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PRENYLATED XANTHONOIDS FROM *CALOPHYLLUM APETALUM*

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Key Word Index—*Calophyllum apetalum*; Guttiferae; roots; stem bark; xanthone; xanthonoid; apetalinones A–D.

Abstract—Three new xanthonoids, apetalinones A–C, were isolated from the roots of *Calophyllum apetalum*, as well as the known compounds, calozeyloxanthone and zeyloxanthonone. The stem bark of this species yielded a new xanthonoid, apetalinone D, and another known xanthonoid, tomentonone. Five known xanthones (3,8-dihydroxy-1,2-dimethoxy-, 1,3-dihydroxy-2,5-dimethoxy-, 1,5-dihydroxy-, 1,3,5-trihydroxy-2-methoxy- and 1,3,5-trihydroxyxanthone) and two flavonoids ((−)-epiafzelechin and (−)-epicatechin) were also characterized as constituents in the stem wood. Among them, apetalinone A was a novel xanthone with 1,1-dimethylallyl ether moiety, which indicated a new biosynthetic pathway including Claisen rearrangement and Diels–Alder reaction. © 1997 Elsevier Science Ltd

INTRODUCTION

Species of Guttiferae generally contain xanthones, which are simply oxygenated and substituted with isoprenyl group(s) [1]. In *Calophyllum* that belongs to the same subfamily as *Mammaea* and *Mesua* [1], a number of xanthones [2], biflavonoids [3] and coumarins [4] have been identified. The chemical constituents of *C. apetalum* distributed in the subtropical area were examined in our continuous phytochemical studies of the Guttiferae directed to search for leads with bioactivity. The seed oil has been used for various medicinal purposes in India [5]. In our previous paper, the isolation and structural elucidation of xanthones with a few C_5 units in this species was described [6]. We deal with here, the isolation and characterization of four new xanthonoids and a plausible biosynthetic pathway for the xanthonoids.

RESULTS AND DISCUSSIONS

Dried and ground stem bark, stem wood and roots of *C. apetalum* were extracted separately with benzene, acetone and 70% methanol. Each extract was repeatedly chromatographed on silica gel and Sephadex LH-20 to give compounds **1**–**5** (from the benzene extract of root), **6** and **7** (from the benzene extract of stem bark), and **8**–**14** (from the acetone extract of stem wood), respectively.

Compound **1**, apetalinone A, was isolated as an orange amorphous powder, which reacted positively, to the $FeCl_3$ test. A $[M]^+$ at *m/z* 448.2239 in the HR EI mass spectrum corresponds to the formula $C_{28}H_{32}O_5$. The IR spectrum exhibited strong bands due to hydroxyls (3500 cm^{-1}) and a conjugated carbonyl group (1642 cm^{-1}). Its UV spectrum closely resembled that of a 1,3,7-trihydroxyxanthone [7]. The ^1H NMR spectrum (Table 1) showed the presence of a chelated hydroxyl group (δ 13.61) and two *ortho*-coupled protons [δ 7.22 and 7.56 (J = 9.3 Hz)], in addition to an isolated aromatic proton (δ 6.44). This spectrum also revealed signals due to a 1,1-dimethylallyl group [δ 1.50 (6H, *s*), 5.19 (1H, *dd*, J = 10.7, 1.5 Hz), 5.27 (1H, *dd*, J = 17.6, 1.5 Hz), 6.22 (1H, *dd*, J = 17.6, 10.7 Hz)] and two isoprenyl groups, which was supported by fragment ions at *m/z* 379 and 323 caused by loss of C_5H_9 and C_4H_8 from the $[M]^+$ in the EI mass spectrum. In the HMBC spectrum (Fig. 1), the chelated hydroxyl group caused cross-peaks with three quaternary aromatic carbons (δ_C 104.6, 111.5 and 162.2), the former two carbons (δ 104.6 and 111.5) being further correlated to the isolated aromatic proton (δ 6.43), indicating that the *para*-position of the hydroxyl group was unsubstituted. The HMBC spectrum also exhibited long-range C–H correlations between the methylene protons at δ 3.37 on one of the isoprenyl groups and two aromatic carbons at δ 111.5

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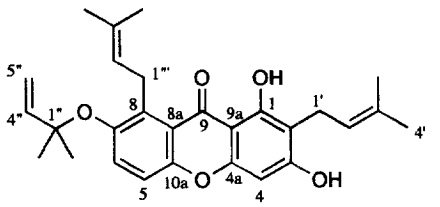

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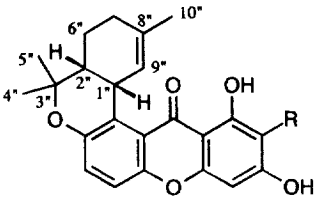

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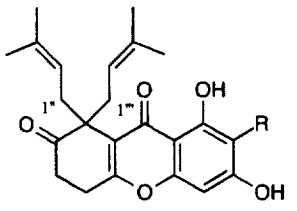
3: R = H



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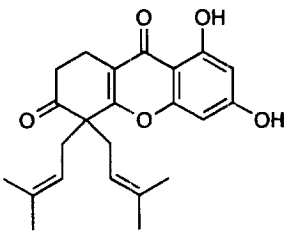

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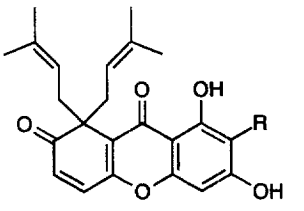


5: R = isoprenyl
7: R = H

and 164.0, which indicated that both *ortho*-positions of the isoprenyl group were substituted with an *O*-function. Then a partial structure of **1a** could be drawn. On the other hand, the methylene protons at δ 4.20 in another isoprenyl group were correlated with two aromatic carbons at δ 136.5 and 151.7 in the HMBC spectrum, which indicated that the isoprenyl group was attached to a *peri*-position in the xanthone nucleus, and one of the *ortho*-positions of the isoprenyl group was substituted with an *O*-function [8]. One of the *ortho*-coupled protons at δ 7.22 was correlated to two aromatic carbons at δ 151.7 and 153.8, suggesting that a 1,4-dioxygenated benzene ring existed in **1**. The protons due to the 1,1-dimethylallyl group (δ 1.50, 5.19, 5.27 and 6.22) caused cross-peaks with the aliphatic quaternary carbon (δ 81.7) in the HMBC spectrum, showing that the group was substituted with an *O*-function. In a NOE experiment, irradiation of the methyl protons at δ 1.50 on the 1,1-dimethylallyl group and of olefinic protons at δ 5.19 and 5.27 showed an enhancement of the proton at δ 7.56. The 1,1-dimethylallyl group was then substituted at an adjacent position to the isolated proton as a 1,1-dimethylalloxyl group. Considering these results, another partial structure of **1b** was formulated. Thus, the total structure of apetalinone A was characterized as **1** after connecting **1a** and **1b**. To the best of our knowledge, the occurrence of a xanthone with a 1,1-dimethylalloxyl group is reported for the first time.

Compound **2**, apetalinone B, an orange oil, gave a positive $FeCl_3$ test and had the molecular formula $C_{28}H_{30}O_5$ supported by the HREI mass spectrum (*m/z* 446.2083). Spectral data showed that **2** had the same partial structure (**1a**) as **1**. The ^{13}C NMR spectrum showed a quaternary olefinic carbon at δ 135.0, another olefinic methine carbon at δ 124.4, eight aliphatic carbons, including three methyl groups, at δ 24.0, 25.48 and 25.52, and a tertiary carbon at δ 77.1. In the ^1H NMR spectrum, **2** showed an olefinic proton (δ 5.74) and an extremely deshielded methine proton (δ 4.68), which correlated with the olefinic carbon at δ 124.4 and a methine carbon at δ 34.0 in the CH-COSY spectrum. In the COLOC spectrum, two aromatic carbons assigned to C-7 (δ 149.3) and C-8 (δ 125.3) in the xanthone and two olefinic carbons (δ 135.0 and 124.4) caused cross-peaks with the proton (δ 4.68), which indicated that a 2-butenyl chain was connected with the xanthone nucleus at C-8. Significant cross-peaks, were observed between the methyl proton at δ 1.62 and three carbons, including two olefinic carbons, at C-8″ (δ 135.0) and C-9″ (δ 124.4) and a methylene carbon at C-7″ (δ 29.0). These spectral data led to another partial structure, 3-methyl-2-butenyl moiety (**2a**) (Fig. 1). Two methyl protons (δ 1.37 and 1.39) were correlated to an aliphatic carbon at C-2″ (δ 40.3) in the COLOC spectrum, and they also caused cross-peaks with a quaternary aliphatic carbon at C-3″ (δ 77.1) bearing an *O*-function. The carbon (δ 40.3) was further correlated to two methylene protons (δ 1.56 and 1.98), which was additionally correlated to the carbon at C-6″ (δ 21.9) in the CH-COSY spectrum. These results indicated that the other moiety was 1,1-dimethyl-2,3-disubstituted propoxyl. An NOE was observed between the benzylic proton at C-1″ (δ 4.68) and the methine proton at C-2″ (δ 1.95), which was further correlated to the methylene carbon at C-7″ (δ 29.0) in the COLOC spectrum. Then, the three partial structures were connected to build **2**, where the methine protons were attributable to those at a ring junction. Fusion

Table 1. ^1H (400 MHz) and ^{13}C (100 MHz) NMR spectral data of xanthonoids **1–3**

No.	**1*** δ_C	δ_H	No.	**2*** δ_C	δ_H	**3†** δ_C	δ_H
1	162.2		1	160.6		162.9	
2	111.5		2	108.8		98.1	6.26 (1H, *s*)
3	164.0		3	162.2		163.6	
4	93.6	6.44 (1H, *s*)	4	93.5	6.31 (1H, *s*)	93.3	6.33 (1H, *s*)
5	116.4	7.22 (1H, *d*, J = 9.3)‡	5	117.2	7.11 (1H, *d*, J = 9.3)	117.0	7.14 (1H, *d*, J = 9.3)
6	128.6	7.56 (1H, *d*, J = 9.3)	6	126.1	7.16 (1H, *d*, J = 9.3)	126.0	7.19 (1H, *d*, J = 9.3)
7	151.7		7	149.3		149.2	
8	136.5		8	125.3		125.2	
9	184.2		9	183.1		182.7	
4a	156.4		4a	155.4		155.7	
8a	120.0		8a	118.9		118.6	
9a	104.6		9a	104.6		104.5	
10a	153.8		10a	152.9		152.6	
1′	22.4	3.37 (2H, *br d*)	1′	21.8	3.46 (2H, *br d*)		
2′	123.8	5.29 (1H, *m*)	2′	121.9	5.31 (1H, *m*)		
3′	131.9		3′	135.6			
4′	26.3[a]	1.65 (3H, *s*)[b]	4′	26.1	1.77 (3H, *s*)		
5′	18.3	1.79 (3H, *s*)	5′	18.2	1.85 (3H, *s*)		
1″	81.7		1″	34.0	4.68 (1H, *br s*)	33.7	4.67 (1H, *br s*)
2″	28.0	1.50 (3H, *s*)	2″	40.3	1.95 (1H, *m*)	39.9	2.00 (1H, *m*)
3″	28.0	1.50 (3H, *s*)	3″	77.1		76.9	
4″	145.9	6.22 (1H, *dd*, J = 17.6, 10.7)	4″	25.48[c]	1.37 (3H, *s*)[d]	25.3[e]	1.37 (3H, *s*)†
5″	114.5	5.19 (1H, *dd*, J = 10.7, 1.5)	5″	25.52[c]	1.39 (3H, *s*)[d]	25.1[e]	1.39 (3H, *s*)†
		5.27 (1H, *dd*, J = 17.6, 1.5)					
1‴	27.4	4.20 (2H, *br d*)	6″	21.9	1.56 (1H, *m*)	21.6	1.58 (1H, *m*)
					1.98 (1H, *m*)		2.01 (1H, *m*)
2‴	125.3	5.21 (1H, *m*)	7″	29.0	1.89 (1H, *m*)	28.6	1.92 (1H, *m*)
					1.97 (1H, *m*)		2.00 (1H, *m*)
3‴	131.5		8″	135.0		134.8	
4‴	26.3[a]	1.65 (3H, *s*)[b]	9″	124.4	5.74 (1H, *br s*)	124.0	5.73 (1H, *br s*)
5‴	19.0	1.83 (3H, *s*)	10″	24.0	1.62 (3H, *s*)	23.8	1.63 (3H, *s*)
OH-C-1		13.61 (1H, *s*)	OH-C-1		13.61 (1H, *s*)		13.34 (1H, *s*)
OH-C-3		9.55	OH-C-3		6.55		

* Measured in acetone-d_6.
† Measured in $CDCl_3$.
‡ Coupling constants (J in Hz) are given in parentheses.
[a,b] Overlapping.
[c–f] Interchangeable.

was *cis*-oriented by NOE results after comparison with the known compound calozeyloxanthone (**3**) isolated from bark of *C. zeylanicum* [9].

Compound **4**, a pale yellow amorphous powder, reacted positively to the Gibb's and $FeCl_3$ tests. The HREI mass spectrum showed a $[M]^+$ at m/z 450.2382, corresponding to the molecular formula $C_{28}H_{34}O_5$, with a partial structure of **1a**. In the ^1H NMR spectrum, methylene protons due to two of three isoprenyl groups appeared at δ 2.65 (2H, *dd*, J = 13.6, 8.3 Hz) and 3.15 (2H, *dd*, J = 13.6, 7.3 Hz), which indicated that the two isoprenyl groups were attached to an identical carbon atom, and that the two protons of each group were deshielded in order to be shifted. The correlations between the aliphatic carbon at δ 55.1 and the methylene protons (δ 2.65 and 3.15) were revealed in the COLOC spectrum. The carbonyl carbon at δ 211.2 and an aromatic carbon at δ 117.4 caused cross-peaks with the methylene protons (δ 2.65 and 3.15), respectively. The carbonyl carbon was further correlated with the methylene protons at δ 2.59. Interaction between a quaternary carbon at δ 166.0 attributed to a double-bond with an *O*-function and the methylene proton at δ 2.59, was observed. Through these correlations, another partial structure **4a** (Fig. 1) was concluded. The total structure was then **4** (zeyloxanthonone), which had already been isolated from *C. zeylanicum* [10]. An alternative structure (**4′**) is also possible. Complete assignment of all carbons by 2D NMR (Table 2) and unambiguous structural elucidation of **4** is described here.

Compound **5**, apetalinone C, orange crystals, reacted positively to the $FeCl_3$ and Gibb's tests. In the HREI mass spectrum, the $[M]^+$ at m/z 448.2236 was attributed to the molecular formula $C_{28}H_{32}O_5$. The ^1H NMR spectrum closely resembled that of **4**, except

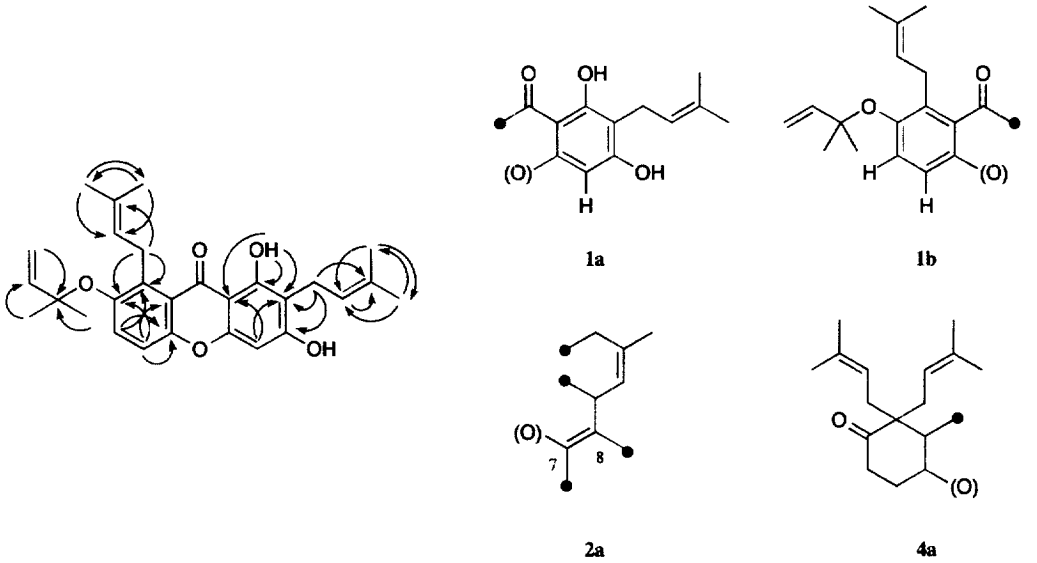


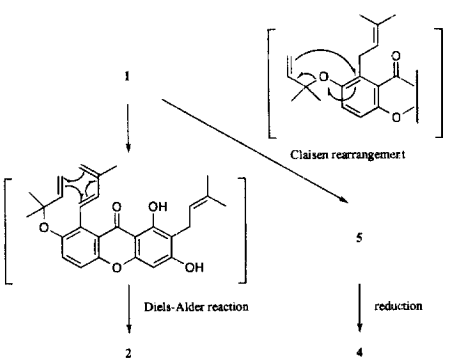
Fig. 1. NOEs and CH long-range correlations in HMBC spectrum (J = 10 Hz) of **1** and partial structures (**1a**, **1b**, **2a** and **4a**).

for the disappearance of two triplet signals due to methylene groups and the appearance of two *cis*-olefinic protons at δ 6.45 and 7.37 (each J = 10.0 Hz), which were correlated to two olefinic carbons at δ 134.1 and δ 137.7 in the CH COSY spectrum. When **4** and **5** were separately treated with H_2 in the presence of palladium, each compound gave a same product. Thus, **5** was a dehydrogenated derivative of **4**. In the ^{13}C NMR spectrum, two carbonyl groups were exhibited at δ 181.2 and 206.4, and the chemical shift of the latter indicated that the carbonyl group was conjugated with a double bond in a fused ring. Therefore, the structure of apetalinone C was characterized as **5**.

Compound **6** has already been isolated from *C. tomentosum* [11] and was identified as tomentonone by spectroscopic analysis and by comparison with **4**. Carbon assignments of **6** in the literature [11] needs to be revised (Table 2).

Compound **7**, apetalinone D, a yellow amorphous powder, reacted positively to the $FeCl_3$ and Gibb's tests on TLC. In the HREI mass spectrum, the $[M]^+$ at m/z 380.1621 corresponds to $C_{23}H_{24}O_5$. Its UV and IR spectrum resembled that of **5**, indicating that **6** has the same skeleton and oxidation pattern as **5**. The ^1H NMR spectrum was also similar to **5**, except for the disappearance of signals for an isoprenyl group and the appearance of signals due to another aromatic proton at C-2. The structure of apetalinone D was thus characterized as **7**, by ^{13}C NMR comparison with **5** (Table 2).

Compounds **8**–**14** were identified as 3,8-dihydroxy-1,2-dimethoxy- (**8**), 1,3-dihydroxy-2,5-dimethoxy- (**9**), 1,5-dihydroxy- (**10**), 1,3,5-trihydroxy-2-methoxy- (**11**), 1,3,5-trihydroxyxanthone (**12**), (−)-epiafzelechin (**13**) and (−)-epicatechin (**14**), respectively, by spectral analysis.



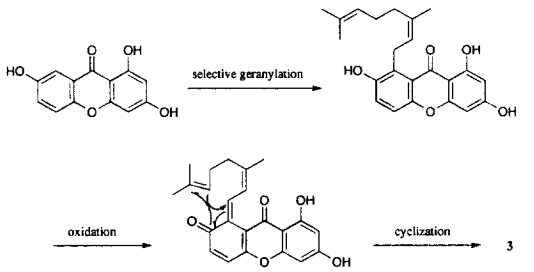
Scheme 1. Possible biosynthetic pathways of compounds **2**, **5** and **4** derived from **1**.

The occurrence of apetalinone A (**1**) suggests the following biosynthetic pathway. Apetalinones B (**2**) and C (**5**) and zeyloxanthonone (**4**) are derived from **1**, in the way shown in Scheme 1. Claisen rearrangement of a 1,1-dimethylalloxyl moiety at C-8 in **1** gives **5**, which further yields **4** after reduction of a double bond. On the other hand, **2** is synthesized by Diels–Alder reaction from **1**. An example of Claisen rearrangement of a 3,3-dimethylallyl group on an *O*-function that resulted in alternation of quinonoid form has been reported in a quinoline alkaloid [12]. A biosynthetic pathway of **3** has been proposed by Gunasekera *et al.* [9]. According to this pathway, **3** was yielded by selective geranylation and successive oxidation and cylization (Scheme 2). However, a corresponding intermediate with a geranyl group has not yet been characterized. The formation of partial struc-

Table 2. NMR spectral data of compounds **4**–**7**

No.	**4*** δ_C	δ_H	**5*** δ_C	δ_H	**6†** δ_C	δ_H	**7†** δ_C	δ_H
1	160.5		160.8		161.9		162.1	
2	112.2		113.0		99.3	6.29 (1H, *d*, $J = 2.4$)	99.6	6.31 (1H, *d*, $J = 2.4$)
3	162.4		163.1		162.9		163.1	
4	93.3	6.44 (1H, *s*)	93.8	6.50 (1H, *s*)	93.4	6.33 (1H, *d*, $J = 2.4$)	93.7	6.37 (1H, *d*, $J = 2.4$)
5	27.4	2.93 (2H, *t*, $J = 7.0$)‡	137.7	7.37 (1H, *d*, $J = 10.0$)	26.8	2.85 (2H, *t*, $J = 7.3$)	136.6	7.16 (1H, *d*, $J = 10.0$)
6	38.4	2.59 (2H, *t*, $J = 7.0$)	134.1	6.45 (1H, *d*, $J = 10.0$)	37.9	2.57 (2H, *t*, $J = 7.3$)	133.1	6.42 (1H, *d*, $J = 10.0$)
7	211.2		206.4		212.1		203.8	
8	55.1		56.8		54.8		56.4	
9	182.9		181.2		181.8		181.0	
4a	156.0		155.8		157.2		154.8	
8a	117.4		123.8		117.3		123.7	
9a	104.9		105.5		105.1		105.5	
10a	166.0		158.3		164.6		157.1	
1′	22.0	3.35 (2H, *br d*)	22.2	3.37 (2H, *br d*)				
2′	123.1	5.27 (1H, *m*)	123.1	5.28 (1H, *m*)				
3′	131.6		131.9					
4′	25.9[a]	1.78 (3H, *s*)	26.0	1.78 (3H, *s*)				
5′	17.9[b]	1.65 (3H, *s*)	18.00	1.65 (3H, *s*)				
1″, 1‴	36.0	2.65 (2H, *dd*, $J = 13.6, 8.3$)	38.6	2.71 (2H, *dd*, $J = 13.6, 8.3$)	35.4	2.70 (2H, *dd*, $J - 14.0, 8.3$)	33.9	2.75 (2H, *dd*, $J = 13.6, 8.3$)
		3.15 (2H, *dd*, $J = 13.6, 7.3$)		3.39 (2H, *dd*, $J = 13.6$ 7.3)		3.14 (2H, *dd*, $J = 14.0, 7.3$)		3.36 (2H, *dd*, $J = 13.6, 7.3$)
2″, 2‴	121.2	4.90 (2H, *m*)	119.7	4.76 (2H, *m*)	119.7	4.81 (2H, *m*)	118.2	4.68 (2H, *m*)
3″, 3‴	134.7		135.1		134.9		135.0	
4″, 4‴	25.9[a]	1.54 (6H, *s*)	25.9	1.54 (6H, *s*)	25.9	1.56 (6H, *s*)	25.7	1.56 (6H, *s*)
5″, 5‴	17.9[b]	1.47 (6H, *s*)	18.07	1.47 (6H, *s*)	17.8	1.48 (6H, *s*)	17.9	1.49 (6H, *s*)
OH-C-1		13.38 (1H, *s*)		13.27 (1H, *s*)		13.08 (1H, *s*)		13.12 (1H, *s*)
OH-C-3		9.70 (1H, *br s*)		9.70 (1H, *br s*)				

* Measured in acetone.
† Measured in $CDCl_3$.
‡ Coupling constants (J in Hz) are given in parentheses.
[a,b] Overlapping.



Scheme 2. Hypothetical biosynthesis of compound **3** through a geranylated precursor [9].

ture **2** might not take place by geranylation, but may be achieved by Diels–Alder reaction between 1,1-dimethylalloxyl and isoprenyl groups (Scheme 1).

EXPERIMENTAL

General. EIMS: (70 eV). ^{1}H and ^{13}C NMR: JEOL JNM EX-400 and GX-270 (TMS as int. standard), UV: MeOH soln. IR: KBr pellets. The following adsorbents were used for purification. TLC: Merck Kieselgel 60 F_{254}. CC: Merck Kieselgel 60, Fuji Davison silica gel BW-300 and Pharmacia Fine Chemicals AB Sephadex LH-20.

Plant material. Roots, stem bark and stem wood of *C. apetalum* Wild. were collected at Tamil Nadu, India, in August, 1995. Voucher specimens are deposited in the Herbarium of Gifu Pharmaceutical University.

Extraction and isolation. Dried and ground roots (1.2 kg) were extracted successively with C_6H_6, Me_2CO and 70% MeOH under reflux. After concn, the extracts gave respective residues of [25 g (C_6H_6), 30 g (Me_2CO) and 50 g (70% MeOH)]. The C_6H_6 extract (22 g) was subjected to silica gel cc (C_6H_6–Me_2CO system) to give 5 frs (^{BR}Fr. 1–5). ^{BR}Fr. 1 (C_6H_6 100%) was further subjected to vacuum liquid chromatography (VLC) on silica gel eluted with an *n*-hexane–Me_2CO system to give 4 frs (^{BR}Fr. 2-1–2-4). Compounds **1** (10 mg) and **5** (15 mg) were obtained by recrystallization (*n*-hexane–EtOAc) from ^{BR}Fr. 2-2 (30:1) and ^{BR}Fr. 2-4 (10:1), respectively. ^{BR}Fr. 3 was subjected to Sephadex LH-20 CC (Me_2CO) to give 3 frs (^{BR}Fr. 3-1–3-3). The crude product obtained from ^{BR}Fr. 3-3 was further sepd by VLC on silica gel (*n*-hexane–Me_2CO system) to give 3 frs (^{BR}Fr. 3-3A–3-3C). Compounds **2** (9 mg) and **4** (12 mg) were obtained from ^{BR}Fr. 3-3B (15:1) and ^{BR}Fr. 3-3C (15:1), respectively. Compound **3** (5 mg) was obtained in a pure form after VLC (C_6H_6–Me_2CO, 30:1) and prep. TLC (cyclohexane–EtOH, 7:1) from ^{B}Fr. 4.

Dried and ground stem bark (1 kg) was extracted in the same manner to give C_6H_6 (90 g), Me_2CO (80 g) and 70% MeOH (120 g) extracts after concn. The C_6H_6 extract was suspended in MeOH and partitioned with *n*-hexane. The MeOH-sol. extract (43 g) was subjected to silica gel CC eluted with C_6H_6–Me_2CO mixts of increasing polarity, to give 6 frs (^{BS}Fr. 1–6). ^{BS}Fr. 2 (10:1) was further subjected to Sephadex LH-20 CC (MeOH) to give 3 frs (^{BS}Fr. 2-1–2-3). ^{BS}Fr. 2-3 was further sepd by VLC on silica gel eluted with an *n*-hexane-EtOAc system to give 7 frs (^{BS}. 2-3A–2.3G). Compounds **6** (5 mg) and **7** (5 mg) were obtained from ^{BS}Fr. 2-3E (7:1) after prep. TLC (cyclohexane–EtOH, 15:1).

Dried and ground stem wood (1.2 kg) was extracted similarly to give C_6H_6 (2 g), Me_2CO (14 g) and 70% MeOH (33 g) extracts after concn. The C_6H_6 extract (1.5 g) was subjected to VLC (*n*-hexane–EtOAc system) to give 8 frs, ^{BW}Fr. 1-8. Compounds **8** (8 mg) and **9** (8 mg) were obtained from ^{BW}Ff. 6 after prep. TLC (cyclohexane–EtOH, 5:1). The Me_2CO extract (12 g) was sepd by silica gel CC eluted with a C_6H_6–EtOAc system to give 12 frs (^{AW}Fr. 1–12). Compounds **10** (5 mg) and **11** (5 mg) were obtained from ^{AW}Fr. 3 (20:1) and ^{AW}Fr. 5 (15:1), respectively, after recrystallization (*n*-hexane–EtOAc). Compound **12** (1 mg) was obtained from ^{AW}Fr. 7 (5:1). The 8th fr. (2:1) was further subjected to VLC ($CHCl_3$–MeOH system) to give 4 frs (^{AW}Fr. 8-1–8-4). ^{AW}Fr. 8-2 and ^{AW}Fr. 8-4 were further purified by recrystallization (EtOAc) to give **13** (5 mg) and **14** (130 mg), respectively.

Catalytic hydrogenation of compounds **4** *and* **5**. A soln containing **4** (2 mg) in dry EtOH (50 ml) was stirred over 10% Pd-C (1 g) under a H_2 atmosphere for 12 hr. Usual work-up afforded the hexahydroderivative of **4** (2 mg). Compound **5** (3 mg) was hydrogenated in the same manner to give the octahydroderivative of **5** (3 mg).

Compound **1** (*apetalinone A*). Orange amorphous powder. HREIMS *m/z* 448.2239 (calcd 448.2249 for $C_{28}H_{32}O_5$). EIMS *m/z* (rel. int.): 448 ([M]$^+$, 14), 446 (18), 431 (6), 390 (15), 380 (21), 379 (36), 363 (7), 347 (5), 337 (17), 323 (100), 309 (24), 305 (14), 281 (21), 269 (5), 241 (4), 69 (8). UV λ (nm): 241, 262, 315, 365. IR ν (cm^{-1}): 3500, 2914, 1642, 1609, 1576. ^{1}H NMR (270 MHz, benzene-d_6): δ 1.28 (6H, *s*, H-2″, 3″), 1.58 (6H, *s*, H-5′, 5‴), 1.69 (3H, *s*, H-4′), 1.70 (3H, *s*, H-4‴), 3.57 (2H, *br d*, H-1′), 4.48 (1H, *br s*, H-1‴), 4.91 (1H, *d*, J = 10.8 Hz, H-5″-Z), 4.98 (1H, *d*, J = 10.8 Hz, H-5″-E), 5.41 (1H, *m*, H-2′), 5.59 (1H, *m*, H-2‴), 5.99 (1H, *dd*, J = 17.1, 10.8 Hz, H-4″), 6.17 (1H, *s*, H-4), 6.89 (1H, *d*, J = 9.2 Hz, H-5), 7.16 (1H, *s*, OH-C-3), 7.26 (1H, *d*, J = 9.2 Hz, H-6), 14.28 (1H, *s*, OH-C-1). ^{1}H and ^{13}C NMR (acetone-d_6): Table 1.

Compound **2** (*apetalinone B*). Orange oil. HREIMS *m/z* 446.2083 (calcd 446.2099 for $C_{28}H_{30}O_5$). EIMS *m/z* (rel. int.): 446 ([M]$^+$, 100), 431 (32), 390 (73), 375 (22), 347 (22), 323 (14), 309 (7), 295 (7), 281 (5), 224 (7), 209 (32), 195 (11), 194 (11), 165 (7), 119 (5), 91 (7), 77 (4), 69 (3), 55 (2). UV λ (nm): 243, 268, 318, 378. IR ν (cm^{-1}): 3392, 2970, 2926, 1702, 1646, 1613, 1580. ^{1}H NMR (400 MHz, acetone-d_6): δ 1.35, 1.37 (3H each, *s*, H-4″, 5″), 1.52 (1H, *m*, H-6″), 1.58 (3H, *s*, H-10″), 1.66 (3H, *s*, H-5′), 1.80 (3H, *s*, H-4′), 1.85–2.02 (4H, *m*, H-2″, 6″, 7″), 3.37 (2H, *br d*, H-1′), 4.66 (1H, *br s*, H-1″), 5.30 (1H, *m*, H-2′), 5.74 (1H, *br s*, H-9″), 6.43 (1H, *s*, H-4), 7.15 (1H, *d*, J = 9.3 Hz,

H-5), 7.23 (1H *d*, $J = 9.3$ Hz, H-6), 8.19 (1H, *s*, OH-C-3), 13.51 (1H, *s*, OH-C-1). ^{1}H and ^{13}C NMR ($CDCl_3$): Table 1.

Compound **4** (*zeyloxanthonone*). Yellow amorphous powder. HREIMS *m/z* 450.2382 (calcd 450.2406 for $C_{28}H_{34}O_5$). EIMS *m/z* (rel. int.): 450 ([M]$^+$, 29), 381 (42), 325 (100), 297 (7), 283 (6), 271 (5), 255 (4), 241 (3), 165 (4), 149 (2), 91 (3), 69 (7), 55 (3). UV λ (nm): 211, 233, 256, 260 sh, 296. IR ν (cm^{-1}): 3235, 2966, 2926, 2856, 1716, 1698, 1651, 1586. ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.49 (6H, *s*, H-5″, 5‴), 1.56 (6H, *s*, H-4″, 4‴), 1.75 (3H, *s*, H-5′), 1.83 (3H, *s*, H-4′), 2.57 (2H, *t*, $J = 7.3$ Hz, H-6), 2.70 (2H, *dd*, $J = 14.2$, 8.3 Hz, H-1″, 1‴), 2.85 (2H, *t*, $J = 7.3$ Hz, H-5), 3.17 (2H, *dd*, $J = 14.2$, 7.3 Hz, H-1″, 1‴), 3.44 (2H, *br d*, H-1′), 4.82 (2H, *m*, H-2″, 2‴), 5.30 (1H, *m*, H-2′), 6.37 (1H, *s*, H-4), 7.25 (1H, *br s*, OH-C-3), 13.42 (1H, *s*, OH-C-1). ^{13}C NMR (100 MHz, $CDCl_3$): δ 18.7 (C-5′), 18.6 (C-5″, 5‴), 22.3 (C-1′), 26.6 (C-4′), 26.7 (C-4″, 4‴), 27.6 (C-5), 36.3 (C-1″, 1‴), 38.8 (C-6), 55.7 (C-8), 94.0 (C-4), 105.6 (C-9a), 111.3 (C-2), 117.8 (C-8a), 120.7 (C-2″, 2‴), 122.3 (C-2′), 135.4 (C-3′), 135.6 (C-3″, 3‴), 156.0 (C-4a), 160.5 (C-1), 162.0 (C-3), 165.0 (C-10a), 182.7 (C-9), 213.4 (C-7). ^{1}H and ^{13}C NMR (acetone-d_6): Table 2.

Compound **5** (*apetalinone C*). Orange crystals ($CHCl_3$), mp 148–150° (decomp). HREIMS *m/z* 448.2236 (calcd 448.2250 for $C_{28}H_{32}O_5$). EIMS *m/z* (rel. int.): 448 ([M]$^+$, 18), 405 (4), 379 (32), 363 (5), 337 (17), 323 (100), 309 (24), 305 (12), 281 (19), 269 (5), 253 (2), 165 (2), 149 (2), 115 (2), 91 (11), 69 (14), 55 (2). UV λ (nm): 207, 229, 269, 289, 332. IR ν (cm^{-1}): 3192, 2965, 2926, 2855, 1641, 1636, 1610, 1585. ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.48 (12H, *s*, H-4″, 4‴, 5″, 5‴), 1.77 (3H, *s*, H-5′), 184 (3H, *s*, H-4′), 2.75 (2H, *dd*, $J = 14.2$, 8.3 Hz, H-1″, 1‴), 3.38 (2H, *dd*, $J = 14.2$, 7.3 Hz, H-1″, 1‴), 3.46 (2H, *br d*, H-1′), 4.66 (2H, *m*, H-2″, 2‴), 5.29 (1H, *m*, H-2′), 6.39 (1H, *s*, H-4), 6.40 (1H, *d*, $J = 9.3$ Hz, H-6), 7.15 (1H, *d*, $J = 9.3$ Hz, H-5), 13.39 (1H, *s*, OH-C-1). ^{13}C NMR (100 MHz, $CDCl_3$): δ 17.9 (C-5′, 5″, 5‴), 22.6 (C-1′), 25.7 (C-4″, 4‴), 25.8 (C-4′), 37.9 (C-1″, 1‴), 56.4 (C-8), 93.6 (C-4), 105.2 (C-9a), 110.4 (C-2), 118.3 (C-2″, 2‴), 121.2 (C-2′), 123.5 (C-8a), 132.8 (C-3′), 134.9 (C-6), 135.8 (C-3″, 3‴), 136.9 (C-5), 154.9 (C-4a), 156.8 (C-10a), 159.8 (C-1), 161.6 (C-3), 180.8 (C-9), 204.2 (C-7). ^{1}H and ^{13}C NMR (acetone-d_6): Table 2.

Compound **7** (*apetalinone D*). Yellow amorphous powder. HREIMS *m/z* 380.1612 (calcd 380.1623 for $C_{23}H_{24}O_5$). EIMS *m/z* (rel. int.): 380 ([M]$^+$, 15), 337 (5), 311 (90), 269 (100), 257 (10), 241 (3), 200 (4), 83 (50), 69 (21). UV λ (nm): 201, 220 sh, 282, 321. IR ν (cm^{-1}): 3185, 2924, 2854, 1740, 1641, 1604, 1582. ^{1}H and ^{13}C NMR ($CDCl_3$): Table 2.

Apetalinone C octahydroderivative. Pale yellow oil. HREIMS *m/z* 456.2867 (calcd 456.2875 for $C_{28}H_{40}O_5$). EIMS *m/z* (rel. int.): 456 ([M]$^+$, 100), 441 (10), 428 (13), 413 (14), 400 (72), 399 (58), 386 (42), 385 (29), 372 (40), 371 (91), 357 (29), 329 (60), 315 (20), 301 (23), 271 (32), 243 (16), 231 (10), 217 (8), 165 (9), 123 (3). UV λ (nm): 219, 233 sh, 255, 262, 297. IR ν (cm^{-1}): 2955, 2926, 2856, 1735, 1718, 1650. ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.78 (6H, *d*, $J = 6.3$ Hz), 0.80 (6H, *d*, $J = 6.8$ Hz), 0.85 (6H, *m*), 0.98 (6H, *d*, $J = 6.8$ Hz), 1.43 (2H, *m*), 1.65 (1H, *m*), 1.98 (2H, *m*), 2.35 (2H, *m*), 2.65 (2H, *m*), 2.68 (2H, *t*, $J = 7.3$ Hz), 2.93 (2H, *t*, $J = 7.3$ Hz), 6.32 (1H, *s*), 13.32 (1H, *s*).

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