Seven New Bifuranocoumarins, Dahuribirin A—G, from Japanese Bai Zhi

Nian-He WANG,[a] Koichiro YOSHIZAKI,[b] and Kimiye BABA*,[b]

Institute of Botany, Jiangsu Province and Academia Sinica,[a] 210014, Nanjing, China and Osaka University of Pharmaceutical Sciences,[b] 4–20–1 Nasahara, Takatsuki, Osaka 569–1094, Japan.

Received March 1, 2001; accepted May 28, 2001

Five new spirobifuranocoumarins, dahuribirins A—E (1—5) and two new bifuranocoumarins, dahuribirins F and G (6 and 7) were isolated from Japanese Bai Zhi (the root of *Angelica dahurica* BENTH. *et* HOOK. var. *dahurica* BENTH. *et* HOOK.) and their structures were established by chemical and spectral means.

Key words *Angelica dahurica*; Japanese Bai Zhi; dahuribirin A—G; Umbelliferae

Japanese Bai Zhi, the root of *Angelica dahurica* var. *dahurica* (Umbelliferae) is contained in numerous Japanese herbal prescription and is claimed to be effective in the treatment of acne, eruption, and erythema. In addition, it is used as an aromatic sedative. Previously, we reported the isolation of 22 coumarins, including 16 linear-type furanocoumarins[1] and an isotretronic acid derivative that imparts its characteristic odor to this drug,[2] and the effects of furanocoumarins isolated on the actions of adrenaline, adrenocorticotropic hormone (ACTH), insulin in fat cells isolated from rats,[3] histamine release in the mouse peritoneal cavity,[4] and human microsomal cytochrome P450 3A activity.[5] Continued investigation of the coumarin components resulted in the isolation of five new spirobifuranocoumarins, dahuribirins A—E (**1**—**5**) and two bifuranocoumarins, dahuribirins F and G (**6**, **7**) by repeated chromatographic separation from this natural medicine. This paper deals with the isolation and the structure elucidation of **1**—**7**.

Results and Discussion

Compounds **1**—**7** were isolated from the coumarin fraction of an ethyl acetate extract and fluoresced yellowish green under UV light (365 nm) and had the UV spectral characteristics of linear-type furanocoumarins.

Compound **1**, a colorless viscous oil, $[\alpha]_D$ −3.6° (c=0.48, dioxane), was assigned the molecular formula $C_{33}H_{30}O_{10}$ ($[M]^+$ m/z 586.1839) by HR-EI-MS. The ^{1}H-NMR spectrum of **1** showed the presence of a C-8-monosubstituted and C-5- and C-8-disubstituted linear-type furanocoumarin units [δ 7.55 (1H, d, J=2.2 Hz), 7.07 (1H, s), 6.86 (1H, d, J=9.7 Hz), 6.68 (1H, d, J=2.2 Hz), 5.72 (1H, d, J=9.7 Hz)] and [δ 8.11 (1H, d, J=9.8 Hz), 7.57 (1H, d, J=2.3 Hz), 6.96 (1H, d, J=2.3 Hz), 6.28 (1H, d, J=9.8 Hz)], a methoxy group [δ 4.17 (3H, s)], 3-methyl-2-butenyl-1-oxy group [δ 5.63 (1H, m, J=7.3, 7.1, 1.0 Hz), 4.83 (1H, dd, J=11.4, 7.3 Hz), 4.78 (1H, dd, J=11.4, 7.1 Hz), 1.76, 1.71 (each 3H, d, J=1.0 Hz)], and a 3-methylbutyl-1,2,3-trioxy group [δ 4.83 (1H, dd, J=7.1, 5.7 Hz), 4.61 (1H, dd, J=10.1, 5.7 Hz), 4.42 (1H, dd, J=10.1, 7.1 Hz), 1.77, 1.46 (each 3H, s)]. Thus **1** was assumed to be a furanocoumarin dimer resulting from the condensation of imperatorin and byakangelicin (**8**) isolated previously.[1] However, the ^{13}C-NMR spectrum of **1** showed one carbonyl carbon signal attributable to a lactone carbonyl carbon at δ 160.1 and a signal assigned to a carbon linked to three oxygen atoms at δ 117.3, indicating that one of two lactone moieties was replaced by the spiro form (orthoester) in **1**. The above fragments could be arranged on the basis of the heteronuclear multiple bond coherence (HMBC) experiment (Fig. 1). To determine the stereostructure of **1**, the absolute configuration of the C-12 position of **8**, which formed a spiro ring in **1**, was confirmed using the modified Mosher's method.[6] A comparison of the ^{1}H-NMR data in $CDCl_3$ for *R*-(+) and *S*-(−)-α-methyl-α-trifluoromethylprenyl lactic acid (MTPA) esters of **8** indicated that the C-12 position of **8** is in the *R* configuration (Fig. 2). In addition, the nuclear Overhauser effect correlation spectroscopy (NOESY) experiment on **1** (Fig. 3) showed that both H-3 and H-11′ had correlation with H-14′, and H-12′ had correlation with H-15′. Consequently, although we made no attempts to determine it directly, it seems reasonable to postulate that the absolute configuration of the C-1 and C-12′ positions of **1** are both *R*.

Compound **2**, a colorless viscous oil, $[\alpha]_D$ −4.6° (c=0.59, dioxane), was assigned the molecular formula $C_{34}H_{34}O_{13}$ ($[M]^+$ m/z 650.2011) by HR-EI-MS. Comparison of the ^{1}H-NMR spectral data of **1** and **2** indicated that **2** is closely related to **1**, except for the presence of the two methoxy groups [δ 4.17, 4.03 (each 3H, s)] and two 3-methylbutyl-1,2,3-trioxy groups [δ 4.51 (1H, dd, J=10.3, 2.9 Hz), 4.24 (1H, dd, J=10.3, 7.6 Hz), 3.78 (1H, br dd, J=7.6, 2.9 Hz), 1.30, 1.28 (each 3H, s)] and [δ 4.88 (1H, dd, J=6.4, 6.2 Hz), 4.58 (1H,

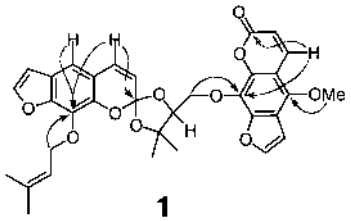

Fig. 1. HMBC Correlations of **1**

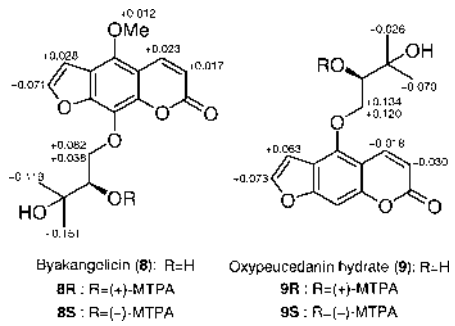

Fig. 2. $\Delta\delta$ Values ($\Delta\delta=\delta S-\delta R$) Obtained from the MTPA Esters of **8** and **9**

* To whom correspondence should be addressed. e-mail: baba@oysun01.oups.ac.jp

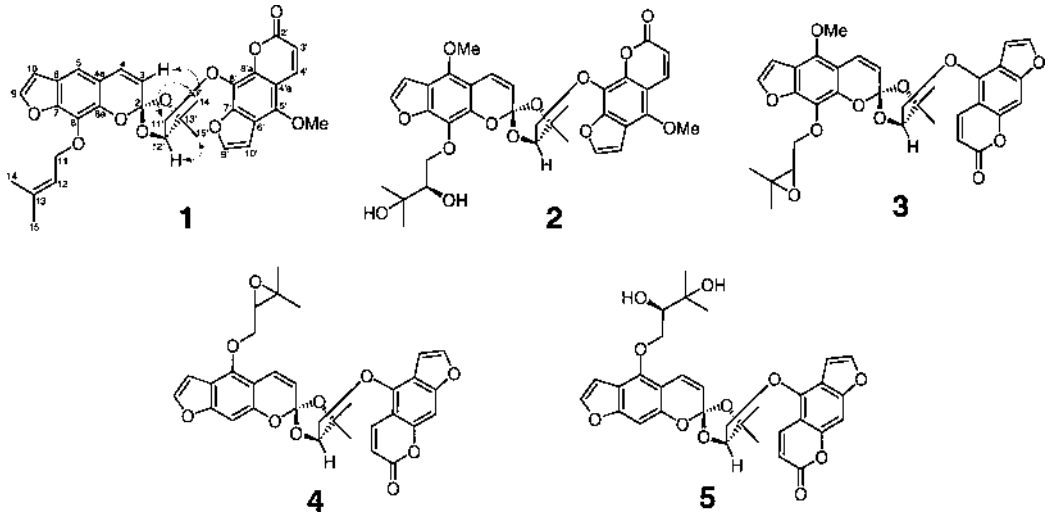

Fig. 3

dd, J=10.3, 6.2 Hz), 4.39 (1H, dd, J=10.3, 6.4 Hz), 1.74, 1.43 (each 3H, s)] instead of signals due to the 3-methyl-2-butenyl-1-oxy group and one aromatic proton. Thus **2** was assumed to be a spirobifuranocoumarin formed by two byakangelicin units. Full assignments were determined by correlation spectroscopy (COSY), HMBC, and nuclear Overhauser effect spectroscopy (NOESY), as described for **2**.

Compound **3**, a colorless viscous oil, $[\alpha]_D$ +20.0° (c=0.48, dioxane), was assigned the molecular formula $C_{33}H_{30}O_{11}$ ($[M]^+$ m/z 602.1777) by HR-EI-MS. The ^{1}H-NMR spectrum of **3** showed signals arising from a spirobicoumarin ring consisting of a C-5-monosubstituted and C-5- and C-8-disubstituted linear-type furanocoumarin units [δ 8.13 (1H, dd, J=9.8, 0.7 Hz), 7.53 (1H, d, J=2.1 Hz), 7.19 (1H, br d, J=0.7 Hz), 6.95 (1H, br d, J=2.1 Hz), 6.21 (1H, d, J=9.8 Hz)] and [δ 7.61 (1H, d, J=2.3 Hz), 7.23 (1H, d, J=9.9 Hz), 6.89 (1H, d, J=2.3 Hz), 5.67 (1H, d, J=9.9 Hz)], a methoxy group [δ 4.06 (3H, s)], a 3-methyl-2,3-epoxybutyl-1-oxy group [δ 4.39 (1H, dd, J=11.2, 5.5 Hz), 4.29 (1H, dd, J=11.2, 6.0 Hz), 3.28 (1H, dd, J=6.0, 5.5 Hz), 1.30, 1.15 (each 3H, s)], and a 3-methylbutyl-1,2,3-trioxy group [δ 4.81 (1H, dd, J=6.4, 5.0 Hz), 4.56 (1H, dd, J=10.7, 6.4 Hz), 4.53 (1H, dd, J=10.7, 5.0 Hz), 1.72, 1.35 (each 3H, s)]. From the above spectral data, **3** was assumed to be a spirobifuranocoumarin formed by condensation of byakangelicol and oxypeucedanin hydrate (**9**). This assumption was supported by the long-range correlation of a methoxy proton to C-5, H-4 and H-11 to C-8, and H-11′ to C-5′ in the HMBC spectrum. The stereostructure of **3** was estimated on the basis of the analysis of its NOESY spectrum and on the fact that the C-12 position of **9** has the *R* configuration (modified Mosher's method) (Fig. 2), similar to **1**.

Compound **4**, a colorless viscous oil, $[\alpha]_D$ −0.22° (c=0.65, dioxane), was assigned the molecular formula $C_{32}H_{28}O_{10}$ ($[M]^+$ m/z 572.1684) by HR-EI-MS. The ^{1}H-NMR spectrum of **4** is closely related to that of **3** except for the presence of the signals due to a C-5-monosubstituted furanocoumarin ring [δ 7.50 (1H, d, J=2.3 Hz), 7.30 (1H, br d, J=10.1 Hz), 6.91 (1H, br s), 6.83 (1H, br d, J=2.3 Hz), 5.86 (1H, d, J=10.1 Hz)] and the lack of a signal due to a methoxy signal, indicating that **4** is a spirobifuranocoumarin consisting of oxypeucedanin and **9**. This presumption was supported by the long-range correlations of H-8 and H-11 to C-5, and H-8′ and H-11′ to C-5′ in the HMBC spectrum. On the other hand, the cross-peaks between H-3, H-11′, and H-14′, H-12′ and H-15′, and H-3′, H-10′, and H-11′ in the NOESY experiment indicated that the configuration of **4** was the same as that of **3**. Thus the stereostructure of **4** was estimated.

As a compound corresponding to **4**, recently fesumtuorin H was isolated from *Ferula sumbul* by Zhou.[7] However, the spectral data of **4** differ markedly from those of fesumtuorin H. In particular, the proton signal assigned to H-4′ of fesumtuorin H was observed at δ 7.74, while that of **4** was at δ 8.12 in ^{1}H-NMR (in $CDCl_3$). Usually, the H-4 resonance is found in the region of δ 7.5—7.9 (in $CDCl_3$) in coumarin lacking a C-5 oxygen function. An oxygen or alkyl substituent at C-5, however, characteristically shifts the resonance of H-4 downfield by *ca.* 0.3 ppm (the *peri* effect), with H-4 now found at δ 7.9—8.2 (in $CDCl_3$).[8] The H-4 resonance and the NOESY experiment with **4** support the structure shown for **4** in this paper.

Compound **5**, a colorless viscous oil, $[\alpha]_D$ +4.6° (c=0.62, dioxane), was assigned the molecular formula $C_{32}H_{30}O_{11}$ ($[M]^+$ m/z 590.1800) by HR-EI-MS. The NMR spectra (^{1}H, ^{13}C, COSY, HMBC) showed the presence of signals due to a 2,3-dihydroxy-3-methyl-1-oxy group instead due to the 3-methyl-2,3-epoxybutyl-1-oxy group in **4**, indicating that **5** is a spirobifuranocoumarin formed by the two sets of **9**. The stereostructure of **5** was assumed based on analysis of the NOESY spectrum.

Compound **6**, a colorless viscous oil, $[\alpha]_D$ −1.1° (c=0.49, dioxane), was assigned the molecular formula $C_{34}H_{32}O_{12}$ ($[M+H]^+$ m/z 633.1968) by HR-SI-MS. The ^{1}H-NMR spectra showed the presence of two sets of C-5- and C-8-disubstituted linear-type furanocoumarin fragment units signals [δ 8.06 (1H, d, J=9.7 Hz), 6.21 (1H, d, J=9.7 Hz), 7.99 (1H, d, J=9.7 Hz), 6.18 (1H, d, J=9.7 Hz), 7.61 (1H, d, J=2.3 Hz), 6.95 (1H, d, J=2.3 Hz), 7.57 (1H, d, J=2.3 Hz), 6.91 (1H, d, J=2.3 Hz)], two methoxy groups [δ 4.15, 4.12 (each 3H, s)], 3-methyl-3-butenyl-1,2-dioxy group [δ 5.14 (1H, br s), 4.95 (1H, br s), 4.58 (1H, br dd, J=7.8, 3.7 Hz), 4.18 (1H, dd,

J=9.9, 3.7 Hz), 4.13 (1H, dd, J=9.9, 7.8 Hz), 1.80 (1H, br s)], and a 2-hydroxy-3-methylbutyl-1,3-dioxy group [δ 4.66 (1H, dd, J=10.4, 3.1 Hz), 4.34 (1H, dd, J=10.4, 8.2 Hz), 4.07 (1H, dd, J=8.2, 3.1 Hz), 3.31 (1H, br s), 1.37, 1.31 (each 3H, s)]. These functional groups was also identified by ^{13}C-NMR. In the HMBC spectrum of **6** (Fig. 4), the long-range correlation of one methoxy proton and H-4 to C-5, H-4 and H-11 to C-8, H-12 to C-13′, H-11′ and H-4′ to C-8′, the remaining methoxy proton and H-4′ to C-5′ were observed. From the above spectral data, the structure of compound **6** was estimated as shown in Fig. 4.

Compound **7**, a colorless viscous oil, $[\alpha]_D$ +5.2° (c=0.54, dioxane), was assigned the molecular formula $C_{34}H_{34}O_{13}$ ($[M+H]^+$ m/z 651.2064) by HR-SI-MS. The ^{1}H-NMR spectra (^{1}H, ^{13}C, COSY, HMBC) were closely related to those of **6**, except for the presence of signals assignable to two sets of the 2-hydroxy-3-methylbutyl-1,3-dioxy group instead of due to a 3-methyl-3-butenyl-1,2-dioxy group and a 2-hydroxy-3-methylbutyl-1,3-dioxy group. From the above spectral data, the structure of **7** was estimated.

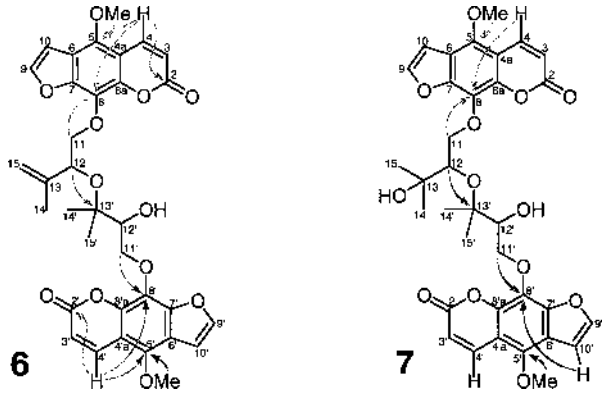

Fig. 4. HMBC Correlations of **6** and **7**

Recently, we have reported that naturally occurring bifuranocoumarins and trifuranocoumarins had a strong inhibitory effect on human microsomal cytochrome P450 3A (CYP3A).[5] Thus compounds **1**—**7** may be also strong inhibitors of CYP3A.

Experimental

General ^{1}H-, ^{13}C-NMR, distortionless enhancement by polarization transfer (DEPT), heteronuclear multiple quantum coherence (HMQC), and HMBC spectra were recorded on a Varian UNITY INOVA-500 spectrometer, operating at 500 MHz for proton and 125 MHz for carbon, with tetramethyl silane (TMS) as an internal standard. HR-EI-MS spectra were obtained from a Hitachi M-4100H (70 eV) mass spectrometer. UV and IR spectra were recorded on a Shimadzu UV-2100 and a Perkin Elmer FT-IR 1720 spectrophotometer, respectively. Optical rotatory dispersion (ORD) spectra were recorded on a JASCO J820 digital polarimeter. Column chromatography (CC): Merck Silica gel F_{254} plate (0.25 mm) and Whatman Silica gel 15A PLK5F (1 mm). Spots and bands were detected by UV irradiation (254, 365 nm).

Plant Material Air-dried roots of *A. dafurica* (9.56 kg) were collected from plants grown in Hokkaido in October 1997, for which a voucher specimen is deposited in Osaka University of Pharmaceutical Sciences.

Extraction and Isolation The roots were chopped into small pieces and extracted with EtOAc (20 l×5) under reflux. The combined EtOAc extracts were concentrated to dryness *in vacuo*. The residue (223.1 g) was subjected to column chromatography on silica gel (2 kg) eluted successively with a hexane–EtOAc solvent system with increasing polarity (5 : 1→1 : 2) to afford 20 fractions (fr.) [fr. 1 (427 g), fr. 2 (24.5 g), fr. 3 (7.6 g), fr. 4 (8.4 g), fr. 5 (9.8 g), fr. 6 (8.2 g), fr. 7 (4.5 g), fr. 8 (8.5 g), fr. 9 (6.8 g), fr. 10 (5.2 g), fr. 11 (7.8 g), fr. 12 (4.6 g), fr. 13 (5.0 g), fr. 14 (5.6 g), fr. 15 (8.6 g), fr. 16 (7.8 g), fr. 17 (5.2 g), fr. 18 (4.8 g), fr. 19 (9.8 g) and fr. 20 (15.6 g). Fractions 7, 8, 11, 14, 17, and 19 were rechromatographed on silica gel with $CHCl_3$ followed by preparative TLC (hexane–EtOAc system) to give **3** (24 mg), **5** (15 mg), **1** (10 mg), **4** (8 mg), **2** (8 mg), **6** (55 mg), and **7** (195 mg), respectively.

Table 1. ^{1}H-NMR Data for Compounds **1**—**7** in $CDCl_3$

	1	2	3	4	5	6	7
3	5.72 d (9.7)	5.67 d (9.8)	5.67 d (9.9)	5.86 d (10.1)	5.67 d (9.9)	6.21 d (9.7)	6.25 d (9.6)
4	6.86 d (9.7)	7.18 d (9.8)	7.23 d (9.9)	7.30 br d (10.1)	7.25 br d (9.9)	8.06 d (9.7)	8.08 d (9.6)
5	7.07 s						
8				6.91 br s	6.91 br s		
9	7.55 d (2.2)	7.51 d (2.3)	7.61 d (2.3)	7.50 d (2.3)	7.50 d (2.3)	7.61 d (2.3)	7.63 d (2.4)
10	6.68 d (2.2)	6.86 d (2.3)	6.89 d (2.3)	6.83 br d (2.3)	6.87 br d (2.3)	6.95 d (2.3)	6.99 d (2.4)
11	4.83 dd (11.4, 7.3)	4.51 dd (10.3, 2.9)	4.39 dd (11.2, 5.5)	4.40 dd (11.0, 4.9)	4.39 dd (9.8, 3.0)	4.18 dd (9.9, 3.7)	4.34 dd (10.1, 4.4)
	4.78 dd (11.4, 7.1)	4.24 dd (10.3, 7.6)	4.29 dd (11.2, 6.0)	4.34 dd (11.0, 6.2)	4.33 dd (9.8, 7.6)	4.13 dd (9.9, 7.8)	4.26 dd (10.1, 5.0)
12	5.63 m (7.3, 7.1, 1.0)	3.78 br dd (7.6, 2.9)	3.28 dd (6.0, 5.5)	3.19 dd (6.2, 4.9)	3.85 dd (7.6, 3.0)	4.58 br,dd (7.8, 3.7)	4.00 dd (5.0, 4.4)
14	1.76 d (1.0)	1.30 s	1.30 s	1.38 s	1.34 s	1.80 br s	1.35 s
15	1.71 d (1.0)	1.28 s	1.15 s	1.27 s	1.30 s	5.14 br s	1.26 s
						4.95 br s	
5-OMe		4.03 s	4.06 s			4.15 s	4.27 s
12-OH		3.57 br s					
13-OH		2.85 s					
3′	6.28 d (9.8)	6.27 d (9.8)	6.21 d (9.8)	6.19 d (9.7)	6.17 d (9.7)	6.18 d (9.7)	6.26 d (9.6)
4′	8.11 d (9.8)	8.10 d (9.8)	8.13 dd (9.8, 0.7)	8.12 d (9.7)	8.11 d (9.7)	7.99 d (9.7)	8.09 d (9.6)
8′			7.19 br d (0.7)	7.19 br s	7.20 br s		
9′	7.57 d (2.3)	7.59 d (2.3)	7.53 d (2.1)	7.61 d (2.3)	7.61 d (2.3)	7.57 d (2.3)	7.62 d (2.4)
10′	6.96 d (2.3)	6.97 d (2.3)	6.95 br d (2.1)	6.95 br d (2.3)	6.95 br d (2.3)	6.91 d (2.3)	6.98 d (2.4)
11′	4.61 dd (10.1, 5.7)	4.58 dd (10.3, 6.2)	4.56 dd (10.7, 6.4)	4.56 dd (10.3, 6.6)	4.55 dd (10.3, 6.4)	4.66 dd (10.4, 3.1)	4.69 dd (10.3, 2.7)
	4.42 dd (10.1, 7.1)	4.39 dd (10.3, 6.4)	4.53 dd (10.7, 5.0)	4.53 dd (10.3, 5.0)	4.53 dd (10.3, 5.5)	4.34 dd (10.4, 8.2)	4.38 dd (10.3, 8.7)
12′	4.83 dd (7.1, 5.7)	4.88 dd (6.4, 6.2)	4.81 dd (6.4, 5.0)	4.73 dd (6.6, 5.0)	4.73 dd (6.4, 5.5)	4.07 dd (8.2, 3.1)	4.11 dd (8.7, 2.7)
14′	1.46 s	1.43 s	1.35 s	1.34 s	1.67 s	1.37 s	1.42 s
15′	1.77 s	1.74 s	1.72 s	1.67 s	1.34 s	1.31 s	1.47 s
5′-OMe	4.17 s	4.17 s				4.12 s	4.26 s
12′-OH						3.31 br s	

Chemical shifts are δ values and followed by multiplicities and J values (in Hz).

Table 2. ^{13}C-NMR Data for Compounds **1**—**7** in $CDCl_3$

	1	**2**	**3**	**4**	**5**	**6**	**7**
2	117.3	117.4	117.5	117.5	117.5	160.2	160.3
3	118.9	118.0	117.1	117.3	117.5	112.7	113.0
4	130.0	124.5	125.2	124.8	124.6	139.2	139.4
4a	117.2	108.0	107.9	107.5	107.4	107.3	107.5
5	112.7	144.4	144.5	150.3	147.7	144.3	144.6
6	122.6	113.3	113.2[a)]	113.1	113.0	114.5	114.5
7	148.2	148.9	152.4	156.7	156.7	150.0	150.4
8	132.3	127.7	127.9	95.0	95.1	127.2	127.1
8a	141.8	141.9	141.9	147.7	150.3	143.6	144.1
9	144.8	143.7	143.8	143.8	143.8	145.2	145.2
10	106.6	105.0	105.0	104.3	104.5	105.0	105.2
11	69.9	75.5	72.3	72.1	74.4	76.6	75.7
12	120.4	75.8	61.5	61.3	76.4	75.1	78.0
13	138.4	71.6	58.2	58.3	71.6	144.8	72.2
14	18.1	26.6	24.6	24.6	26.6	18.7	26.5
15	25.8	25.3	18.7	18.9	25.1	113.4	24.7
5-OMe		60.9	60.8			60.7	60.8
2′	160.1	160.3	160.9	160.9	161.0	160.2	160.2
3′	112.9	112.9	113.2[a)]	113.2	113.1	112.5	112.7
4′	139.3	139.3	139.0	138.2	139.0	139.1	139.2
4′a	107.5	107.5	107.2	107.3	107.3	107.2	107.6
5′	144.7	144.8	148.1	152.5	148.1	144.2	144.4
6′	114.6	114.5	113.9	114.0	114.1	114.3	114.8
7′	150.1	150.2	158.0	158.0	158.0	150.3	150.0
8′	126.6	126.6	94.9	95.0	95.0	127.2	127.0
8′a	143.8	143.9	152.6	148.0	152.5	143.8	143.8
9′	145.2	145.2	145.3	145.3	145.4	145.0	145.2
10′	105.1	105.1	105.0	104.5	104.5	104.9	105.1
11′	71.6	71.5	71.3	71.3	71.3	75.6	75.8
12′	80.8	80.8	81.1	81.0	81.0	76.4	76.3
13′	83.0	83.4	82.2	82.0	82.1	77.9	78.0
14′	22.6	22.5	22.7	22.7	27.6	21.6	24.3
15′	27.7	27.1	27.8	27.6	22.7	23.0	22.8
5′-OMe	60.7	60.7				60.5	60.7

a) Assignment may be reversed.

Daphuribirin A (**1**): Colorless viscous oil, HR-EI-MS: *m/z* 586.1839 $[M]^+$ (Calcd for $C_{33}H_{30}O_{10}$: 586.1837). $[\alpha]_D^{28}$ −3.6° (*c*=0.48, dioxane), IR (KBr) cm^{-1}: 3129, 1738, 1644, 1607, 1593, 1547. UV λ_{max} (dioxane) nm (log ε): 309.0 (2.47), 286.0 (2.29 sh), 260.5 (2.83), 242.0 (3.17), 227.0 (3.00). ^{1}H- and ^{13}C-NMR data are shown in Tables 1 and 2.

Daphuribirin B (**2**): Colorless viscous oil, HR-EI-MS: *m/z* 650.2011 $[M]^+$ (Calcd for $C_{34}H_{34}O_{13}$: 650.1999). $[\alpha]_D^{30}$ −4.6° (*c*=0.59, dioxane), IR (KBr) cm^{-1}: 3433, 1736, 1724, 1643, 1606, 1593, 1551, 1481. UV λ_{max} (dioxane) nm (log ε): 307.0 (2.40), 291.0 (2.60 sh), 262.0 (2.77), 245.5 (2.99), 231.0 (2.82). ^{1}H- and ^{13}C-NMR data are shown in Tables 1 and 2.

Daphuribirin C (**3**): Colorless viscous oil, HR-EI-MS: *m/z* 602.1777 $[M]^+$ (Calcd for $C_{33}H_{30}O_{11}$: 602.1786). $[\alpha]_D^{31}$ +20.0° (*c*=0.48, dioxane). ^{1}H- and ^{13}C-NMR data are shown in Tables 1 and 2.

Daphuribirin D (**4**): Colorless viscous oil, HR-EI-MS: *m/z* 572.1684 $[M]^+$ (Calcd for $C_{32}H_{28}O_{10}$: 572.1682). $[\alpha]_D^{24}$ −0.22° (*c*=0.65, dioxane), IR (KBr) cm^{-1}: 1729, 1626, 1581, 1546, 1460. UV λ_{max} (dioxane) nm (log ε): 304.0 (2.23), 289.0 (2.16), 264.0 (2.56 sh), 244.5 (2.90), 209.0 (2.47). ^{1}H- and ^{13}C-NMR data are shown in Tables 1 and 2.

Daphuribirin E (**5**): Colorless viscous oil, HR-EI-MS: *m/z* 590.1800 $[M]^+$ (Calcd for $C_{32}H_{30}O_{11}$: 590.1788). $[\alpha]_D^{24}$ +4.6° (*c*=0.62, dioxane), IR (KBr) cm^{-1}: 3434, 3125, 1723, 1626, 1580, 1545, 1508, 1460. UV λ_{max} (dioxane) nm (log ε): 308.5 (2.29), 289.0 (2.14), 268.0 (2.49), 257.5 (2.43), 248.0 (2.52), 243.0 (2.53), 237.5 (2.50), 224.0 (2.68), 211.0 (2.62). ^{1}H- and ^{13}C-NMR data are shown in Tables 1 and 2.

Daphuribirin F (**6**): Colorless viscous oil, HR-SI-MS: *m/z* 633.1968 $[M+H]^+$ (Calcd for $C_{34}H_{33}O_{12}$: 633.1972). $[\alpha]_D^{24}$ −1.1° (*c*=0.49, dioxane), IR (KBr) cm^{-1}: 3443, 2973, 1729, 1593, 1550, 1480, 1433. UV λ_{max} (dioxane) nm (log ε): 308.5 (2.29), 289.0 (2.14), 268.0 (2.49), 257.5 (2.47), 248.0 (2.52), 243.0 (2.53), 237.5 (2.50), 224.0 (2.68), 211.0 (2.62). ^{1}H- and ^{13}C-NMR data are shown in Tables 1 and 2.

Daphuribirin G (**7**): Colorless viscous oil, HR-SI-MS: *m/z* 651.2064 $[M+H]^+$ (Calcd for $C_{34}H_{35}O_{13}$: 651.2067). $[\alpha]_D^{24}$ +5.2° (*c*=0.54, dioxane), IR (KBr) cm^{-1}: 3423, 2973, 1724, 1606, 1592, 1547, 1480, 1433. UV λ_{max} (dioxane) nm (log ε): 307.0 (2.15), 287.0 (2.00), 267.0 (2.33), 258.0 (2.29), 250.0 (2.37), 246.0 (2.36), 243.0 (2.36), 237.0 (2.34), 223.0 (2.55), 201.5 (2.27). ^{1}H- and ^{13}C-NMR data are shown in Tables 1 and 2.

(*R*)-(+)-MTPA and (*S*)-(−)-MTPA Esters of Byakangelicin (8) A solution of **8** (33.5 mg) in pyridine (0.5 ml) and (+)-MTPA Cl (20 mg) in CCl_4 (0.5 ml) were left to stand for 13 h at room temperature with stirring. *N*,*N*-diethylethylendiamine (1 ml) was added with stirring, allowed to stand for 10 min and diluted with Et_2O (20 ml), washed with dil HCl, saturated with Na_2CO_3 and H_2O, and then dried. The filtered Et_2O solution was concentrated, and the residue was purified by preparative TLC with hexane–EtOAc (2 : 1) to afford **8**-*sec*-*O*-(*R*)-(+)-MTPA ester (**8*R***, 12 mg). Similarly, **8**-*sec*-*O*-(*S*)-(−)-MTPA ester (**8*S***, 10 mg) was obtained from **8** (33.5 mg) and (−)-MTPA Cl (20 mg).

(*R*)-(+)-MTPA and (*S*)-(−)-MTPA Esters of Oxypeucedanin Hydrate (9) A solution of **9** (34.3 mg) in pyridine (0.5 ml) and (+)-MTPA Cl (20 mg) in CCl_4 (0.5 ml) was treated in the same way as described for **8** to afford **9**-*sec*-*O*-(*R*)-(+)-MTPA ester (**9*R***, 5.5 mg). Similarly, **9**-*sec*-*O*-(*S*)-(−)-MTPA ester (**9*S***, 8.6 mg) was obtained from **9** (38.9 mg) and (−)-MTPA Cl (20 mg).

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