A New Sesquiterpenoid Quinone and Other Related Compounds from the Okinawan Marine Sponge *Dactylospongia elegans*

Hidemichi Mitome,[†] Takahiro Nagasawa,[†] Hiroaki Miyaoka,[†] Yasuji Yamada,*[,†] and Rob W. M. van Soest[‡]

School of Pharmacy, Tokyo University of Pharmacy and Life Science, 1432-1 Horinouchi, Hachioji, Tokyo 192-0392, Japan, and Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, P.O. Box 94766, 1090 GT Amsterdam, The Netherlands

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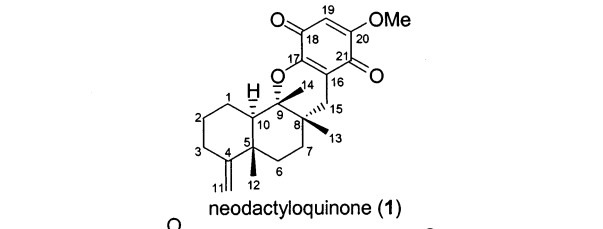
The new sesquiterpenoid quinone, neodactyloquinone (**1**), and dactylolactones A−D (**2**−**5**) were isolated from the Okinawan sponge *Dactylospongia elegans*. The structures of these compounds were determined by spectroscopic analysis.

Numerous sesquiterpenoid quinones have been isolated from various species of marine sponges,[1] many of considerable interest with regard to their biological activity.[2] The isolation of structurally unique sesquiterpenoid quinones dactyloquinones A−E, from the Okinawan sponge *Dactylospongia elegans*, was recently reported.[3] Each of these compounds has a unique cyclic-ether structure with ether linkages between the C-1, C-8, or C-10 position of the 4,9-friedodrimane sesquiterpene skeleton and the C-17 position of the 1,4-benzoquinone moiety. Further examination for other sesquiterpenoid quinones and related compounds from this sponge led to the isolation of the new sesquiterpenoid quinone neodactyloquinone (**1**) and dactylolactones A−D (**2**−**5**). Neodactyloquinone (**1**) has a rare rearranged-drimane skeleton,[6] different from that of the dactyloquinones. Dactylolactones A−D (**2**−**5**) each possess a unique lactone structure, which is possibly produced in the sponge by oxidative degradation of the quinone of dactyloquinone A or D. Herein, the isolation and structural elucidation of these compounds are presented.



Results and Discussion

Sponge specimens of *D. elegans* were extracted with MeOH and then acetone.[3] Repeated chromatographic separation of the EtOAc-soluble portion of the extract gave neodactyloquinone (**1**) and dactylolactones A−D (**2**−**5**), along with dactyloquinones[3] and other known sesquiterpenoid quinones (see Experimental Section).

Neodactyloquinone (**1**) was found to have the molecular formula $C_{22}H_{28}O_4$ on the basis of high-resolution mass measurement. A 1,4-benzoquinone chromophore appeared present from IR (1665 and 1643 cm^{-1}) and UV (λ_{max} 291 nm) spectra. ^{13}C NMR and DEPT spectra demonstrated 22 carbons and the presence of four methyls, six sp^3 methylenes, one sp^2 methylene, one sp^3 methine, one sp^2 methine, three sp^3 quaternary carbons, and six sp^2 quaternary carbons (Table 1). ^1H and ^{13}C NMR correlations were evident from the HMQC spectrum. ^1H and ^{13}C NMR indicated a dialkoxy-1,4-benzoquinone moiety [δ_H 5.74 (1H, s), δ_C 104.7 (CH), 114.6 (C), 151.2 (C), 159.5 (C), 181.5 (C), 181.5 (C)], an oxygenated sp^3 quaternary carbon [δ_C 86.4 (C)], an *exo*-methylene [δ_H 4.54 (2H, s), δ_C 103.7 (CH_2), 158.3 (C)], a methoxy [δ_H 3.80 (3H, s), δ_C 56.3 (CH_3)], and three methyls [δ_H 0.92 (3H, s), 1.07 (3H, s), 1.41 (3H, s), δ_C 19.1 (CH_3), 20.8 (CH_3), 24.3 (CH_3)]. COSY cross-peaks indicated sequences of C-3 to C-10 and C-6 to C-7. The planar structure of **1** was determined on the basis of the following correlations in the HMBC spectrum: H-11/C-3, C-4, C-5; Me-12/C-4, C-5, C-6, C-10; Me-13/C-7, C-8, C-9, C-15; Me-14/C-8, C-9, C-10; H-15/C-7, C-8, C-9, C-13, C-16, C-17, C-21; and H-19/C-17, C-18, C-20, C-21. Thus, C-15 was shown not to be connected to C-9 in dactyloquinones A−E but rather to C-8. A cyclic-ether structure was revealed by the absence of any hydroxy group absorption in the IR spectrum and by the molecular formula. The relative configuration of **1** was established from the following NOESY correlations: Me-14/Me-13, Me-12; H-15β (δ_H 2.04)/Me-13; and H-10/H-15α (δ_H 2.72).

The molecular formula of dactylolactone A (**2**) was shown to be $C_{23}H_{32}O_6$ on the basis of HREIMS analysis. IR and UV spectra of **2** demonstrated an ester (IR 1745 cm^{-1}) and β-alkoxybutenolide (IR 1777 and 1701 cm^{-1}, UV λ_{max} 242 nm). The 23 carbons of **2** were identified as five methyls, seven sp^3 methylenes, one sp^2 methylene, one sp^2 methine, four sp^3 quaternary carbons, and five sp^2 quaternary carbons, from ^{13}C NMR and DEPT spectra (Table 2). ^1H and ^{13}C NMR indicated a methyl ester [δ_H 3.65 (3H, s), δ_C 52.0 (CH_3), 167.3 (C)], β,γ-dialkoxybutenolide [δ_C 101.0 (C), 101.7 (C), 168.5 (C), 169.5 (C)], an oxygenated sp^3 quaternary carbon [δ_C 93.1 (C)], an *exo*-methylene [δ_H 4.61 (1H, s), 4.70 (1H, s), δ_C 106.0 (CH_2), 154.7 (C)], a methoxy [δ_H 3.21 (3H, s), δ_C 50.4 (CH_3)], and three methyls [δ_H 0.83 (3H, d, J = 6.1), 1.03 (3H, s), 1.28 (3H, s), δ_C 16.4 (CH_3), 19.4

* To whom correspondence should be addressed. Tel: +81 426 76 3063. Fax: +81 426 76 3048. E-mail: yamaday@ps.toyaku.ac.jp.
[†] Tokyo University of Pharmacy and Life Science.
[‡] University of Amsterdam.

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Table 1. NMR Data for **1**

no.	^{13}C NMR[a]	^{1}H NMR[b]
1	21.2 (CH_2)	1.59 (1H, m)
		1.77 (1H, m)
2	27.7 (CH_2)	1.20 (1H, m)
		1.81 (1H, m)
3	32.7 (CH_2)	2.12 (1H, m)
		2.24 (1H, dt, J = 4.9, 13.8)
4	158.3 (C)	
5	41.4 (C)	
6	30.8 (CH_2)	1.44 (1H, m)
		2.00 (1H, m)
7	32.3 (CH_2)	1.57 (1H, m)
		1.79 (1H, m)
8	34.6 (C)	
9	86.4 (C)	
10	47.8 (CH)	1.45 (1H, m)
11	103.7 (CH_2)	4.54 (2H, s)
12	20.8 (CH_3)	1.07 (3H, s)
13	24.3 (CH_3)	0.92 (3H, s)
14	19.1 (CH_3)	1.41 (3H, s)
15	26.8 (CH_2)	2.04 (1H, d, J = 18.6)
		2.72 (1H, d, J = 18.6)
16	114.6 (C)	
17	151.2 (C)	
18	181.5 (C)	
19	104.7 (CH)	5.71 (1H, s)
20	159.5 (C)	
21	181.5 (C)	
20-OMe	56.3 (CH_3)	3.80 (3H, s)

[a] 125 MHz, $CDCl_3$. [b] 500 MHz, $CDCl_3$.

(CH_3), 23.9 (CH_3)]. COSY cross-peaks demonstrated connected proton spin systems between C-1 to C-3 and C-6 to C-13. These partial structures were connected to each other via quaternary carbons, as evident from the following correlations in the HMBC spectrum: H-11/C-3, C-4, C-5; Me-12/C-4, C-5, C-6, C-10; Me-13/C-9; Me-14/C-8, C-9, C-10, C-15; H-15/C-8, C-9, C-10, C-14, C-16, C-17, C-21; H-19/C-17, C-18, C-20; 20-OMe/C-20; and 18-OMe/C-18 and H-2/C-10. The 4,9-friedodrimane skeleton was thus shown to be connected to a β-alkoxy-γ-methoxybutenolide. A cyclic-ether structure was revealed by the absence of any hydroxy group absorption in the IR spectrum and by the molecular formula. The relative configuration of **2** was elucidated from the following NOESY correlations: Me-14/H-1 (δ_H 1.99), Me-12, Me-13; H-1 (δ_H 1.99)/H-2 (δ_H 1.63); H-8/20-OMe; and H-2 (δ_H 1.61)/18-OMe (Figure 1).

Dactylolactone B (**3**) was shown to have the molecular formula $C_{23}H_{32}O_6$ from high-resolution mass measurement. Its planar structure was identical to that of **2** on the basis of ^{1}H NMR and ^{13}C NMR spectra and two-dimensional NMR (COSY, HMQC, and HMBC) data and, thus, was likely a stereoisomer. The relative configuration of **3** was determined from the following NOESY correlations: Me-14/Me-12, Me-13; H-6 (δ_H 1.42)/Me-12; and 18-OMe/H-6 (δ_H 1.98), H-8, from which its structure could be determined.

The molecular formula of dactylolactone C (**4**) was determined as $C_{23}H_{32}O_6$, the same as that of **2** or **3**, on the basis of high-resolution mass measurement. Functional groups identified from spectroscopic data of **4** were quite similar to those of **2** and **3**, although all methyl groups of **4** appeared as singlets in the ^{1}H NMR spectra (Table 3). ^{1}H and ^{13}C NMR indicated a methyl ester [δ_H 3.61 (3H, s), δ_C 51.9 (CH_3), 167.2 (C)], β,γ-dialkoxybutenolide [δ_C 101.4 (C), 101.7 (C), 167.9 (C), 168.0 (C)], an oxygenated sp^3 quaternary carbon [δ_C 88.5 (C)], an *exo*-methylene [δ_H 4.45 (1H, s), 4.46 (1H, s), δ_C 102.8 (CH_2), 158.9 (C)], a methoxy [δ_H 3.22 (3H, s), δ_C 50.3 (CH_3)], and three methyls [δ_H 1.07 (3H, s), 1.11 (3H, s), 1.27 (3H, s), δ_C 20.9 (CH_3), 21.3 (CH_3), 23.1 (CH_3)]. Connected proton spin systems between C-3 to C-10 and C-6 to C-7 were confirmed by COSY. These partial structures were connected to each other through quaternary carbons, as indicated by the following correlations in the HMBC spectrum: H-11/C-3, C-4, C-5; Me-12/C-4, C-5, C-6, C-10; Me-13/C-7, C-8, C-9; Me-14/C-8, C-9, C-10, C-15; H-15/C-8, C-9, C-10, C-14, C-16, C-17, C-21; H-19/C-17, C-18, C-20; 20-OMe/C-20; and 18-OMe/C-18. An ether linkage between C-8 and C-17 was demonstrated by the absence of any hydroxy group absorption in the IR spectrum and by the molecular formula. The relative configuration of **4** was evident from the following NOESY correlations: Me-14/Me-12, Me-13; Me-12/H-6 (δ_H 1.42); 18-OMe/Me-13; and H-10/H-6 (δ_H 1.92) (Figure 2).

The planar structure of dactylolactone D (**5**) was shown to be identical to **4** on the basis of high-resolution mass, ^{1}H NMR, and ^{13}C NMR spectra and two-dimensional NMR (COSY, HMQC, and HMBC) data (Table 3), thus suggesting **5** to be a stereoisomer of **4**. The relative configuration of **5** was established from the following NOESY correlations: Me-14/Me-12, Me-13; Me-12/H-6 (δ_H 1.45); H-10/H-6 (δ_H 2.07); and 18-OMe/H-10.

Neodactyloquinone (**1**) is the first example of a sesquiterpenoid quinone that possesses a rare rearranged-drimane skeleton[6] and containing a C-9−C-17 cyclic-ether structure. The structure of neodactyloquinone (**1**) was similar to that of dactyloquinones, but the sesquiterpene skeleton was different. Dactylolactones A−D (**2**−**5**) may be regarded as unique oxidized metabolites of dactyloquinone A or D. Oxidative C−C bond cleavage of dactyloquinone A[3a] between C-20 and C-21 in the 1,4-benzoquinone moiety may provide a ketocarboxylic acid in the biosynthetic pathway (Figure 3), and subsequent lactonization may lead to the formation of dactylolactones A (**2**) and B (**3**). In a similar manner, dactylolactones C (**4**) and D (**5**) may possibly be derived from dactyloquinone D.[3b]

In the present study, neodactyloquinone (**1**) was found to express moderate cytotoxic activity toward HeLa cells with an IC_{50} of 86 μM. The biological activity of dactylolactones A (**2**), B (**3**), C (**4**), and D (**5**) is presently under investigation.

Experimental Section

General Experimental Procedures. Optical rotations were measured with a JASCO DIP-360 polarimeter. IR spectra were recorded with a JASCO FT-IR/620 spectrometer, UV spectra with a JASCO V-550 spectrometer. ^{1}H and ^{13}C NMR spectra were recorded with a Bruker DRX-500 spectrometer. Chemical shifts were given on the δ (ppm) scale with tetramethylsilane (TMS) as the internal standard. EIMS were obtained with a Thermo Quest TSQ 700 spectrometer, and high-resolution EIMS (HREIMS) spectra were obtained using a VG Auto Spec E spectrometer. Flash column chromatography was carried out on Kanto Chemical silica gel 60N (spherical, neutral) 40−50 μm or ODS Wakogel LP-40 C-18. HPLC separations were performed using a YMC-Pack R&D ODS (250 × 20 mm) column and a UV detector (254 nm).

Animal Material. Sponge specimens (dark brown thin encrustations) were obtained from the coral reef of Ishigaki Island, Okinawa, Japan, at a depth of 5 m by hand using scuba, in November 2000.

The sponge specimen was *Dactylospongia elegans* (Thiele, 1899), class Demospongiae, order Dictyoceratida, family Thorectidae. A voucher specimen has been deposited at University of Amsterdam (ZMA POR. 16688), and another is maintained at Tokyo University of Pharmacy and Life Science (S-00-7).

Extraction and Isolation. Wet specimens (2.5 kg) were cut into small pieces and extracted with MeOH (12.5 L × 3) and then acetone (7.0 L × 2). The combined extracts were

Table 2. NMR Data for **2** and **3**

	2		**3**	
no.	^{13}C NMR[a]	^{1}H NMR[b]	^{13}C NMR[a]	^{1}H NMR[b]
1	25.3 (CH_2)	1.62 (1H, m) 1.99 (1H, m)	24.8 (CH_2)	1.70 (1H, m) 1.93 (1H, m)
2	21.7 (CH_2)	1.61 (1H, m) 1.63 (1H, m)	22.0 (CH_2)	1.43 (1H, m) 1.61 (1H, m)
3	31.2 (CH_2)	2.17 (1H, m) 2.44 (1H, m)	31.1 (CH_2)	2.15 (1H, m) 2.04 (1H, dt, J = 5.5, 13.9)
4	154.7 (C)		154.5 (C)	
5	43.9 (C)		43.8 (C)	
6	30.7 (CH_2)	1.40 (1H, m) 1.96 (1H, m)	30.7 (CH_2)	1.42 (1H, m) 1.98 (1H, m)
7	26.8 (CH_2)	1.54 (1H, m) 2.01 (1H, m)	26.8 (CH_2)	1.56 (1H, m) 1.57 (1H, m)
8	31.5 (CH)	1.52 (1H, m)	32.8 (CH)	1.49 (1H, m)
9	38.2 (C)		38.4 (C)	
10	93.1 (C)		93.5 (C)	
11	106.0 (CH_2)	4.61 (1H, s) 4.70 (1H, s)	106.0 (CH_2)	4.59 (1H, s) 4.69 (1H, s)
12	23.9 (CH_3)	1.28 (3H, s)	24.0 (CH_3)	1.28 (3H, s)
13	16.4 (CH_3)	0.83 (3H, d, J = 6.1)	16.4 (CH_3)	0.85 (3H, d, J = 6.5)
14	19.4 (CH_3)	1.03 (3H, s)	19.5 (CH_3)	1.04 (3H, s)
15	26.5 (CH_2)	1.98 (1H, d, J = 17.4) 2.29 (1H, d, J = 17.4)	27.0 (CH_2)	2.02 (1H, d, J = 17.6) 2.31 (1H, d, J = 17.6)
16	101.0 (C)		102.6 (C)	
17	168.5 (C)		168.4 (C)	
18	101.7 (C)		102.3 (C)	
19	39.6 (CH_2)	2.91 (1H, d, J = 14.9) 3.00 (1H, d, J = 14.9)	40.1 (CH_2)	2.87 (1H, d, J = 15.8) 3.04 (1H, d, J = 15.8)
20	167.3 (C)		167.7 (C)	
21	169.5 (C)		169.6 (C)	
18-OMe	50.4 (CH_3)	3.21 (3H, s)	51.2 (CH_3)	3.25 (3H, s)
20-OMe	52.0 (CH_3)	3.65 (3H, s)	51.9 (CH_3)	3.63 (3H, s)

[a] 125 MHz, $CDCl_3$. [b] 500 MHz, $CDCl_3$.

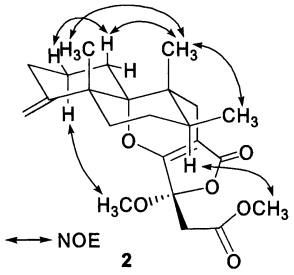

Figure 1. Selected NOE correlations of **2**.

concentrated and partitioned between EtOAc (2.5 L × 4) and water (2.0 L) to give an EtOAc-soluble portion (10.7 g).

The EtOAc-soluble portion was chromatographed on Si gel using a hexane−EtOAc (3:1) to EtOAc gradient and MeOH as eluent to produce fractions 1 (1.3 g), 2 (2.5 g), and 3 (5.9 g). Fraction 2 was subjected to flash Si gel column chromatography (elution with hexane−EtOAc (3:1 to 5:3)) to give fractions 2-1, 2-2, and 2-3. Fraction 2-1 was subjected to repeated flash Si gel and ODS column chromatography to give fractions 2-1-1 and 2-1-2. Fraction 2-1-2 was subjected to repeated flash ODS column chromatography to provide dactyloquinone C (1.9 mg).[3b] Fraction 2-1-1 was subjected to repeated flash Si gel and ODS column chromatography to provide dactylolactones A (**2**) (0.9 mg), B (**3**) (0.9 mg), C (**4**) (0.9 mg), and D (**5**) (1.1 mg). From fraction 2-2, ilimaquinone[4] (369.7 mg) was obtained. On fraction 2-3, repeated flash Si gel column chromatography (elution with hexane−EtOAc (5:3)) was conducted to give fractions 2-3-1, 2-3-2, and 2-3-3. Fraction 2-3-1 was subjected to repeated flash ODS column chromatography (elution with MeOH−acetone (3:1) and acetone−water (4:1)) and ODS-HPLC (elution with MeOH−water (6:1 to 4:1)) to give dactyloquinone A[3a] (9.6 mg), 5-epiilimaquinone[5] (15.8 mg), cyclospongiaquinone-1[7] (0.7 mg), dactyloquinones B[3a] (1.0 mg), D[3b] (3.5 mg), and E[3b] (1.4 mg), and neodactyloquinone (**1**) (2.3 mg), respectively. Fraction 2-3-2 was subjected to repeated flash Si gel column chromatography (elution with $CHCl_3$−MeOH (19:1) and hexane−EtOAc (2:1)) to produce smenospondiol[8] (11.0 mg), pelorol[9] (106.0 mg), and smenospongine[10] (11.8 mg).

Neodactyloquinone (1): pale yellow amorphous; $[\alpha]^{27}_D$ +28.6° (*c* 0.4, $CHCl_3$); UV (EtOH) λ_{max} (log ϵ) 291 (4.2) nm; IR (KBr) ν_{max} 1665, 1643 cm^{-1}; ^{1}H NMR and ^{13}C NMR, see Table 1; HMBC correlations (H/C) H-1/C-2, C-3, C-5, C-9, C-10; H-2/C-1, C-3; H-3/C-2, C-4, C-5, C-11; H-6/C-4, C-5, C-7, C-8, C-10, C-12; H-7/C-5, C-6, C-8, C-9, C-13, C-15; H-10/C-1, C-2, C-4, C-5, C-6, C-8, C-9, C-12, C-14; H-11/C-3, C-4, C-5; H-15/C-7, C-8, C-9, C-13, C-16, C-17, C-21; H-19/C-17, C-18, C-20, C-21; Me-12/C-4, C-5, C-6, C-10; Me-13/C-7, C-8, C-9, C-15; Me-14/C-8, C-9, C-10; OMe-20/C-20; NOE correlations (H/H) H-1β (δ_H 1.59)/H-2β (δ_H 1.81), Me-12, Me-14; H-1α (δ_H 1.77)/H-2α (δ_H 1.20), H-10; H-2α (δ_H 1.20)/H-3α (δ_H 2.12); H-2β (δ_H 1.81)/H-3; H-3α (δ_H 2.12)/H-11; H-3β (δ_H 2.24)/Me-12; H-6β (δ_H 1.44)/H-7, H-11, Me-12; H-6α (δ_H 2.00)/H-7α (δ_H 1.57), H-10, H-15α (δ_H 2.72); H-7α (δ_H 1.57)/Me-13; H-7β (δ_H 1.79)/Me-12, Me-13, Me-14; H-10/H-15α (δ_H 2.72); Me-12/Me-14; Me-13/Me-14, H-15β (δ_H 2.04); OMe-20/H-19; EIMS *m/z* 356 [M$^+$] (10), 189 (100), 175 (42), 161 (56), 133 (21), 119 (29), 91 (32); HREIMS *m/z* 356.1974 (calcd for $C_{22}H_{28}O_4$, 356.1988).

Dactylolactone A (2): colorless amorphous; $[\alpha]^{25}_D$ +10.0° (*c* 0.1, $CHCl_3$); UV (EtOH) λ_{max} (log ϵ) 242 (3.3) nm; IR (KBr) ν_{max} 1777, 1745, 1701 cm^{-1}; ^{1}H NMR and ^{13}C NMR, see Table 2; HMBC correlations (H/C) H-1/C-2, C-3, C-9, C-10; H-2/C-1, C-10; H-6/C-8, C-10, C-12; H-7/C-5, C-6, C-8, C-9, C-13; H-8/C-6, C-7, C-13, C-15; H-11/C-3, C-5; H-15/C-8, C-9, C-10, C-14, C-16, C-17, C-19; H-20/C-17, C-18, C-21; Me-12/C-4, C-5, C-6, C-10; Me-13/C-7, C-8, C-9; Me-14/C-8, C-9, C-10, C-15; OMe-18/C-18, OMe-21/C-21; NOE correlations (H/H) H-1α (δ_H 1.62)/H-15α (δ_H 1.98); H-1β (δ_H 1.99)/H-2β (δ_H 1.63), Me-12, Me-14; H-2α (δ_H 1.61)/H-3α (δ_H 2.17), OMe-18; H-2β (δ_H 1.63)/H-3; H-3α (δ_H 2.17)/H-11 (δ_H 4.70); H-3β (δ_H 2.44)/Me-12; H-6β (δ_H 1.40)/H-7α (δ_H 2.01), H-11 (δ_H 4.61), Me-12; H-6α (δ_H 1.96)/H-8, H-11 (δ_H 4.61); H-7β (δ_H 1.54)/Me-12, Me-13, Me-14; H-8/Me-13, OMe-21; Me-12/Me-14; Me-13/Me-14, H-15β (δ_H 2.29), OMe-21; Me-14/H-15; EIMS *m/z* 404 [M$^+$] (47), 389 (100), 376 (45); HREIMS *m/z* 404.2190 (calcd for $C_{23}H_{32}O_6$, 404.2199).

Table 3. NMR Data for **4** and **5**

	4		**5**	
no.	^{13}C NMR[a]	^{1}H NMR[b]	^{13}C NMR[a]	^{1}H NMR[b]
1	22.1 (CH_2)	1.46 (1H, m) 1.59 (1H, m)	22.1 (CH_2)	1.51 (1H, m) 1.61 (1H, m)
2	27.7 (CH_2)	1.35 (1H, m) 1.84 (1H, m)	28.8 (CH_2)	1.06 (1H, m) 1.89 (1H, m)
3	32.7 (CH_2)	2.07 (1H, m) 2.27 (1H, dt, J = 5.1, 13.6)	32.6 (CH_2)	2.06 (1H, m) 2.27 (1H, dt, J = 5.2, 13.8)
4	158.9 (C)		158.9 (C)	
5	39.3 (C)		39.4 (C)	
6	31.0 (CH_2)	1.42 (1H, m) 1.92 (1H, m)	31.1 (CH_2)	1.45 (1H, m) 2.04 (1H, m)
7	30.6 (CH_2)	1.92 (1H, m) 2.03 (1H, m)	30.6 (CH_2)	1.91 (1H, m) 2.07 (1H, m)
8	88.5 (CH)		88.9 (CH)	
9	38.3 (C)		38.3 (C)	
10	43.3 (C)	1.17 (1H, m)	45.1 (C)	1.13 (1H, m)
11	102.8 (CH_2)	4.45 (1H, s) 4.46 (1H, s)	103.1 (CH_2)	4.47 (1H, s) 4.52 (1H, s)
12	20.9 (CH_3)	1.11 (3H, s)	20.9 (CH_3)	1.12 (3H, s)
13	23.1 (CH_3)	1.27 (3H, s)	22.9 (CH_3)	1.25 (3H, s)
14	21.3 (CH_3)	1.07 (3H, s)	21.1 (CH_3)	1.06 (3H, s)
15	26.5 (CH_2)	1.86 (1H, d, J = 17.6) 2.61 (1H, d, J = 17.6)	26.7 (CH_2)	1.89 (1H, d, J = 17.6) 2.59 (1H, d, J = 17.6)
16	101.4 (C)		101.5 (C)	
17	168.0 (C)		168.5 (C)	
18	101.7 (C)		102.3 (C)	
19	38.8 (CH_2)	2.89 (1H, d, J = 16.3) 3.00 (1H, d, J = 16.3)	40.6 (CH_2)	2.92 (1H, d, J = 15.1) 3.02 (1H, d, J = 15.1)
20	167.2 (C)		167.7 (C)	
21	168.0 (C)		169.4 (C)	
18-OMe	50.3 (CH_3)	3.22 (3H, s)	51.1 (CH_3)	3.18 (3H, s)
20-OMe	51.9 (CH_3)	3.61 (3H, s)	51.9 (CH_3)	3.64 (3H, s)

[a] 125 MHz, $CDCl_3$. [b] 500 MHz, $CDCl_3$.

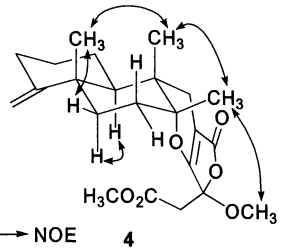

Figure 2. Selected NOE correlations of **4**.

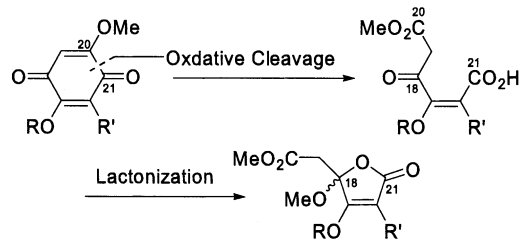

Figure 3. Possible biosynthetic pathway of dactylolactones.

Dactylolactone B (3): colorless amorphous; $[\alpha]^{28}_D$ +12.5° (c 0.2, $CHCl_3$); UV (EtOH) λ_{max} (log ϵ) 241 (3.5) nm; IR (KBr) ν_{max} 1777, 1745, 1701 cm^{-1}; ^{1}H NMR and ^{13}C NMR, see Table 2; HMBC correlations (H/C) H-1/C-2; H-2/C-1, C-3, C-10; H-3/C-1, C-2, C-4, C-5, C-11; H-6/C-5, C-7, C-10, C-12; H-7/C-5, C-6, C-8, C-9; H-8/C-7, C-9, C-13, C-14, C-15; H-11/C-3, C-4, C-5; H-15/C-8, C-9, C-10, C-14, C-16, C-17, C-19; H-20/C-17, C-18, C-21; Me-12/C-4, C-5, C-6, C-10; Me-13/C-7, C-8, C-9; Me-14/C-8, C-9, C-10, C-15; OMe-18/C-18, OMe-21/C-21; NOE correlations (H/H) H-1α (δ_H 1.70)/H-15α (δ_H 2.02); H-1β (δ_H 1.93)/H-2β (δ_H 1.61), Me-12, Me-14; H-2α (δ_H 1.43)/H-3α (δ_H 2.15); H-2β (δ_H 1.61)/H-3β (δ_H 2.40); H-3α (δ_H 2.15)/H-11 (δ_H 4.69); H-3β (δ_H 2.40)/Me-12; H-6β (δ_H 1.42)/H-7, H-11 (δ_H 4.59), Me-12; H-6α (δ_H 1.98)/H-7α (δ_H 1.56), H-11 (δ_H 4.59), OMe-18; H-7α (δ_H 1.56)/Me-13; H-7β (δ_H 1.57)/Me-12, Me-13, Me-14; H-8/Me-13, H-15β (δ_H 2.31), OMe-18; Me-12/Me-14; Me-13/Me-14, H-15β (δ_H 2.31); Me-14/H-15; EIMS m/z 404 [M$^+$] (57), 373 (35), 358 (28), 339 (18), 189 (100); HREIMS m/z 404.2182 (calcd for $C_{23}H_{32}O_6$, 404.2199).

Dactylolactone C (4): colorless amorphous; $[\alpha]^{28}_D$ −23.1° (c 0.13, $CHCl_3$); UV (EtOH) λ_{max} (log ϵ) 239 (3.5) nm; IR (KBr) ν_{max} 1776, 1750, 1703 cm^{-1}; ^{1}H NMR and ^{13}C NMR, see Table 3; HMBC correlations (H/C) H-2/C-1, C-10; H-3/C-2, C-4, C-5, C-11; H-6/C-5, C-7, C-8, C-10, C-12; H-7/C-5, C-6, C-8; H-10/C-1, C-5, C-9, C-12, C-14, C-15; H-11/C-3, C-4, C-5; H-15/C-8, C-9, C-10, C-14, C-16, C-17, C-19; H-20/C-17, C-18, C-21; Me-12/C-4, C-5, C-6, C-10; Me-13/C-7, C-8, C-9; Me-14/C-8, C-9, C-10, C-15; OMe-18/C-18, OMe-21/C-21; NOE correlations (H/H) H-1β (δ_H 1.46)/H-2β (δ_H 1.84), Me-12, Me-14; H-1α (δ_H 1.59)/H-10, H-15α (δ_H 2.61); H-2α (δ_H 1.35)/H-3α (δ_H 2.07), H-10; H-2β (δ_H 1.84)/H-3; H-3α (δ_H 2.07)/H-11 (δ_H 4.45); H-3β (δ_H 2.27)/Me-12; H-6β (δ_H 1.42)/H-7, H-11 (δ_H 4.46), Me-12; H-6α (δ_H 1.92)/H-10, H-11 (δ_H 4.46); H-7α (δ_H 1.92)/Me-13; H-7β (δ_H 2.03)/Me-12, Me-13, Me-14; Me-12/Me-14; Me-13/Me-14, H-15β (δ_H 1.86), OMe-18; Me-14/H-15β (δ_H 1.86); EIMS m/z 404 [M$^+$] (26), 373 (93), 339 (100); HREIMS m/z 404.2195 (calcd for $C_{23}H_{32}O_6$, 404.2199).

Dactylolactone D (5): colorless amorphous; $[\alpha]^{28}_D$ −22.7° (c 0.22, $CHCl_3$); UV (EtOH) λ_{max} (log ϵ) 240 (3.7) nm; IR (KBr) ν_{max} 1772, 1744, 1691 cm^{-1}; ^{1}H NMR and ^{13}C NMR, see Table 3; HMBC correlations (H/C) H-1/C-2, C-3, C-5, C-9, C-10; H-2/C-1, C-3, C-10; H-3/C-1, C-2, C-4, C-5, C-11; H-6/C-4, C-5, C-7, C-8, C-10, C-12; H-7/C-5, C-6, C-8, C-9, C-13; H-10/C-1, C-2, C-4, C-5, C-6, C-8, C-9, C-12, C-14, C-15; H-11/C-3, C-4, C-5; H-15/C-8, C-9, C-10, C-14, C-16, C-17, C-19; H-20/C-17, C-18, C-21; Me-12/C-4, C-5, C-6, C-10; Me-13/C-7, C-8, C-9; Me-14/C-8, C-9, C-10, C-15; OMe-18/C-18, OMe-21/C-21; NOE correlations (H/H): H-1β (δ_H 1.51)/Me-12, Me-14; H-1α (δ_H 1.61)/H-2α (δ_H 1.06), H-15α (δ_H 2.59); H-2α (δ_H 1.06)/H-3α (δ_H 2.06), H-10; H-2β (δ_H 1.89)/H-3; H-3α (δ_H 2.06)/H-11 (δ_H 4.47); H-3β (δ_H 2.27)/Me-12; H-6β (δ_H 1.45)/H-7, H-11 (δ_H 4.52), Me-12; H-6α (δ_H 2.04)/H-7α (δ_H 1.91), H-10, H-11 (δ_H 4.52); H-7α (δ_H 1.91)/Me-13; H-7β (δ_H 2.07)/Me-12, Me-13, Me-14; H-10/OMe-18; Me-12/Me-14; Me-13/Me-14, H-15β (δ_H 1.89); Me-14/H-15β

(δ_H 1.89); EIMS *m*/*z* 404 [M^+] (19), 373 (12), 216 (30), 189 (100), 175 (60); HREIMS *m*/*z* 404.2185 (calcd for $C_{23}H_{32}O_6$, 404.2199).

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Supporting Information Available: ^{1}H NMR, ^{13}C NMR, ^{1}H−^{1}H COSY, HMQC, HMBC, and NOESY spectra of neodactyloquinone (**1**) and dactylolactones A−D (**2**−**5**). This material is available free of charge via the Internet at http://pubs.acs.org.

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