PERGAMON

Phytochemistry 58 (2001) 369–374

PHYTOCHEMISTRY

www.elsevier.com/locate/phytochem

Taxane diterpenoids from the bark of *Taxus yunnanensis*

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Received 30 August 2000; received in revised form 4 April 2001

Abstract

Further investigation on the alcohol extract of the barks of *Taxus yunnanensis* led to the isolation of four taxoids, namely, 7β-xylosyl-taxol D, taxuyunnanines P, Q and R, along with the known taxuyuntin G (**2**). Four are rearranged taxoids with an 11(15→1)-*abeo*taxoid skeleton and an opened oxetane ring moiety. Structures were determined by spectroscopic and chemical means.

Keywords: *Taxus yunnanensis*; Taxaceae; Bark; *abeo*Taxoids; 7β-Xylosyl-taxol D; Taxuyunnanines P–R; Taxuyuntin G

1. Introduction

Since the discovery of the anticancer agent paclitaxel in 1971 (Wani et al., 1971), nearly 400 taxoids have been reported. Our previous studies on *Taxus yunnanensis* Cheng et L.K. Fu have resulted in the isolation of paclitaxel, and 41 other taxoids from the root (Zhang et al., 1993, 1994a,b, 1995a,b, 1997; Xiang et al., 1999); two new bacctin III type (Li et al., 1998) and five new rearranged taxoids (Li et al., 2000) from the bark. Investigation on the more polar part of the alcohol extract of the bark of *T. yunnanensis* afforded a new paclitaxel related compound, 7β-xylosyl-taxol D (**1**), and three new 11(15→1)-*abeo*-taxoids, taxuyunnanines P–R (**3**–**5**), together with a known *abeo*taxoid, taxuyuntin G (**2**) (Fig. 1). This paper deals with the isolation and structure elucidation of these compounds.

2. Results and discussion

7β-Xylosyl-taxol D (**1**) was assigned a molecular formula of $C_{49}H_{61}NO_{18}$ based on its HRFABMS (*m*/*z* 952.4054 ($[M+H]^+$, calc. 952.3967). The ^1H NMR (Table 1) spectrum showed the presence of four characteristic taxane methyl (δ 1.17, 1.16, 1.95 and 1.72) and two acetyl methyl (δ 2.34 and 2.18) groups; a xylosyl group, and a complex side chain of *N*-butanoylphenylisoserine as found in taxol D and its derivatives (Appendino et al., 1994; Guo et al., 1995). A detailed comparison of the ^1H NMR spectral data of **1** and those of 7β-xylosyl-10-deacetyl-taxol D (Guo et al., 1995) indicated that, except for the existence of an additional acetyl group in **1**, the two compounds were very much alike. In the lowfield region, the sharp proton signal at δ 5.37 (1H, *s*) of 7β-xylosyl-10-deacetyl-taxol D was found to have shifted to δ 6.50, which suggested that the additional acetyl group in **1** is positioned at C-10. Since the ^{13}C NMR data of 7β-xylosyl-10-deacetyl-taxol D are not available in the literature for comparative purposes, ^{13}C and 2D NMR (including ^1H–^1H COSY, HMQC, HMBC) experiments were carried out to confirm the proposed structure for **1** and for its unambiguous assignments. The presence of an acetoxy group at C-10 was confirmed by the ^1H–^{13}C long-range correlation of H-10 with an acetyl carbonyl carbon in the HMBC spectrum.

Compound **2** was identified as the known taxayuntin G by comparison of its spectroscopic data (^1H and ^{13}C NMR and FABMS) with those previously reported in the literature (Yue et al., 1995).

Taxuyunnanine P (**3**), $C_{24}H_{38}O_{10}$ (HRFABMS: *m*/*z* 485.2401 ($[M-H]^+$, calc. 485.2487), showed both ester (1718 and 1271 cm^{-1}) and free hydroxyl (3399 cm^{-1}) absorptions in its IR spectrum. Its ^1H NMR spectrum

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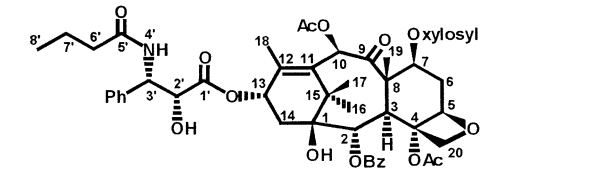
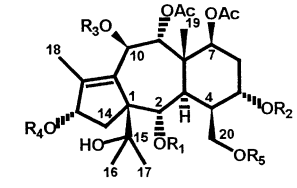
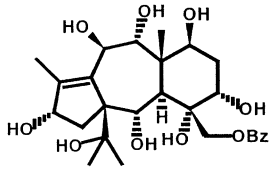
PII: S0031-9422(01)00218-7







R_1=R_2=OAc, R_3=R_4=R_5=H
R_1=R_2=R_3=R_4=R_5=OAc
R_1=R_2=R_4=R_5=OAc, R_3=H
R_1=R_2= R_3=R_4=R_5=H
R_1=R_2=R_4=R_5=H, R_3=OAc
R_2=R_3=R_4=R_5=OAc, R_1=H

Fig. 1. Compounds **1**–**5** isolated from *Taxus yunnanensis*.

(Table 1) indicated the presence of four taxoid methyl groups at δ 1.40, 1.03, 1.85 and 1.02 (singlets) ascribable to Me-16, -17, -18 and -19, respectively, together with two acetyl methyl groups at δ 2.07 (3H, *s*) and 2.06 (3H, *s*). The ^{13}C NMR (Table 2) spectrum disclosed the existence of two olefinic quaternary carbons at δ 140.0 (C-11) and 145.8 (C-12), one oxygen-bearing quaternary carbon at δ 77.3 (C-15), and a quaternary carbon at δ 69.5 (C-1). These data suggested a 5/7/6 membered 11 (15→1)-*abeo*taxoid skeleton, which was confirmed by the long-range ^{1}H–^{13}C correlation of H-10 [δ 4.58 (1H, *d*, J=10.1 Hz)] to C-1 in the HMBC spectrum. The COSY, HMQC and HMBC experiments showed that, unlike normal taxoids or *abeo*taxoids, the C-4 of **3** was a methine carbon instead of an oxygen-bearing quaternary carbon; and H-3 of **3** was a doublet of doublets rather than a simple doublet. The relationships of H-2/H-3/H-4/H_2-20 were well displayed in the ^{1}H–^{1}H COSY spectrum. Thus, **3**, like **2**, belongs to the rare group of *abeo*taxoids devoid of an oxygenated substituent at C-4. The opened oxetane ring system was inferred from the relatively highfield chemical shift of C-20 [δ 63.5 (*t*)] in the ^{13}C NMR spectrum and six double bond equivalents in its molecular formula. The downfield chemical shifts of H-7 [δ 5.38 (1H, *dd*, J=4.8, 11.5 Hz)] and H-9 [δ 5.55 (1H, *brd*, J=10.00 Hz)] in the ^{1}H NMR, combined with the HMBC correlations of H-7 and H-9 signals with the two carbonyl carbon resonances at δ 172.1 and 173.0, affixed the two acetyl groups to C-7 and C-9, respectively. The relative stereochemistry of **3** was established by comparison of its coupling constants with those of **2** (Yue et al., 1995). Thus, the structure of taxuyunnanine P was established as 7β, 9α-diacetoxy-2α, 5α, 10β, 13α, 15, 20-hexahydroxy-11(15→1)*abeo*taxa-11-*ene* (**3**).

Taxuyunnanine Q (**4**) has the molecular formula of $C_{26}H_{40}O_{11}$ as shown by its HRFABMS (*m*/*z* 527.2464 ([M–H]$^+$, calc. 527.2492). Analysis of the IR and NMR spectra (including ^{1}H, ^{13}C, COSY, HMQC and HMBC) (Tables 1 and 2) implied that **4** is an *abeo*taxoid related to **3**, differing in the presence of an additional acetyl

Table 1
^{1}H NMR spectral data of compounds **3**–**5** ([a] 400 MHz, [b]500 MHz, δ_H in ppm, J in Hz)

Proton	**3**[a]	**4**[a]	**5**[b]
H-2	4.47 (1H, *d*, 8.2)	4.52 (1H, *d*, 8.2)	4.49 (1H, *d*, 7.7)
H-3	2.57 (1H, *dd*, 4.7, 8.2)	2.50 (1H, *dd*, 4.7, 8.3)	2.62 (1H, *d*, 7.4)
H-4	2.19 (1H, *m*)	2.18 (1H, *m*)	
H-5	3.97 (1H, *brd*, 2.2)	3.99 (1H, *brd*, 2.3)	3.98 (1H, *brs*)
H-6a	1.88 (1H, *m*)	1.87 (1H, *m*)	1.91 (2H, *m*, H_2-6)
H-6b	1.67 (1H, *m*)	1.76 (1H, *m*)	
H-7	5.38 (1H, *dd*, 4.8, 11.5)	5.45 (1H, *dd*, 4.9, 11.4)	4.16 (1H, *dd*, 5.2, 11.0)
H-9	5.55 (1H, *brd*, 10.0)	5.66 (1H, *brd*, 10.1)	4.00 (1H, *d*, 10.4)
H-10	4.58 (1H, *d*, 10.1)	6.17 (1H, *d*, 10.7)	4.45 (1H, *d*, 10.0)
H-13	4.41 (1H, *t*, 7.5)	4.43 (1H, *t*, 7.4)	4.47 (1H, *t*, 8.8)
H-14a	4.41 (1H, *t*, 7.5)	2.33 (1H, *dd*, 7.7, 15.3)	2.05 (1H, *dd*, 6.9, 14.0)
H-14b	1.71 (1H, *dd*, 7.7, 14.6)	1.78 (1H, *dd*, 8.1, 14.3)	1.82 (1H, *dd*, 7.6, 14.1)
Me-16	1.40 (3H, *s*)	1.28 (3H, *s*)	1.36 (3H, *s*)
Me-17	1.03 (3H, *s*)	1.25 (3H, *s*)	1.08 (3H, *s*)
Me-18	1.85 (3H, *s*)	1.85 (3H, *s*)	1.86 (3H, *s*)
Me-19	1.02 (3H, *s*)	1.03 (3H, *s*)	1.29 (3H, *s*)
H-20a	3.84 (1H, *dd*, 5.4, 10.6)	3.86 (1H, *dd*, 6.0, 11.0)	4.96 (1H, *d*, 12.1)
H-20b	3.48 (1H, *dd*, 8.4, 10.5)	3.47 (1H, *dd*, 8.6, 10.4)	4.65 (1H, *d*, 12.0)
OAc	2.07 (3H, *s*)	2.03 (3H, *s*)	
	2.06 (3H, *s*)	1.97 (3H, *s*)	
		1.92 (3H, *s*)	
Obz			8.03 (2H, *d*, 7.4)
			7.59 (1H, *t*, 7.4)
			7.46 (2H, *t*, 7.5)

Table 2
^{13}C NMR spectral data of compounds **3**–**5** (125 MHz, δ_C in ppm)

Carbon	**3**[b]	**4**[b]	**5**[b]
1	69.5 *s*	69.3 *s*	69.5 *s*
2	66.6 *d*	67.3 *d*	69.5 *d*
3	41.7 *d*	41.1 *d*	44.8 *d*
4	47.2 *d*	47.2 *d*	77.6 *s*
5	68.9 *d*	68.8 *d*	69.8 *d*
6	33.6 *t*	33.4 *t*	34.9 *t*
7	71.5 *d*	71.3 *d*	70.5 *d*
8	45.1 *s*	45.3 *s*	44.1 *s*
9	81.2 *d*	78.4 *d*	81.7 *d*
10	68.2 *d*	70.4 *d*	70.1 *d*
11	140.0 *s*	135.9 *s*	139.9 *s*
12	145.8 *s*	151.3 *s*	145.9 *s*
13	78.5 *d*	77.8 *d*	78.3 *d*
14	40.3 *t*	40.6 *t*	39.8 *t*
15	77.3 *s*	77.9 *s*	77.6 *s*
16	27.0 *q*	27.3 *q*	26.6 *q*
17	28.0 *q*	28.0 *q*	28.2 *q*
18	11.3 *q*	11.9 *q*	11.3 *q*
19	14.5 *q*	14.4 *q*	15.3 *q*
20	63.5 *t*	63.5 *t*	67.0 *t*
OAc	173.0 *s*; 172.1 *s*	172.1 *s*; 171.8 *s*; 170.2 *s*	
	21.8 *q*; 21.5 *q*	21.6 *q*; 21.0 *q*; 20.8 *q*	
OBz-1′			168.2 *s*
2′			131.4 *s*
3′			130.7 (2C, *d*)
4′			129.5 (2C, *d*)
5′			134.3 *d*

group at C-10. In the ^1H NMR spectrum, the H-10 signal moved downfield from δ 4.58 (1H, *d*, $J=10.1$ Hz) in **3** to δ 6.17 (1H, *d*, $J=10.7$ Hz) in **4**. This assignment was confirmed by the HMBC cross-peak signal of H-10 to an acetyl carbonyl carbon at δ 170.2. Compound **4** was deduced to have the same relative stereochemistry as **3** by virtue of their similar coupling patterns, and was identified as 7β, 9α, 10β-triacetoxy-2α, 5α, 13α, 15, 20-pentahydroxy-11(15→1)*abeo*taxa-11-*ene* (**4**).

Theoretically, compounds **2**, **3** and **4** can be converted to the same heptacetate, which would confirm their proposed structures. Accordingly, they were subjected to acetylation experiments. Under normal conditions, only **2** yielded the expected heptacetate product (**2a**) plus a hexacetate (**2b**). Compounds **3** and **4** afforded the same hexacetate product (**3a**=**4a**) with the hydroxy group at C-2 remained unacetylated even under more vigorous conditions. The failure of **3** and **4** to form heptacetates may be caused by the steric hindrance around the 2-OH group or due to the formation of a hydrogen-bond between the 2-OH and one of the other oxy-groups.

Taxuyunnanine R (**5**), $C_{27}H_{37}O_{10}$ established by HR–FABMS: *m*/*z* 521.2371 $[M-H]^+$, calc. 521.2387. The IR spectrum showed carbonyl, hydroxyl and ester groups at 1711, 3385 and 1279 cm^{-1}, respectively. As in the case of isolates **2**–**4**, spectral features of 11(15→1)-*abeo*taxoids were clearly evident in the NMR (Tables 1 and 2) spectra of **5**. However, contrary to the protonated C-4 in **2**–**4**, the C-4 of **5** was an oxygenated quaternary carbon: the H-3 (δ 2.62) of **5** was a doublet instead of the doublet of doublet found in **2**–**4**; and the H_2-20 were a pair of AB doublets instead of two doublet of doublets. The downfield chemical signals of H_2-20 [δ 4.96 (1H, *ABd*, $J=12.1$ Hz) and 4.65 (1H, *ABd*, $J=12.0$ Hz)] suggested that the benzoxy group could be assigned to C-20. Confirmation for this linkage was achieved by a HMBC experiment, in which the H_2-20 and aromatic protons at δ 8.03 (2H, *d*, $J=7.4$ Hz) correlated with the carbonyl carbon signal at δ 168.2 simultaneously. It is interesting to note that although compound **5** possessed nine oxygenated carbons (one oxymethylene, six oxymethines and two oxyquaternary carbons), there was only one ester substitute group (benzoate) present. Normally, such a highly oxygenated taxane would contain two or more esterified substituents.

In order to determine the relative stereochemistry of compound **5**, a ROESY experiment was performed (Fig. 2). The orientation of the benzoxymethyl at C-4 was established as β due to the NOE correlation between H_2-20 and Me-19. NOE correlations of H-2 with Me-16, 17 and 19, H-7 with H-3, H-9 with H-2 and Me-19, H-10 with H-3 and Me-18, and H-13 with Me-16 and 17, fixed the orientation of the hydroxy groups at C-2, C-7, C-9, C-10 and C-13 as α-, β-, α-, β- and α-, respectively. The configuration of the 5-OH was assigned an α-orientation due to its small coupling constant (H-5, *brs*). Hence the structure of taxuyunnanine R was deduced as 20-benxoxyl-2α, 4α, 5α, 7β, 9α, 10β, 13α, 15-octahydroxy-11(15→1)*abeo*taxa-11-*ene* (**5**).

With the exception of **1**, the isolates obtained in this study belong to the rare 11(15→1)-*abeo*taxoids possessing an opened oxetane ring moiety. To-date, only a few such taxoids have been reported. Further, *abeo*taxoids with a C-4 methine are rarer still (Baloglu and Kingston, 1999; Parmar et al., 1999). To our knowledge, taxuyunnanine R is the most highly oxygenated *abeo*taxoid isolated to-date that contains only a single ester substituent.

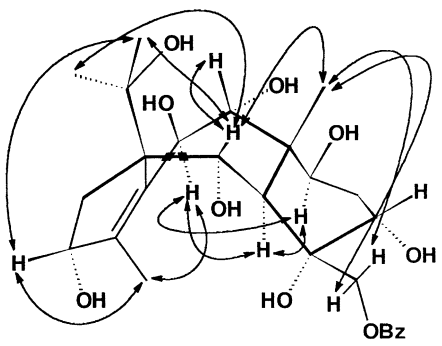


Fig. 2. Significant ROESY correlations of compound **5**.

3. Experimental

3.1. General

1D and 2D NMR experiments were performed either on a Bruker AM-400 or DRX-500 spectrometer. Unless otherwise specified, chemical shifts (δ) were expressed in ppm with reference to the solvent signals. FABMS and HRFABMS were taken on a VG Auto Spec-3000 or on a Finnigan MAT 90 instrument. IR spectra were recorded on a Bio-Rad FTS-135 spectrometer with KBr pellets. UV spectral data were obtained on a UV 210A spectrometer. Optical rotations were carried out on a HORIBA SEPA-300 High Sensitive Polarimeter or Perkin-Elmer model 241 Polarimeter. Column chromatography was performed either on Si gel (200–300 mesh, Qingdao Marine Chemical Inc., China), Si gel H (10–40 μm, Qingdao Marine Chemical Inc., China), Lichroprep RP_{18} gel (40–63 μm, Merck, Darmstadt, Germany), or on. MCI gel (70–150 μm, Mitsubishi Chemical Corporation, Tokyo, Japan). Fractions were monitored by TLC and spots were visualized by heating Si gel plates sprayed with 10% H_2SO_4 in EtOH.

3.2. Plant material

The barks of *T. yunnanensis* Cheng et L. K. Fu (Taxaceae) were collected in Lijiang Prefecture of Yunnan Province of Peoples Republic of China. A voucher specimen has been deposited at the Yunnan Academy of Forestry, Kunming, Yunnan, People's Republic of China.

3.3. Extraction and isolation

Dried bark (50 kg) was milled, extracted and fractionated by silica gel column chromatography as described previously. Briefly, the $CHCl_3$ fraction was successively chromatographed over three columns of silica gel. Fractions 14–29 from the third silica gel column were combined (4.9 g) and chromatographed on silica gel, eluted with $CHCl_3$–*iso*-PrOH (9:1) (Li et al., 2000). The more polar fractions obtained were combined and sequentially re-chromatographed on RP_{18} Si gel eluted with MeOH–H_2O (1:1) and acetonitrile–H_2O (2:8), and on silica gel eluted with petroleum ether–*iso*-PrOH (8:2) to yield compounds **1** (14 mg) and **2** (2 mg). A post Frs. 14–29 combined fraction (14.0 g) obtained from the third silica gel column referred to above was further fractionated successively on MCI gel with Me_2CO–H_2O (2:8), on silica gel with petroleum ether–*iso*-PrOH (8:2) and on silica gel with $CHCl_3$–*iso*-PrOH (7:1) as eluting solvents to provide compound **4** (5 mg). A second post Frs. 14–29 fraction (10.0 g) was also subjected to extensive chromatography on MCI gel using Me_2CO–H_2O (2:8), on silica gel using $CHCl_3$–MeOH (9:1), on silica gel using $CHCl_3$–*iso*-PrOH (5:1) and on RP_{18} gel using acetonitrile–H_2O (1:5) as eluents, stepwise, to afford Compounds **3** (13 mg) and **5** (3 mg).

7β-Xylosyl-taxol D (**1**): white powder, $[\alpha]_D^{28}$: −25.0° (*c* 0.25 MeOH). UV (MeOH) λ_{max} (log ε): 202 (4.3), 229 (4.2). IR (KBr) ν_{max} (cm^{-1}): 3440, 2935, 1723, 1654, 1519, 1453, 1373, 1316, 1247, 1179, 1106, 1071, 1048, 981, 709. Positive FABMS *m*/*z* (%): 952 ($[M+H]^+$, 4), 894 (2), 820 (1), 760 (1), 642 (2), 569 (1), 510 (2), 405 (2), 327 (4), 286 (16), 252 (35), 206 (16), 176 (7), 136 (12), 105 (100), 77 (15). HR–FABMS *m*/*z* 952.4054 ($C_{49}H_{62}NO_{18}$, calc. 952.4093). ^1H NMR (500 MHz, CD_3OD) δ: 5.65 (1H, *d*, *J* = 7.1 Hz, H-2), 3.82 (1H, *d*, *J* = 7.5 Hz, H-3), 4.97 (1H, *d*, *J* = 8.0 Hz, H-5), 2.68 (1H, *m*, H-6a), 1.92 (1H, *m*, H-6b), 4.27 (1H, *dd*, *J* = 6.9, 10.6 Hz, H-7), 6.50 (1H, *s*, H-10), 6.11 (1H, *t*, *J* = 9.2 Hz, H-13), 2.25 (1H, *m*, H-14a), 2.04 (1H, *m*, H-14b), 1.17 (3H, *s*, Me-16), 1.16 (3H, *s*, Me-17), 1.95 (3H, *s*, Me-18), 1.72 (3H, *s*, Me-19), 4.19 (2H, *m*, H_2-20), 4.58 (1H, *d*, *J* = 4.6 Hz, H-2′), 5.45 (1H, *d*, *J* = 4.6 Hz, H-3′), 2.27 (2H, *m*, H_2-6′), 1.61 (2H, *m*, H_2-7′), 0.91 (3H, *t*, *J* = 7.5 Hz, Me-8′), 2.34 (3H, *s*, 4-OAc), 2.18 (3H, *s*, 10-OAc); 3′-Ph: 7.41 (4H, *m*), 7.27 (1H, *t*, *J* = 7.0 Hz); 2-OBz: 8.10 (2H, *dd*, *J* = 1.5, 8.5 Hz), 7.66 (1H, *t*, *J* = 7.5 Hz), 7.56 (2H, *t*, *J* = 7.5 Hz); 7-xylosyl: 4.24 (1H, *d*, *J* = 7.3 Hz, H-1″), 3.06 (1H, *dd*, *J* = 7.4, 8.9 Hz, H-2″), 3.28 (1H, *t*, *J* = 8.9 Hz, H-3″), 3.42 (1H, *ddd*, *J* = 5.3, 8.8 Hz, 10.0, H-4″), 3.81 (1H, *dd*, *J* = 5.2, 11.5 Hz, H-5″a), 3.18 (1H, *dd*, *J* = 10.2, 11.5 Hz, H-5″b). ^{13}C NMR (125 MHz, CD_3OD) δ: 78.8 (*s*, C-1), 76.1 (*d*, C-2), 47.9 (*d*, C-3), 82.1 (*d*, C-4), 85.4 (*d*, C-5), 36.5 (*t*, C-6), 80.6 (*d*, C-7), 58.8 (*s*, C-8), 204.6 (*s*, C-9), 77.2 (*d*, C-10), 134.8 (*s*, C-11), 142.0 (*s*, C-12), 72.3 (*d*, C-13), 36.5 (*t*, C-14), 44.6 (*s*, C-15), 22.1 (*q*, Me-16), 26.9 (Me-17),14.9 (*q*, Me-18), 11.8 (*q*, Me-19), 77.5 (*t*, Me-20); 2-OBz: 167.6 (*s*), 131.3 (*s*),131.2 (2C, *d*), 129.7 (2C, *d*), 134.6 (*d*); OAc: 172.0 (*s*), 171.7 (*s*), 23.2 (*q*), 21.1 (*q*); C-13 side chain moiety: 174.4 (*s*, C-1′), 74.7 (*d*, C-2′), 56.8 (*d*, C-3′), 175.9 (*s*, C-5′), 20.4 (*t*, C-6′), 38.9 (*t*, C-7′), 14.0 (*q*, C-8′), 3′-Ph: 140.2 (*s*), 129.7 (2C, *d*), 128.4 (2C, *d*), 128.9 (*d*); 7-xylosyl moiety: 104.9 (*d*, C-1″), 74.8 (*d*, C-2″), 77.4 (*d*, C-3″), 70.9 (*d*, C-4″), 66.8 (*t*, C-5″).

Taxayuntin G (**2**): colorless prism. Negative FABMS *m*/*z* (%): 569 $[M-H]^+$ (100), 527 (18), 449 (8), 389 (10), 325 (8), 245 (4), 153 (11), 97 (6). ^1H NMR (400 MHz, acetone-d_6) δ: 5.78 (1H, *d*, *J* = 8.1 Hz, H-2), 2.84 (1H, *dd*, *J* = 4.4, 8.1 Hz, H-3), 1.95 (1H, *m*, H-4), 5.07 (1H, *brt*, *J* = 2.7 Hz, H-5), 1.93 (1H, *m*, H-6a), 1.73 (1H, *m*, H-6b), 5.25 (1H, *dd*, *J* = 4.9, 11.6 Hz, H-7), 5.61 (1H, *d*, *J* = 10.0 Hz, H-9), 4.61 (1H, *d*, *J* = 10.0 Hz, H-10), 4.55 (1H, *t*, *J* = 7.2 Hz, H-13), 2.18 (1H, *dd*, *J* = 7.1, 14.4 Hz, H-14a), 1.76 (1H, *dd*, *J* = 7.1, 14.4 Hz, H-14b), 1.19 (3H, *s*, Me-16), 0.95 (3H, *s*, Me-17), 1.93 (3H, *s*, Me-18), 1.04 (3H, *s*, Me-19), 3.44 (2H, *m*, H_2-20); OAc: 2.11, 2.07, 2.05, 2.03 (each in 3H of singlet). ^{13}C NMR (100 MHz, acetone-d_6) δ: 69.3 (*s*, C-1), 69.5 (*d*, C-2), 42.2 (*d*, C-3), 46.6 (*d*, C-4), 72.6 (*d*, C-5), 30.4 (*t*, C-6), 70.8 (*d*, C-7), 44.8 (*s*, C-8), 80.7 (*d*, C-9), 68.1 (*d*, C-10), 138.5 (*s*, C-

11), 145.8 (*s*, C-12), 77.5 (*d*, C-13), 41.1 (*t*, C-14), 76.6 (*s*, C-15), 25.5 (*q*, Me-16), 28.2 (*q*, Me-17), 11.2 (*q*, Me-18), 14.6 (*q*, Me-19), 62.0 (*t*, C-20); OAc: 173.3 (*s*), 172.7 (*s*), 172.2 (*s*), 171.9 (*s*), 21.6 (*q*, 2C), 21.3 (*q*, 2C).

Acetylation of **2**: The sample of **2** (2 mg) in dissolved in pyridine (0.3 ml) and Ac_2O (0.3 ml) was stirred for 24 h at room temperature, and worked-up to give a mixture (3 mg) of **2a** and **2b**, which was purified by Si gel CC, eluting with $CHCl_3$–Me_2CO (5:1) to provide **2a** (1 mg) and **2b** (1 mg). **2a**: Negative FABMS *m*/*z* (%): 695 $[M–H]^+$ (3), 653 (2), 554 (2), 461 (3), 369 (6), 276 (22), 244 (10), 184 (100), 151 (25), 192 (25), 59 (47). ^1H NMR (400 MHz, CD_3OD) δ: 5.91 (1H, *d*, $J=8.4$, H-2), 2.75 (1H, *dd*, $J=4.6$, 8.4, H-3), 2.13 (1H, *m*, H-4), 5.07 (1H, *brdd*, $J=2.7$, 5.3, H-5), 2.02 (1H, *m*, H-6a), 1.87 (1H, *m*, H-6b), 5.38 (1H, *dd*, $J=5.0$, 11.5, H-7), 5.87 (1H, *d*, $J=10.7$, H-9), 6.28 (1H, *d*, $J=10.7$, H-10), 5.66 (1H, *t*, $J=7.2$, H-13), 2.60 (1H, *dd*, $J=7.1$, 14.5, H-14a), 1.78 (1H, *dd*, $J=7.9$, 14.5, H-14b), 1.26 (3H, *s*, Me-16), 1.09 (3H, *s*, Me-17), 1.91 (3H, *s*, Me-18), 1.22 (3H, *s*, Me-19), 4.21 (1H, *dd*, $J=8.5$, 11.9, H-20a), 3.91 (1H, *d*, $J=11.8$, H-20b); OAc: 2.18 (3H, *s*), 2.11 (3H, *s*), 2.09 (3H, *s*), 2.06 (6H, *s*), 2.03 (3H, *s*), 1.98 (3H, *s*). **2b**: Negative FABMS *m*/*z* (%): 654 $[M]^+$ (5), 612 (1), 476 (6), 325 (3), 185 (5), 119 (6), 59 (100). ^1H NMR (400 MHz, CD_3OD) δ: 5.83 (1H, *d*, $J=8.2$ Hz, H-2), 2.79 (1H, *dd*, $J=4.5$, 8.2 Hz, H-3), 2.18 (1H, *m*, H-4), 5.05 (1H, *brdd*, $J=2.7$, 5.4 Hz, H-5), 2.03 (1H, *m*, H-6a), 1.81 (1H, *m*, H-6b), 5.30 (1H, *dd*, $J=5.0$, 11.7 Hz, H-7), 5.72 (1H, *d*, $J=10.2$ Hz, H-9), 4.68 (1H, *d*, $J=10.2$ Hz, H-10), 5.64 (1H, *t*, $J=7.0$ Hz, H-13), 2.40 (1H, *dd*, $J=7.0$, 14.4 Hz, H-14a), 1.75 (1H, *dd*, $J=7.7$, 14.4 Hz, H-14b), 1.23 (3H, *s*, Me-16), 1.07 (3H, *s*, Me-17), 1.93 (3H, *brd*, $J=0.8$ Hz, Me-18), 1.13 (3H, *s*, Me-19), 4.21 (1H, *dd*, $J=8.5$, 12.1 Hz, H-20a), 3.91 (1H, *d*, $J=11.9$ Hz, H-20b); OAc: 2.17 (3H, *s*), 2.11 (6H, s), 2.09 (3H, *s*), 2.07 (3H, *s*), 2.06 (3H, *s*).

Taxuyunnanine P (**3**): white powder, $[\alpha]_D^{28}$: -12.7° (*c* 0.65, MeOH). UV (MeOH) λ_{max} (log ε): 208 (4.1). IR (KBr) ν_{max} (cm^{-1}): 3399, 2928, 1718, 1653, 1440, 1376, 1271, 1159, 1061, 1028, 984, 943, 605. Negative FABMS *m*/*z* (%): 485 $[M–H]^+$ (47), 425 (30), 339 (92), 325 (100), 311 (63), 277 (19), 185 (55), 127 (15), 92 (57), 80 (18), 60 (15). HR–FABMS *m*/*z* 485.2401 ($C_{24}H_{37}O_{10}$, calc. 485.2387). ^1H NMR data: see Table 1. ^{13}C NMR data: see Table 2.

Taxuyunnanine Q (**4**): white powder, $[\alpha]_D^{28}$: -44.0° (*c* 0.25, MeOH). UV (MeOH) λ_{max} (log ε): 204 (4.4). IR (KBr) ν_{max} (cm^{-1}): 3413, 2935, 1748, 1654, 1438, 1374, 1261, 1067, 1031, 943, 903, 602. Negative FABMS *m*/*z* (%): 527 ($[M–H]^+$, 100), 468 (14), 409 (3), 345 (2), 311 (3), 244 (5), 152 (8). HR–FABMS *m*/*z* 527.2464 ($C_{26}H_{39}O_{11}$, calc. 527.2492). ^1H NMR data: see Table 1. ^{13}C NMR data: see Table 2.

Acetylation of **3** and **4**: samples of **3** or **4**, 2 mg each, was acetylated separately in 0.6 ml pyridine–Ac_2O (1:1) in the same manner as that of **2** to give **3a** (3 mg) and **4a** (3 mg) respectively. The 2-OH groups of **3** and **4** were not acetylated after 24 h. The ratio of Ac_2O–pyridine was then changed from 1:1 to 5:1, and then to 10:1, and the reaction was allowed to proceed for four days. However, the 2-OH remained unacetylated. **3a** and **4a**: Negative FABMS *m*/*z* (%): 654 $[M]^+$ (3), 536 (2), 475 (3), 415 (1), 339 (7), 119 (6), 59 (100). ^1H NMR (400 MHz, CD_3OD) δ: 4.53 (1H, *d*, $J=8.1$ Hz, H-2), 2.49 (1H, *dd*, $J=4.9$, 8.1 Hz, H-3), 2.28 (1H, *m*, H-4), 5.02 (1H, *brdd*, $J=2.8$, 5.2 Hz, H-5), 2.00 (1H, *m*, H-6a), 1.85 (1H, *m*, H-6b), 5.33 (1H, *dd*, $J=4.9$, 11.6 Hz, H-7), 5.69 (1H, *brd*, $J=10.3$ Hz, H-9), 6.19 (1H, *d*, $J=10.8$ Hz, H-10), 5.60 (1H, *t*, $J=7.5$ Hz, H-13), 2.43 (1H, *dd*, $J=7.2$, 14.5 Hz, H-14a), 1.69 (1H, *dd*, $J=7.9$, 14.5 Hz, H-14b), 1.31 (3H, *s*, Me-16), 1.28 (3H, *s*, Me-17), 1.84 (3H, *s*, Me-18), 1.04 (3H, *s*, Me-19), 4.23 (1H, *t*, $J=10.4$ Hz, H-20a), 4.31 (1H, *d*, $J=9.8$ Hz, H-20b); OAc: 2.12 (3H, *s*), 2.06 (3H, *s*), 2.04 (3H, *s*), 2.03 (6H, *s*), 1.99 (3H, *s*), 1.94 (3H, *s*).

Taxuyunnanine R (**5**): white powder, $[\alpha]_D^{28}$: -5.0° (*c* 0.10, MeOH). UV (MeOH) λ_{max} (log ε): 212 (4.2), 229 (4.3). IR (KBr) ν_{max} (cm^{-1}): 3385, 2978, 1711, 1610, 1452, 1279, 1177, 1113, 1068, 1027, 936, 784, 708, 611. Negative FABMS *m*/*z* (%): 521 ($[M–H]^+$, 100), 504 (13), 417 (19), 399 (11), 325 (22), 311 (19), 297 (8), 181 (36), 121(79), 71 (10), 59 (30). HR–FABMS *m*/*z* 521.2371 ($C_{27}H_{37}O_{10}$, calc. 521.2387). ^1H NMR data: see Table 1. ^{13}C NMR data: see Table 2.

Acknowledgements

The authors wish to thank the members of the analytical group of the Phytochemistry Laboratory of Kunming Institute of Botany, Academic Sinica, for measurement of the spectral data. This project was supported by grants from the National Science Foundation of China (3950081), the Young Academic and Technical Leader Raising Foundation of Yunnan Province (awarded to H.-J.Z.), and the Special Supported Bioscience and Biotechnique Foundation of Academia Sinica (STZ-11).

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