Pergamon

S0031-9422(96)00136-7

*Phytochemistry*, Vol. 42, No. 5, pp. 1447–1453, 1996

0031-9422/96 $15.00 + 0.00

# THREE BIFLAVONOIDS FROM *DAPHNE ODORA**

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(*Received in revised form* 23 *January* 1996)

**Key Word Index**—*Daphne odora*; Thymelaeaceae; biflavonoids; daphnodorins G–I; modified Mosher's method.

**Abstract**—Three new biflavonoids, daphnodorins G–I, were isolated from the roots of *Daphne odora* and their structures established from spectral and chemical means. These are two C-7/C-2″, C-8/C-3″ biflavonoids (upper half: apigenin, lower half: afzelechin), daphnodorins G and H and a spirobiflavonoid, daphnodorin I.

## INTRODUCTION

In the course of our studies on constituents of thymelaeaceous plants, we have already reported the isolation of two new furanobiflavonoids, daphnodorins A and B, a new spirobiflavonoid, daphnodorin C, two C-8/C-3″ biflavonoids, atropisomers, daphnodorin $D_1$ and $D_2$ and two new C-7/C-2″, C-8/C-3″ biflavonoids, daphnodorins E and F, from the roots of *Daphne odora* [1–5]. We now report three new biflavonoids.

## RESULTS AND DISCUSSION

Three new biflavonoids, daphnodorins G–I (**1**–**3**), were isolated from the polyphenol fraction by chromatographic purification. Compound **1**, $[\alpha]_D^{21}$ +43.6°, was isolated as a pale yellow amorphous powder and assigned the molecular formula $C_{30}H_{22}O_{11}$ by HR-SI mass spectrometry (*m/z* 559.1242 $[M+H]^+$). The UV spectrum showed absorption maxima at 330 sh, 297 sh, 284 and 228 nm. The IR spectrum showed absorption bands at 3300–2600, 1631, 1518 and 1466 $cm^{-1}$, suggesting the presence of hydroxyl and carbonyl groups and an aromatic ring. The $^1H$ NMR spectrum (Table 1) showed signals assignable to two pairs of 4-oxyphenyl groups [$\delta$ 7.04, 6.73 (each 2H, *d*, *J* = 8.8 Hz), 7.35 and 6.81 (each 2H, *d*, *J* = 8.8 Hz)], a 2,4,6-trioxyphenyl group [$\delta$ 6.04, 5.75 (each 1H, *d*, *J* = 2.2 Hz)], a 3-hydroxy-2,8 (or 2,6)-disubstituted 5,7-dioxy-3,4-dihydrobenzopyran [$\delta$ 6.28 (1H, *s*), 4.71 (1H, *d*, *J* = 7.3 Hz), 4.26 (1H, *d*, *J* = 4.9 Hz), 3.88 (1H, *m*), 2.80 (1H, *dd*, *J* = 16.4 and 5.2 Hz) and 2.55 (1H, *dd*, *J* = 16.4 and 7.8 Hz)], an alcoholic hydroxyl group [$\delta$ 5.39 (1H, *s*)] and five phenolic hydroxyl groups [$\delta$ 11.56, 10.10, 9.14, 8.81 and 8.47 (each 1H, *s*)]. These signals were closely related to those of daphnodorin E (**5**), except for the presence of signals due to a 3-hydroxy-2,8 (or 2,6)-disubstituted 5,7-dioxy-3,4-dihydrobenzopyran instead of the signals due to a 2,8-disubstituted 5,7-dioxy-3,4-dihydrobenzopyran [$\delta$ 6.24 (1H, *s*), 4.95 (1H, *dd*, *J* = 10.1 and 1.9 Hz), 2.61 (2H, *m*), 2.13 (1H, *m*) and 1.73 (1H, *m*)]. The $^{13}C$ NMR spectrum of **1** (Table 2) was also related to that of **5** except for the presence of a methine carbon signal at ($\delta$ 68.1) and the lack of a methylene carbon signal at ($\delta$ 30.4). Methylation of **1** with diazomethane afforded a hexamethyl ether (**8**), whose methoxyl signals were observed at ($\delta$ 56.0 × 2, 55.9, 55.6, 55.5 and 54.0) in the $^{13}C$ NMR spectrum. Thus, **1** was deduced to be 3-hydroxydaphnodorin E.

Compound **2**, $[\alpha]_D^{21}$ −170.4°, was isolated as a pale yellow amorphous powder and assigned the molecular formula $C_{30}H_{22}O_{11}$, the same as **1**, by HR-SI mass spectrometry (*m/z* 559.1239 $[M+H]^+$). The UV spectrum of **2** showed absorption maxima at 327 sh, 293, 284 sh and 225 nm. The IR spectrum showed absorption bands at 3300–2600, 1641, 1519 and 1466 $cm^{-1}$, indicating the presence of hydroxyl and carbonyl groups and an aromatic ring. The $^1H$ NMR spectrum of **2** (Table 1) showed signals owing to two pairs of 4-oxyphenyl groups [$\delta$ 7.28 and 6.81 (each 2H, *d*, *J* = 8.8 Hz), 7.36 and 6.81 (each 2H, *d*, *J* = 8.8 Hz)], a 2,4,6-trioxyphenyl group [$\delta$ 5.95 and 5.92 (each 1H, *d*, *J* = 2.2 Hz)], a 3-hydroxy-2,8 (or 2,6)-disubstituted 5,7-dioxy-3,4-dihydrobenzopyran [$\delta$ 6.28 (1H, *s*), 4.66 (1H, *d*, *J* = 7.3 Hz), 4.18 (1H, *d*, *J* = 5.0 Hz), 4.02 (1H, *m*), 2.88 (1H, *dd*, *J* = 16.2 and 5.2 Hz) and 2.55 (1H, *dd*, *J* = 16.2 and 7.9 Hz)], an alcoholic hydroxyl group [$\delta$ 5.29 (1H, *s*)] and five phenolic hydroxyl groups [$\delta$ 11.41, 9.81, 8.94, 8.64 and 8.34 (each 1H, *s*)]. These signals were closely related to those of daphnodorin F (**6**). On the other hand, the $^{13}C$ NMR spectrum of **2** (Table 2) was very similar to that of **1**. Furthermore, the NMR profile of the hexamethyl ether of **2** (**9**) was

*Part 13 in the series 'Chemical Studies on the Constituents of Thymelaeaceous Plants'. For part 12 see ref. [1].

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Table 1. $^1$H NMR data for compounds **1**, **2**, **5** and **6** in acetone-$d_6$

| H | 1 | 2 | 5 | 6 |
|---|---|---|---|---|
| 2 | 4.71 *d* (7.3) | 4.66 *d* (7.3) | 4.95 *dd* (10.1, 1.9) | 4.84 *br d* (8.4) |
| 3 | 3.88 *m* | 4.02 *m* | 2.13 *m* | 2.26 *m* |
| (OH or H) | 4.26 *d* (4.9) | 4.18 *d* (5.0) | 1.73 *m* | 1.86 *m* |
| 4 | 2.80 *dd* (16.4, 5.2) | 2.88 *dd* (16.2, 5.2) | 2.61 *m* | 2.65 *m* |
| | 2.55 *dd* (16.4, 7.8) | 2.55 *dd* (16.2, 7.9) | | |
| 6 | 6.28 *s* | 6.28 *s* | 6.24 *s* | 6.27 *s* |
| 2′,6′ | 7.04 *d* (8.8) | 7.28 *d* (8.8) | 7.13 *d* (8.8) | 7.30 *d* (8.8) |
| 3′,5′ | 6.73 *d* (8.8) | 6.81 *d* (8.8) | 6.78 *d* (8.8) | 6.84 *d* (8.8) |
| 3″-OH | 5.39 *s* | 5.29 *s* | 5.29 *s* | 5.35 *s* |
| 6″ | 6.04 *d* (2.2) | 5.95 *d* (2.2) | 6.03 *d* (2.1)* | 5.95 *d* (2.2)* |
| 8″ | 5.75 *d* (2.2) | 5.92 *d* (2.2) | 5.93 *d* (2.1)* | 5.92 *d* (2.2)* |
| 2‴,6‴ | 7.35 *d* (8.8) | 7.36 *d* (8.8) | 7.34 *d* (8.8) | 7.35 *d* (8.8) |
| 3‴,5‴ | 6.81 *d* (8.8) | 6.81 *d* (8.8) | 6.90 *d* (8.8) | 6.80 *d* (8.8) |
| -OH | 11.56 *s* | 11.41 *s* | 11.61 *s* | 11.51 *s* |
| | 10.10 *s* | 9.81 *s* | 9.85 *s* | 10.07 *s* |
| | 9.14 *s* | 8.94 *s* | 8.87 *s* | 9.06 *s* |
| | 8.81 *s* | 8.64 *s* | 8.61 *s* | 8.76 *s* |
| | 8.47 *s* | 8.34 *s* | 8.29 *s* | 8.47 *s* |

*Assignments in each column may be interchanged.

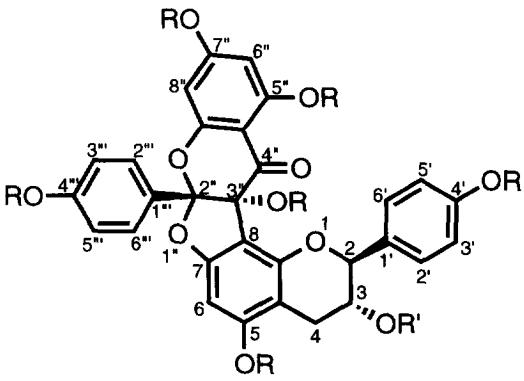
also similar to that of **8**. Thus, **2** was assumed to be 3-hydroxydaphnodorin F, i.e. a stereoisomer of **1**.

The relative configuration between C-2 and C-3 in **1** and **2** were concluded to be *trans*-catechin type from the characteristic feature of the 2-H signals [**1**: $\delta$ 4.71, *d*, $J$ = 7.3 Hz; **2**: $\delta$ 4.66, *d*, $J$ = 7.3 Hz] in the $^1$H NMR spectrum. The determination of the absolute configuration of C-3 in **1** and **2** were carried out by the modified Mosher method [6] applied to those of genkwanol B and C [7, 8]. A comparison of the $^1$H NMR data in chloroform-*d* for *R*-(+)-$\alpha$-methoxy-$\alpha$-trifluoromethylphenylacetic acid (MTPA) esters of **8** and **9** (**10** and **12**) and acetates of **8** and **9** (**11** and **13**) reveals a shielding of B-ring protons in **10** and **12** relative to the chemical shifts of those protons in **11** and **13** [**10**: $\Delta\delta$ −0.008, 2′,6′-H(B); −0.005, 3′,5′-H(B); **12**: $\Delta\delta$ −0.081, 2′,6′-H(B); −0.101, 3′,5′-H(B)] similar to those of (+)-catechin, respectively. Thus, the absolute

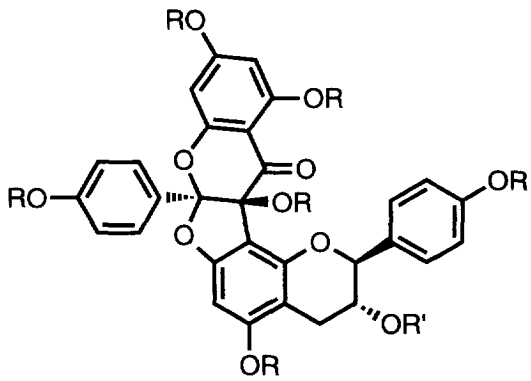
Table 2. $^{13}$C NMR spectral data for compounds **1**, **2**, **5** and **6** in acetone-$d_6$

| C | 1 | 2 | 5 | 6 |
|---|---|---|---|---|
| 2 | 82.2 | 82.3 | 78.0 | 77.9 |
| 3 | 68.1 | 67.7 | 30.4 | 29.3 |
| 4 | 28.7 | 28.9 | 20.1 | 20.4 |
| 4a | 103.9 | 104.3 | 105.2 | 105.6 |
| 5 | 159.9 | 159.9* | 154.3* | 154.4* |
| 6 | 92.5 | 92.4 | 92.1 | 92.2 |
| 7 | 161.4 | 161.3 | 158.1* | 158.1* |
| 8 | 108.0 | 108.1 | 108.3 | 108.5 |
| 8a | 153.4 | 153.7 | 159.7* | 159.7* |
| 1′ | 131.1 | 130.8 | 133.8 | 133.2 |
| 2′,6′ | 129.1 | 129.6 | 127.9 | 128.4 |
| 3′,5′ | 116.1 | 116.0† | 116.2 | 116.1 |
| 4′ | 158.3 | 158.4 | 159.9* | 159.9* |
| 2″ | 118.9 | 118.8 | 118.7 | 118.9 |
| 3″ | 82.2 | 82.2 | 82.4 | 82.2 |
| 4″ | 194.5 | 194.1 | 194.4 | 194.4 |
| 4″a | 100.0 | 100.1 | 100.1 | 100.1 |
| 5″ | 165.5 | 165.4 | 161.2* | 161.1* |
| 6″ | 97.6 | 97.5 | 95.8† | 95.8† |
| 7″ | 168.4 | 168.3 | 163.4* | 163.3* |
| 8″ | 95.7 | 95.8 | 97.5† | 97.5† |
| 8″a | 163.4 | 163.3 | 165.5* | 165.4* |
| 1‴ | 126.4 | 126.4 | 124.4 | 126.4 |
| 2‴,6‴ | 129.8 | 129.9 | 129.8 | 129.8 |
| 3‴,5‴ | 115.9 | 115.9† | 115.8 | 115.9 |
| 4‴ | 159.9 | 159.8* | 168.4* | 168.4* |

*,†Assignments in each column may be interchanged.



Daphnodorin G (**1**): R=R'=H
**8**: R=Me, R'=H
**10**: R=Me, R'=(+)-MTPA
**11**: R=Me, R'=Ac



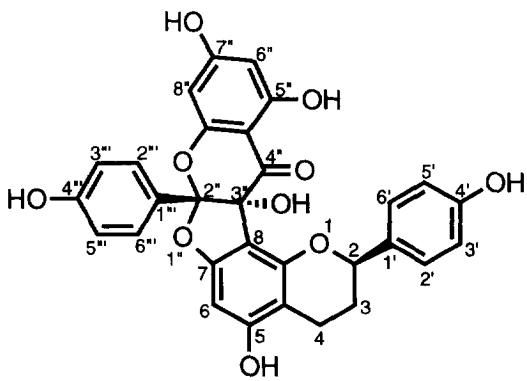
Daphnodorin H (**2**): R=R'=H
**9**: R=Me, R'=H
**12**: R=Me, R'=(+)-MTPA
**13**: R=Me, R'=Ac

configuration at the C-2 and C-3 positions in both **1** and **2** were assigned as *R* and *S*, respectively. The absolute configurations of C-2″ and C-3″ in **1** and **2** have been established by comparison of their circular dichroic (CD) spectra with those of **5** and **6** (Fig. 1).

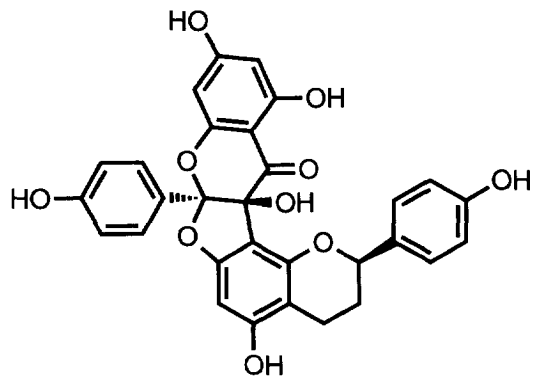
Compound **3**, $[\alpha]_D^{21}$ −250.0°, was isolated as a pale yellow amorphous powder and assigned the molecular formula $C_{30}H_{22}O_{10}$ by HR-SI mass spectrometry (*m/z* 543.1296 $[M+H]^+$). The UV spectrum of **3** showed absorption maxima at 321 sh, 278 and 227 nm. The IR spectrum showed absorption bands at 3300–2600, 1615, 1519 and 1470 $cm^{-1}$, indicating the presence of hydroxyl and carbonyl groups and an aromatic ring. The $^1H$ NMR spectrum of **3** (Table 3) showed signals assignable to two pairs of 4-oxyphenyl groups [$\delta$ 7.08 and 6.71 (each 2H, *d*, *J* = 8.8 Hz), 7.14 and 6.75 (each 2H, *d*, *J* = 8.8 Hz)], a 2,4,6-trioxyphenyl group [$\delta$ 5.75 and 5.59 (each 1H, *d*, *J* = 2.1 Hz)], a 3-hydroxy-2,8 (or 2,6)-disubstituted 5,7-dioxy-3,4-dihydrobenzopyran [$\delta$ 6.17 (1H, *s*), 4.61 (1H, *d*, *J* = 7.5 Hz), 4.20 (1H, *d*, *J* = 4.9 Hz), 3.83 (1H, *m*), 2.87 (1H, *dd*, *J* = 16.0 and 5.2 Hz) and 2.55 (1H, *dd*, *J* = 16.0 and 8.1 Hz)], a benzylmethine [$\delta$ 5.60 (1H, *s*)] and five phenolic hydroxyl groups [$\delta$ 9.40, 8.93, 8.77, 8.47 and 8.24 (each 1H, *s*)]. These signals were closely related to those of daphnodorin C (**4**), except for the presence of signals due to a 3-hydroxy-2,8 (or 2,6)-disubstituted 5,7-dioxy-3,4-dihydrobenzopyran instead of the signals due to a 2,8-disubstituted 5,7-dioxy-3,4-dihydrobenzopyran [$\delta$ 6.16 (1H, *s*), 4.85 (1H, *dd*, *J* = 8.6 and 1.2 Hz), 2.69 (2H, *m*), 2.29 (1H, *m*) and 1.68 (1H, *m*)]. The $^{13}C$ NMR spectrum of **3** (Table 4) was very similar to that of genkwanol A (**7**), indicating that **3** is a stereoisomer of **7**. The absolute configuration of the C-2 and C-3 positions in **3** was determined to be *R* and *S* because of the conversion of **3** into daphnodorin B upon heating in methanol with a small quantity of HCl similar to **7**. The absolute configuration of the C-2″ and C-3″ positions have been established to be *R* and *S*, respectively, by comparison of their CD spectra with those of **4** and **7** (Fig. 2).

## EXPERIMENTAL

*General.* EIMS: 70 eV. SIMS: glycerol matrix. $^1H$ and $^{13}C$ NMR: 300 and 75.4 MHz with TMS as int. standard. CC: Merck silica gel 60 (70–230 mesh), Merck silica gel 60H and Sephadex LH-20. TLC and



Daphnodorin E (**5**)



Daphnodorin F (**6**)

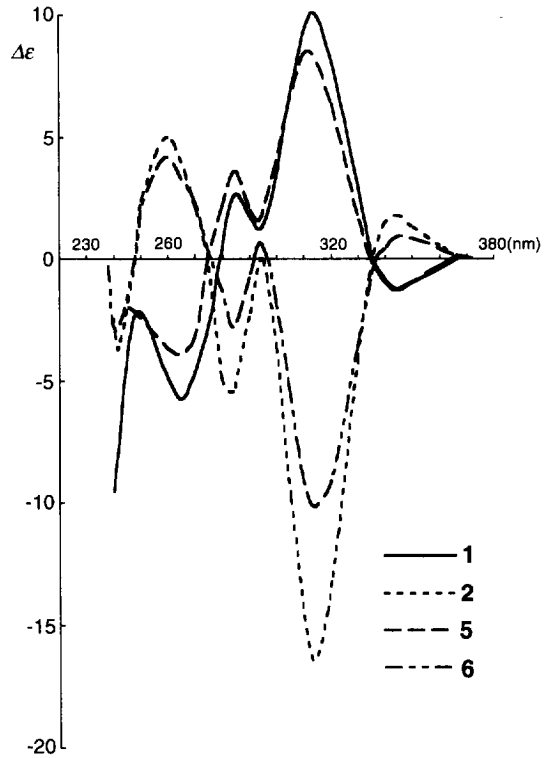



Fig. 1. The CD spectra of **1**, **2**, **5** and **6** in dioxane.

prep. TLC: Merck silica gel 60 $F_{254}$ plate (0.25 mm) and Whatman silica gel 150A PLK5F (1 mm). Spots and bands were detected by UV irradiation (254 and 365 nm).

*Plant material.* Plants of *D. odora* Thumb. were cultivated and collected in the botanical garden of the Osaka University of Pharmaceutical Sciences in January 1992. A voucher specimen is deposited at this university.

*Extraction and isolation.* Air-dried roots (4.5 kg) were chopped into small pieces and extracted with EtOAc (20 l × 5) under reflux. The combined EtOAc

Table 3. $^1$H NMR data for compounds **3**, **4** and **7** in acetone-$d_6$

| H | 3 | 4 | 7 |
|---|---|---|---|
| 2 | 4.61 *d* (7.5) | 4.85 *dd* (8.6, 1.2) | 4.62 *d* (7.7) |
| 3 | 3.83 *m* | 2.29 *m* | 3.80 *m* |
| (OH or H) | 4.20 *d* (4.9) | 1.68 *m* | 4.20 *d* (4.9) |
| 4 | 2.87 *dd* (16.0, 5.2) | 2.69 *m* | 2.89 *dd* (16.1, 5.7) |
| | 2.55 *dd* (16.0, 8.1) | | 2.54 *dd* (16.1, 8.4) |
| 6 | 6.17 *s* | 6.16 *s* | 6.17 *s* |
| 2′,6′ | 7.08 *d* (8.8) | 6.98 *d* (8.7) | 6.89 *d* (8.8) |
| 3′,5′ | 6.71 *d* (8.8) | 6.70 *d* (8.7) | 6.60 *d* (8.8) |
| 2″ | 5.60 *s* | *s* | 5.63 *s* |
| 6″ | 5.75 *d* (2.1) | 5.85 *d* (1.8) | 5.79 *d* (2.0) |
| 8″ | 5.59 *d* (2.1) | 5.66 *d* (1.8) | 5.77 *d* (2.0) |
| 10″,14″ | 7.14 *d* (8.8) | 7.15 *d* (8.7) | 7.15 *d* (8.8) |
| 11″,13″ | 6.75 *d* (8.8) | 6.77 *d* (8.7) | 6.77 *d* (8.8) |
| -OH | 9.40 *s* | 9.43 *s* | 9.55 *s* |
| | 8.93 *s* | 8.86 *s* | 8.95 *s* |
| | 8.77 *s* | 8.82 *s* | 8.60 *s* |
| | 8.47 *s* | 8.45 *s* | 8.50 *s* |
| | 8.24 *s* | 8.21 *s* | 8.25 *s* |

Table 4. $^{13}C$ NMR spectral data for compounds **3** and **7** in acetone-$d_6$

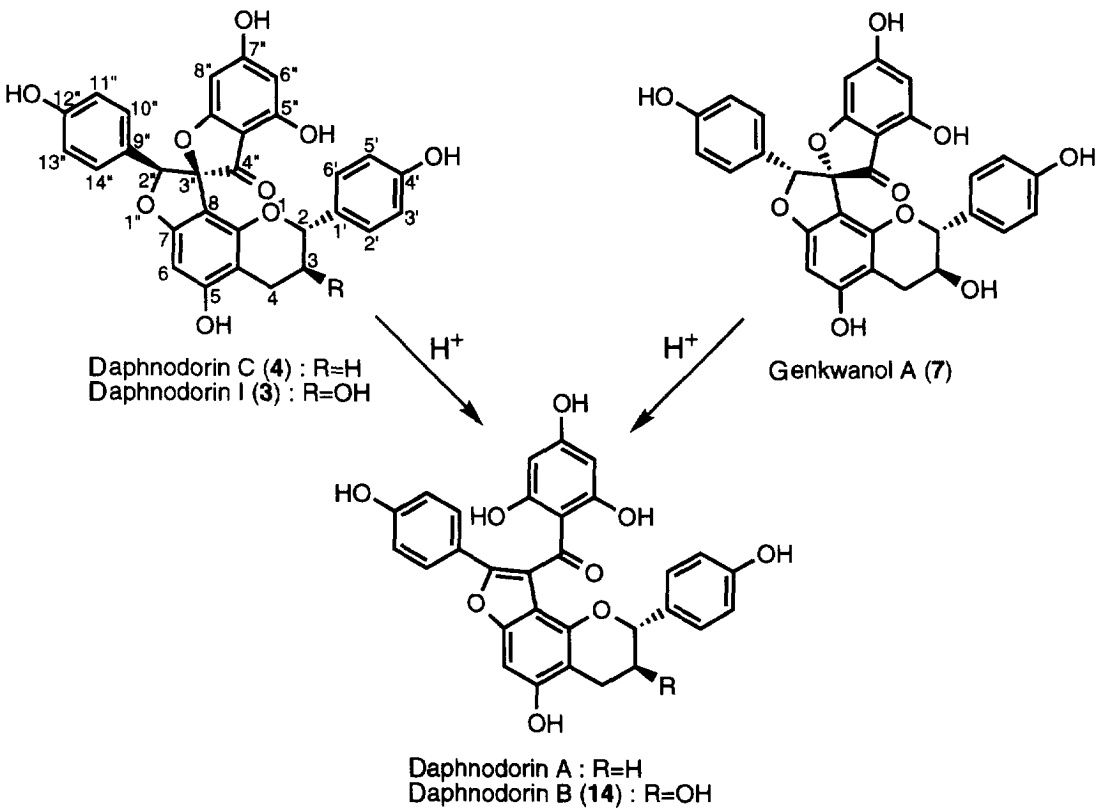
| C | 3 | 7 |
|---|---|---|
| 2 | 82.2 | 82.1 |
| 3 | 86.5 | 68.5 |
| 4 | 28.8 | 28.9 |
| 4a | 102.7 | 102.9 |
| 5 | 163.2* | 163.1* |
| 6 | 91.1 | 91.1 |
| 7 | 160.7* | 160.7* |
| 8 | 103.8 | 104.1 |
| 8a | 153.3 | 153.2 |
| 1′ | 130.9 | 130.8 |
| 2′,6′ | 129.0 | 128.7 |
| 3′,5′ | 116.0† | 115.9 |
| 4′ | 158.1 | 158.0 |
| 2″ | 92.7 | 92.4 |
| 3″ | 95.9 | 96.2 |
| 4″ | 197.2 | 196.7 |
| 4″a | 104.6 | 104.6 |
| 5″ | 158.6 | 158.6 |
| 6″ | 97.2 | 97.4 |
| 7″ | 169.9 | 170.1 |
| 8″ | 91.3 | 91.2 |
| 8″a | 173.6 | 173.6 |
| 9″ | 125.4 | 125.5 |
| 10″,14″ | 130.2 | 130.1 |
| 11″,13″ | 116.0† | 116.1 |
| 12″ | 159.1 | 159.1 |

*,†Assignments in each column may be interchanged.

extracts were concd to dryness *in vacuo*. The residue (825 g) was subjected to CC on silica gel eluted successively with hexane–EtOAc systems of increasing polarity. The 50% EtOAc eluates were rechromatographed on silica gel with $CHCl_3$–MeOH, then on Sephadex LH-20 with MeOH to give **1** (1.0 g), **2** (1.0 g) and **3** (0.3 g).

*Daphnodorin G* (**1**). Pale yellow amorphous powder. HR-SIMS *m/z* 559.1242 $[M+H]^+$ (calc. for $C_{30}H_{23}O_{11}$, 559.1239). UV $\lambda_{max}^{dioxane}$ nm (log $\varepsilon$): 330 (3.69), 297 sh (4.11), 284 (4.18), 228 (4.66). ORD (dioxane; *c* 0.76) $[\alpha]^{21}$ (nm): +43.6° (589), +54.5° (550), +76.4° (500), +101.8° (450), +203.6° (400), +349.1° (370), +43.6° (360). CD (dioxane; *c* $4.12 \times 10^{-5}$) $\Delta\varepsilon^{18}$ (nm): 0 (367), −1.32 (345), 0 (335.5), +10.10 (313), +1.18 (294), +2.65 (285), 0 (279.5), −5.73 (266), −2.35 (248), −9.56 (240). $^1H$ and $^{13}C$ NMR: see Tables 1 and 2.

*Hexamethyl ether of* **1** (**8**). Pale yellow viscous oil. HR-MS *m/z* 642.2107 $[M]^+$ (calc. for $C_{36}H_{34}O_{11}$, 642.2099). UV $\lambda_{max}^{dioxane}$ nm (log $\varepsilon$): 318 sh (3.66), 297 sh (3.91), 282 (4.01), 225 (4.53). CD (dioxane; *c* $3.43 \times 10^{-5}$) $\Delta\varepsilon^{18}$ (nm): 0 (356), +3.04 (319), 0 (308), −9.34 (294.5), 0 (287.5), +13.97 (278), 0 (259), −19.45 (237). $^1H$ NMR ($CDCl_3$): $\delta$ 7.49 (2H, *d*, *J* = 8.8 Hz), 6.94 (2H, *d*, *J* = 8.8 Hz), 6.86 (2H, *d*, *J* = 8.8 Hz), 6.65 (2H, *d*, *J* = 8.8 Hz), 6.33 (1H, *s*), 6.07 (1H, *d*, *J* = 2.2 Hz), 6.02 (1H, *d*, *J* = 2.2 Hz), 5.25 (1H, *d*, *J* = 3.8 Hz), 4.23 (1H, *m*), 3.80, 3.79, 3.78, 3.76, 3.55, 3.06 (each 3H, *s*), 2.71 (1H, *dd*, *J* = 16.5, 4.4 Hz),



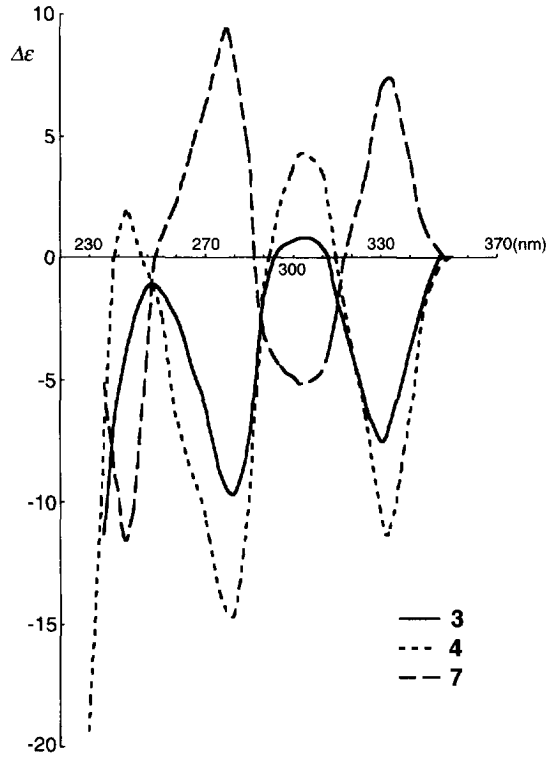



Fig. 2. The CD spectra of **3**, **4** and **7** in dioxane.

2.40 (1H, *dd*, $J = 16.5$, 4.4 Hz). $^{13}C$ NMR ($CDCl_3$): $\delta$ 187.8 (*s*), 165.9 (*s*), 162.9 (*s*), 161.8 (*s*), 161.7 (*s*), 161.4 (*s*), 160.9 (*s*), 159.3 (*s*), 153.0 (*s*), 131.8 (*s*), 128.6 (*d*) ×2, 127.8 (*s*), 127.2 (*d*) ×2, 117.7 (*s*), 113.9 (*d*) ×2, 113.8 (*d*) ×2, 104.6 (*s*), 103.6 (*s*), 102.5 (*s*), 94.0 (*d*), 93.5 (*d*), 88.2 (*s*), 88.1 (*d*), 80.8 (*d*), 67.3 (*d*), 56.0 (*q*) ×2, 55.9 (*q*), 55.6 (*q*), 55.5 (*q*), 54.0 (*q*), 23.8 (*t*).

(R)-(+)-*MTPA ester of* **8** (**10**). Compound **8** (6.0 mg) in pyridine (0.5 ml) and (+)-MPTA Cl (0.1 mmol) in $CCl_4$ (0.2 ml) were left to stand for 28 hr at room temp. *N,N*-Diethylethylenediamine (1 ml) was added with stirring, allowed to stand for 10 min and diluted with $Et_2O$ (30 ml), washed with dil. HCl, satd $Na_2CO_3$ and $H_2O$, then dried. The filtered $Et_2O$ soln was concd, and the residue was purified by prep. TLC with hexane–EtOAc (2:1) to afford **10** (5.1 mg).

*Compound* **10**. Viscous oil, HR-MS *m/z* 858.2488 $[M]^+$ (calc. for $C_{46}H_{41}F_3O_{13}$, 858.2497). $^1H$ NMR ($CDCl_3$): $\delta$ 7.46 (2H, *d*, $J = 8.8$ Hz), 7.45–7.25 (5H, *m*), 6.86 (2H, *d*, $J = 8.8$ Hz), 6.80 (2H, *d*, $J = 8.8$ Hz), 6.63 (2H, *d*, $J = 8.8$ Hz), 6.40 (1H, *s*), 6.04 (1H, *d*, $J = 2.2$ Hz), 5.92 (1H, *d*, $J = 2.2$ Hz), 5.49 (1H, *m*), 5.39 (1H, *br s*), 3.81, 3.79, 3.78, 3.76, 3.39, 3.36, 3.11 (each 3H, *s*), 2.93 (1H, *dd*, $J = 17.9$, 4.0 Hz), 2.39 (1H, *dd*, $J = 17.9$, 4.0 Hz).

*Acetate of* **8** (**11**). Viscous oil, HR-MS *m/z* 684.2209 $[M]^+$ (calc. for $C_{38}H_{36}O_{12}$, 684.2205). $^1H$ NMR ($CDCl_3$): $\delta$ 7.50 (2H, *d*, $J = 8.8$ Hz), 6.88 (2H, *d*, $J = 8.8$ Hz), 6.81 (2H, *d*, $J = 8.8$ Hz), 6.63 (2H, *d*, $J = 8.8$ Hz), 6.38 (1H, *s*), 6.05 (1H, *d*, $J = 2.2$ Hz), 5.92 (1H, *d*, $J = 2.2$ Hz), 5.37 (1H, *br s*), 5.27 (1H, *m*), 3.80, 3.79, 3.77, 3.76, 3.38, 3.37 (each 3H, *s*), 2.73 (1H, *dd*, $J = 17.2$, 4.0 Hz), 2.34 (1H, *dd*, $J = 17.2$, 4.2 Hz), 1.95 (3H, *s*).

*Daphnodorin H* (**2**). Pale yellow amorphous powder. HR-SIMS *m/z* 559.1239 $[M + H]^+$ (calc. for $C_{30}H_{23}O_{11}$, 559.1239). UV $\lambda_{max}^{dioxane}$ nm (log $\varepsilon$): 327 sh (3.81), 293 (4.19), 284 sh (4.16), 226 (4.72). ORD (dioxane; *c* 0.54) $[\alpha]^{21}$ (nm): −170.4° (589), −207.4° (550), −277.8° (500), −425.9° (450), −703.7° (400), −1000.0° (370). CD (dioxane; $c\ 4.12 \times 10^{-5}$) $\Delta\varepsilon^{18}$ (nm): 0 (367), +1.76 (345), 0 (335.5), −16.46 (313), 0 (295), −5.44 (284), 0 (274.5), +5.00 (260), 0 (248), −3.68 (242). $^1H$ and $^{13}C$ MMR: see Tables 1 and 2.

*Hexamethyl ether of* **2** (**9**). Pale yellow viscous oil. HR-MS *m/z* 642.2105 $[M]^+$ (calc. for $C_{36}H_{34}O_{11}$, 642.2099). UV $\lambda_{max}^{dioxane}$ nm (log $\varepsilon$): 314 sh (3.56), 293 sh (3.88), 281 (3.96), 225 (4.55). CD (dioxane; $c\ 3.12 \times 10^{-5}$) $\Delta\varepsilon^{18}$ (nm): 0 (358), −2.33 (315.5), 0 (307), +6.52 (294), 0 (287), −10.51 (278), −3.21 (258), −5.45 (245), 0 (236), +5.06 (232), 0 (229), −17.51 (225). $^1H$ NMR ($CDCl_3$): $\delta$ 7.50 (2H, *d*, $J = 8.7$ Hz), 7.26 (2H, *d*, $J = 8.7$ Hz), 6.91 (2H, *d*, $J = 8.7$ Hz), 6.88 (2H, *d*, $J = 8.7$ Hz), 6.36 (1H, *s*), 5.99 (1H, *d*, $J = 2.1$ Hz), 5.96 (1H, *d*, $J = 2.1$ Hz), 4.55 (1H, *d*, $J = 7.7$ Hz), 3.92 (1H, *m*), 3.84, 3.92, 3.80, 3.72, 3.46, 3.31 (each 3H, *s*), 2.96 (1H, *dd*, $J = 16.7$, 5.5 Hz), 2.54 (1H, *dd*, $J = 16.7$, 8.4 Hz). $^{13}C$ NMR ($CDCl_3$): $\delta$ 187.9 (*s*), 165.5 (*s*), 162.5 (*s*), 161.5 (*s*), 161.4 (*s*), 161.3 (*s*), 161.0 (*s*), 150.2 (*s*), 153.2 (*s*), 130.0 (*s*), 128.7 (*d*) ×2, 128.3 (*d*) ×2, 127.8 (*s*), 118.0 (*s*), 114.4 (*d*) ×2, 113.9 (*d*) ×2, 105.4 (*s*), 105.0 (*s*), 103.3 (*s*), 93.9

(*d*), 93.6 (*d*), 88.7 (*d*), 87.7 (*s*), 81.6 (*d*), 68.5 (*d*), 56.2 (*q*), 56.1 (*q*), 55.8 (*q*), 55.6 (*q*) ×2, 54.5 (*q*), 27.8 (*t*).

(R)-(+)-*MTPA ester of* **9** (**12**). Compound **9** (8.7 mg) in pyridine (0.5 ml) and (+)-MTPA Cl (0.1 mmol) in $CCl_4$ (0.2 ml) were left to stand for 28 hr at room temp. *N,N*-Diethylethylenediamine (1 ml) was added with stirring, allowed to stand for 10 min and diluted with $Et_2O$ (30 ml), washed with dil. HCl, satd $Na_2CO_3$ and $H_2O$, then dried. The filtered $Et_2O$ soln was concd, and the residue was purified by prep. TLC with hexane–EtOAc (2:1) to afford **12** (6.1 mg).

*Compound* **12**. Viscous oil, HR-MS *m/z* 858.2493 $[M]^+$ (calc. for $C_{46}H_{41}F_3O_{13}$, 858.2497). $^1H$ NMR ($CDCl_3$): $\delta$ 7.49 (2H, *d*, $J = 8.7$ Hz), 7.40–7.20 (5H, *m*), 7.14 (2H, *d*, $J = 8.7$ Hz), 6.87 (2H, *d*, $J = 8.7$ Hz), 6.76 (2H, *d*, $J = 8.7$ Hz), 6.38 (1H, *s*), 5.94 (1H, *d*, $J = 2.2$ Hz), 5.91 (1H, *d*, $J = 2.2$ Hz), 5.41 (1H, *m*), 4.92 (1H, *d*, $J = 6.5$ Hz), 3.83, 3.80, 3.79, 3.70, 3.47, 3.30, 3.21 (each 3H, *s*), 3.00 (1H, *dd*, $J = 17.0$, 5.0 Hz), 2.80 (1H, *dd*, $J = 17.0$, 6.6 Hz).

*Acetate of* **9** (**13**). Viscous oil, HR-MS *m/z* 684.2200 $[M]^+$ (calc. for $C_{38}H_{36}O_{12}$, 684.2205). $^1H$ NMR ($CDCl_3$): $\delta$ 7.50 (2H, *d*, $J = 8.8$ Hz), 7.22 (2H, *d*, $J = 8.8$ Hz), 6.88 (2H, *d*, $J = 8.8$ Hz), 6.86 (2H, *d*, $J = 8.8$ Hz), 6.36 (1H, *s*), 6.00 (1H, *d*, $J = 2.0$ Hz), 5.98 (1H, *d*, $J = 2.0$ Hz), 5.13 (1H, *m*), 4.86 (1H, *d*, $J = 6.6$ Hz), 3.83, 3.81, 3.80, 3.73, 3.56, 3.30 (each 3H, *s*), 2.91 (1H, *dd*, $J = 16.8$, 5.1 Hz), 2.61 (1H, *dd*, $J = 16.8$, 7.1 Hz), 1.87 (3H, *s*).

*Daphnodorin I* (**3**). Pale yellow amorphous powder. HR-SIMS *m/z* 543.1296 $[M+H]^+$ (calc. for $C_{30}H_{23}O_{10}$, 543.1290). UV $\lambda_{max}^{dioxane}$ nm (log $\varepsilon$): 321 sh (3.62), 278 (4.29), 227 (4.65). ORD (dioxane; *c* 0.54) $[\alpha]^{21}$ (nm): −250.0° (589), −314.8° (550), −416.7° (500), −592.6° (450), −1000.0° (400), −2111.1° (360). CD (dioxane; *c* $3.69 \times 10^{-5}$) $\Delta\varepsilon^{18}$ (nm): 0 (355), −7.54 (331), 0 (310), +0.82 (303), 0 (294), −9.68 (280), −1.31 (250), −11.32 (235). $^1H$ and $^{13}C$ NMR: see Table 3.

*Conversion of* **3** *into* **14**. Compound **3** (51.0 mg) was dissolved in MeOH (5 ml), and 8% HCl–MeOH (5 ml) was added. The mixt. was heated at 100° for 1 min, diluted with ice–$H_2O$ (100 ml) and extracted with EtOAc. The EtOAc soln was treated with 5% $NaHCO_3$, washed with $H_2O$, dried and concd *in vacuo*. The residue was purified by prep. TLC ($CHCl_3$–MeOH, 20:3) to afford **14** (29.5 mg).

## REFERENCES


1. Baba, K., Yoshikawa, M., Taniguchi, M. and Kozawa, M. (1995) *Phytochemistry* **38**, 1021.
2. Baba, K., Takeuchi, K., Hamasaki, F. and Kozawa, M. (1986) *Chem. Pharm. Bull.* **34**, 595.
3. Baba, K., Takeuchi, K., Doi, M., Inoue, M. and Kozawa, M. (1986) *Chem. Pharm. Bull.* **34**, 1540.
4. Baba, K., Takeuchi, K., Doi, M. and Kozawa, M. (1987) *Chem. Pharm. Bull.* **35**, 1853.
5. Baba, K., Takeuchi, K. and Kozawa, M. (1987) *Yakygaku Zasshi* **107**, 863.
6. Hundt, A. F., Burger, J. W., Steynberg, J. P., Steenkamp, J. A. and Ferreira, D. (1990) *Tetrahedron Letters* **31**, 5073.
7. Baba, K., Taniguchi, M., Ohishi, H. and Kozawa, M. (1993) *Phytochemistry* **32**, 221.
8. Baba, K., Taniguchi, M. and Kozawa, M. (1993) *Phytochemistry* **33**, 913.