New Taxanes from the Needles of *Taxus canadensis*

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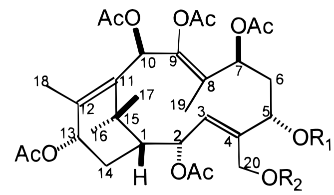
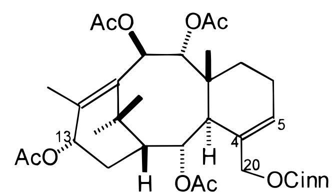
Nine minor taxanes were identified for the first time in the Canadian yew needles. Four of these metabolites are new: 5-*epi*-cinnamoylcanadensene (**1**), 2,9,10,13-tetraacetoxy-20-cinnamoyloxy-taxa-4(5),11(12)-diene (**2**), 2′-acetyl-*epi*-taxol (**3**), and 9-deacetyltaxinine E (**4**).

The initial report of paclitaxel[1] from the bark of *Taxus brevifolia* has stimulated the isolation of almost 350 natural taxanes from yews.[2−4] *Taxus canadensis* Marsh. (Taxacae) differs from other species in this genus by its modest appearance (low trailing bush) and by the taxanes specific to this yew.[5−8] We have therefore started [9−12] a systematic analysis of the needles of this yew.

In the present work, the detailed structures of nine minor taxanes isolated from the needles of *Taxus canadensis* for the first time were characterized, and four of them are new taxanes. One of them, 5-*epi*-cinnamoylcanadensene (**1**), is the third bicyclic highly oxygenated taxane isolated from the needles of the Canadian yew.[13−15] In addition, a highly oxygenated derivative of taxa-4(5),11(12)-diene, 2,9,10,13-tetraacetyl-20-cinnamoyloxy-taxa-4(5),11(12)-diene (**2**), 2′-acetyl-7-*epi*-taxol (**3**), and 9-deacetyl-taxinine E (**4**) are new taxanes reported here. Five other metabolites found in other yews are characterized for the first time in the needles of the Canadian yew.



R_1=R_2=H 5-*epi*-canadensene
1 R_1=Cinn, R_2=H
1a R_1=H, R_2=Cinn
1b R_1=R_2=Cinn



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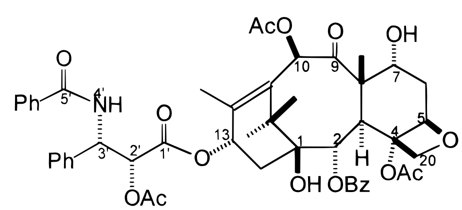

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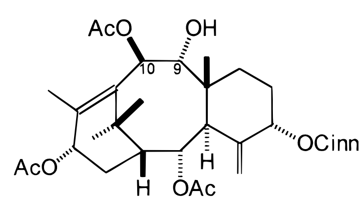

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Results and Discussion

The NMR data of compound **1** are shown in Table 1. Its ^{1}H NMR, COSY, and HMQC spectra (^{1}H and ^{13}C NMR data, see Table 1) revealed the presence of five acetyl groups, one cinnamoyl unit, and four methyls (on nonprotonated carbons). Two of the methyl singlets (δ 1.11 and 1.25 ppm) were COSY-correlated peaks as geminal methyls (Me-16 and Me-17). The presence of three aliphatic methylene groups (δ 2.78 and 2.05, H_2-6; δ 2.58 and 2.08, H-14a and H-14b, and δ 4.65 and 3.55, H-20a and H-20b) were also observed from the COSY spectrum. The HMBC correlations of H-2 (δ 5.73) to the olefinic C-3 (δ 121.7); Me-19 to C-7 (δ 66.7) and to the olefinic C-8 and C-9 (δ 124.3 and 143.0); and the highly deshielded H-10 (δ 7.25) to olefinic C-9, C-12 (δ 135.7), and C-15 (δ 36.1) revealed that **1** is a bicyclic taxane. The relative stereochemistry was determined on the basis of the NOESY connectivities (Table 1) and shown to be similar to 5-*epi*-canadensene,[15] in particular around the two double bonds at C-3(C-4), C-8 (C-9), and H-5β. The positioning of the cinnamoyl group on C-5 is delicate, as we did not observe a HMBC correlation of H-5 to its carbonyl carbon. We observed a very weak NOESY correlation of H-5 with the α-CH of the cinnamoyl group, but due to the large distance involved between these two protons we cannot take this observation as solid proof. The best evidence that the cinnamoyl group is indeed positioned at C-5 came from the influence this group had on the NMR shifts of neighboring positions: H-5, C-5, C-4, and C-6 relative to 5-*epi*-canadensene. It is interesting to note that the C-5α-cinnamoyl unit influences the NMR shift of H-7 and H-10, resulting in substantial deshielding on these protons, and also causes H-3 and Me-18 to shift, because of the *U*-shape of the molecule (H-3 is substantially more shielded, while Me-18 experiences a large deshield-

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Table 1. ^{1}H and ^{13}C NMR Data for Taxane **1** in $CDCl_3$

position	δ ^{1}H mult.[a] (*J* in Hz)	δ ^{13}C[b]	HMBC	NOESY
1	1.73 o dd (7.4; 4.0)	46.8		2/3, 14a, Me-16, Me-17
2	5.73 o dd (11.6; 4.0)	70.3	3	1, 5, 20a, Me-17
3	5.71 o d (11.6)	121.7		see H-2
4		137.4		
5	5.91 br s	69.5		6a, CH=α
6a	2.78 ddd (15.9; 12.8; 2.8)	35.3		5, 6b, 20b, Me-19
6b	2.05 o m		4, 7, 8	5, 6a, 7
7	5.45 d (9.9)	66.7	5, 9, 19, 169.2	2/3, 20a, Me-18
8		124.3		
9		143.0		
10	7.25 o s	68.4	9, 12, 15, 167.6	7, Me-18
11		136.3		
12		135.7		
13	5.27 d (9.5)	70.0	11, 12	14a, Me-16, Me-18
14a	2.58 ddd (17.4; 9.4; 7.4)	26.0		13, Me-16
14b	2.08 o m			13, 14a
15		36.1		
16	1.11 s	33.1	1, 11, 15, 17	1, 13, 14a
17	1.25 s	24.9	1, 11, 15, 16	
18	2.24 s	16.8	11, 12, 13	2/3, 7, 13, CH=α
19	1.62 s	12.1	7, 8, 9	6a, 20b, Me-17
20a	4.65 d (12.9)	57.4	5	2/3, 20b
20b	3.55 br d (12.9)		3, 4	6a, 20a, Me-19
OAc	2.19 s	20.3	167.6	
	2.00 s × 2	21.1	169.2, 170.4	
	1.94 s	20.6	167.6	
	1.82 s	21.1	169.2	
OCinn				
C=O		165.4		
CH=α	6.57 d (16.1)	117.9	Ph-1, C=O	
CH=*β*	7.87 d (16.1)	145.7	C α, C=O, Ph-*o*	
Ph-1		134.2		
o	7.53 m	127.8	Ph-1, Ph-*m*	
m	7.40 m	129.0		
p	7.40 m	130.4		

[a] Mult. = multiplicity: br, broad; d, doublet; m, multiplet; o, overlapping; s, singlet; t, triplet. The precision of the coupling constants is ±0.5 Hz. [b] The ^{13}C NMR chemical shifts were extracted from the HMQC and HMBC (for quaternary carbons) experiments (±0.2 ppm).

ing). To confirm these observations, a small amount of 5-*epi*-canadensene was esterified with cinnamic acid without prior protection of the C-20 hydroxyl group. The expected 20-cinnamoyl-5-*epi*-canadensene (**1a**) and 5,20-biscinnamoyl-*epi*-canadensene (**1b**) were obtained. Their NMR data were in accord with the structure of **1** being 5-*epi*-cinnamoylcanadensene. HRFABMS confirmed the elemental composition of the sodiated quasimolecular ions of **1**, 20-cinnamoyl-5-*epi*-canadensene (**1a**) and 5,20-bis-cinnamoyl-*epi*-canadensene (**1b**).

The NMR data of the second new taxane (**2**) are shown in Table 2. The ^{1}H NMR spectrum showed signals corresponding to four skeleton methyls, four acetyl groups, and one cinnamoyl substituent. The spectra resembled taxinine E[11,16] except for the presence of an AB system (δ 4.98 and 4.78) with a very large coupling constant (J = 14.0 Hz) that could only be assigned to the methylene H-20. COSY and HMQC experiments revealed that H-5 (δ 5.79) was an olefinic proton, suggesting the presence of a double bond at C-4 and C-5 (we could not obtain the chemical shift of C-4 from the HMBC spectrum due to insufficient correlations). The positions of the acetyl groups at C-2, C-9, and C-10 were secured by the appropriate HMBC correlations between H-2 (δ 5.56), H-9 (δ 5.94), and H-10 (δ 5.91) with the carbonyl groups at 169.1, 169.6, and 169.9 ppm, respectively. The only other groups requiring placement were an acetyl and a cinnamoyl group. Unfortunately, HMBC correlations, which would rigorously prove their location, could not be observed. Comparative analysis between the observed NMR shifts of **2** with various taxanes having acetyls or cinnamoyls at C-13 or C-20 was therefore used. The only known natural taxane with a six-membered ring A and a cinnamoyl substituent on C-13, 13-cinnamoyl-baccatin III, [17,18] exhibits a chemical shift of δ 6.21 for H-13. On the other hand, for C-13-acetoxy taxanes, the H-13 chemical shift is in the range of δ 5.2−5.8. It was concluded, therefore, that the structure of taxane **2** (H-13 δ 5.6, Table 2) is 2,9,10,13-tetraacetoxy-20-cinnamoyloxy-taxa-4(5),11(12)-diene. This compound is a highly oxygenated derivative of taxa-4(5),11(12)-diene, the proven precursor of taxol in *T. brevifolia*.[19,20] Compound **2** is the second oxygenated derivative of taxa-4(5),11(12)-diene isolated as a natural product. The first one, 2α,20-dihydroxy-9α-acetoxytaxa-4,11-dien-13-one, was isolated from the needles and bark of *T. chinensis* var. *mairei*.[21] The relative stereochemistries of the different groups in **2** were derived from the NOESY correlations shown in Table 2. HRFABMS confirmed the elemental composition of the sodiated quasimolecular ion of **2**. The co-metabolites **1** and **2** suggest that in *T. canadensis* there might be two alternate biosynthetic pathways of taxanes: (a) formation of the tricyclic hydrocarbon taxa-4(5),11(12)-diene, which is then oxygenated to give taxane **2**, and (b) formation of a yet unidentified bicyclic hydrocarbon, which is oxygenated to give the canadensene family, including **1**. The canadensenes might be dead-end metabolites or may be further cyclized to tricyclic taxanes.

Taxane **3** was isolated as an analogue of 7-*epi*-taxol,[22] and the ^{1}H NMR data of the two compounds were very similar. The only difference was at C-2′; H-2′ had a chemical shift at δ 5.55 (J = 3.3 Hz) in **3**, while in 7-*epi*-taxol it occurred at δ 4.81 (d, J = 2.6 Hz). The downfield shift of this proton signal suggested the location of an acetate at C-2′. This was confirmed by the HMBC correla-

Table 2. ^{1}H and ^{13}C NMR Data for Taxane **2** in $CDCl_3$

position	δ ^{1}H mult.[a] (*J* in Hz)	δ ^{13}C[b]	HMBC	NOESY
1	1.79 br d (8.5)	46.1	11, 15	2, 14a, Me-16
2	5.56 br d (4.0)	71.9	3, 8, 14, 169.1	3, 9, Me-17, Me-19
3	3.35 m	44.4		2, 7b, 10, 14b, 20b, Me-18
4				
5	5.79 m (3.4)	125.1		6, 20a
6a, 6b	2.12 m	22.5		5, 7b, Me-19
7a	2.01m	28.2		7b, Me-19
7b	1.42 dt (11.9; 6.9)			3, 6, 7a, 10
8		42.0		
9	5.94 d (10.7)	76.1	7, 8, 10, 19, 169.6	2, Me-17, Me-19
10	5.91 d (10.7)	72.2	9, 12, 15, 169.9	3, 7b, Me-18
11		135.8		
12		137.9		
13	5.61 br d (10.1)	69.1		14a, Me-16
14a	2.78 ddd (16.1; 10.1; 8.5)	28.9		1, 13, 14b, Me-16
14b	1.88 dd (16.1; 3.5)			3, 14a, 20b
15		38.0		
16	1.03 s	33.0	1, 11, 15, 17	13, 14a, Me-17
17	1.76 s	25.5	1, 11, 15, 16	2, 9, Me-16
18	1.97 s	15.6	11, 12, 13	3, 10, 13
19	0.96 s	17.6	3, 7, 8, 9	2, 6, 7a, 9
20a	4.98 d (14.0)	67.0		5, 20b
20b	4.78 d (14.0)			3, 14b, 20a
OAc	2.09 s	20.9	170.5	
	2.06 s	20.9	169.6	
	2.06 s	21.7	169.1	
	2.01 s	21.1	169.9	
OCinn				
C=O		166.6		
CH=α	6.46 d (16.0)	117.8	Ph-1, C=O	
CH=β	7.70 d (16.0)	144.8	C α, C=O, Ph-*o*	
Ph-1		134.4		
o	7.53 m	128.1	Ph-*p*	
m	7.38 m	129.1	Ph-1, Ph-*o*, Ph-*p*	
p	7.38 m	130.3		

[a] Mult. = multiplicity: br, broad; d, doublet; m, multiplet; o, overlapping; s, singlet; t, triplet. The precision of the coupling constants is ±0.5 Hz. [b] The ^{13}C NMR chemical shifts were extracted from the HMQC and HMBC (for quaternary carbons) experiments (±0.2 ppm).

tions of H-2′ to its geminal acetyl (δ 169.8) as well as to the C-1′ carboxylate (δ 167.8). The stereochemistry of compound **3** as determined by NOESY correlations was the same as that for 7-*epi*-taxol. Natural taxanes with a C-2′-acetyl have not been reported among the yews. However, these derivatives are easily prepared by acetylation.[23] Indeed, acetylation of 7-*epi*-taxol yielded a compound identical to **3**, whose structure was, therefore, 2′-acetyl-7-*epi*-taxol. HRFABMS confirmed the elemental composition of its quasimolecular ion.

Taxane **4** was identified as 9-deacetyl-taxinine E from its NMR data, which were very different from the NMR data reported for 10-deacetyl-taxinine E, a compound isolated from the leaves and stems of *T. chinensis*.[24] The HMBC correlations confirmed the assignments of H-9 and H-10: the Me-19 protons showed the expected four correlations (^2J and ^3J) to C-3, C-7, C-8, and C-9; H-9 was correlated to C-7, C-8, C-10, and C-19, whereas H-10 was correlated to C-9, C-11, C-12, and C-15 and to the acetyl carbonyl at δ 170.0. The ^{1}H NMR data obtained were very similar to those of taxinine E,[11,16] except for H-9 (δ 4.34), which was shielded, indicating the presence of a hydroxyl group. This was further confirmed by a COSY correlation of a hydroxyl proton to H-9. The stereochemistry obtained from the NOESY spectrum also showed the same relative stereochemistry as taxinine E. HRFABMS confirmed the elemental composition of the sodiated quasimolecular ion of **4**. Proof of this structure was given by acetylation of taxane **4**, which gave a product identical to taxinine E.[11,16]

In addition, five known taxanes were isolated for the first time from this plant. Their structures were determined as 2-deacetyl-taxinine J,[25] 2-deacetyl-5-decinnamoyl-taxinine E,[26] 1β,7β-dihydroxy-4β,20-epoxy-2α,5α,9α,10β,13α-pentaacetoxytax-11-ene,[27] 1β,9α-dihydroxy-4β,20-epoxy-2α,5α,7β,10β,13α-pentaacetoxytax-11-ene,[27] and 1β-hydroxy-10-deacetyl-baccatin I,[28] based on the NMR and HRFABMS data. The compounds 1β,7β-dihydroxy-4β,20-epoxy-2α,5α,9α,10β,13α-pentaacetoxytax-11-ene and 1β,9α-dihydroxy-4β,20-epoxy-2α,5α,7β,10β,13α-pentaacetoxytax-11-ene were isolated as a mixture. Indeed, the facile intramolecular acyl migration among C-7, C-9, and C-10 made their separation very difficult. This observation has been made by other researchers.[28]

Experimental Section

General Experimental Procedures. Optical rotations were recorded on a JASCO DIP-370 digital polarimeter. All NMR and HRFABMS data were obtained with the same conditions and instruments reported previously.[11] Similarly, liquid column chromatography and preparative TLC were performed on Si gel and precoated Si gel plates, respectively.[11] Analytical HPLC and preparative HPLC were carried out on the same instruments and conditions published,[11] except that only a 50-min linear gradient method (25% to 100% of CH_3CN in H_2O, flow rate: 18 mL/min) was used. Semipreparative HPLC was performed on the same system as the preparative HPLC but using two Partisil 10 ODS-2 MAG-9 semipreparative columns (Whatman) connected in series (9.4 × 500 mm), and a 50-min gradient method was used with a flow rate at 3 mL/min.

Plant Material. *T. canadensis* Marsh. was collected in September 1997, at St-Jean, Quebec, Canada, and stored at 4 °C before drying when needed. Several specimens representing this collection have been deposited in the herbarium of the Montreal Botanical Gardens.

Extraction and Isolation. Ground, dried needles of *T. canadensis* (4.7 kg) were extracted and treated as described previously[11] to yield 119 g of a dark brown residue. This extract was separated using dry-column chromatography on Si gel (Si gel 60, 70−230 mesh, Selecto Science, Norcross, GA, 1.5 kg, 8 × 83 cm) eluted with CH_2Cl_2−*i*-PrOH (9:1, 3.5 L). After elution, the Si gel was cut into 19 equal bands, and each band was individually eluted with EtOAc−MeOH (1:1, 600 mL). The eluents of the columns from bands 5 through 8 were combined and evaporated to yield 38 g of residue A, which was then subjected to Si gel column chromatography (840 g, 9.5 × 22 cm) with hexane (1 L), hexane−CH_2Cl_2 (3:1 and 1:1, each 2 L), CH_2Cl_2 (2 L), CH_2Cl_2−EtOAc (4:1, 3:2, 2:3, and 1:4, each 2 L), EtOAc (2 L), and EtOAc−MeOH [4:1 (2 L), 3:2 (4 L)], to yield fractions B (7.0−8.2 L), C (9.0−10.0 L), and D (10.0−11.2 L).

Fraction B (4.1 g) was applied to a Si gel column (140 g, 3.5 × 39 cm), eluted with hexane (200 mL), hexane−EtOAc (9:1, 8:2, 7:3, 6:4, 1:1, 4:6, 3:7, 2:8, and 1:9, each 200 mL), EtOAc (200 mL), and EtOAc−MeOH (9:1, 200 mL), to yield fractions B1 (1440−1520 mL, 353 mg) and B2 (1660−1820 mL, 81 mg). B1 was further purified by preparative HPLC to afford 2-deacetyl-taxinine J[25] (6.2 mg). Similarly, purification of B2 by preparative HPLC was followed by preparative TLC (CH_2Cl_2−MeOH, 95:5) to give **1** (1.1 mg).

Fraction C (5.7 g) was applied to a Si gel column (126 g, 4.5 × 21 cm) and eluted with hexane−CH_2Cl_2 [1:1 (300 mL), 4:6, 3:7, 2:8, and 1:9, each 200 mL], CH_2Cl_2 (200 mL), CH_2Cl_2−EtOAc (9:1, 8:2, 7:3, 6:4, 1:1, 4:6, 3:7, and 2:8, each 200 mL), EtOAc (200 mL), and EtOAc−MeOH (8:2, 400 mL) to afford fraction C1 (2480−3060 mL). Fraction C1 (449.5 mg) was further purified by preparative HPLC, followed by preparative TLC (CH_2Cl_2−Me_2CO, 8:2 and hexane−*n*-BuOH, 8:2) and semipreparative HPLC, to finally yield 1*β*,7*β*-dihydroxy-4*β*,20-epoxy-2α,5α,9α,10*β*,13α-pentaacetoxytax-11-ene[27] and 1*β*,9α-dihydroxy-4*β*,20-epoxy-2α,5α,7*β*,10*β*,13α-pentaacetoxytax-11-ene[27] as a mixture (1.4 mg) and 1*β*-hydroxy-10-deacetyl-baccatin I[28] (0.5 mg).

Fraction D (5.6 g) was applied to a Si gel column (125 g, 4.5 × 20 cm) and eluted with CH_2Cl_2 (200 mL), CH_2Cl_2−EtOAc (9:1, 8:2, 7:3, 6:4, 1:1, 4:6, 3:7, 2:8, and 1:9, each 200 mL), EtOAc (200 mL), and EtOAc−MeOH (9:1 and 8:2, each 200 mL), to obtain fractions D1 (500−700 mL), D2 (700−1000 mL), and D3 (1740−1840 mL). Fraction D1 (130 mg) was further purified by preparative HPLC, followed by semipreparative HPLC, to yield **2** (2.5 mg). Fraction D2 (206 mg) was also subjected to preparative HPLC to give **3** (1.8 mg). The other fractions from this HPLC column were further purified by preparative TLC (hexane−*n*-BuOH, 8:2, CH_2Cl_2−MeOH, 9:1, and CH_2Cl_2−Me_2CO, 8:2) to afford **4** (4.9 mg). Fraction D3 (225 mg) was purified on a preparative HPLC column, followed by preparative TLC (EtOAc and CH_2Cl_2−Me_2CO, 8:2), to produce 2-deacetyl-5-decinnamoyl-taxinine E[26] (2.3 mg).

5-*epi*-Cinnamoylcanadensene (1): $[\alpha]^{23}_D$ +110° (*c* 0.01, $CHCl_3$); ^1H and ^{13}C NMR, see Table 1; HRFABMS *m*/*z* 747.29889 (calcd for $C_{39}H_{48}O_{13}Na$, 747.29926); HPLC, t_R = 42.68 min; visualized as a brown spot on TLC plate with R_f = 0.45 (CH_2Cl_2−MeOH, 95:5).

2,9,10,13-Tetraacetoxy-20-cinnamoyloxy-taxa-4(5),11(12)-diene (2): $[\alpha]^{23}_D$ +53° (*c* 0.06, $CHCl_3$); ^1H and ^{13}C NMR, see Table 2; HRFABMS *m*/*z* 673.29904 (calcd for $C_{37}H_{46}O_{10}Na$, 673.29887); HPLC, t_R = 53.82 min; visualized as a black spot on TLC plate with R_f = 0.85 (CH_2Cl_2−MeOH, 95:5).

2′-Acetyl-7-*epi*-taxol (3): $[\alpha]^{22}_D$ −30° (*c* 0.05, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 8.16 (2H, d, *J* = 7.8 Hz, OBz-*o*), 7.72 (2H, d, *J* = 7.7 Hz, 5′-Ph-*o*), 7.60 (1H, t, *J* = 7.4 Hz, OBz-*p*), 7.52 (2H, t, *J* = 7.2 Hz, OBz-*m*), 7.49−7.30 (8H, m, 3′-Ph and 5′-Ph-*m*, *p*), 6.87 (1H, d, *J* = 9.1 Hz, H-4′), 6.82 (1H, s, H-10), 6.22 (1H, t, *J* = 9.0 Hz, H-13), 5.97 (1H, dd, *J* = 9.1, 3.3 Hz, H-3′), 5.74 (1H, d, *J* = 7.1 Hz, H-2), 5.55 (1H, d, *J* = 3.3 Hz, H-2′), 4.93 (1H, dd, *J* = 8.6, 3.4 Hz, H-5), 4.67 (1H, d, *J* = 11.4 Hz, 7-O*H*), 4.38 (2H, br s, H-20a and b), 3.93 (1H, d, *J* = 7.1 Hz, H-3), 3.70 (1H, br ddd, *J* = 11.4, 4.7, 1.7 Hz, H-7), 2.53 (3H, s, OAc), 2.36 (1H, m, H-14a), 2.33, 2.28 (each, 1H, m, H-6a and b), 2.18 (3H, s, OAc), 2.13 (4H, m, H-14b and OAc), 1.90 (3H, s, H-18), 1.66 (3H, s, H-19), 1.17 (3H, s, H-16), 1.13 (3H, s, H-17); ^{13}C NMR ($CDCl_3$) δ 207.4 (C-9), 171.7 (O*C*OCH$_3$), 169.8 (C-2′ and O*C*OCH$_3$), 169.1 (O*C*OCH$_3$), 167.8 (C-1′), 167.3 (O*C*OPh), 167.0 (C-5′), 140.2 (C-12), 138.0−128.0 (3′-Ph, not assigned), 133.7 (OBz-*p*), 132.9 (C-11), 132.4 (5′-Ph-*p*), 130.3 (OBz-*o*), 129.5 (OBz-1), 129.1 (OBz-*m* and 5′-Ph-*m*), 127.4 (5′-Ph-*o*), 83.0 (C-5), 82.1 (C-4), 79.1 (C-1), 78.0 (C-10), 77.9 (C-20), 75.7 (C-7), 75.6 (C-2), 74.0 (C-2′), 71.8 (C-13), 57.6 (C-8), 52.9 (C-3′), 42.5 (C-15), 40.6 (C-3), 35.8 (C-14), 35.2 (C-6), 25.9 (C-16), 22.5 (OCO*C*H$_3$), 21.3 (C-17), 20.9, 20.7 (both OCO*C*H$_3$), 16.2 (C-19), 14.6 (C-18); HMBC correlations H-2/C-1, -3, -8, and OBz; OH-7/C-6 and -7; H-10/C-9, -11, -12, -15, and OAc; H-16/C-1, -11, -15, and -17; H-17/C-1, -11, -15, and -16; H-18/C-11, -12, and -13; H-19/C-3, -7, -8, and -9; H-20/C-3 and -4; H-2′/C-1′ and OAc; H-3′/C-5′; H-4′/C-5′; NOESY correlations H-2/H-20, -17, and -19; H-3/H-6a, OH-7, -10, -14a, and -18; H-5/H-6a, -6b, OH-7 and -20; H-6a/H-3, -5, and OH-7; H-6b/H-5 and -7; OH-7/H-3, -5, -6a, -6b, -7, -10, and -18; H-10/H-3, OH-7, and -18; H-13/H-14b, -16 and -18; H-16/H-13; H-17/H-2; H-18/H-3, OH-7, -10, -13, and -2′; H-19/H-2, -7, and -20; H-20/H-2, -5, and -19; H-2′/H-18, -3′, and OAc; H-3′/H-2′, -4′, and OAc; H-4′/H-3′; HRFABMS *m*/*z* 918.33123 (calcd for $C_{49}H_{53}NO_{15}Na$, 918.33129); HPLC, t_R = 43.12 min; visualized as a black spot on TLC plate with R_f = 0.70 (CH_2Cl_2−Me_2CO, 8:2).

Acetylation of 7-*epi*-taxol. 7-*epi*-Taxol[7] (6 mg) was treated with 0.5 mL of acetic anhydride and 0.5 mL of pyridine at room temperature for 24 h and yielded a major product identical to **3**: $[\alpha]^{21}_D$ −27° (*c* 0.34, $CHCl_3$); (NMR, HRFABMS, HPLC, and TLC).

9-Deacetyl-taxinine E (4): $[\alpha]^{23}_D$ +85° (*c* 0.11, $CHCl_3$); ^1H NMR ($CDCl_3$) δ (1H, d, *J* = 16.0 Hz, C*H*═β OCinn) 7.49 (2H, m, Ph-*m* OCinn), 7.40 (3H, m, Ph-*m*, *p*-OCinn), 6.67 (1H, d, *J* = 16.0 Hz, C*H*═α OCinn), 5.86 (1H, d, *J* = 9.7 Hz, H-10), 5.78 (1H, br t, *J* = 8.0 Hz, H-13), 5.47 (1H, t, *J* = 3.0 Hz, H-5), 5.42 (1H, dd, *J* = 6.0, 1.9 Hz, H-2), 5.38, 5.01 (each 1H, s, H-20a and 20b), 4.34 (1H, dd, *J* = 9.7, 2.4 Hz, H-9), 3.34 (1H, d, *J* = 6.0 Hz, H-3), 2.65 (1H, m, H-14a), 2.31 (3H, s, H-18), 2.17 (1H, o m, OH-9), 2.11 (3H, s, OCOC*H*$_3$), 2.03 (3H, s, OCOC*H*$_3$), 1.97 (1H, m, H-7a), 1.86 (1H, m, H-6a), 1.82 (1H, br d, *J* = 8.8 Hz), 1.79 (3H, s, OCOC*H*$_3$), 1.73 (1H, m, H-6b), 1.66 (1H, m, H-7b), 1.62 (1H, s, H-17), 1.47 (1H, dd, *J* = 15.3, 7.6 Hz, H-14b), 1.10 (6H, s, H-16 and H-19); ^{13}C NMR ($CDCl_3$) δ 170.4, 170.0, 169.2 (3 × O*C*OCH$_3$), 166.0 (OCinn), 145.0 (*C*H═β OCinn), 136.4 (C-12), 134.1 (Ph-1 OCinn), 134.0 (C-11), 130.4 (Ph-*p* OCinn), 129.1 (Ph-*m* OCinn), 127.9 (Ph-*o* OCinn), 118.7 (*C*H═α OCinn), 117.7 (C-20), 78.8 (C-5), 75.8 (C-9), 75.6 (C-10), 72.2 (C-2), 70.2 (C-13), 47.9 (C-1), 44.2 (C-8), 43.7 (C-3), 37.3 (C-15), 31.4 (C-16), 28.7 (C-6), 28.4 (C-14), 27.1 (C-17), 25.7 (C-7), 21.5, 21.4, 21.0 (3 × OCO*C*H$_3$), 15.2 (C-19), 18.2 (C-19); HMBC correlations H-3/C-2, -8, and -19; H-9/C-7, -8, -10, and -19; H-10/C-9, -11, -12, -15, and OAc; H-14a/C-2, -12, and -13; H-16/C-1, -11, -15, and -17; H-17/C-1, -11, -15, and -16; H-18/C-11, -12, and -13; H-19/C-3, -7, -8, and -9; NOESY correlations H-1/H-2, -14a, -16, and -17; H-2/H-1, -9, -17, and -19; H-3/H-7b, -14b, and -18; H-5/H-6a, -6b, and -20a; H-6a/H-5 and -6b; H-6b/H-5, -6a, and -19; H-7a/H-7b and -19; H-7b/H-3, -7a, -10, and -18; H-9/H-2, -17, and -19; H-10/H-7b and -18; H-13/H-14a and -16; H-14a/H-1, -13, -14b, and -16; H-14b/H-3 and -14a; H-16/H-1, -13, -14a, and -17; H-17/H-2, -9, -16, and -19; H-18/H-3, -7, -10, -13, and CH═α; H-19/H-2, -6b, -7a, -9, -17, and -20b; H-20a/H-20b; H-20b/H-20a; HRFABMS *m*/*z* 631.28824 (calcd for $C_{35}H_{44}O_9Na$, 631.28830); HPLC, t_R = 47.27 min; visualized as a black spot on TLC plate with R_f = 0.60 (CH_2Cl_2−Me_2CO, 8:2).

Acetylation of 4. Compound **4** (2 mg) was treated with acetic anhydride (0.5 mL) in pyridine (0.5 mL) at room temperature for 22 h, and the product was determined by $[\alpha]^{21}_D$ +47° (*c* 0.12, $CHCl_3$), ^1H NMR, and HPLC data to be identical to taxinine E.[11,16]

2-Deacetyl-taxinine J: $[\alpha]^{23}_D$ +17° (*c* 0.15, $CHCl_3$);[25] HRFABMS *m*/*z* 689.29406 (calcd for $C_{37}H_{46}O_{11}Na$, 689.29378); HPLC, t_R = 43.89 min; visualized as a black spot on TLC plate with R_f = 0.75 (CH_2Cl_2−Me_2CO, 8:2).

Acetylation of 2-deacetyl-taxinine J. This compound (1.7 mg) was treated with acetic anhydride (0.5 mL) in pyridine (0.5 mL) at room temperature for 22 h. It gave a product with $[\alpha]^{24}_D$ +34° (*c* 0.21, $CHCl_3$), ^1H NMR, and HPLC data identical to literature values for taxinine J.[2,25]

2-Deacetyl-5-decinnamoyl-taxinine E:[26] $[\alpha]^{23}_D$ +20° (*c* 0.26, $CHCl_3$); HRFABMS *m*/*z* 501.24648 (calcd for $C_{26}H_{38}O_8$-Na, 501.24644); HPLC, t_R = 30.61 min; visualized as a brown spot on TLC plate with R_f = 0.45 (CH_2Cl_2−Me_2CO, 8:2).

1*β*,7*β*-Dihydroxy-4*β*,20-epoxy-2α,5α,9α,10*β*,13α-pentaacetoxytax-11-ene and 1*β*,9α-Dihydroxy-4*β*,20-epoxy-2α, 5α,7*β*,10*β*,13α-pentaacetoxytax-11-ene:[27] HRFABMS *m*/*z* 633.25234 (calcd for $C_{30}H_{42}O_{13}Na$, 633.25231); HPLC, t_R = 27.26 min; visualized as a green spot on TLC plate with R_f = 0.60 (CH_2Cl_2−Me_2CO, 8:2).

1*β*-Hydroxy-10-deacetyl-baccatin I:[28] $[\alpha]^{23}_D$ +60° (*c* 0.01, $CHCl_3$); HRFABMS *m*/*z* 633.25221 (calcd for $C_{30}H_{42}O_{13}Na$, 633.25231); HPLC, t_R = 26.17 min; visualized as a green spot on TLC plate with R_f = 0.35 (CH_2Cl_2−Me_2CO, 8:2).

Esterification of 5-*epi*-canadensene. To a solution of 5-*epi*-canadensene[15] (7 mg, 0.013 mmoL) in dry toluene was added 10 mg of cinnamic acid (0.065 mmoL, 5 equiv), 14 mg of DCC (dicyclohexylcarbodiimide, 0.065 mmoL, 5 equiv), and 8 mg of DMAP [4-(dimethylamino)pyridine, 0.065 mmoL, 5 equiv]. The mixture was stirred at 90 °C under nitrogen for 5 h (TLC showed no starting material left) and then evaporated to dryness. This residue was then purified by preparative HPLC and yielded 20-cinnamoyl-5-*epi*-canadensene (**1a**, 2.1 mg, 22% yield) and 5,20-biscinnamoyl-*epi*-canadensene (**1b**, 5.3 mg, 48% yield).

20-Cinnamoyl-5-*epi*-canadensene (1a): ^1H NMR δ 7.46 (1H, d, J = 16.0 Hz, CH=α), 7.49 (2H, m, Ph-H), 7.38 (3H, m, Ph-H), 6.92 (1H, s, H-10), 6.51 (1H, d, J = 11.6 Hz, H-3), 6.37 (1H, d, J = 16.0 Hz, CH=*β*), 5.84 (1H, dd, J = 11.6, 4.3 Hz, H-2), 5.28 (1H, d, J = 9.2 Hz, H-7), 5.08 (1H, d, J = 7.7 Hz, H-13), 4.93 (1H, d, J = 12.8 Hz, H-20a), 4.55 (1H, o d, J = 12.8 Hz, H-20b), 4.54 (1H, br s, H-5), 3.93 (1H, d, J = 3.9 Hz, OH-5), 2.63 (1H, dd, J = 16.1, 7.8 Hz, H-6a), 2.53 (1H, m, H-14a), 2.21 (3H, s, Ac), 2.18 (1H, o m, H-14b), 2.17 (3H, s, Ac), 2.09 (3H, s, Ac), 2.03 (1H, dd, J = 16.1, 4.5 Hz, H-6b), 1.97 (3H, s, Ac), 1.96 (3H, s, Ac), 1.94 (3H, s, Me-18), 1.82 (1H, t, J = 5.2 Hz, H-1), 1.67 (3H, s, Me-19), 1.29 (3H, s, Me-17), 1.12 (3H, s, Me-16); HRFABMS *m*/*z* 747.29889 (calcd for $C_{39}H_{48}O_{13}Na$, 747.29926).

5,20-Biscinnamoyl-*epi*-canadensene (1b): ^1H NMR δ 7.89 (1H, d, J = 16.0 Hz, CH=α1), 7.69 (1H, d, J = 16.1 Hz, CH=α2), 7.52 (4H, m, Ph-H), 7.39 (6H, m, Ph-H), 7.28 (1H, s, H-10), 6.59 (1H, d, J = 16.0 Hz, CH=*β*1), 6.43 (1H, d, J = 16.1 Hz, CH=*β*2), 5.99 (1H, d, J = 11.0 Hz, H-3), 5.84 (1H, br s, H-5), 5.84 (1H, m, H-2), 5.49 (1H, d, J = 9.1 Hz, H-7), 5.27 (1H, d, J = 9.4 Hz, H-13), 5.03 (1H, d, J = 13.0 Hz, H-20a), 4.57 (1H, d, J = 13.0 Hz, H-20b), 2.58 (2H, m, H-6a and -14a), 2.27 (3H, s, Me-18), 2.21 (3H, s, Ac), 2.12 (1H, m, H-6b), 2.02 (1H, m, H-14b), 1.98 (3H, s, Ac), 1.97 (3H, s, Ac), 1.95 (3H, s, Ac), 1.86 (3H, s, Ac), 1.82 (1H, t, J = 5.6 Hz, H-1), 1.66 (3H, s, Me-19), 1.34 (3H, s, Me-17), 1.12 (3H, s, Me-16); HRFABMS *m*/*z* 877.34148 (calcd for $C_{48}H_{54}O_{14}Na$, 877.34113).

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