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TAXANES FROM THE ROOTS OF *TAXUS MAIREI*

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Key Word Index—*Taxus mairei*; Taxaceae; taxane diterpenoids; taxumairols C, D and E.

Abstract—Extensive column chromatography of the ethanolic extracts from the roots of *Taxus mairei* and subsequent purification of taxanes by HPLC gave two derivatives of baccatin I and one derivative of taxchin. The structural assignments of the taxoids were based on their spectral data, including 2D NMR experiments and chemical correlation. X-ray crystallographic analysis of 1β-hydroxybaccatin I provided unambiguous characterization for the structures and relative stereochemistries of the other taxanes. Copyright © 1997 Elsevier Science Ltd

INTRODUCTION

The antitumour agent paclitaxel (Taxol), which was first found in the bark of *Taxus brevifolia*, is one of the most important drugs in cancer chemotherapy [1, 2]. Because the supply of the drug is limited, biotechnological approaches such as different types of cell cultures and various synthetic methods for the production of paclitaxel are becoming more urgent [3–7]. On the other hand, very few biosynthetic studies have been described and the mode of regulation of taxol metabolism remains unknown [8]. Taiwan yew is an evergreen shrub growing at medium to high altitudes in northern and central parts of Taiwan [9]. This plant was developed for sculptural materials and ornamental purposes. The diterpenoids in the barks and heartwoods of *T. mairei* have been extensively investigated in the past decade [10–15]. The roots of *T. mairei* have been used in Chinese folk medicine for treatment of diabetes [16]. Previous studies on the bioactive diterpenes in the roots of this species have resulted in the isolation of taxumairols A (**6**) and B (**3**) and an additional nine known taxoids [17, 18]. As part of our continuing study on the constituents of *T. mairei*, we report herein the isolation and structural elucidation of five taxane diterpenes from the roots of this plant. Three of the five compounds isolated have not been reported before. The new compounds are 2α, 5α, 13α-triacetoxy-1β, 7β, 9α, 10β-tetrahydroxy-4β, 20-epoxytax-11-ene, 2α, 5α, 7β, 9α, 13α-penta-acetoxy-1β,10β-dihydroxy-4β, 20-epoxytax-11-ene and 5α, 7β, 9α, 10β, 13α-penta-acetoxy-2α, 20-dihydroxytax-11-ene, named taxumairols C (**1**), D (**2**) and E (**5**), respectively. Known compounds are baccatin III (**8**) and taxumairol B (**3**).

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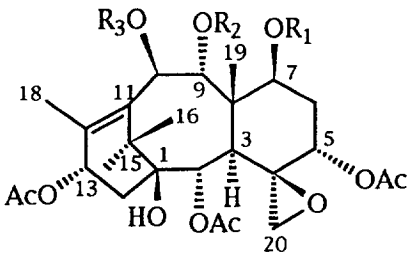
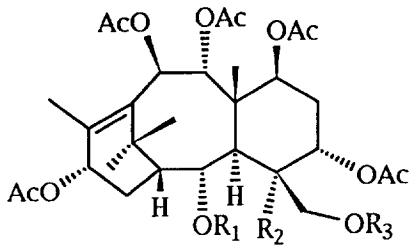
RESULTS AND DISCUSSION

The extract of *T. mairei* roots gave five compounds **1**–**3**, **5** and **8**. Their structures were established as follows.

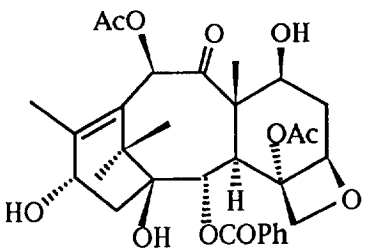
Compound **1**, $[\alpha]_D+78^\circ$ (chloroform), had the composition $C_{26}H_{38}O_{11}$ as derived from EI mass and ^{13}C NMR spectral data. Its UV and IR bands indicated the presence of hydroxyl (3472 cm^{-1}) and acetyl (226 nm, 1730 cm^{-1}) groups. The presence of three acetyl and four hydroxyl groups was verified by the observation of ^1H and ^{13}C NMR spectral data (Tables 1 and 2). As in **3**, the characteristic resonances of four methyl singlets (δ 1.30, 1.39, 1.59 and 2.00) indicated that **1** is a taxane. The proton connectivities were established by the COSY spectrum. A pair of doublets at δ 2.31 (J = 5.1 Hz) and 3.49 (J = 5.1 Hz) accounted for the C-20 methylene protons of the epoxide ring. The isolated spin system comprised two doublets at δ 4.41 (H-9) and 4.97 (H-10) (J = 10 Hz) indicative of a *trans*-oriented configuration [2, 19]. A comparison of the ^1H and ^{13}C NMR spectra of **1** with those of **3** indicated that the two compounds are closely related, but differ at C-10. Further, the spectra of **1** displayed only three acetate signals. Compound **2** had five acetyl (δ 2.19, 2.11, 2.10, 2.08 and 2.03) and four methyl (δ 2.06, 1.67, 1.29 and 1.22) groups, and a pair of doublets (δ 3.54 and 2.29, J = 5.4 Hz), indicating a close analogue (Table 1). However, the proton signals of H-7 and H-9 were observed at δ 5.41 and 5.91, respec-



1, R_1= R_2= R_3= H
2, R_1= R_2= Ac, R_3= H
3, R_1= R_2= H, R_3= Ac
4, R_1= R_2= R_3= Ac



5, R_1= R_2= R_3= H
6, R_1= H, R_2= OH, R_3= COC_6H_5
7, R_1= R_3= Ac, R_2 = H



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tively, suggesting that the acetyl groups were located at C-7 and C-9, in addition to those on the C-2, C-5 and C-13 positions. An HMBC study revealed that correlation of the H-10 at δ 5.18 with those of C-11 and C-12 carbons (δ 139.3 and 137.2) unambiguously confirmed the location of the hydroxyl group at C-10. Other correlations were also in agreement with the structure **2**. The stereochemistry of **1** and **2** was assigned by comparison of the observed chemical shifts and coupling constants with those of **3**, and chemical correlation with a known compound. Because the magnetic anisotropy of the oxirane ring causes H-5 to resonate at 4.2 ppm, some compounds were originally assigned a wrong pattern, with a free hydroxyl at C-5 and the C-1 hydroxyl acetylated [10, 20].

To confirm the structures of **1**–**3**, they were acetylated to give a triacetate, a monoacetate and a diacetate, respectively, the spectral data for which corresponded to those described for 1β-hydroxybaccatin I (**4**). Compound **4** was also isolated as one of the components of the roots as mentioned before [18]. An ORTEP stereo drawing of **4** (Fig. 1) from X-ray crystallographic analysis established the complete structure and stereochemistry of **4**, and thus confirmed unequivocally the structures of **1**–**3**. The compound **4** molecule interaction, which stabilizes the structure in the solid state, as shown in the stereo drawing of the mode of packing, is illustrated in Fig. 2. It is worth noting that the occurrence of C-1 hydroxyl/C-5 acetoxyl and the relative configuration at each chiral carbon in **1**–**3** are the same as those reported for 1β-hydroxybaccatin I [21]. Thus, the structures of taxumairols C (**1**) and D (**2**) were elucidated as 7β, 9α, 10β-trideacetyl-1β-hydroxybaccatin I and 10β-deacetyl-1β-hydroxybaccatin I, respectively.

Compound **5**, $[\alpha]_D$ +54.9°, had the composition $C_{30}H_{44}O_{12}$ as determined by a combination of EI mass and DEPT spectroscopies. Its UV and IR bands indicated the presence of hydroxyl (3468 cm^{-1}) and acetyl (225 nm, 1740 cm^{-1}) groups. This was also supported by fragment ions at m/z 518 $[M-HOAc-H_2O]^+$, 476 $[M\text{-}2HOAc-H_2O]^+$ 416, 356 and 296 in the EI mass spectrum of **5**. Detailed analysis of the ^1H and ^{13}C NMR spectra (Tables 1 and 2) revealed that **5** was a 6/8/6 taxene with an opened oxetane ring. A COSY experiment established the relationships of H-2/H-3/H-4/H-20, the locations of hydroxyls at C-2 and C-20, and the assignment of the acetyl moieties at C-5, C-7, C-9, C-10 and C-13. Spectral (^{13}C NMR) comparison of **5** with that of taxchin A revealed that they are very similar except for signals of C-2, C-4 and C-20. Compound **5** had signals at δ 71.3 (C-2), 46.8 (C-4) and 65.0 (C-20) while taxchin A showed corresponding carbon data at δ 68.6, 42.0 and 66.8 [22–24]. On acetylation, **5** yielded a diacetate (**7**), which exhibited a fragment ion at m/z 620 $[M-HOAc]^+$ in the EI mass spectrum. Additionally, the H-2 and H-20 signals in the ^1H NMR spectrum of **7** were shifted downfield to δ 5.39 and 3.74/4.03. Close comparison the spectral data with those of taxchin B also confirmed the assigned structure of **5** [24, 25].

The stereochemistry of **5** was determined on the basis of extensive NOE experiments and comparison of the observed coupling constants with those of taxchins A, B and **6**. Irradiation of Me-19 at δ 0.93 enhanced the intensity of H-5, H-9, H-20a and H-20b by 2.8, 3.7, 4.5 and 3.3%, respectively, determining the orientation of H-5, H-9, Me-19 and the C-20 methylene as β. Irradiation of Me-16 at δ 1.68 caused not only the enhancement of Me-17 (2.3%), but also the increase of H-9 (3.6%) and H-2 (1.9%), suggesting H-

Table 1. ^{1}H NMR ($CDCl_3$, 300 MHz)* spectral data for compounds **1**–**3** and **5**

H	1	2	3	5
1				2.00 (*m*)
2	5.36 (*d*, 3.3)	5.45 (*d*, 4.2)	5.33 (*d*, 3.3)	4.28 (*d*, 3.9)
3	3.07 (*d*, 3.3)	3.19 (*d*, 3.0)	3.08 (*d*, 3.9)	2.58 (*m*)
4				2.00 (*m*)
5	4.21 (*br s*)	4.19 (*br s*)	4.21 (*br s*)	5.05 (*m*)
6	2.05 (*m*)	2.15 (*m*)		2.00 (*m*)
	1.83 (*m*)	1.70 (*m*)		1.70 (*m*)
7	4.21 (*m*)	5.41 (*dd*, 12.3, 4.2)	4.21 (*dd*, 11.7, 5.1)	5.37 (*dd*, 10.8, 6.0)
9	4.41 (*d*, 10)	5.91 (*d*, 11)	4.58 (*d*, 10.3)	5.77 (*d*, 11)
10	4.97 (*d*, 10)	5.18 (*d*, 11)	6.05 (*d*, 10.3)	6.16 (*d*, 11)
13	6.08 (*m*)	6.08 (*m*)	6.06 (*m*)	5.94 (*dd*, 7.8, 8.4)
14α	1.83 (*m*)	1.85 (*m*)		1.60 (*m*)
14β	2.52 (*m*)	2.52 (*m*)	2.52 (*m*)	2.59 (*m*)
16	1.59 (*s*)	1.67 (*s*)	1.53 (*s*)	1.68 (*s*)
17	1.30 (*s*)	1.29 (*s*)	1.24 (*s*)	1.16 (*s*)
18	2.00 (*s*)	2.06 (*s*)	2.18 (*s*)	2.20 (*s*)
19	1.39 (*s*)	1.22 (*s*)	1.39 (*s*)	0.93 (*s*)
20	3.49 (*d*, 5.1)	3.54 (*d*, 5.4)	3.48 (*d*, 5.4)	3.99 (*dd*, 10.5, 2.1)
	2.31 (*d*, 5.1)	2.29 (*d*, 5.4)	2.33 (*d*, 5.4)	3.30 (*m*)
OAc	2.10 (*s*)	2.11 (*s*)	2.14 (*s*)	2.11 (*s*)
OAc	2.06 (*s*)	2.10 (*s*)	2.10 (*s*)	2.04 (*s*)
OAc	2.18 (*s*)	2.08 (*s*)	2.06 (*s*)	2.02 (*s*)
OAc		2.03 (*s*)	2.19 (*s*)	1.96 (*s*)
OAc		2.19 (*s*)		2.21 (*s*)

*δ in ppm (J in Hz); TMS as internal standard.

2 to be in the β-orientation. The close spatial relationship between H-3, H-7 and H-10 was observed by irradiation of H-7 at δ 5.37. The results (3.6 and 4.6% increases for H-3 and H-10, respectively) established that H-3, Me-17 and H-10 all have an α-orientation. Thus, the structure of **5** was elucidated as 5α, 7β, 9α, 10β, 13α-penta-acetoxy-2α, 20-dihydroxytax-11-ene. A proposed model in agreement with the results of NOE studies is given in Fig. 3.

In summary, **1**, **2** and **5** are new taxane diterpenes. Compound **5** is a new example of a taxoid oxygenated at C-20, but lacking a D-ring and a hydroxyl group at C-4. It might be a precursor of **6**, previously isolated from the roots of *T. mairei* [17]. Compounds of this type have been proposed as intermediates in the biosynthesis of **8** and paclitaxel [23].

EXPERIMENTAL

General. Optical rotations: Jasco DIP-1000 polarimeter. IR and UV spectra: Hitachi T-2001 and on V-3210 spectrophotometers, respectively. EIMS and FABMS: VG Quattro 5022 mass spectrometer. X-ray data: Rigaku AFC6S diffractometer. The ^{1}H, COSY, DEPT, ^{13}C NMR and NOE spectra: Varian FT-300 and FT-400 spectrometers. HMBC spectra: Bruker 300-AC spectrometer. Chemical shifts are given in δ (ppm) and coupling constants in Hz. Sephadex LH-20, silica gel 60 and RP-C18 were used for CC and HPLC, and pre-coated silica gel plates (Kieselgel 60 F_{254}, 1 mm) for prep. TLC.

Plant materials. Roots of *T. mairei* were purchased in Kaohsiung, Taiwan, 1993. A voucher specimen was deposited in the Institute of Marine Resources, National Sun Yat-sen University, Kaohsiung, Taiwan.

Extraction and isolation. Dried roots (60 kg) were ground and repeatedly extracted with EtOH (200 l) at room temp. The combined extracts were concd to a brown tar, to which was added a mixt. of MeOH (10 l) and H_2O (10 l) and stirred overnight. The MeOH–H_2O soluble fr. was extracted exhaustively with $CHCl_3$ (20 l). The lower layer ($CHCl_3$–MeOH) was concd *in vacuo* to give a residue (1.5 kg). Part of the residue (200 g) was applied to a Sephadex LH-20 column (1 kg) and eluted with MeOH to afford a taxoids-containing fr. (85 g). The taxoid fr. was subjected to CC on silica gel (850 g) and eluted with a mixt. of $CHCl_3$–Me_2CO by increasing polarity to provide 7 frs. Fr. E (11.8 g) was rechromatographed on silica gel and eluted with $CHCl_3$–*n*-hexane–MeOH according to the following ratios and vols (10:10:1, 9:9:1, 8:8:1, 7:7:1, 6:6:1 and 5:5:1, each 1 l) to yield a residue (4.4 g). Sepn of this residue by reverse phase C-18 open-column chromatography (100 g) using mixts of MeOH–H_2O of decreasing polarity (7:3, 7:4, 7:5, 7:6 and 1:1, each 300 ml) to give 7 frs: a (235 mg), b (175 mg), c (85 mg), d (420 mg), e (165 mg), f (500 mg) and g (210 mg). Fr. b was sepd by a LH-20 column and eluted with *n*-hexane–$CHCl_3$–MeOH (1:1:2) to provide **3** (115 mg) and a fr. which was purified by prep. TLC (silica gel) developed with *n*-hexane–$CHCl_3$–

Table 2. ^{13}C NMR ($CDCl_3$, 75 MHz)* spectral data for compounds **1**–**3** and **5**

C	1	2	3	5
1	76.2 *s*	76.2 *s*	76.0 *s*	51.7 *d*
2	71.3 *d*	72.4 *d*	71.2 *d*	71.3 *d*
3	40.3 *d*	41.2 *d*	40.2 *d*	40.7 *d*
4	58.3 *s*	58.2 *s*	58.4 *s*	46.8 *d*
5	78.2 *d*	77.2 *d*	78.2 *d*	70.0 *d*
6	33.2 *t*	31.2 *t*	33.1 *t*	30.0 *t*
7	70.1 *d*	68.9 *d*	69.6 *d*	69.1 *d*
8	45.9 *s*	46.7 *s*	46.5 *s*	45.7 *s*
9	76.9 *d*	77.8 *d*	78.3 *d*	75.8 *d*
10	71.0 *d*	68.7 *d*	74.0 *d*	71.7 *d*
11	139.5 *s*	139.3 *s*	136.2 *s*	133.3 *s*
12	137.2 *s*	137.2 *s*	140.1 *s*	137.6 *s*
13	72.7 *d*	71.3 *d*	72.6 *d*	70.6 *d*
14	38.5 *t*	38.5 *t*	38.6 *t*	27.6 *t*
15	43.5 *s*	43.4 *s*	43.4 *s*	37.8 *s*
16	21.8 *q*	21.8 *q*	21.7 *q*	27.3 *q*
17	15.7 *q*	15.4 *q*	15.5 *q*	31.8 *q*
18	28.8 *q*	28.7 *q*	28.4 *q*	14.9 *q*
19	13.4 *q*	13.7 *q*	13.5 *q*	14.2 *q*
20	49.8 *t*	50.0 *t*	49.9 *t*	65.0 *t*
OAc	169.9 *s*	169.4 *s*	169.9 *s*	169.7 *s*
	21.4 *q*	21.5 *q*	21.4 *q*	21.4 *q*
OAc	169.1 *s*	169.2 *s*	169.8 *s*	169.1 *s*
	21.0 *q*	20.9 *q*	21.2 *q*	20.9 *q*
OAc	170.1 *s*	170.1 *s*	169.2 *s*	170.0 *s*
	21.7 *q*	20.9 *q*	20.9 *q*	20.8 *q*
OAc		170.3 *s*	170.1 *s*	170.4 *s*
		21.7 *q*	22.1 *q*	21.5 *q*
OAc		170.4 *s*		170.4 *s*
		21.7 *q*		21.7 *q*

*s = C, d = CH, t = CH_2, q = CH_3. Multiplicities and assignments made by the DEPT and HMBC techniques.

MeOH (5:4:1) to give **1** (3 mg). Fr. d was subjected to CC on LH-20 (*n*-hexane–$CHCl_3$–MeOH, 1:1:2 and 1:1:1) to give fr. d-1b (100 mg). Sepn of fr. d-1b by HPLC (silica gel) using *n*-hexane–$CHCl_3$–MeOH (5:5:1) to afford **2** (40 mg). A mixt. of **5** and **8** were isolated from fr. e by using a LH-20 column (MeOH) to give 2 frs: e1 (80 mg) and e2 (52 mg). Fr. e1 was methylated with CH_2N_2, freshly prepd from diazald (N-methyl-N-nitroso-P-toluene sulphonamide), 1g, to give a residue which was purified by HPLC (silica gel, *n*-hexane–$CHCl_3$–MeOH, 5:5:1) to yield **5** (29 mg). Fr. e2 was also methylated with CH_2N_2 to provide a residue which was further purified by prep. TLC (silica gel, *n*-hexane–$CHCl_3$–MeOH, 5:5:1) to furnish **8** (18 mg). Compound **8** showed identical spectral data (^1H NMR, ^{13}C NMR, EIMS and [α]) to those reported for baccatin III [21, 26].

Taxumairol C (**1**). Isolated as amorphous powder: $[\alpha]_D^{25}+78^\circ$ ($CHCl_3$, *c* 0.2); IR υ_{max}^{neat} cm^{-1}: 3472, 3404, 3016, 1730, 1656, 1636, 1444, 1374, 1248, 1036, 758; UV λ_{max}^{MeOH} nm (log ε): 226 (3.8). ^1H and ^{13}C NMR ($CDCl_3$) spectral data: Tables 1 and 2, respectively. EIMS *m/z* (rel. int.): 466 (0.1), 448 (0.2), 406 (0.4), 388 (1.0), 373 (1.0), 241 (2.0), 211 (2.1), 149 (34), 105 (19), 91 (15), 55 (15), 43 (100).

Acetylation of taxumairol C (**1**). Acetylation (Ac_2O–pyridine; 1:1; room temp.) of **1** (1.5 mg) gave a product which showed identical ^1H NMR data and R_f values with those of 1β-hydroxybaccatin I (**4**).

Taxumairol D (**2**). Isolated as amorphous powder, $[\alpha]_D^{25}+75^\circ$ ($CHCl_3$, *c* 0.26); UV λ_{max}^{MeOH} (log ε) nm: 226 (3.7). ^1H and ^{13}C NMR ($CDCl_3$) spectral data: Tables 1 and 2, respectively. EIMS *m/z* (rel. int.): 550 (0.4), 491 (2.3), 490 (1.7), 472 (0.2), 448 (0.5), 430 (1.0), 388 (0.5), 371 (0.8), 327 (0.6), 311 (0.9), 251 (0.6), 195 (26), 153 (12), 123 (26), 109 (17), 55 (16), 43 (100).

Acetylation of taxumairol D (**2**). Acetylation (Ac_2O–pyridine; 1:1; room temp.) of **2** (10 mg) furnished a residue, which, after work-up, was purified to give **4**.

Taxumairol E (**5**). Isolated as amorphous powder: $[\alpha]_D^{25}+54.9^\circ$ ($CHCl_3$, *c* 0.75); IR υ_{max}^{neat} cm^{-1}. 3468, 2936, 1740, 1462, 1440, 1376, 1246, 1026, 992, 754; UV λ_{max}^{MeOH} (log ε) nm: 225 (3.60); ^1H and ^{13}C NMR ($CDCl_3$) spectral data: Table 1 and 2, respectively. EIMS *m/z* (rel. int.): 518 (0.01), 491 (0.01), 476 (0.03), 458 (0.01), 434 (0.03), 416 (0.08), 398 (0.03), 374 (0.07), 356 (0.12),

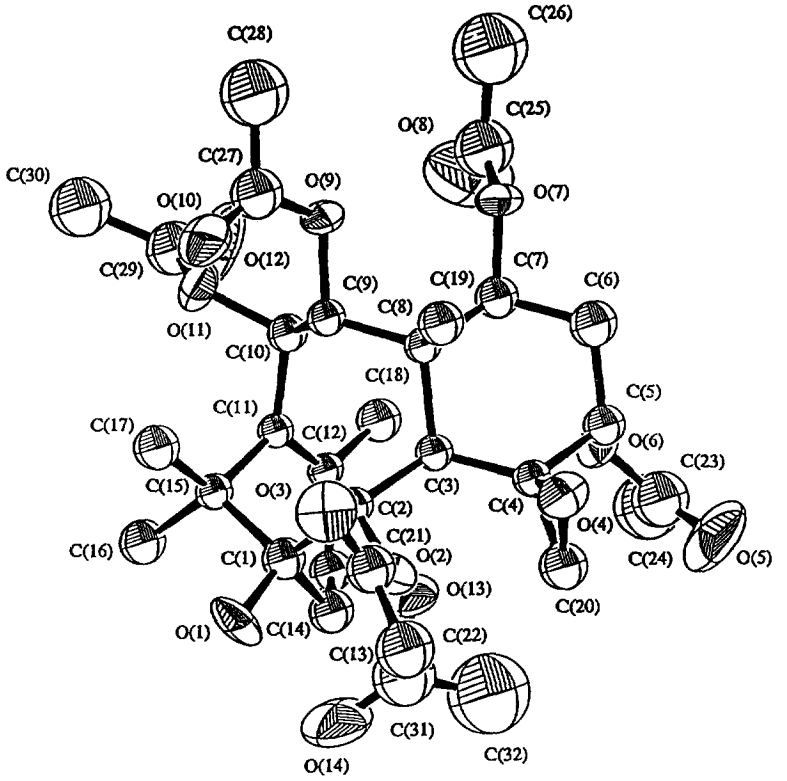

Fig. 1. ORTEP diagram showing the crystallographic atom numbering scheme and solid state conformation of compound **4**; the hydrogen atoms have been omitted for clarity.

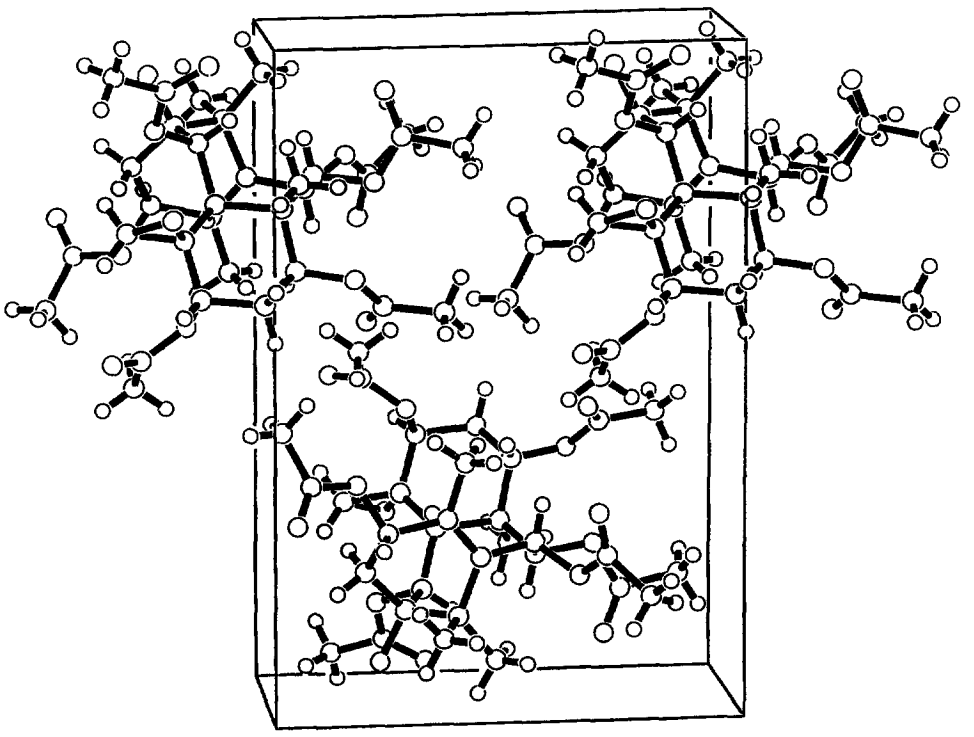

Fig. 2. Stereodrawing of the mode of packing of compound **4** molecules.

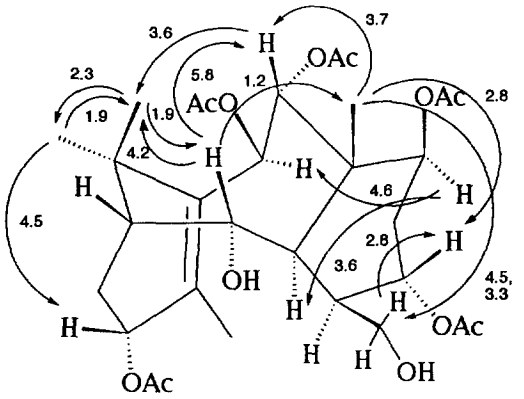

Fig. 3. NOE studies and proposed conformation of taxumairol E (**5**).

341 (0.05), 314 (0.15), 296 (0.2), 281 (0.2), 263 (0.2), 255 (0.45), 195 (0.93), 163 (1.0), 135 (2.8), 121 (3.9), 105 (4.8), 91 (4.6), 79 (3.0), 61 (6.8), 43 (100).

Acetylation of taxumairol E (**5**). Acetylation (Ac_2O–pyridine; 1:1; room temp.) of **5** (15 mg) gave, after work-up, **7**. ^1H NMR (300 MHz, $CDCl_3$): δ 5.39 (1H, *m*, H-2), 2.78 (1H, *t*, J = 5.4 Hz, H-3), 5.00 (1H, *m*, H-5), 1.86 (2H, *m*, H-6), 5.42 (1H, *m*, H-7), 5.87 (1H, *d*, J = 10.8 Hz, H-9), 6.15 (1H, *d*, J = 10.8 Hz, H-10), 5.92 (1H, *t*, J = 8.4 Hz, H-13), 1.42 (1H, *dd*, J = 15.2, 8.0 Hz, H-14α), 2.60 (1H, *m*, H-14β), 1.74 (3H, *s*, H-16), 1.14 (3H, *s*, H-17), 2.22 (3H, *s*, H-18), 0.90 (3H, *s*, H-19), 3.74 (1H, *d*, J = 11.2 Hz, H-20a), 4.03 (1H, *dd*, J = 11.2, 8.0 Hz, H-20b), 2.24, 2.06, 2.05, 2.02, 1.98, 1.96, 1.60 (3H × 7, *s*, $OCOMe_3$). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ 47.6 (*d*, C-1), 70.8 (*d*, C-2), 39.4 (*d*, C-3), 42.2 (*d*, C-4), 70.7 (*d*, C-5), 29.7 (*t*, C-6), 69.4 (*d*, C-7), 45.6 (*s*, C-8), 75.5 (*d*, C-9), 71.7 (*d*, C-10), 133.7 (*s*, C-11), 137.7 (*s*, C-12), 70.5 (*d*, C-13), 27.9 (*t*, C-14), 37.8 (*s*, C-15), 27.9 (*q*, C-16), 31.6 (*q*, C-17), 14.9 (*q*, C-18), 14.2 (*q*, C-19), 65.4 (*t*, C-20), 169.2, 169.4, 169.7, 169.9 (×2), 170.0, 170.3 (*s*, OCOMe), 21.8, 21.5, 21.4, 20.9 (×3), 20.8 (*q*, $OCOCH_3$): EIMS *m/z* (rel. int.): 620 $[M-HOAc]^+$ (2), 578 (4), 560 $[M-2HOAc]^+$ (45), 518 (90), 476 (8), 458 (14), 416 (10), 398 (11), 356 (11), 338 (15), 296 (22), 278 (25), 263 (66), 221 (100), 195 (62), 179 (13), 161 (59), 133 (32), 121 (25), 119 (19), 105 (17), 83 (8), 69 (8), 43 (48).

Acetylation of taxumairol B (**3**). Acetylation (Ac_2O–pyridine; 1:1; room temp.) of **3** (30 mg) gave, after work-up, a solid, which was recrystallied from *n*-hexane-Me_2CO to give prisms. It showed identical spectral data (^1H NMR, EIMS and [α]) with those of **4**. A single crystal of **4** was subjected to X-ray crystallographic analysis.

X-ray crystallography. A prismatic crystal of $C_{32}H_{43}O_{14}$ displayed monoclinic symmetry, and the cell constants of a = 8.913 (4), b = 11.312 (7), c = 16.719 (5) Å, V = 1682 (1) Å^3 and β = 93.65 (3)° were determined from a least-squares refinement using the setting angles of 20 carefully centred reflections in the range 8.71 < 2θ < 14.56°. The data were collected using the ω–2θ scan technique to a max. 2θ value of 47.1°. A total of 2844 reflections were collected using Mo-K_α radiation, and 1667 were taken as observed [$I > 3.00\ \sigma(I)$]. Data were corrected for Lorentz and polarization effects. The structure was solved by direct methods and expanded using Fourier techniques. Neutral atom scattering factors were taken from Cromer and Waber [27]. Some non-H atoms were refined anisotropically, while the rest were refined isotropically. Final discrepancy indices were R = 0.075 and R_w = 0.054. Atomic parameters and equivalent

Table 3. Non-hydrogen atom fractional coordinates and equivalent isotropic thermal parameters for compound **4** (estimated standard deviations in parentheses)

Atom	x	y	z	B_{eq}
O(1)	0.5599(7)	0.7509	0.0527(4)	4.4(2)
O(2)	0.8194(7)	0.7462(9)	0.1226(4)	3.2(2)
O(3)	0.9077(9)	0.634(1)	0.0247(5)	5.6(3)
O(4)	1.0370(7)	0.7153(9)	0.2448(4)	4.1(2)
O(5)	0.929(1)	0.842(1)	0.4614(5)	8.7(4)
O(6)	0.8097(8)	0.6803(10)	0.4154(4)	4.0(2)
O(7)	0.8786(9)	0.3252(9)	0.3470(4)	4.2(2)
O(8)	0.676(1)	0.290(1)	0.4206(7)	10.5(4)
O(9)	0.7208(8)	0.2757(9)	0.2121(4)	3.4(2)
O(10)	0.7009(9)	0.252(1)	0.0765(5)	5.3(2)
O(11)	0.4350(8)	0.3230(9)	0.1848(4)	3.7(2)
O(12)	0.294(1)	0.291(1)	0.2871(6)	9.5(4)
O(13)	0.4348(8)	0.8061(9)	0.3275(5)	4.7(2)
O(14)	0.267(1)	0.941(1)	0.2794(8)	9.0(4)
C(1)	0.558(1)	0.695(1)	0.1305(6)	3.2(2)
C(2)	0.729(1)	0.650(1)	0.1474(6)	2.5(2)
C(3)	0.776(1)	0.617(1)	0.2368(6)	2.5(2)
C(4)	0.900(1)	0.688(1)	0.2822(6)	2.5(2)
C(5)	0.934(1)	0.652(1)	0.3684(6)	3.0(2)
C(6)	0.960(1)	0.518(1)	0.3769(7)	3.8(3)
C(7)	0.832(1)	0.448(1)	0.3354(6)	3.2(2)
C(8)	0.809(1)	0.475(1)	0.2438(6)	2.4(2)
C(9)	0.684(1)	0.404(1)	0.2012(6)	2.5(2)
C(10)	0.521(1)	0.415(1)	0.2304(6)	2.7(2)
C(11)	0.459(1)	0.537(1)	0.2145(6)	2.2(2)
C(12)	0.429(1)	0.611(1)	0.2740(6)	2.2(2)
C(13)	0.407(1)	0.741(1)	0.2558(6)	3.1(2)
C(14)	0.510(1)	0.785(1)	0.1917(6)	3.4(2)
C(15)	0.448(1)	0.586(1)	0.1271(6)	2.4(2)
C(16)	0.284(1)	0.627(1)	0.1056(6)	3.7(3)
C(17)	0.482(1)	0.502(1)	0.0571(6)	3.7(3)
C(18)	0.420(1)	0.573(1)	0.3584(6)	3.5(3)
C(19)	0.955(1)	0.447(1)	0.2002(6)	3.6(3)
C(20)	0.942(1)	0.810(1)	0.2676(7)	4.0(3)
C(21)	0.900(1)	0.726(1)	0.0605(7)	4.1(3)
C(22)	0.976(1)	0.837(1)	0.0354(7)	5.9(4)
C(23)	0.822(2)	0.777(2)	0.4629(9)	5.8(4)
C(24)	0.692(2)	0.789(2)	0.5104(8)	8.0(4)
C(25)	0.787(2)	0.259(2)	0.3924(9)	6.0(4)
C(26)	0.855(2)	0.133(2)	0.3999(10)	9.5(5)
C(27)	0.721(1)	0.216(1)	0.1432(8)	4.6(3)
C(28)	0.747(2)	0.087(2)	0.1619(9)	7.8(4)
C(29)	0.326(1)	0.270(1)	0.2215(8)	5.1(3)
C(30)	0.244(1)	0.181(1)	0.1653(8)	6.5(4)
C(31)	0.353(2)	0.907(2)	0.332(1)	7.0(4)
C(32)	0.383(2)	0.968(2)	0.412(1)	12.0(6)

thermal factors for non-H atoms of **4** molecules as well as their standard deviations are listed in Table 3. The final X-ray model is shown in Fig. 1. All data including atomic coordinates, thermal parameters, bond distances, angles and observed and calculated structure factors have been deposited at the Cambridge Crystallographic Data Centre and can be obtained on request from Dr Olga Kennard, University Chemical Laboratory, 12 Union Road, Cambridge CB2 1EZ, U.K.

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