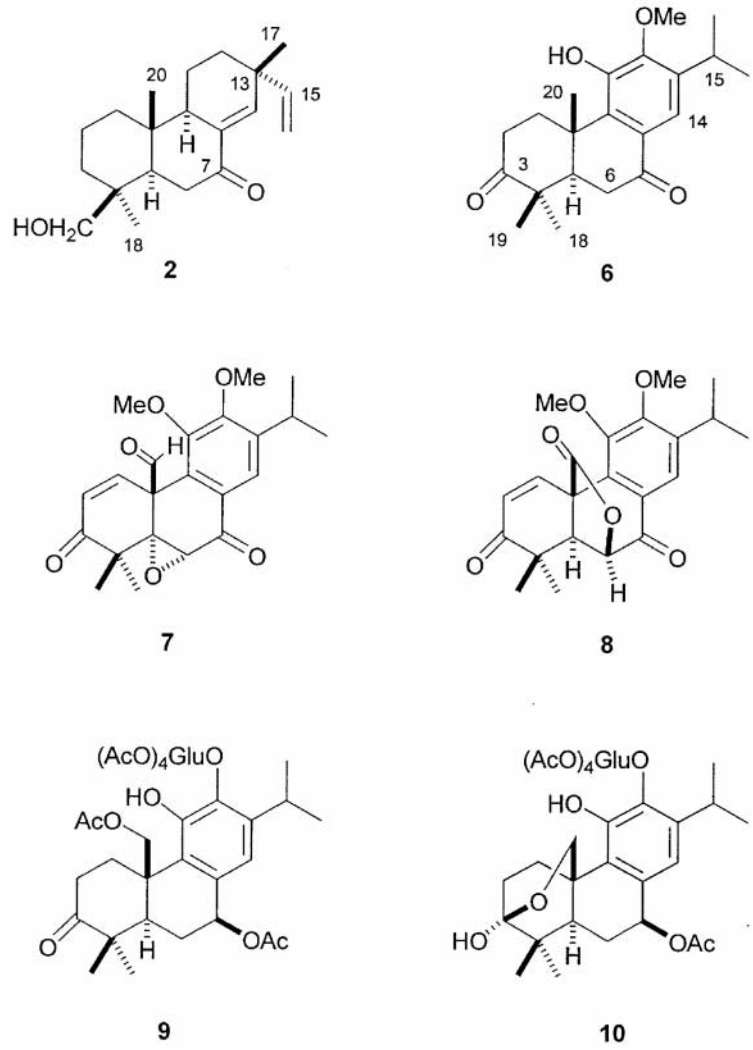
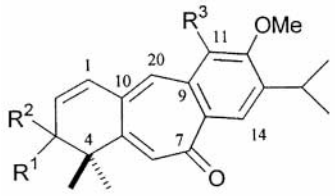


a correlation of the methoxy group at C-12 with the isopropyl group at C-13, supporting the assigned regiochemistry. Due to the deshielding effect of the C-11 hydroxyl group, H-1β occurred at a lower field of δ 3.30 than H-1α at δ 1.99.

The structure of **7** (named taxusabietane B) was determined as 11,12-dimethoxy-3,7-dioxo-5α,6α-epoxyabieta-1,8,11,13-tetraen-20-al according to the spectral analyses. The exact mass of molecular ion at m/z 384.1576 was in agreement with the molecular formula $C_{22}H_{24}O_6$. The carbon resonances at δ 200.1 (C-3), 191.6 (C-7) and 196.5 (C-20) were attributable to three carbonyl groups. One of them (C-20) belonged to an aldehyde group, which showed the characteristic proton resonance at δ 9.63 (*s*). The aromatic proton (H-14) occurred at δ 7.71 (*s*) due to the deshielding effect of the carbonyl group at C-7. According to the HMBC spectrum, two geminal methyl groups at C-4 (appearing at δ_H 0.86 and 1.16) were correlated with the carbonyl group at C-3. The H-19 signal appeared at a higher field of δ 0.86, presumably due to the shielding effect of the aldehyde group. One of the epoxy carbons (C-5 at δc 67.3) showed ^3J-correlations with H-20 (at δ 9.63) and H-1 (at δ 6.34). The other epoxy carbon (C-6) appeared at δ_C 51.5, and the corresponding carbinyl proton occurred at δ_H 4.59 (*s*). Irradiation of H-19 (at δ 0.86) caused enhancements of H-6 (7.1%) and H-20 (4.9%) signals, supporting the assigned stereochemistry.

Compound **8** also has a molecular formula $C_{22}H_{24}O_6$ according to the exact mass measurement of its molecular ion, $[M]^+$ at m/z 384.1575. The IR spectrum showed diagnostic absorptions at 1688 (conjugated C=O), 1724 (C=O) and 1788 cm^{-1} (γ-lactone). There was only a carbinyl carbon occurring at δ_C 79.0 in the ^{13}C NMR spectrum. The corresponding carbinyl proton occurred at δ_H 5.84 (*s*), indicating its attachment to a carboxyl group. By comparison of the ^1H and ^{13}C NMR spectra of **8** with those of **7**, the structure of **8** (named taxusabietane C) was assigned as 11,12-dimethoxy-6β,20-epoxy-20-oxoabieta-1,8,11,13-tetraene-3,7-dione. The assignment was also confirmed by the HMQC

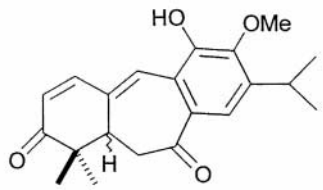


11 R^1, R^2 = O, R^3 = OH

12 R^1, R^2 = O, R^3 = OMe

13 R^1 = OH, R^2 = H, R^3 = OH

14 R^1 = OH, R^2 = H, R^3 = OMe



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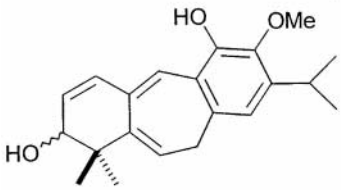

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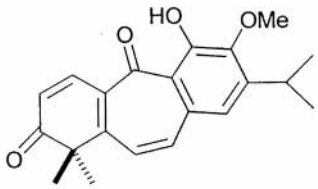

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and HMBC spectral analyses. The ^3J-correlations of H-18 (at δ_H 1.42) and H-19 (at δ_H 1.29) with C-3 (at δ_C 200.2) were also observed. An examination of the molecular model revealed that H-5 (at δ 3.23) and H-6 (at δ 5.84) are nearly orthogonal to display as two singlets in the ^{1}H NMR spectrum.

Compounds **9** and **10** were obtained from the plant extract after acetylation. It is unknown whether the original constituents in *T. mairei* exist as free alcohols or as acetates. The structure of compound **9** (named taxusabietane D) was determined as 7β,20-diacetoxy-11,12-dihydroxyabieta-8,11,13-trien-3-one 12-(2,3,4,6-*O*-tetraacetyl-β-glucopyranoside) by the analyses of its spectroscopic properties. The C-11 hydroxyl group on a phenyl ring, appearing at δ_H 7.08 (*s*), was presumably too hindered to undergo acetylation under such reaction conditions (Ac_2O, pyridine, 25°, 1 day). The β-glycoside linkage was inferred from the coupling constant of the anomeric proton at δ 4.69 (*d*, J = 8 Hz). In the NOESY spectrum, the anomeric proton exhibited correlations with the signals of 11-OH (at δ 7.08) and H-15 (at δ 3.18). An aromatic proton (H-14) occurred at a normal field of δ 6.58 differing from the down-field shifted protons in compounds **6–8** (δ 7.50–7.71). A carbonyl group appearing at δ_C 216.0 was assigned to the C-3 position as it showed correlations with H-18 (at δ 1.12) and H-19 (at δ 1.10) in the HMBC spectrum. The C-7 with an acetoxy substituent occurred at δ_C 71.8 and the axially oriented H-7 displayed at δ 5.91 as a doublet of doublets (J = 6.0, 10.0 Hz). The C-20 also contained an acetoxy substituent and the two geminal protons displayed at δ 4.08 and 4.59 as an AB pattern (J = 11.6 Hz).

The ^{13}C NMR spectrum of **10** (named taxusabietane E) was similar to that of **9**, except for the absence of carbonyl group. Instead, a resonance at δ_C 98.0 was attributable to an acetal carbon. The structure of **10** was assigned as 7β-acetoxy-3β,20-epoxy-3α,11,12-trihydroxyabieta-8,11,13-triene 12-(2,3,4,6-*O*-tetraacetyl-β-glucopyranoside). The C-11 hydroxyl group appeared at δ_H 6.93 (*s*). The anomeric proton occurred at δ 4.69 with a coupling constant of 7.8 Hz, and showed an NOE correlation with H-15 (at δ 3.18). The axially oriented H-7 appeared at δ 5.91 as a doublet of doublets (J = 4.2, 10.0 Hz). The two geminal protons at C-20 displayed at δ 3.95 (*d*) and 4.75 (*d*) with a coupling constant of 8.8 Hz. The HMBC spectrum confirmed the correlations of the acetal carbon (C-3 at δ 98.0) with H-20 (at δ 4.75) and two C-4 methyl groups (at δ 0.98 and 1.07). The exact mass measurement, showing the molecular ion at m/z 720.2923, was consistent with the structure of **10** ($C_{36}H_{48}O_{15}$).

By analyses of spectroscopic properties, compounds **13–17** (named as taxamairins D–H) were found to be 9(10 → 20)*abeo*-abietanes. Compound **13** ($C_{21}H_{24}O_4$), $[\alpha]_D^{29}$ −3.6 ($CHCl_3$, *c* 0.9), is a C-3 alcohol analog of taxamairin A (**11**). Thus, **11** was reduced with $NaBH_4/CeCl_3$ to give (±)-**13** in addition to other products. The carbinyl proton in compound **13** occurred at δ 4.33 (*d*, J = 3.3 Hz).

The characteristic resonances at low field of δ 8.11 and 8.07 were attributable to H-14 and H-20.

The structure of compound **14** ($C_{22}H_{26}O_4$) was similarly deduced to be an alcohol analog of taxamairin B (**12**). The racemic mixture of **14** was also obtained by a reduction of **12** with $NaBH_4/CeCl_3$. Compound **14** (named taxamairin E) is laevorotatory, however, its absolute configuration is unknown.

Compound **15** showed the molecular ion at *m/z* 340.1673 conforming to a molecular formula $C_{21}H_{24}O_4$. The ^{13}C NMR spectrum showed two carbonyl signals at δ_C 202.1 and 201.0, which were ascribed to C-3 and C-7. The aromatic proton (H-14) occurred at a low field of δ 7.27 due to the deshielding effect of the C-7 carbonyl group. The ^3J-correlations of C-3 (at δ 202.1) with H-18 (at δ 1.29) and H-19 (at δ 1.04) were found in the HMBC spectrum. Compound **15** (named taxamairin F) was thus determined as the 5,6-dihydro derivative of taxamairin A. The resonances of H-5 and two H-6 displayed at δ 2.92 (*d*, J = 8.6 Hz), 2.90 (*dd*, J = 8.6, 13.6 Hz) and 3.06 (*d*, J = 13.6 Hz) as an ABX pattern.

Compound **16** ($C_{21}H_{26}O_3$) exhibited an IR absorption at 3400 cm^{-1} attributable to a hydroxyl group. No carbonyl group was present. A resonance at δ_C 75.3 was ascribed to a carbinyl carbon at 3-position, which showed correlations with H-18 (at δ 1.02) and H-19 (at δ 1.07) in the HMBC spectrum. Compound **16** (named taxamairin G) was determined as the 7,7-dihydro-7-deoxo derivative of taxamairin D. Three protons at C-6 and C-7 appeared as an ABX pattern at δ 2.90 (*dd*, J = 6.9, 12.9 Hz), 2.99 (*dd*, J = 7.2, 12.9 Hz) and 5.69 (*dd*, J = 6.9, 7.2 Hz). An aromatic proton (H-14) occurred at δ 6.53 (*s*). The positions of 12-methoxy and 13-isopropyl groups were established by a correlation between MeO group (at δ_H 3.76) and H-15 (at δ 3.21) in the NOESY spectrum.

The exact mass measurement of molecular ion, $[M]^+$ at *m/z* 338.1505, led to a molecular formula $C_{21}H_{22}O_4$ for compound **17** (named taxamairin H). Two carbonyl groups were indicated by the resonances at δ_C 202.3 and 191.3. The resonance at δ_C 202.3 was ascribed to C-3 as it showed a correlation with the C-4 methyl groups at δ_H 1.49 in the HMBC spectrum. The resonance at δ_C 191.3 was assigned to C-20 as it strongly coordinated with the 11-OH group, which occurred at a very low field of δ_H 13.5. The positions of 12-methoxy and 13-isopropyl groups were similarly deduced from the NOESY spectrum as that described for **16**. The ^1H NMR spectrum displayed four olefinic protons as two sets: one set for H-1 and H-2 appearing at δ 8.10 (*d*, J = 10.2 Hz) and 6.28 (*d*, J = 10.2 Hz), and the other set for H-6 and H-7 occurring at δ 6.77 (*d*, J = 12.3 Hz) and 7.32 (*d*, J = 12.3 Hz). The structure of **17** was thus assigned.

EXPERIMENTAL

General

Yanagimoto micro melting point apparatus; Jasco Dip-180 digital polarimeter, Finnigan TSQ-46c mass spectrometer; Perkin-Elmer 983G infrared spectrophotometer; Bruker AM-300 WB nuclear magnetic resonance spectrometer; ^1H NMR: 300 MHz; ^{13}C NMR: 75 MHz; Waters M-45 high-pressure liquid chromatograph with Hibar Lichrosorb Si 60 column (10 μm or 7 μm, 25 × 1 cm i.d.) were used.

Plant material

The twigs (1.2 kg) of *T. mairei* were collected in the remote mountains at an elevation of *ca.* 2100 m (Tong-Shi, Taichung county). A voucher specimen is deposited in the Herbarium of National Taiwan University. The air-died material were exhaustively extracted with Me_2CO (7 l. × 3). The Me_2CO extract was concentrated to give 100 g of residue, which was diluted with H_2O and extracted × 3 with EtOAc. The combined EtOAc extracts were concentrated to give an oil (75 g), which was absorbed with 110 g of silica gel and then chromatographed on a column packed with 650 g of silica gel by elution with gradients of hexane and EtOAc. The components obtained from the elution of EtOAc–hexane (30–60%) were further separated by flash chromatography and HPLC with elution of EtOAc–CH_2Cl_2–hexane to give compounds **11** (0.043%, 32 mg), **12** (0.035%, 26 mg), **13** (0.008%, 6 mg), **14** (0.007%, 5 mg), **6** (0.008%, 6 mg), **15** (0.016%, 12 mg), **16** (0.005%, 4 mg), **17** (0.012%, 9 mg), **7** (0.007%, 5 mg), **8** (0.005%, 4 mg), **3** (0.016%, 12 mg), **4** (0.009%, 7 mg), **5** (0.015%, 11 mg), **2** (0.008%, 6 mg), **1** (0.019%, 14 mg) in the ascending order of polarity. The portion obtained from the elution of EtOAc was subjected to acetylation (Ac_2O, pyridine, 25°, 1 day) to give compounds **9** (0.032%, 24 mg) and **10** (0.006%, 5 mg) after separation by flash chromatography and HPLC.

*Sandaracopimaric acid (***1***)*

Needles, mp 167–169°, $[\alpha]_D^{29}$-18.5 (EtOH; *c* 1.4) {lit. [8], mp 173.5–175°, $[\alpha]_{29}^{D}$-14 (EtOH; *c* 1.1)}.

*19-(Hydroxy)sandaracopimara-8(14),15-dien-7-one (***2***)*

Gum, $[\alpha]_D^{29}$ −30 ($CHCl_3$; *c* 0.2). IR υ_{max}^{neat} cm^{-1}: 3380, 2964, 1688, 1630, 1038. ^1H NMR ($CDCl_3$, 400 MHz): δ 0.81 (*s*, H-20), 0.95 (*s*, H-18), 1.08 (*s*, H-17), 1.40–2.10 (11 H), 1.52 (*m*, H-5), 2.33 (*dd*, J = 14.1, 18.3 Hz, H-6a), 2.56 (*dd*, J = 4.8, 18.3 Hz, H-6b), 3.49 (*d*, J = 10.8 Hz, H-19a), 3.80 (*d*, J = 10.8 Hz, H-19b), 4.95 (*dd*, J = 1.4, 10.5 Hz, H-16b), 4.97 (*dd*, J = 1.4, 17.4 Hz, H-16a), 5.77 (*dd*, J = 10.5, 17.4 Hz, H-15), 6.68 (*br s*, H-14). ^{13}C

NMR ($CDCl_3$, 300 MHz): δ 14.8 (C-20), 18.3 (C-2), 19.1 (C-11), 25.8 (C-17), 26.2 (C-18), 29.6 (C-10), 34.0 (C-12), 35.4 (C-6), 37.0 (C-4), 38.0 (C-3), 38.6 (C-13), 38.9 (C-1), 50.8 (C-5), 51.2 (C-9), 64.5 (C-19), 111.8 (C-16), 134.9 (C-8), 144.4 (C-15), 146.3 (C-14), 200.0 (C-7). EI-MS (70 eV) *m/z* (rel. int.): 302 $[M]^+$ (100), 287 (20), 274 (30), 261 (20), 231 (20), 133 (70). HR-MS: $C_{20}H_{30}O_2$ requires 302.2245, found *m/z* 302.2102.

*Hinokiol (***3***)*

Needles, mp 234–236°, $[\alpha]_D^{29}+73$ ($CHCl_3$; *c* 1.1) {lit. [9], mp 234–235°, $[\alpha]_{29}^{D}+74.4$ ($CHCl_3$; *c* 1.0)}.

*Sugiol (***4***)*

Needles, mp 292–293°, $[\alpha]_D^{29}+26.0$ (EtOH; *c* 1.4) {lit. [10], mp 292–294°, $[\alpha]_{29}^{D}+26$ (EtOH; *c* 1.0)}.

*3β-Hydroxysugiol (***5***)*

Needles, mp 125–127°, $[\alpha]_D^{29}+20.2$ ($CHCl_3$; *c* 1.4) {lit. [11], mp 126–127°}.

*Taxusabietane A (***6***)*

Oil, $[\alpha]_D^{29}+90$ ($CHCl_3$; *c* 1.2). IR υ_{max}^{neat} cm^{-1}: 3425, 1713, 1691, 1593, 1314. ^1H NMR ($CDCl_3$, 300 MHz): δ 1.15 (*s*, H-18), 1.15 (*s*, H-19), 1.23 (*d*, *J* = 6.9 Hz, H-16), 1.23 (*d*, *J* = 6.9 Hz, H-17), 1.44 (*s*, H-20), 1.99 (*m*, H-1α), 2.43 (*dd*, *J* = 3.6, 13.5 Hz, H-5), 2.53 (*m*, H-6a), 2.63 (*m*, H-6b), 2.63 (*m*, H-2), 3.19 (*sept*, *J* = 6.9 Hz, H-15), 3.30 (*m*, H-1*β*), 3.80 (*s*, OMe), 7.60 (*s*, H-14), ^{13}C NMR ($CDCl_3$, 75 MHz): δ 17.6 (C-20), 20.7 (C-19), 23.4 (C-16), 23.5 (C-17), 26.7 (C-15), 26.9 (C-18), 34.4 (C-2), 35.3 (C-1), 36.1 (C-6), 38.8 (C-10), 47.0 (C-4), 49.4 (C-5), 61.9 (OMe), 117.3 (C-14), 128.2 (C-8), 135.6 (C-9), 139.8 (C-13), 146.6 (C-11), 149.3 (C-12), 197.5 (C-7), 216 (C-3). EI-MS (70 eV) *m/z* (rel. int.): 344 $[M]^+$ (100), 329 (50), 311 (10), 287 (50), 259 (30), 233 (40), 219 (20). HR-MS: $C_{21}H_{28}O_4$ requires 344.1987, found *m/z* 344.1980.

*Taxusabietane B (***7***)*

Oil, $[\alpha]_D^{29}+13$ ($CHCl_3$; *c* 0.5). IR υ_{max}^{neat} cm^{-1}: 2968, 1733, 1687, 1670, 1593. UV λ_{max}^{MeOH} nm (ε): 280 (7400), 238 (21 250). ^1H NMR ($CDCl_3$, 300 MHz): δ 0.86 (*s*, H-19), 1.16 (*s*, H-18), 1.21 (*d*, *J* = 6.9 Hz, H-16), 1.23 (*d*, *J* = 6.9 Hz, H-17), 3.31 (*sept*, *J* = 6.9 Hz, H-15), 3.95 (*s*, OMe), 3.98 (*s*, OMe), 4.59 (*s*, H-6), 6.22 (*d*, *J* = 10.0 Hz, H-2), 6.34 (*d*, *J* = 10.0 Hz, H-1), 7.71 (*s*, H-14), 9.63 (*s*, H-20). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 19.0 (C-18), 22.9 (C-16), 23.0 (C-17), 24.5 (C-19), 27.5 (C-15), 48.7 (C-4), 51.5 (C-6), 60.0 (C-10), 60.9 (OMe), 61.8 (OMe), 67.3 (C-5), 121.3 (C-14), 127.8 (C-8), 128.4 (C-9), 132.0 (C-2), 142.3 (C-1), 145.6 (C-13), 152.2 (C-11), 156.0 (C-12), 191.6 (C-7), 196.5 (C-20), 200.1 (C-3). FAB-MS (NBA) *m/z* (rel. int.): 384 $[M]^+$ (50), 339 (40), 325 (15), 235 (30), 178 (10), 154 (50), 136 (45). HR-MS: $C_{22}H_{24}O_6$ requires 384.1572, found *m/z* 384.1576.

*Taxusabietane C (***8***)*

Gum, $[\alpha]_D^{29}-8.9$ ($CHCl_3$; *c* 0.5). IR υ_{max}^{neat} cm^{-1}: 2987, 1778, 1724, 1688, 1600, 1496. UV λ_{max}^{MeOH} nm (ϵ): 277 (6471), 215 (23 111). ^1H NMR ($CDCl_3$, 400 MHz): δ 1.22 (*d*, *J* = 6.8 Hz, H-16), 1.23 (*d*, *J* = 6.8 Hz, H-17), 1.29 (*s*, H-19), 1.42 (*s*, H-18), 3.23 (*s*, H-5), 3.34 (*sept*, *J* = 6.8 Hz, H-15), 3.99 (*s*, OMe), 4.01 (*s*, OMe), 5.84 (*s*, H-6), 6.08 (*d*, *J* = 10.0 Hz, H-2), 6.25 (*d*, *J* = 10.0 Hz, H-1), 7.50 (*s*, H-14), ^{13}C NMR ($CDCl_3$, 100 MHz): δ 22.7 (C-18), 23.0 (C-16), 23.0 (C-17), 23.9 (C-19), 27.6 (C-15), 42.4 (C-4), 50.5 (C-5), 58.2 (C-10), 60.9 (OMe), 61.5 (OMe), 79.0 (C-6), 118.6 (C-14), 129.2 (C-2), 129.7 (C-8), 137.5 (C-1), 139.5 (C-9), 148.7 (C-13), 150.7 (C-11), 157.7 (C-12), 173.2 (C-20), 199.2 (C-7), 200.2 (C-3). FAB-MS (NBA) *m/z* (rel. int.): 385 $[M + 1]^+$ (52), 384 $[M]^+$ (30). HR-MS: $C_{22}H_{24}O_6$ requires 384.1572, found *m/z* 384.1575.

*Taxusabietane D (***9***)*

Gum, $[\alpha]_D^{29}+78.4$ ($CHCl_3$; *c* 3.0). IR υ_{max}^{neat} cm^{-1}: 3460, 2964, 1743, 1231, 1038. ^1H NMR ($CDCl_3$, 400 MHz): δ 1.01 (*d*, *J* = 7.2 Hz, H-17), 1.10 (*s*, H-19), 1.12 (*s*, H-18), 1.18 (*d*, *J* = 7.2 Hz, H-16), 1.87 (*m*, H-6a), 1.83–2.11 (OAc), 2.08 (*m*, H-6b), 2.23 (*m*, H-5), 2.62 (*m*, H-1), 3.18 (*sept*, *J* = 7.2 Hz, H-15), 3.66 (*m*, H-5′), 4.07 (*dd*, *J* = 5.4, 12.6 Hz, H-6a′), 4.08 (*d*, *J* = 11.6 Hz, H-20b), 4.13 (*dd*, *J* = 1.6, 12.6 Hz, H-6a′), 4.59 (*d*, *J* = 11.6 Hz, H-20a), 4.69 (*d*, *J* = 8.0 Hz, H-1′), 5.11 (*dd*, *J* = 9.6, 9.6 Hz, H-4′), 5.18 (*dd*, *J* = 9.6, 9.6 Hz, H-3′), 5.30 (*dd*, *J* = 8.0, 9.6 Hz, H-2′), 5.91 (*dd*, *J* = 6.0, 10.0 Hz, H-7), 6.58 (*s*, H-14), 7.08 (*s*, OH). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 18.4 (C-19), 20.4 (Ac), 20.5 (Ac), 20.8 (Ac), 21.3 (Ac), 22.2 (Ac), 22.4 (Ac), 23.8 (C-16), 25.2 (C-17), 25.8 (C-15), 26.3 (C-18), 28.6 (C-1), 32.0 (C-6), 34.0 (C-2), 40.1 (C-10), 46.0 (C-4), 46.4 (C-5), 61.2 (C-6′), 64.2 (C-20), 67.5 (C-4′), 71.1 (C-2′), 71.8 (C-7), 72.5 (C-5′), 72.6 (C-3′), 103.1 (C-1′), 114.9 (C-14), 127.4 (C-8), 134.2 (C-9), 140.3 (C-13), 141.2 (C-12), 147.9 (C-11), 168.8 (Ac), 169.1 (Ac), 170.0 (Ac), 170.1 (Ac), 170.4 (Ac), 170.8 (Ac), 216.0 (C-3). FAB-MS (NBA) *m/z* (rel. int.): 785 $[M + Na]^+$ (4), 725 (2). HR-MS: $C_{38}H_{50}O_{16}$ requires 762.3098, found *m/z* 762.3059.

*Taxusabietane E (***10***)*

Gum, $[\alpha]_D^{29}+24.8$ ($CHCl_3$; *c* 0.7). IR υ_{max}^{neat} cm^{-1}: 3472, 2963, 1754, 1220, 1040. ^1H NMR ($CDCl_3$, 400 MHz): δ 0.98 (*s*, H-19), 1.04 (*d*, *J* = 6.8 Hz, H-17), 1.07 (*s*, H-18), 1.21 (*d*, *J* = 6.9 Hz, H-16), 1.35 (*m*, H-6a), 1.64 (*m*, H-1α), 1.74 (*m*, H-5), 1.80 (*m*, H-2a), 2.01 (2 Ac), 2.08 (2 Ac), 2.21 (Ac), 2.10 (*m*, H-1*β*), 2.27 (*m*, H-2b), 3.18 (*sept*, *J* = 6.8 Hz, H-15), 3.31 (*m*, H-6b), 3.66 (*m*, H-5′), 3.95 (*d*,

J = 8.8 Hz, H-20a), 4.03 (*dd*, J = 5.4, 12.6 Hz, H-6a′), 4.19 (*dd*, J = 1.6, 12.6 Hz, H-6a′), 4.69 (*d*, J = 7.8 Hz, H-1′), 4.75 (*d*, J = 8.8 Hz, H-20b), 5.12 (*dd*, J = 9.3, 9.6 Hz, H-4′), 5.22 (*dd*, J = 9.0, 9.3Hz, H-3′), 5.34 (*dd*, J = 7.8, 9.0 Hz, H-2′), 5.85 (*dd*, J = 4.2, 10.0 Hz, H-7), 6.61 (*s*, H-14), 6.93 (*s*, OH). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 18.1 (C-19), 20.4 (Ac), 20.5 (Ac), 20.7 (Ac), 21.2 (Ac), 22.3 (C-17), 22.8 (Ac), 23.8 (C-16), 25.8 (C-15), 26.4 (C-1), 26.8 (C-18), 29.0 (C-2), 29.6 (C-6), 37.1 (C-4), 40.5 (C-10), 46.5 (C-5), 61.5 (C-6′), 66.3 (C-20), 67.6 (C-4′), 71.1 (C-2′), 72.1 (C-7), 72.5 (C-5′), 72.6 (C-3′), 98.0 (C-3), 103.2 (C-1′), 114.0 (C-14), 123.7 (C-8), 135.4 (C-9), 139.8 (C-13), 140.9 (C-12), 148.5 (C-11), 168.4 (Ac), 169.2 (Ac), 170.1 (Ac), 170.4 (Ac), 170.8(Ac). FAB-MS (NBA) m/z (rel. int.): 743 $[M + Na]^+$ (4), 683 (2). HR-MS: $C_{36}H_{48}O_{15}$ requires 720.2993, found m/z 720.2923.

Taxamairin A (**11**)

Yellow needles, mp 223–224°, {lit. [2], mp 223–224° (from EtOH)}.

Taxamairin B (**12**) *[2]*

Yellow needles, mp 246–247°.

Taxamairin D (**13**)

Yellow gum, $[\alpha]_D^{29}$ −3.6 ($CHCl_3$; c 0.9). IR υ_{max}^{neat} cm^{-1}: 3423, 2960, 1670. ^{1}H NMR (pyridine-d_5, 300 MHz): δ 1.25 (*d*, J = 6.9 Hz, H-16), 1.27 (*d*, J = 6.9 Hz, H-17), 1.35 (*s*, H-18), 1.47 (*s*, H-19), 3.42 (*sept*, J = 6.9 Hz, H-15), 3.77 (OMe), 4.33 (*d*, J = 3.3 Hz, H-3), 6.19 (*dd*, J = 3.3, 9.6 Hz, H-2), 6.49 (*d*, J = 9.6 Hz, H-1), 7.19 (*s*, H-6), 8.07 (*s*, H-20), 8.11 (*s*, H-14). EI-MS (70 eV) m/z (rel. int.): 340 $[M]^+$ (10), 322 (5), 307 (70), 289 (50), 273 (20), 154 (100). HR-MS: $C_{21}H_{24}O_4$ requires 340.1674, found m/z 340.1604.

Taxamairin A (28 mg) in EtOH (95%, 5 mL) was treated with $CeCl_3$ (*ca.* 3 mg) and $NaBH_4$ (25 mg) at 25°C for 10 min to yield a violet mixture. Complete consumption of taxamairin A was shown by TLC analysis. The reaction was quenched by addition of aqueous HCl (1 *N*). The mixture was extracted with EtOAc, and separated by HPLC with elution of CH_2Cl_2–EtOAc–hexane = (3:1:3) to give taxamairin D (3.5 mg, 12% yield), the 7-hydroxy analog (3.0 mg, 10% yield) and other unidentified products.

The *abeo*-abietane numbering system is used for the above assignments, although the IUPAC nomenclature for taxamairin D is 2,6-dihydroxy-1,1-dimethyl-8-isopropyl-7-methoxy-1*H*-dibenzo[*a*,*d*]-cyclohepten-10-one.

Taxamairin E (**14**)

Yellow gum, $[\alpha]_D^{29}$ −4.5 ($CHCl_3$; c 0.9). IR υ_{max}^{neat} cm^{-1}: 3420, 2961, 1670. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 1.12 (*s*, H-18), 1.22 (*d*, J = 6.9 Hz, H-16), 1.24 (*d*, J = 6.9 Hz, H-17), 1.32 (*s*, H-19), 3.34 (*sept*, J = 6.9 Hz, H-15), 3.89 (*s*, OMe), 3.93 (*s*, OMe), 4.02 (*d*, J = 4.2 Hz, H-3), 6.01 (*dd*, J = 4.2, 10.0 Hz, H-2), 6.40 (*d*, J = 10.0 Hz, H-1), 6.81 (*s*, H-6), 7.45 (*s*, H-20), 7.83 (*s*, H-14). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 22.8, 23.0, 23.0, 26.5, 27.7, 42.7, 60.6, 61.0, 74.2, 122.7, 127.8, 128.3, 129.7, 130.6, 131.2, 132.8, 133.0, 135.5, 145.8, 150.6, 153.7, 189.4. EI-MS (70 eV) m/z (rel. int.): 354 $[M]^+$ (100), 339 (10), 326 (50), 311 (70), 295 (20), 283 (98). HR-MS: $C_{22}H_{26}O_4$ requires 354.1831, found m/z 354.1838.

Taxamairin B (24 mg) was reduced by $NaBH_4$/$CeCl_3$, according to the above described procedure, to give taxamairin E (3.7 mg, 15% yield), the 7-hydroxy analog (2.5 mg, 10% yield), the 3,7-dihydroxy derivative (2.3 mg, 9% yield) and other unidentified products.

The *abeo*-abietane numbering system is used for the above assignments, although the IUPAC nomenclature for taxamairin E is 6,7-dimethoxy-1,1-dimethyl-2-hydroxy-8-isopropyl-1*H*-dibenzo[*a*,*d*]-cyclohepten-10-one.

Taxamairin F (**15**)

Yellow gum, $[\alpha]_D^{29}$ +17.2 ($CHCl_3$; c 1.2). IR υ_{max}^{neat} cm^{-1}: 3317, 2962, 1669. UV λ_{max}^{MeOH} nm (ε): 378 (16 485), 269 (18 560), 236 (18 740). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 1.04 (*s*, H-19), 1.21 (*d*, J = 6.8, H-16), 1.23 (*d*, J = 6.8 Hz, H-17), 1.29 (*s*, H-18), 2.90 (*dd*, J = 8.6, 13.6 Hz, H-6b), 2.92 (*d*, J = 8.6 Hz, H-5), 3.06 (*d*, J = 13.6 Hz, H-6a), 3.21 (*sept*, J = 6.8 Hz, H-15), 3.83 (*s*, OMe), 5.94 (*d*, J = 10.0 Hz, H-2), 7.14 (*d*, J = 10.0 Hz, H-1), 7.24 (*s*, H-20), 7.27 (*s*, H-14). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 21.2 (C-19), 23.2 (C-17), 23.3 (C-16), 23.5 (C-18), 27.0 (C-15), 43.2 (C-6), 43.8 (C-5), 45.6 (C-4), 62.0 (OMe), 118.6 (C-14), 119.4 (C-9), 124.5 (C-2), 129.8 (C-20), 135.0 (C-8), 137.7 (C-10), 142.4 (C-13), 147.4 (C-11), 147.6 (C-12), 147.8 (C-1), 201.0 (C-7), 202.1 (C-3). EI-MS (70 eV) m/z (rel. int.): 340 $[M]^+$ (40), 281 (10), 219 (5), 165 (10), 136 (25), 55 (40). HR-MS: $C_{21}H_{24}O_4$ requires 340.1674, found m/z 340.1673.

The *abeo*-abietane numbering system is used for the above assignments, although the IUPAC nomenclature for taxamairin F is 11,11a-dihydro-1,1-dimethyl-6-hydroxy-8-isopropyl-7-methoxy-1*H*-dibenzo[*a*, *d*]cycloheptene-2,10-dione.

Taxamairin G (**16**)

Yellow gum, $[\alpha]_D^{29}$ +5.3 ($CHCl_3$; c 0.4). IR υ_{max}^{neat} cm^{-1}: 3400, 2960, 1600, 1500, 1390. UV λ_{max}^{MeOH} nm (ε): 305 (12 141), 260 (11 666), 211 (19 333). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 1.02 (*s*, H-18), 1.07 (*s*, H-19), 1.22 (*d*, J = 6.9 Hz, H-16), 1.24 (*d*, J = 6.9 Hz, H-17), 2.90 (*dd*, J = 6.9, 12.9 Hz, H-7a), 2.99 (*dd*, J = 7.2, 12.9 Hz, H-7b), 3.21 (*sept*, J = 6.9 Hz, H-15), 3.83 (*d*, J = 4.2 Hz, H-3), 5.69 (*dd*, J = 6.9, 7.2 Hz, H-6), 5.78 (*dd*, J = 4.2,

9.6 Hz, H-2), 6.34 (*d*, J = 9.6 Hz, H-1), 6.53 (*s*, H-14), 7.08 (*s*, H-20). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 21.9 (C-19), 23.5 (C-16), 23.7 (C-17), 25.8 (C-18), 26.7 (C-15), 33.9 (C-7), 41.0 (C-4), 61.8 (OMe), 75.3 (C-3), 115.6 (C-14), 121.0 (C-9), 122.6 (C-6), 126.3 (C-20), 128.0 (C-2), 132.9 (C-1), 135.3 (C-8), 136.1 (C-13), 137.7 (C-10), 141.5 (C-11), 141.8 (C-12), 145.9 (C-5). EI-MS (70 eV) m/z (rel. int.): 326 $[M]^+$ (40), 309 (50), 289 (20), 267 (5), 154 (100), 136 (70). HR-MS: $C_{21}H_{26}O_3$ requires 326.1881, found m/z 326.1886.

The *abeo*-abietane numbering system is used for the above assignments, although the IUPAC nomenclature for taxamairin G is 2,6-dihydroxy-1,1-dimethyl-8-isopropyl-7-methoxy-1*H*-dibenzo[*a*,*d*]-cycloheptene.

*Taxamairin H (***17***)*

Yellow gum, IR υ_{max}^{neat} cm^{-1}: 3470, 2962, 1663, 1624, 1334, 1261. UV λ_{max}^{MeOH} nm (ε): 478 (11 120), 349 (12 838), 267 (21 348), 206 (23 074). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 1.25 (*d*, J = 6.9 Hz, H-16), 1.25 (*d*, J = 6.9 Hz, H-17), 1.47 (*s*, H-18), 1.47 (*s*, H-19), 3.43 (*sept*, J = 6.9 Hz, H-15), 6.28 (*d*, J = 10.2 Hz, H-2), 6.77 (*d*, J = 12.3 Hz, H-6), 7.02 (*s*, H-14), 7.32 (*d*, J = 12.3 Hz, H-7), 8.10 (*d*, J = 10.2 Hz, H-1). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 22.8 (C-16), 22.8 (C-17), 26.5 (C-18), 26.5 (C-19), 27.5 (C-15), 49.6 (C-4), 60.5 (OMe), 121.6 (C-14), 122.9 (C-9), 124.5 (C-6), 124.8 (C-2), 131.9 (C-10), 135.3 (C-8), 136.1 (C-13), 140.1 (C-7), 142.4 (C-1), 147.2 (C-12), 148.7 (C-11), 158.1 (C-5), 191.3 (C-20), 202.3 (C-3). EI-MS (70 eV) m/z (rel. int.): 338 $[M]^+$ (50), 307 (45), 289 (20), 267 (5), 154 (100), 136 (70). HR-MS: $C_{21}H_{22}O_4$ requires 338.1518, found m/z 326.1505.

The *abeo*-abietane numbering system is used for the above assignments, although the IUPAC nomenclature for taxamairin H is 1,1-dimethyl-6-hydroxy-8-isopropyl-7-methoxydibenzo[*a*, *d*]cyclo-heptene-2,5-dione.

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