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SESQUITERPENE ESTERS FROM *TRIPTERYGIUM WILFORDII* HOOK FIL. VAR. *REGELII*, STRUCTURES OF TRIPTOFORDINS A–C-1

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Key Word Index—*Tripterygium wilfordii*; *Celastraceae*; triptofordin; sesquiterpene.

Abstract—New sesquiterpene esters, triptofordins A, B, C-1 and C-2 have been isolated from the leaves of *Tripterygium wilfordii* Hook fil var. *regelii* and their structures established. The absolute structure of triptofordins B and C-1 were determined by using the CD dibenzoate chirality method.

INTRODUCTION

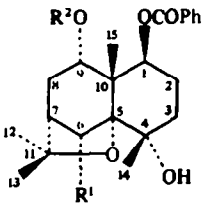
Tripterygium wilfordii Hook has been used as a drug for the treatment of cancer and as an insecticide by the Chinese for hundreds of years. Recently, this plant has been used to treat rheumatoid arthritis and ankylosing spondylitis in some Chinese clinics [1]. Information on its chemistry is limited to the root bark of *T. wilfordii* which contains antitumour diterpenes[2] and insecticidal sesquiterpene alkaloids [3]. We now describe the isolation and structure elucidation of four new sesquiterpenes, triptofordins A(1), B(2), C-1(3), and C-2(4) from the leaves of *Tripterygium wilfordii* Hook fil. var. *reglii*.

RESULTS AND DISCUSSION

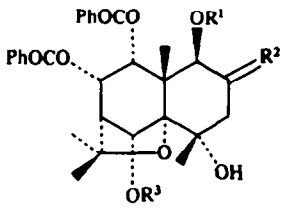
The leaves of *T. wilfordii* Hook fil. var. *regelii* were dried, and extracted with methanol. The methanol extracts were concentrated and partitioned between ethyl acetate and water. Column chromatography of the ethyl acetate extracts on silica gel and Sephadex LH-20 afforded triptofordins A(1), B(2), C-1(3), and C-2(4).

Compound 1, triptofordin A, showed absorption at 3400(OH) and 1710(COO) cm^{-1} in the IR spectrum. The UV spectrum of 1 showed the presence of benzoate and cinnamate moieties.

The presence of benzoate and cinnamate ester groups in 1 was also revealed by the NMR (Tables 1 and 2) spectra and the consecutive loss of *m/z* 122(C_6H_5COOH) and 148($C_6H_5CH{=}CHCOOH$) units in the mass spectrum. The ^1H NMR spectrum of 1 showed four singlets at δ1.31–1.45, which were attributed to four quaternary methyl groups. The tertiary hydroxy group is responsible for a signal at δ2.73 (exchangeable with D_2O). It also showed benzoate and cinnamate at δ6.24 (*d*, J = 16.1 Hz), 7.32 (*d*, J = 16.1), and 7.1–7.8 (10 H). The ^{13}C NMR spectrum (Table 2) of 1 showed four methyls, four methylenes, one methine, two methines attached to an oxygen function, one tertiary carbon, and three tertiary carbons attached to an oxygen function. These facts agreed with a molecular formula of 1 as $C_{31}H_{36}O_6$. The data presented account for five of the six oxygen atoms present being in two ester and one hydroxy groupings in compound 1. The sixth oxygen atom must be an ether



1 R¹ = H, R² = COCH=CHPh
2 R¹ = OH, R² = COPh



Ac

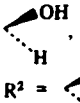
3 R¹ = R³ = Ac, R² = O
4 R¹ = R³ = Ac, R² = 
4b R¹ = H, R² =  , R³ = H
4c R¹ = H, R² =  , R³ = H
4d R¹ = R³ = Ac, R² = 

Table 1. ^{1}H NMR spectral data for triptofordins A (1), B(2), C-1(3), C-2(4) and the derivatives (4b–4d)

	1	2	3	4	4b	4c	4d
H-1	5.63 *dd* (11.8) (4.0)	5.61 *dd* (11.7) (4.2)	5.90 *s*	5.45 *d* (3.4)	4.56 *t* (3.9)	5.47 *d* (3.7)	5.53 *s*
H-2				4.37 *m*	5.31 *m*	4.41 *m*	5.53 *s*
H-3	2.41 *ddd* (12.2) (4.6) (2.9)		2.58 *d* (12.8) 3.11 *d* (12.8)	2.08 *d* (2.9)		2.10 *d* (2.7)	
H-6		4.51 *d* (5.6)	5.71 *s*	5.72 *s*	4.67 *d* (5.3)	4.69 *d* (5.1)	5.73 *s*
H-7	—	—	2.69 *d* (3.4)	2.60 *d* (3.2)	2.68 *d* (3.1)	2.64 *d* (3.0)	2.62 *d* (3.3)
H-8	2.20 *ddd* (16.6) (5.4) (3.9)	2.34 *ddd* (15.4) (6.4) (2.9)	5.89 *dd* (6.4) (3.4)	5.89 *dd* (6.3) (3.2)	5.73 *dd* (6.5) (3.1)	5.72 *dd* (6.4) (3.0)	5.89 *dd* (6.3) (3.3)
H-9	4.93 *d* (5.4)	5.08 *d* (6.4)	5.52 *d* (6.4)	5.47 *d* (6.3)	5.42 *d* (6.5)	5.42 *d* (6.4)	5.46 *d* (6.3)
H-12	1.45 *s*	1.53 *s*	1.86 *s*	1.75 *s*	1.83 *s*	1.88 *s*	1.76 *s*
H-13	1.32 *s*	1.60 *s*	1.66 *s*	1.69 *s*	1.78 *s*	1.77 *s*	1.64 *s*
H-14	1.31 *s*	1.65 *s*	1.33 *s*	1.58 *s**	1.46 *s**	1.61 *s**	1.53 *s**
H-15	1.41 *s*	1.51 *s*	1.41 *s*	1.59 *s**	1.61 *s**	1.65 *s**	1.59 *s**

1: Benzoate and cinnamate [6.24, 7.32 (each 1H, *ABq*, J = 16.1 Hz), 7.08–7.80 (10 H)]; 2: benzoate × 2[7.18–7.78 (10 H)]; 3: Ac × 2[1.77, 2.15 (each 3H, *s*)], benzoate × 2[7.20–7.93 (10H)]; 4: Ac × 2[1.77, 2.15 (each 3H, *s*)], benzoate × 2[7.20–7.93 (10H)]; 4b: Ac[2.09 (3H, *s*)], benzoate × 2[7.23–8.04 (10H)]; 4c: Ac[1.75 (3H, *s*)], benzoate × 2[7.20–7.94 (10 H)]; 4d: Ac × 3[1.67, 2.06, 2.16 (each 3H, *s*)], benzoate × 2[7.20–7.93(10H)].

Figures in parentheses are coupling constants in Hz, run at 200 MHz in $CDCl_3$.

*Values in any vertical column may be interchanged.

†The signal could not be observed owing to overlapping.

which led us to propose a dihydroagarofuran skeleton [4], as shown in structure 1. Since the ^{1}H NMR spectrum of 1 showed signals at δ5.63 (1H, *dd*) and 4.93 (1H, *d*), the ester groups must be attached to secondary carbon atoms. The similarity of the signals observed at δ5.63 (*dd*, J = 11.8, 4.0 Hz) with the signal shown by the C-1 proton in mortonol A [5] (δ5.75, *dd*, J = 10, 5 Hz) led us to place one of the ester groups at C-1 with an equatorial configuration, as found in all the sesquiterpenes with a dihydroagarofurane skeleton isolated from plants of the Celastraceae [4]. The second ester must be axially attached at C-9, since it is responsible for the doublets observed at δ4.93 (J = 5.4), due to equatorial–axial interactions with the C-8 methylene groups [6]. A spin decoupling experiment showed that the C-8 axial proton appeared at δ2.20 (*ddd*, J = 16.6, 5.4, 3.9 Hz) and coupled with H-9. The tertiary hydroxy group was shown to be attached to C-4.

The location of the ester and relative stereochemistry were determined by NOE experiments (Table 3). On irradiation of H-15 the intensity of the H-9 signal was increased (11.7%). When the H-12 signal was irradiated, an increase (3.3%) in intensity of the cinnamoyl proton (δ6.24) signal occurred, demonstrating that the cinnamoyl ester was attached at C-9. Thus the structure of triptofordin A was shown to be 1.

The IR spectrum of compound 2, triptofordin B, $C_{29}H_{34}O_7$, showed the presence of hydroxy and ester groups. The UV spectrum of 2 showed the presence of benzoate. The ^{1}H NMR spectrum of 2 suggested the presence of two benzoate groups (δ7.18–7.78, 10 H) and two hydroxy groups (δ3.32 and 5.16, each signal exchangeable with D_2O).

The structural similarity between triptofordins A (1) and B(2) was indicated by the resemblance of the ^{13}C NMR spectra of both compounds except at C-6. Comparison of the ^{1}H NMR spectra of 1 and 2 clearly indicated the location of the secondary hydroxy group to be at C-6 in 2. Furthermore, the signal of H-9 in 2 occured at lower field than that of 1, which was explained by the change of ester from cinnamate to benzoate in 2. The relative stereochemistry was determined by NOE experiments as shown in Table 3. Thus, the structure of triptofordin B was proposed to be 2.

The absolute configuration of 2 was determined by the application of the dibenzoate chirality method [7]. The CD spectrum of 2 gave a split Cotton curve: $[\theta]_{239}$ +96 000°, $[\theta]_{223}$ −67 000°, thus corroborating the (1*S*, 9*S*)-configuration of 2.

The IR spectrum of compound 3, triptofordin C-1, $C_{33}H_{36}O_{11}$, showed the presence of hydroxy, ketone and esters groups. The ^{1}H and ^{13}C NMR spectra of 3 showed two benzoate groups, two acetate groups and one ketone. Further, the following groups (I–IV) were shown to be present in 3 by analysis of the ^{1}H NMR spin–spin coupling patterns, with the aid of the double resonance experiments. Characteristic signal patterns were observed due to an ABX system (δ5.52, 5.89, 2.69) AB system (δ2.58, 3.11),

Table 2. ^{13}C NMR spectral data for the skeletal carbons of Triptofordins A(1), B(2), C-1(3) and C-2(4)

	1	2	3	4
C-1	73.1 *d***	73.5 *d*	76.6 *d*	72.6 *d***
2	24.0 *t*	23.4 *t*	200.5 *s*	67.7 *d*
3	37.1 *t*	37.3 *t*	54.7 *t*	44.1 *t*
4	70.3 *s*	73.1 *s*	74.1 *s*	70.2 *s*
5	90.7 *s*	91.5 *s*	91.3 *s*	91.7 *s*
6	31.2 *t*	79.7 *d*	69.4 *d*	69.2 *d*
7	43.7 *d*	50.2 *d*	53.9 *d*	54.1 *d*
8	31.6 *t*	32.0 *d*	77.1 *d*	77.3 *d*
9	73.8 *d***	73.2 *d*	72.1 *d*	72.3 *d***
10	48.2 *s*	50.6 *s*	51.9 *s*	50.1 *s*
11	83.5 *s*	84.5 *s*	85.8 *s*	84.8 *s*
12*	24.0 *q*	26.6 *q*	26.5 *q*	26.7 *q*
13	30.1 *q*	30.1 *q*	30.3 *q*	30.3 *q*
14*	24.4 *q*	23.8 *q*	25.0 *q*	25.5 *q*
15	19.3 *q*	20.3 *q*	19.9 *q*	20.7 *q*
COO	165.8 *s*	165.2 *s*	164.7 *s*	164.8 *s*
	165.9 *s*	165.4 *s*	165.1 *s*	165.7 *s*
			169.1 *s*	170.0 *s*
			169.7 *s*	170.0 *s*
CH_3CO			20.6 *q*	21.4 *q*
			21.3 *q*	21.8 *q*

1: Cinnamate [118.2*d*, 144.9*d*, 134.6*s*, 128.0*d*, 128.1*d*, 130.0*d*], benzoate [130.6*s*, 129.3*d*, 128.6*d*, 132.6*d*]; 2: benzoate × 2[129.3*s*, 130.0*s*, 129.0*d*, 129.8*d*, 127.9*d*, 127.9*d*, 132.5*d*, 132.8*d*]; 3: benzoate × 2[128.9*s*, 129.2*s*, 129.6*d*, 129.9*d*, 128.4*d*, 128.5*d*, 133.2*d*, 133.6*d*]; 4: benzoate × 2[129.3*s*, 129.4*s*, 129.6*d*, 130.2*d*, 128.2*d*, 128.3*d*, 133.1*d*, 133.4*d*].

*,**Assignment may be interchanged in each compounds.

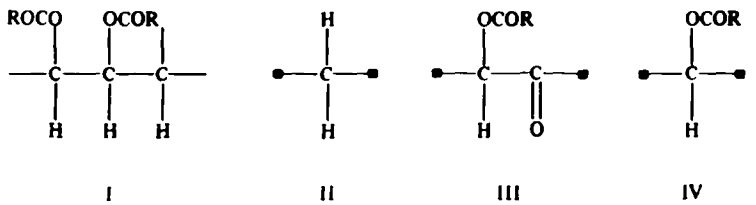
Table 3. NOE of triptofordins A(1), B(2) and C-1(3)

Compound	Proton irradiated	Proton observed	Enhancement (%)
1	H-12	C_6H_5CH=CH	3.3
	H-14	H-3	5.6
	H-15	H-9	11.7
2	H-14	H-6	8.3
	H-15	H-6	16.8
		H-9	16.0
	H-3α	H-1α	6.1
	H-6	H-15	12.0
		H-7	10.4
3	H-8	H-6	7.3
		H-9	17.8
	H-13	H-7	10.3
	H-14	H-3	7.2
		H-6	5.5
	H-15	H-6	15.0
		H-9	15.0

two singlet protons (δ5.71, 5.90) attached to the carbon atom bearing the secondary ester group, and tertiary hydroxy proton (δ3.24). The tertiary hydroxy group was shown to be attached to C-4 in the dihydroagarofuran skeleton in vew of the fact that 3 had four methyl groups. There are three possible structures in accordance with partial structures I–IV. The partial structure I was placed at C-9 to C-7. The ketone was placed at C-2 because the signals at δ2.58 and 3.11 (*ABq*, J = 12.8 Hz) were assigned to methylene adjacent to a ketone. There are three possible positions (C-1, C-3, C-6) to put partial structure II. The location of partial structure and stereochemistry of 3 was inferred from the NOE experiments on 3, and the results are summarized in Table 3. On irradiation of H-15 the intensities of the H-9 and H-6 signals were increased, which indicated that H-9 and H-6 are in the β-configuration. When the H-14 signal was irradiated, an increase in intensities of the H-3 and H-6 signals occurred, demonstrating that the partial structure III is located at C-1 and C-2. The increasing intensity from H_{ax}-3 to H-1 and from H-8 to H_{ax}-6 indicated that H-1 and H-8 were oriented in the α- and β-configurations, respectively. Thus, the stereostructure of 3 was represented as shown, but the locations of the acetate and benzoate moieties were not determined at this stage.

Compound 4, triptofordin C-2, $C_{33}H_{38}O_{11}$, contained two acetate, two benzoate and two hydroxy groups as revealed by the NMR, UV, mass and IR spectra. The ^1H NMR spectra of 3 and 4 were very similar except for the H-1, H-2 and H-3 signals, the H-1 signal in 4 was shifted upfield to appear at δ5.45 (*d*) when compared to that of 3. Also the ^{13}C NMR spectra of 3 and 4 were very similar except that the C-1, C-2, and C-3 signals of 4 appeared further upfield at δ72.6, 67.7, and 44.1. These facts led us to propose that C-2 in 4 bears the hydroxy group, whereas C-2 in 3 has the ketone function. Oxidation of 4 using Jones reagent afforded **4a**, which was identical with 3 on direct comparison (TLC, $[\alpha]_D$, mass and ^1H NMR spectra). This fact indicated that the stereochemistry of 4, with the exception of C-2, was the same as that of 3. Based on the coupling constant (J_{12} = 3.4) in the ^1H NMR spectrum of 4 the *cis*-relationship between H-1 and H-2 was established.

In order to establish the positions of the acetate and benzoate groups in 4, the partial hydrolysis and acetylation of 4 was attempted. The partial hydrolysis of 4 using K_2CO_3–MeOH afforded **4b** and **4c**. The ^1H NMR spectra of **4b** and **4c** showed the loss of one acetate group compared with 4, the position of one acetate group in 4 was located at C-6 by the upfield shift of the signal due to H-6 [4; δ5.72, **4c**; δ4.69] The ^1H NMR comparison of **4b** and **4c** showed that the H-1 signal (δ4.56) of **4b** was shifted upfield compared to that of **4c** (H-1; δ5.47) and the H-2 signal (δ5.31) of **4b** was shifted downfield relative to that of **4c** (H-2: δ4.41). This observation indicated that ester group migration from C-2 to C-1 occurred during the hydrolysis.



I II III IV

If the migrating group is acetate, the acetylation of compounds **4** and **4b** will give the same product. However, if the migrating group is benzoate then the acetylation of compounds **4** and **4b** will give different compounds. In fact, the acetylation of compounds **4** and **4b** using acetic anhydride–pyridine afforded the same compound **4d** These facts reveal that the position of the acetate group in compound **4** is at C-2 and that the position of the two benzoate groups is at C-8 and C-9. The absolute configuration of **4** was determined in the same manner as described above and the structures of triptofordins C-1 and C-2 were determined as **3** and **4**, respectively.

EXPERIMENTAL

Mps were uncorr. ^{1}H NMR 200 MHz, with TMS as internal standard; ^{13}C NMR: 50.1 MHz; CC: silica gel Merck 60, Sephadex LH-20.

Isolation of triptofordins A(**1**), *B*(**2**), *C*-1(**3**) *and C*-4(**4**).

(1) The dry leaves (2.75 kg) of *T. wilfordii* Hook fil var. *regelii* Makino were collected in October 1983 at Mt. Turugi (Tokushima Prefecture, Japan) and extracted with × 3 MeOH (15 l) at 60°C. The MeOH extracts were concentrated *in vacuo* to give a residue (565 g). The residue was partitioned between *n*-hexane and 90% MeOH. The aq. layer was partitioned between EtOAc and H_2O. The EtOAc layer was concentrated to give a residue (176 g), which was chromatographed on a silica gel (1 kg) column. The column was eluted with solvents on increasing polarity [$CHCl_3$, $CHCl_3$–MeOH and MeOH] to give thirteen fractions (fr. 1–13). Fractions (Fr 2, 17.28 g) containing **1**, **2** and **3** were chromatographed on silica gel with hexane–EtOAc. Fractions (0.45 g) containing **1** were further chromatographed on Sephadex LH-20 (MeOH-$CHCl_3$, 3:2) and crystallized from MeOH yielding **1** (25 mg). Fractions (0.57 g) containing **2** were chromatographed on Sephadex LH-20 and crystallized from MeOH yielding **2** (52 mg). Fractions (1.05 g) containing **3** were chromatographed on silica gel ($CHCl_3$-acetone, 95:5) and crystallized from MeOH yielding **3** (20 mg).

(2) The dry leaves (9.0 kg) of the same plant were extracted as described above to give an EtOAc residue (585 g), which was chromatographed repeatedly on silica gel and Sephadex LH-20 columns to give an amorphous powder triptofordin C-2 (**4**) (568 mg).

Triptofordin A (**1**). Mp 220–221°. $[\alpha]_D^{28}$ + 191.7° (MeOH *c* 0.23); IR ν_{max}^{KBr} cm^{-1}: 3400, 1710, 1630, 1170, 1120. UV λ_{max}^{MeOH} nm (ε): 223 (23500), 230(17400), 280(20900). EIMS *m/z* (rel. int.): 504[M]$^+$ (1.6), 489 [M − CH_3]$^+$ (3.1), 382 [M − C_6H_5CH=CHCOOH]$^+$ (4.0), 356 [M − C_6H_5COOH]$^+$ (6.0), 341 (14.1), 251 (12.6), 131 (100), 105 (68.7). FAB-MS *m/z*: 505 [M + H]$^+$. HR-MS *m/z*: 504.2517[M]$^+$. $C_{31}H_{36}O_6$ requires: 504.2512.

Triptofordin B (**2**). Granules, mp 193–195°, $[\alpha]_D^{27}$ + 75.6° (MeOH; *c* 0.23), IR ν_{max} cm^{-1}: 3400, 1700, 1600, 1580, 1450, 1280, 1130. UV λ_{max}^{MeOH} nm (ε): 233 (20300), 276 (3300), 292 (3100). EIMS *m/z* (rel. int.): 494 [M]$^+$ (1.0), 479 [M − CH_3]$^+$ (1.0), 372 [M − C_6H_5COOH]$^+$, (2.2), 122 [C_6H_5COOH]$^+$ (15.1), 105 (100). FABMS *m/z*: 517 [M + Na]$^+$. HRMS *m/z*: 494.2309 [M]$^+$. $C_{29}H_{34}O_7$ required: 494.2305. CD (EtOH, *c* 0.1): $[\theta]_{223}$ − 67 000°, $[\theta]_{239}$ + 96 000°.

Triptofordin C-1 (**3**). Needles, mp 249–251°, $[\alpha]_D^{28}$ − 22.6° (MeOH, *c* 0.22). IR ν_{max}^{KBr} cm^{-1}: 3450, 2950, 1750, 1730, 1280, 1220, 1110, 1030, 710. UV λ_{max}^{MeOH} nm (ε): 230 (23000), 274 (2100), 282 (1700). EI-MS *m/z* (rel. int.): 608[M]$^+$ (0.2), 548 [M − CH_3COOH]$^+$ (1.0), 486 [M − C_6H_5COOH]$^+$ (1.0), 471 (3.5), 426 [M − CH_3COOH − C_6H_5COOH]$^+$ (2.0), 105 [C_6H_5CO]$^+$ (100). HRMS *m/z*: 608.2275 $C_{33}H_{36}O_{11}$ required 608.2258.

Triptofordin C-2 (**4**). Amorphous powder, mp 128–131°, $[\alpha]_D^{22}$ − 44.7° (MeOH, *c* 0.27). IR ν_{max}^{KBr} cm^{-1}: 3450, 2950, 1730, 1280, 1230, 710. UV λ_{max}^{MeOH} nm (ε): 230 (26100), 274 (3900), 281 (3600). EIMS *m/z* (rel. int.): 610 [M]$^+$ (1.0), 593 [M − OH]$^+$ (2.0), 550 [M − CH_2COOH] (20), 490 [M − 2 × CH_3COOH]$^+$ (10), 488 [M − C_6H_5COOH]$^+$ (22), 470 (13), 368 [M − 2 × CH_3COOH − C_6H_5COOH]$^+$ (16), 366 [M − 2 × C_6H_5COOH]$^+$ (13), 246(8), 131 (51), 105 (100), 43 (65). HRMS *m/z*: 610.2402. $C_{33}H_{34}O_{11}$ required 610.2414. CD (EtOH; *c* 0.1): $[\theta]_{224}$ + 15200°, $[\theta]_{237}$ − 45 600°.

Oxidation of compound **4**. Compound **4** (54 mg) was dissolved in Me_2CO (5 ml) and 4 drops of Jones reagent were added. The reaction mixture was stirred at room temp. for 1 hr and treated in the usual way to give a residue, which was chromatographed on a silica gel column (solv. benzene–EtOAc 3:1) afforded **4a** (30 mg), mp 249–251°, $[\alpha]_D^{22}$ − 23.5° (MeOH; *c* 0.22), ^{1}H NMR ($CDCl_3$) δ: 1.33, 1.41, 1.66, 1.86 (each 3H, *s*), 1.76, 2.16 (each 3H, *s*, $COCH_3$), 2.58 (1H, *d*, *J* = 12.8 Hz, H-3) 2.70 (1H, *d*, *J* = 3.4 Hz, H-7), 3.11 (1H, *d*, *J* = 12.8 Hz, Hα-3), 3.25 (1H, *s*, 4-OH), 5.52 (1H, *d*, *J* = 6.4 Hz, H-9), 5.71 (1H, *s*, H-6), 5.89 (1H, *dd*, *J* = 6.4 and 3.4 Hz, H-8), 5.90 (1H, *s*, H-1), 7.23 – 7.95 (10H, aromatic H). **4a** was identical with **3** on direct comparison (TLC, $[\alpha]_D$, MS and ^{1}H NMR).

Partial hydrolysis of compound **4**. A soln of **4** (50 mg) in 0.02 mmol K_2CO_3–MeOH (4 ml) was stirred at room temp. for 1 hr, the reaction mixture was neutralized with 1% HCl, concentrated to give a residue, which was chromatographed on silica gel column (solv. benzene–EtOAc, 2:1) afforded **4b** (9.4 mg), and **4c** (11.0 mg). **4b**: ^{1}H NMR ($CDCl_3$) δ: 1.46, 1.61, 1.78, 1.83 (each 3H, *s*, CH_3), 1.94 (1H, *d*, *J* = 4.6 Hz, 1-OH), 2.09 (3H, *s*, $COCH_3$), 2.68 (1H, *d*, *J* = 3.1 Hz, H-7), 3.28 (1H, *s*, 4-OH), 4.56 (1H, *dd*, *J* = 4.6 and 3.9 Hz, H-1), 4.67 (1H, *d*, *J* = 5.3 Hz, H-6), 4.99 (1H, *d*, *J* = 5.3 Hz, 6-OH), 5.31 (1H, *m*, H-2), 5.42 (1H, *d*, *J* = 6.5 Hz, H-9), 5.73 (1H, *dd*, *J* = 6.5 and 3.1 Hz, H-8), 7.23–8.04 (10H, aromatic H). **4c**: ^{1}H-NMR ($CDCl_3$) δ: 1.61, 1.65, 1.77, 1.88 (each 3H, *s*, CH_3), 1.75 (3H, *s*, $COCH_3$), 2.10 (2H, *d*, *J* = 2.7 Hz, H-3), 2.64 (1H, *d*, *J* = 3.0 Hz, H-7), 3.25 (1H, *s*, 4-OH), 4.41 (1H, *m*, H-2), 4.69 (1H, *d*, *J* = 5.1 Hz, H-6), 5.11 (1H, *d*, *J* = 5.1 Hz, 6-OH), 5.42 (1H, *d*, *J* = 6.4 Hz, H-9), 5.47 (1H, *d*, *J* = 3.7 Hz, H-1), 5.72 (1H, *dd*, *J* = 6.4 and 3.0 Hz, H-8), 7.20–7.94 (10H, aromatic H).

Acetylation of compounds **4** *and* **4b**. A soln of **4** (20 mg) in a mixture of pyridune (0.5 ml) and Ac_2O (0.5 ml) was stirred at 70° for 13 hr, then MeOH (4 ml) was added to the soln which was evaporated to give a residue. This was purified by CC on silica gel (benzene-EtOAc, 2:1) to give **4e** (13 mg). Compound **4e**: ^{1}H NMR ($CDCl_3$) δ: 1.53, 1.59, 1.64, 1.76 (each 3H, *s*, CH_3), 1.67, 2.06, 2.16 (each, 3H, *s*, $COCH_3$), 2.62 (1H, *d*, *J* = 3.3 Hz, H-7), 2.95 (1H, *s*, 4-OH), 5.46 (1H, *d*, *J* = 6.2 Hz, H-9), 5.53 (2H, *s*, H-1 and H-2), 5.73 (1H, *s*, H-6), 5.89 (1H, *dd*, *J* = 6.2 and 3.3 Hz, H-8), 7.20–7.93 (10H, aromatic H).

Acetylation of **4b** (10 mg) was treated in the same way as for **4** to give an amorphous powder **4d** (8 mg). Compound **4d** was identical with **4e** on direct comparison (TLC and ^{1}H NMR).

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