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Novel Picrotoxane Norditerpene Lactones from *Picrodendron baccatum*

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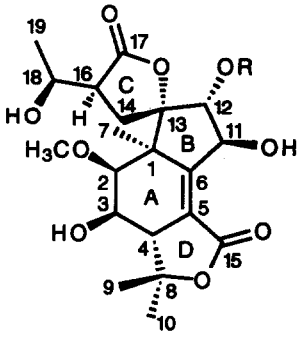
Abstract: Three novel norditerpene lactones, picrodendrins U, V and W, were isolated from the bark of *Picrodendron baccatum*. Their structures were determined by spectral and X-ray diffraction analyses. Their absolute stereochemistries were unambiguously determined by the non-empirical exciton circular dichroism method carried out on their *p*-bromobenzoate derivatives. Picrodendrins U, V and W reported here belong to a new class of rearranged C_{19}-picrotoxane skeleton.

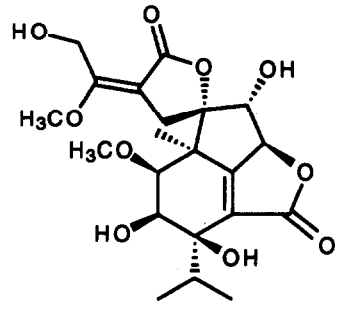
Picrodendron baccatum Klug et Urban (Euphorbiaceae) is used in folk medicine as an insecticide in Dominica.[1] Our chemical studies of the extracts of this plant have resulted in the discovery of a variety of nineteen terpene lactones, which were named picrodendrins, with a picrotoxane framework.[2] Some of these compounds have potent inhibitory activity at the $GABA_A$ receptor-coupled picrotoxinin binding site in rat brains.[3] In addition to previously described compounds, we have found three new norditerpene lactones, picrodendrins U (**1**), V (**2**), and W (**3**), which exhibit a novel class of rearranged picrotoxane skeleton. The structures of the new compounds have been established, as described below, with the aid of spectral techniques and X-ray diffraction analysis.

RESULTS AND DISCUSSION

Compound **1**, $[\alpha]_D$ -70.5° (pyridine), which was obtained as prisms. The molecular formula, $C_{20}H_{28}O_9$, required seven degrees of unsaturation. A band in the IR spectrum at 1752 cm^{-1} indicated that the molecule contained a γ-lactone. Resonances in the ^{13}C NMR spectrum at δ 177.1 (s), 173.5 (s), 170.1 (s), and 131.8 (s) and the UV absorption at 228 nm confirmed the presence of two γ-lactones, one of which was conjugated to a tetrasubstituted alkene. The ^{13}C NMR and DEPT spectra contained no evidence for additional unsaturated functionalties, and thus we concluded that compound **1** was tetracyclic. The ^1H NMR data (Table 1) defined the presence of the three tertiary methyls (δ 1.50, 1.59, 1.86, each 3H, s), one secondary methyl (δ 1.59, 3H, d, *J*=6.1 Hz), and one methoxyl (δ 3.68, 3H, s) groups. The ^1H-^1H COSY spectrum contained three isolated spin systems (H-2 to H-4, H-11 to H-12, H-14 to H-19), and the couplings were defined.



1 R=H
1a R=*p*-Br-Benz



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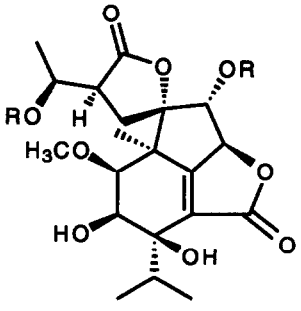

3 R=H
3a R=*p*-Br-Benz

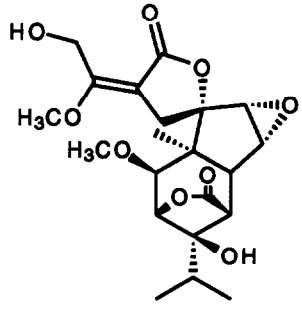

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Figure 1.

Using a combination of HSQC and HMBC spectra and starting from the γ-lactone carbonyl at δ 177.1 (C-17), a three bond correlation could be observed with H-14 and H-18; the former is also coupled with a spiro carbon at δ 96.6 (C-13), a quaternary carbon at δ 50.5 (C-1), and an oxygenated methine carbon at δ 82.0 which was assigned to C-12 because this is also connected by two bond correlation to H-11. A sharp singlet at δ 1.50 (H-7) had HMBC correlation to carbon signals at δ 50.5, 86.9, 96.6, and 170.1 which permitted assignment of the quaternary carbon at δ 50.5 (C-1) and the olefinic quaternary carbon at δ 170.1 (C-6) to the ring junction. HMBC correlation observed from the carbon resonance at δ 51.9 (C-4) to protons at δ 1.59 (H-9) and 1.86 (H-10) resulted in the location of an oxyisopropyl group at C-4. The relative configuration was confirmed by a single crystal X-ray diffraction analysis after **1** was crystallized from methanol; a perspective view of the structure of **1** is shown in Figure 2. The ring system is formed by the fusion of one six-membered and one five-membered rings and two γ-lactone rings characterized by one spiro connected B/C rings and two quasi *cis* connected A/B and A/D rings, for hydroxyl substituents at C-3, C-11, C-12, and C-18, and one methoxyl group at C-2. Ring A adopted a half-chair conformation, and the five-membered ring B adopted an envelope.

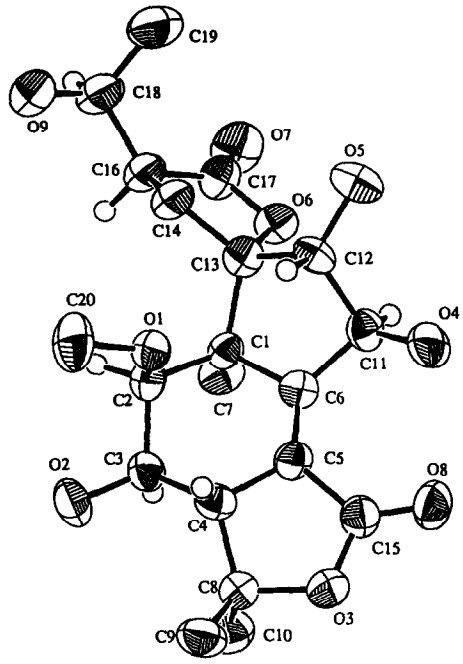


Figure 2. ORTEP drawing of picrodendrin U (**1**)

Compound **2**, $[\alpha]_D$ -87.5° (pyridine), was an obtained as amorphous solid. From the positive ion FABMS (*m/z* 463 $[M+Na]^+$ and 441 $[M+H]^+$) and ^{13}C NMR data of **2**, the molecular formula was concluded to be $C_{21}H_{28}O_{10}$. The IR and UV spectra of **2** indicated the presence of hydroxyl (3437 cm^{-1}) and an α-methylene γ-lactone (1750 cm^{-1} and 254 nm) groups. Two carbon signals (δ 170.4 and 171.4) in the ^{13}C NMR spectrum (Table 2) suggested that **2** has two γ-lactone carbonyls. The NMR data for the spiro γ-lactone portion of the molecule were similar to those of picrodendrin A (**4**).[2a] This suggested that the C16-C18 double bond had an *E*-configuration. From a ^1H-^1H COSY, the H-2 (δ 3.82) was correlated to H-3 (δ 4.57), and the H-8 (δ 2.68) was correlated to two methyls at H-9 (δ 1.25) and H-10 (δ 1.20), showing that these signals were assigned to an isopropyl group. The H-11 (δ 5.66) was also correlated to H-12 (δ 4.17). The principal feature was H-11 resonance at δ 5.66 (1H, d, *J*=8.1) and its HMBC correlations to C-5 (δ 132.1), C-6 (δ 168.9), C-12 (δ 83.0) and C-15 (δ 171.4), which suggested a γ-lactone linkage between C-11 and C-15. The stereochemistry of **2** was determined by NOESY experiment. The NOE correlations are illustrated by arrows in Figure 3. Thus the structure of picrodendrin V was concluded to have the relative stereostucture **2**.

Compound **3**, $[\alpha]_D$ -71.7° (pyridine), which was obtained as prisms, had a molecular formula of $C_{20}H_{28}O_9$, the same as compound **1**, as determined by HREIMS. A conjugated γ-lactone system was indicated by IR absorption at 1754 cm^{-1} and UV absorption at 222 nm. Two γ-lactone carbonyls showed ^{13}C NMR signals at δ 171.3 and 177.0. Other functional groups indicated by the ^1H and ^{13}C NMR spectra of **3** were three secondary methyls at δ 1.20, 1.24 and 1.58, one tertiary methyl at δ 1.38, and a tetrasubstitued

double bond (between δ 132.4 and 168.4). Examination of the ^{1}H and ^{13}C NMR spectra and comparison with those of **1** and **2** located two γ-lactone carbonyls at C-15 and C-17 and double bond at C-5, C-6, in addition to the γ-lactone linkage between C-11 and C-15 by HMBC correlations. The comparison of NOESY spectra for **2** and **3** supported the observation that **3** had the same stereochemistry as **2**. A strong NOESY correlation between H-2 and H-3 found in **3** together with a small vicinal coupling (J=1.8 Hz) confirmed a *cis* equatorial relationship, while a large coupling (J=8.0 Hz) was observed between H-11 and H-12 which suggested a *trans* diaxial relationship. Thus, the structure of picrodendrin W is **3**.

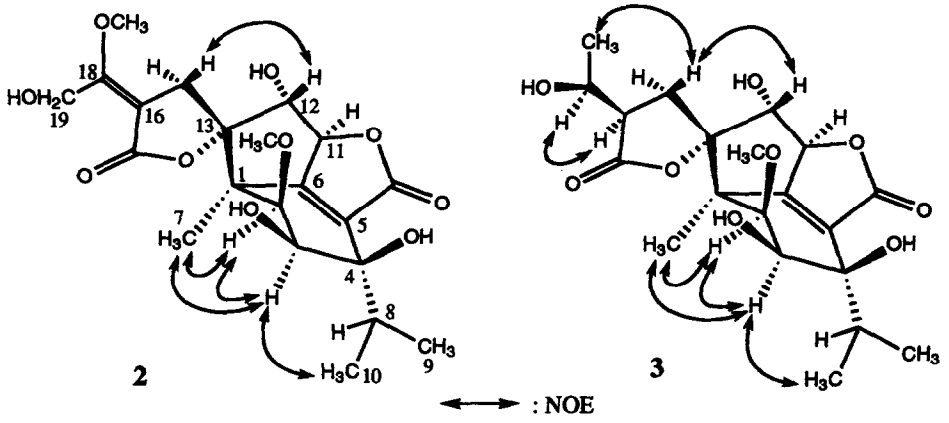
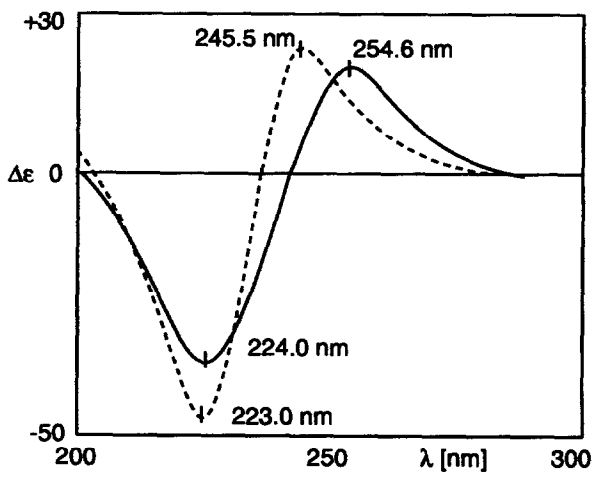


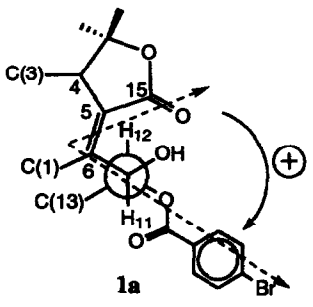
Figure 3. NOE correlations of picrodendrins V(**2**) and W (**3**),

Absolute configuration. The CD exciton chirality method predicts that when two chromophores exhibiting strong π →π* interactions are located in chiral positions with respect to each other, the orientation between the two chromophores will determine the sign of the first CD band of the CD spectrum.[4] In order to unambiguously determine the absolute configuration of picrodendrins U (**1**) and W (**3**), we applied the CD exciton chirality method to **1** and **3**. Because picrodendrins U (**1**) and W (**3**) contain only one chromophore, a second chromophore was introduced into **1** and **3** in the form of the *p*-bromobenzoate ester of each alcohol at C-12, in order to apply this method. The derivation at C-12 is evidenced by the ^{1}H NMR data with the H-12 proton shifting downfield from δ 4.22 to 5.89 for **1a** and δ 4.15 to 5.96 for **3a**. The CD spectrum of **1a** showed a distinct positive split Cotton effect due to exciton coupling as seen in Figure 4. Based on the exciton coupling theory, the first Cotton effect (that at higher wavelength) was positive and the second was negative when the electronic transition dipole moments of the two chromophores subtended a right-hand helicity, as is exhibited by **1a** in Figure 4; this leads to the 11*S* and 12*R* configurations. Compound **1** thus has the absolute stereochemistry of **1** as 1*S*, 2*S*, 3*R*, 4*R*, 11*S*, 12*R*, 13*S*, 16*S* and 18*S*. A similar argument established the absolute configuration of **3** as 1*S*, 2*S*, 3*R*, 4*R*, 11*S*, 12*R*, 13*S*, 16*S* and 18*S*.

Table 1. ^{1}H NMR Spectral Data for Picrodendrins U , V , W and A (1-4) in pyridine-d_5.

Proton	1	2	3	4
2	3.84 (d, 1.8)	3.82 (d, 1.5)	3.87 (d, 1.8)	3.70 (s)
3	5.12 (br d, 7.0)	4.57 (d, 1.5)	4.56 (br s)	5.15 (d, 1.1)
4	3.18 (d, 7.0)			3.47 (d, 1.1)
5				
7	1.50 (s)	1.35 (s)	1.38 (s)	1.89 (s)
8		2.68 (sep, 7.0)	2.64 (sep, 6.7)	2.74 (sep, 6.2)
9	1.86 (s)	1.25 (d, 7.0)	1.24 (d, 6.7)	1.48 (d, 6.2)
10	1.59 (s)	1.20 (d, 7.0)	1.20 (d, 6.7)	1.21 (d, 6.2)
11	5.51 (d, 7.7)	5.66 (d, 8.1)	5.58 (d, 8.0)	4.18 (d, 2.9)
12	4.22 (d, 7.7)	4.17 (d, 8.1)	4.15 (d, 8.0)	3.66 (d, 2.9)
14α	2.68 (dd, 14.7, 11.0)	3.13 (d, 18.0)	2.68 (dd, 14.7, 11.6)	4.74 (d, 17.2)
14β	2.74 (dd, 14.7, 8.6)	3.23 (d, 18.0)	2.73 (dd, 14.7, 7.9)	3.44 (d, 17.2)
16	3.28 (ddd,11.0, 8.6, 6.1)		3.27 (ddd,11.6, 7.9, 5.5)	
18	4.59 (quin, 6.1)		4.60 (quin, 6.1)	
19a	1.59 (d, 6.1)	5.30 (d, 13.6)	1.58 (d, 6.1)	5.29 (dd, 13.2, 4.0)
19b		5.46 (d, 13.6)		5.37 (dd, 13.2, 4.0)
2-OCH_3	3.68 (s)	3.64 (s)	3.66 (s)	3.31 (s)
18-OCH_3		4.13 (s)		3.96 (s)





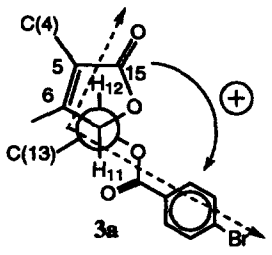


Figure 4. CD spectra of *p*-bromo benzoates **1a** (——) and **3a** (- - - -).

Table 2. ^{13}C NMR Spectral Data for Picrodendrins U, V, W and A (1-4) in pyridine-d_5.

Carbon	1	2	3	4
1	50.5	49.0	49.5	53.0
2	86.9	87.2	87.2	87.9
3	73.0	71.8	72.1	83.2
4	51.9	74.5	74.6	82.2
5	131.8	132.1	132.4	57.8
6	170.1	168.9	168.4	78.2
7	17.2	16.9	17.1	25.1
8	72.5	35.1	35.3	31.0
9	28.9	18.4	18.4	15.6
10	31.2	18.6	18.6	18.2
11	85.7	84.7	84.8	62.9
12	82.0	83.0	82.0	63.2
13	96.6	93.7	96.4	89.3
14	28.1	31.7	28.5	34.3
15	173.5	171.4	171.3	175.8
16	47.0	103.7	47.0	104.3
17	177.1	170.4	177.0	170.1
18	67.7	166.4	67.8	166.3
19	20.7	53.7	20.8	53.6
2-OCH_3	60.9	61.1	61.0	59.1
18-OCH_3		56.0		55.8

EXPERIMENTAL

General Procedures. Melting points are uncorrected. IR spectra were recorded as KBr pellets on a JASCO 7300 FTIR spectrometer. UV spectra were recorded on a Hitachi 340 spectrophotometer in MeOH. CD spectrum were recorded on a JASCO J-720W in MeOH. Optical rotations were determined on a JASCO DIP-4 digital polarimeter. Low-resolution EIMS were measured on a JEOL D-300 mass spectrometer. HREIMS and FABMS were measured on a JEOL DX-303 mass spectrometer. ^1H, ^{13}C and 2D NMR spectra were recorded on a JEOL α-500 spectrometer (^1H at 500 MHz, ^{13}C at 125 MHz) for compound **1** and a JEOL EX-400 spectrometer (^1H at 400 MHz, ^{13}C at 100 MHz) for compounds **2** and **3**, using tetramethylsilane as internal standard.

Isolation. Dried bark (8.0 kg) of *Picrodendron baccatum* collected in Indonesia in September, 1986 was extracted with MeOH (49 l). The residue remaining (1.9 kg) after removal of the solvent was extracted successively with $CHCl_3$, EtOAc and *n*-BuOH. The *n*-BuOH fraction (302 g) was chromatographed on reversed phase highly porous polymer resin Diaion HP-20 (2 Kg, Mitsubishi Kasei) and eluted with following gradient, H_2O, H_2O-MeOH (8:2, 6:4, 4:6, 2:8) and MeOH. The H_2O-MeOH (8:2) eluent was further purified by medium pressure LC [silica gel D-60 (Fuji Silysia) with the solvent system $CHCl_3$-MeOH(20:1)]to afford picrodendrin U (**1**, 12 mg) and W (**3**, 5 mg). The H_2O-MeOH (4:6) eluent was further purified by preparative TLC [silica gel 60GF_{254} (Merck)] to afford picrodendrin V (**2**, 2 mg).

Picrodendrin U (1). Prisms (MeOH), mp 210°C (dec.), $[\alpha]^{22}_D$ -70.5° (*c*=0.82, pyridine). UV λ MeOH nm (log ε): 228 (3.84). IR ν_{max} (KBr) cm^{-1}: 3397, 3293, 2981, 2938, 1752, 1370, 1279, 1244, 1209, 1182, 1147, 1113, 1096, 1082, 1066, 1024, 1004, 953. EIMS *m/z* (rel. int.) : 413 ($[M+H]^+$, 1), 395 (4), 376 (5), 318 (3), 290 (2), 254 (5), 231 (5), 219 (10), 205 (15), 177 (17), 149 (58), 132 (27), 115 (33), 59 (100), 44 (71). HREIMS *m/z*: 413.1833 $[M+H]^+$ (Calcd for $C_{20}H_{29}O_9$, 413.1803). HMBC: C-1→H-2, 7,14α, 14β; C-2→H-7, 2-OCH_3; C-3→H-2, 4; C-4→H-2, 9, 10; C-5→H-4, 11; C-6→H-2, 4, 7, 11; C-7→H-2; C-8→ H-9, 10; C-9→H-10, C-10→H-9, C-11→H-12; C-12→H-11, 14α, 14β; C-13→H-7, 14α, 14β; C-14→H-12,18; C-16→H-14α, 14β, 19; C-17→H-14α,14β, 16, 18; C-18→H14α, 14β;2-OCH_3→H-2.

p-Bromobenzoylation of 1. To a solution of **1** (2 mg) in dry pyridine (2 ml) was added *p*-bromobenzoyl chloride (20 mg) and *N,N*-dimethylaminopyridine (10 mg), and the mixture was stirred at 80°C for 12 hr. The reaction mixture was poured onto ice-H_2O and extracted with $CHCl_3$. The extracts were washed with saturated $NaHCO_3$ and brine. After drying over $MgSO_4$, the solvent was removed under reduced pressure to leave the residue, which was purified by preparative TLC to afford 12-*p*-bromobenzoate **1a** (0.5 mg). Compound **1a**: ^1H NMR (400 MHz, δ in pyridine-d_5): 1.54 (3H, d, *J*=6.6 Hz, H-19), 1.58 (3H, s, H-7), 1.64 (3H, s, H-9), 1.88 (3H, s, H-10), 2.73 (1H, dd, *J*=14.5, 11.0 Hz, H-14α), 2.83 (1H, dd, *J*=14.5, 9.5 Hz, H-14β), 3.18 (1H, m, H-16), 3.24 (1H, d, *J*=6.6 Hz, H-4), 3.75 (3H, s, 2-OCH_3), 3.95 (1H, d, *J*=1.8 Hz, H-2), 4.24 (1H, m, H-18), 5.23 (1H, br d, *J*=6.6 Hz, H-3), 5.89 (1H, d, *J*=8.1 Hz, H-12), 5.93 (1H, d, *J*=8.1 Hz, H-11), 7.37, 8.01 (each 2H, d, *J*=8.0 Hz, benzoyl-H). UV λ MeOH nm (log ε): 246 (4.07). CD (MeOH) Δε:+19.5 at 254.6 nm, -31.4 at 224.0 nm.

Crystal data for 1. Crystals of **1**, crystallized from methanol, belong to the monoclinic space group $P2_1$. Lattice constants and intensity data were measured on a Rigaku AFC-7R diffractometer equipped with a device for graphite-monochromated CuKα radiation. Crystal data: $C_{20}H_{28}O_9 \cdot H_2O$, a=10.206(2), b=7.849(2), c=13.684(2) Å, β=97.26(1)°, Z=2, F.W.=430.45, Dc=1.315 g/cm^3, μ(CuKa)=8.96 cm^{-1}. A total of 1577 independent reflections with I>3.00σ(Io) were used for structure analysis. The structure was determined by a direct method (SHELXS86)[5] and refined by full-matrix least squares (DIRDIF92)[6]. The final refinement cycle gave R=0.041 (Rw=0.074). The final Fourier difference synthesis showed a maximum and minimum of +0.21 and -0.15 $e^-/Å^3$, respectively. Atomic coordinates, bond lengths, bond angles, thermal parameters and structure factors have been entered into the Cambridge crystallographic Data Centre.

Picrodendrin V (2). Amorphous solid, $[\alpha]^{25}_D$ -87.5° (*c*=0.53, pyridine). UV λ MeOH nm (log ε): 254 (4.13). IR ν_{max} (KBr) cm^{-1}: 3437, 2962, 2929, 1750, 1654, 1288, 1109, 1088, 1019. EIMS *m/z* (rel. int.) : 413 ($[M+H-CO]^+$, 1), 397 (3), 379 (2), 333 (6), 319 (2), 301 (3), 236 (7), 221 (25), 205 (43), 189 (59), 177 (30), 155 (42), 127 (100). FABMS *m/z*: 463 $[M+Na]^+$, 441 $[M+H]^+$. HMBC: C-1→H-2, 7,14α, 14β; C-2→H-3, 7, 2-OCH_3; C-3→H-2, 8; C-4→H-2, 8, 9, 10; C-5→H-8, 11; C-6→H-2, 7, 11; C-7→H-2; C-8→ H-3, 9, 10; C-9→H-8, 10, C-10→H-8, 9, C-11→H-12; C-12→H-11, 14α, 14β;C-13→H-7, 14α, 14β; C-14→H-12; C-15→H-11; C-16→H-14α, 14β, 19; C-17→H-14α, 14β; C-18→H14α, 14β, 19, 18-OCH_3; 2-OCH_3→H-2.

Picrodendrin W (3). Prisms (MeOH), mp 261-163°C, $[\alpha]^{25}_D$ -71.7° (*c*=0.12, pyridine). UV λ MeOH nm (log ε): 222 (3.90). IR ν_{max} (KBr) cm^{-1}: 3423, 2963, 2926, 2853, 1754, 1568, 1465, 1387, 1289, 1206, 1134, 1080, 1027. EIMS *m/z* (rel. int.) : 413 ($[M+H]^+$, 1), 395 (4), 369 (28), 351 (10), 323 (6), 305 (12), 295 (4), 277 (9), 265 (17), 236 (17), 221 (42), 205 (54), 179 (100), 151 (35), 141 (28), 127 (26), 115

(30). HREIMS *m/z*: 413.1837 $[M+H]^+$ (Calcd for $C_{20}H_{29}O_9$, 413.1803). HMBC: C-1→H-7,14α, 14β; C-2→H-3, 7, 2-OCH_3; C-3→H-2, 8; C-4→H-2, 8, 9, 10; C-5→H-8, 11; C-6→H-2, 4, 7, 11; C-7→H-2; C-8→ H-3, 9, 10; C-9→H-8, 10, C-10→H-8, 9, C-11→H-12; C-12→H-11, 14α, 14β; C-13→H-7, 14α, 14β; C-14→H-18; C-15→H-11; C-16→H-14α, 14β, 19; C-17→H-14α, 14β, 16, 18; C-18→H14α, 14β, 16, 19; 2-OCH_3→H-2.

***p*-Bromobenzoylation of 3.** To a solution of **3** (2 mg) in dry pyridine (2 ml) was added *p*-bromobenzoyl chloride (20 mg) and *N,N*-dimethylaminopyridine (10 mg), and the mixture was stirred at 80°C for 4 hr. The reaction mixture was poured onto ice-H_2O and extracted with $CHCl_3$. The extracts were washed with saturated $NaHCO_3$ and brine. After drying over $MgSO_4$, the solvent was removed under reduced pressure to leave the residue, which was purified by preparative TLC to afford 12, 18-di-*p*-bromobenzoate **3a** (0.5 mg). Compound **3a**: ^1H NMR (500 MHz, δ in pyridine-d_5): 1.20 (3H, d, *J*=7.0 Hz, H-10), 1.26 (3H, d, *J*=7.0 Hz, H-9), 1.45 (3H, d, *J*=6.2 Hz, H-19), 1.51 (3H, s, H-7), 2.61 (1H, sep, *J*=7.0 Hz, H-8), 2.67 (1H, dd, *J*=14.3, 11.0 Hz, H-14α), 2.83 (1H, dd, *J*=14.3, 11.0 Hz, H-14β), 3.71 (3H, s, 2-OCH_3), 3.76 (1H, m,, H-16), 4.06 (1H, br s, H-2), 4.63 (1H, d, *J*=7.3 Hz, H-3), 5.75 (1H, d, *J*=8.0 Hz, H-11), 5.96 (1H, d, *J*=8.0 Hz, H-12), 5.71 (1H, quint, *J*=6.4 Hz, H-18), 7.49, 7.57, 7.88, 7.92 (each 2H, d, *J*=8.5 Hz, benzoyl-H). UV λ MeOH nm (log ε): 246 (4.07). CD (MeOH) Δε:+25.1 at 245.4 nm, -42.7 at 223.0 nm.

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REFERENCES AND NOTES

1. Webber, I. E. *J. Am. Botany*, **1936**, *23*, 577-587; Hayden, J. *J. Arnord Arboretum*, **1977**, *58*, 257-279; Hayden, W. J.; Gillis, W. T.; Stone, D. E.; Broome, C. R.; Webster, G. L. *J. Arnord Arboretum*, **1984**, *65*, 105-127; Hakki, M. I. *Bot. Jahrb. Syst.*, **1985**, *107*, 379-394.
2. (a)Ohmoto, T.; Koike, K.; Fukuda, H.; Mitsunaga, K.; Kagei. K.; Kawai, T.; Sato, T. *Chem. Pharm. Bull.*, **1989**, *37*, 1805-1807; (b)Ohmoto, T.; Koike, K.; Fukuda, H.; Mitsunaga, K.; Ogata. K.; Kagei, K. *Chem. Pharm. Bull.*, **1989**, *37*, 2988-2990; (c)Koike, K.; Fukuda, H.; Mitsunaga, K.; Ohmoto, T. *Chem. Pharm. Bull.*, **1991**, *39*, 934-936; (d)Koike, K.; Ohmoto, T.; Kawai, T.; Sato, T. *Phytochemistry*, **1991**, *30*, 3353-3356; (e)Suzuki, Y.; Koike, K.; Ohmoto, T. *Phytochemistry*, **1992**, *31*, 2059-2064; (f)Koike, K.; Suzuki, Y.; Ohmoto, T. *Phytochemistry*, **1994**, *35*, 701-704.
3. Ozoe, Y; Hasegawa, H.; Mochida, K.; Koike, K.; Suzuki, Y.; Nagahisa, M.; Ohmoto, T. *Biosci. Biotech. Biochemistry*, **1994**, *58*, 1806-1807.
4. Harada, N.; Nakanishi, K. *Circular Dichroic Spectroscopy-Exciton Coupling in Organic Stereochemistry*, University Science. Book, Mill Valley, CA and Oxford University Press, Oxford, **1983**.
5. SHELXS86: Sheldrick, G.M. *Crystallographic Computing* 3 (eds G.M. Sheldrick, C. Kruger and R. Goddard) Oxford University Press, **1985**, pp 175-189.
6. DIRDIF92: Beurskens, P. T.; Admiraal. G.; Beurskens, G.; Bosma, W. P.; Garcia-Granda, S.; Gould, R. O.; Smits, J. M. M.; Smykalla, C. (**1992**) The DIRDIF program system, Technical Report of the Crystallography Laboratory, University of Nijimegen, The Netherlands.

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