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TRIFARIENOLS A–E, TRIFARANE-TYPE SESQUITERPENOIDS FROM THE MALAYSIAN LIVERWORT *CHEILOLEJEUNEA TRIFARIA*

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Key Word Index—*Cheilolejeunea trifaria*; Jungermanniales; Hepaticae; liverwort; trifarienols A–E; trifaranes; striatanes; sesquitepenoids; X-ray crystallography; biogenesis.

Abstract—Five new bicyclic non-isoprenoid sesquiterpene alcohols, named trifarienols A–E, have been isolated from the Malaysian liverwort *Cheilolejeunea trifaria*, belonging to the Lejeuneaceae. Their absolute structures were established by a combination of NMR, CD and X-ray crystallographic analysis. Trifarienols are a new sesquiterpene series in bryophytes. They might be biosynthesized *via* striatane-type sesquiterpenids co-occurring in the same plant.

INTRODUCTION

Most liverworts contain oil bodies, which are rich sources of mono-, sesqui- and di-terpenoids and lipophilic aromatic compounds possessing a variety of carbon skeletons [1–3]. Furthermore, liverworts occasionally produce unique constituents that have not been found in higher plants, fungi or marine organisms. Many liverworts contain biologically active compounds exhibiting, for example, antifungal, anticancer and insect antifeedant properties, pungent tastes, bitterness as well as other, as yet uncharacterized, interesting biologically active compounds [4–8]. We have reported the distribution of more than 200 terpenoids and 70 aromatic compounds in 800 species of liverworts [1, 3]. In the course of our investigation of the Malaysian liverworts we isolated two new skeletal sesquiterpene alcohols, named trifarienols A (**1**) and B (**2**), from the ether extract of *Cheilolejeunea trifaria* (Reinw. *et al.*) Mizut. belonging to the Lejeuneaceae and reported briefly on their structures [9]. Further fractionation of the same extract resulted in the isolation of three additional trifarane-type sesquiterpenoids, trifarienols C–E (**3**–**5**). Here we report the structural characterization of five new sesquiterpenoids in detail.

RESULTS AND DISCUSSION

Dry *C. trifaria* was extracted with ether to give a green viscous oil, a small amount of which was directly analysed by TLC and GC-MS. The presence of striatenol (**11**), striatene (**12**) [10, 11] and β-caryophyllene were detected by comparing their mass spectra and R_fs with those of authentic samples. The remaining crude oil was chromatographed on silica gel and Sephadex LH-20 to give five trifarienols (**1**–**5**).

Trifarienol A (**1**)

The molecular formula of trifarienol A (**1**) was determined as $C_{15}H_{26}O_2$ ([M]$^+$ 238.1930) by high-resolution MS. The ^{1}H and ^{13} NMR spectra (Tables 1 and 2) contained two tertiary (δ0.84, 0.92, each *s*) and one secondary methyl group (δ0.86, *d*, J = 7.3 Hz), an exocyclic methylene group [δ4.63, 4.79, each *d*, J = 2.2 Hz), four sp^3 methylenes, two sp^3 methines, two quaternary carbons and two carbons bearing secondary (δ76.6) and primary hydroxyl groups (δ63.7). The presence of a primary and a secondary hydroxyl group was confirmed by the IR spectrum (3354 cm^{-1}) and the formation of the diacetate **6**, $C_{19}H_{30}O_4$ ([M]$^+$ = m/z 322; δ2.04, 2.09, each *s*, 4.03, 1H, *dd*, J = 11.9, 9.2 Hz, 4.41, 1H, *dd*, J = 11.9, 2.4 Hz, 5.25, 1H, *dd*, J = 9.2, 2.4 Hz). Oxidation of **1** by $NaIO_4$ gave an aldehyde (**7**), $C_{14}H_{22}O$ ([M]$^+$ m/z = 206; 1726 cm^{-1}; δ9.49, *s*), indicating the presence of a vicinal diol. The relative structure of **1** was determined by DQF, HMQC, ^{1}H–^{1}H and ^{13}C–^{1}H long-range 2D COSY, HMBC (Fig. 1) and NOESY spectra (Fig. 2). The absolute stereochemistry of the secondary hydroxyl group was elucidated by the CD spectra of **1** in the presence of the shift reagent [Eu(fod)$_3$] and its dibenzoate (**8**), which showed positive first Cotton effects at 307 nm (in **1**) and 250 nm (in **8**) and negative second Cotton effects at 282 nm (in **1**) and 233 nm (in **8**) [12]. As trifarienol A (**1**) crystallized from *n*-hexane to give a single crystal, its X-ray crystallographic analysis was carried out. The ORTEP drawing of **1** is shown in Fig. 3. Thus, the absolute configuration of trifarenol A was established as depicted in **1**.

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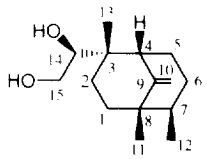
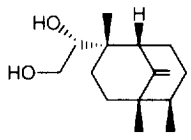
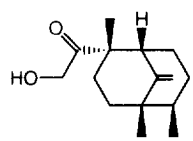
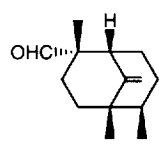






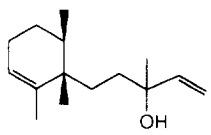


1: $R^1=R^2=H$
3: $R^1=H$, $R^2=Ac$
6: $R^1=R^2=Ac$
8: $R^1=R^2=P$-Br-Bz

2: $R^1=R^2=H$
4: $R^1=H$, $R^2=Ac$
9: $R^1=R^2=P$-Br-Bz

5: R=H
10: R=Ac

7



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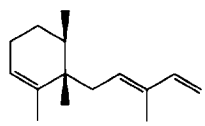

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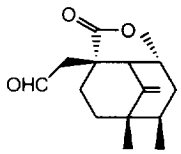

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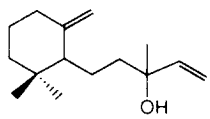

14

Table 1. ^{1}H NMR spectral data for compounds **1–5**

H	1*	2†	3‡	4†	5‡
1	1.63 *m*‡	1.60 *m*	1.66 *m*	1.66 *m*	1.36 *m*
	1.63 *m*	1.60 *m*	1.66 *m*	1.66 *m*	1.36 *m*
2	1.21 *m*	1.24 *m*	1.27 *m*	1.27 *m*	1.55 *m*
	1.95 *m*	1.60 *m*	1.99 *m*	1.99 *m*	2.67 *dt* (13.9,6.8)
4	2.23 *m*	2.33 *m*	2.31 *m*	2.31 *m*	2.38 *br d* (5.4)
5	1.63 *m*	1.60 *m*	1.66 *m*	1.66 *m*	1.72 *m*
	1.95 *m*	1.60 *m*	1.99 *m*	1.99 *m*	1.22 *m*
6	1.21 *m*	1.24 *m*	1.27 *m*	1.27 *m*	1.72 *m*
	2.23 *m*	2.33 *m*	2.31 *m*	2.31 *m*	2.22 *m*
7	1.63 *m*	1.60 *m*	1.66 *m*	1.66 *m*	1.75 *m*
10	4.63 *d* (2.2)	4.59 *d* (2.0)	4.60 *d* (2.0)	4.60 *d* (2.0)	4.72 *d* (1.6)
	4.79 *d* (2.2)	4.75 *d* (2.0)	4.81 *d* (2.0)	4.81 *d* (2.0)	4.90 *d* (1.6)
11	0.92 *s*	0.92 *s*	0.93 *s*	0.93 *s*	1.11 *s*
12	0.86 *d* (7.3)	0.85 *d* (7.1)	0.86 *d* (7.1)	0.86 *d* (7.1)	0.84 *d* (7.1)
13	0.84 *s*	0.81 *s*	0.89 *s*	0.89 *s*	0.92 *s*
14	3.80 *dd* (9.5, 2.6)	3.80 *dd* (9.7, 2.6)	4.25 *dd* (11.2, 2.0)	4.25 *dd* (11.2, 2.0)	
15	3.54 *dd* (11.2, 9.7)	3.49 *dd* (11.2, 9.7)	3.91 *dd* (9.2, 2.0)	3.91 *dd* (9.2, 2.0)	4.35 *d* (18.8)
	3.70 *dd* (11.2, 2.6)	3.71 *dd* (11.2, 2.6)	4.02 *dd* (11.2, 9.2)	4.02 *dd* (11.2, 9.2)	4.41 *d* (18.8)
OAc			2.12 *s*	2.12 *s*	

* Measured in $CDCl_3$ (600 MHz).

† Measured in $CDCl_3$ (400 MHz).

‡ All assignments were confirmed by ^{1}H–^{1}H and ^{13}C–^{1}H-COSY, HMBC, HMQC and NOESY experiments. Coupling constants (*J* in Hz) in parentheses.

Trifarienol B (**2**)

Compound **2**, $C_{15}H_{22}O$ ($[M]^+$ m/z = 238.1925), has the same molecular formula as that of **1** and its spectral data and chromatographic behaviour resembled those of **1**, indicating that **2** might be the stereoisomer at C-14. The CD spectra of **2** with the shift reagent [Eu(fod)$_3$] and of its dibenzoate (**9**) showed negative first Cotton effects at 304 nm (in **2**) and 250 nm (in **9**) and positive second Cotton effects at 280 nm (in **2**) and 233 nm (in **9**) [12],

Table 2. ^{13}C NMR spectral data for compounds **1–5**

C	1*	2†	3†	4†	5†
1	38.5‡	38.2	38.4	38.2	37.4
2	32.9	33.7	32.0	33.4	29.0
3	40.7	40.9	41.0	40.9	51.2
4	46.9	48.2	46.7	48.4	48.5
5	24.4	24.4	24.5	24.4	26.1
6	29.7	29.5	29.7	29.5	28.5
7	41.0	41.0	41.0	41.2	40.7
8	39.7	39.7	39.8	39.6	39.7
9	152.7	152.7	152.6	152.5	150.4
10	106.8	106.6	107.1	106.8	108.5
11	25.8	25.9	25.8	25.8	25.7
12	17.7	17.7	17.7	17.8	17.6
13	19.1	18.9	19.1	18.8	24.1
14	76.6	78.4	74.6	76.4	215.1
15	63.7	62.0	66.9	65.5	64.3
OAc			171.5	171.5	
			21.0	21.0	

* Measured in $CDCl_3$ (150 MHz).
† Measured in $CDCl_3$ (100 MHz).
‡ All assignments were confirmed by ^{13}C–^{1}H long-range COSY, HMBC, HMQC experiments.

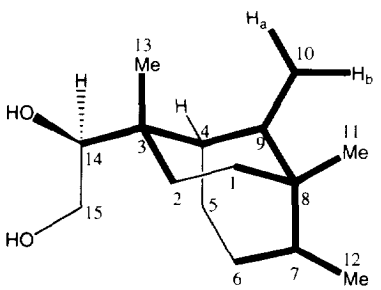

Fig. 1. HMBC (——) of trifarienol A (**1**).

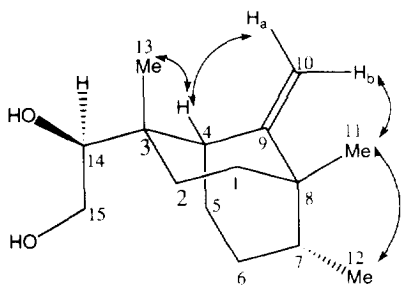

Fig. 2. NOESY (↷) of trifarienol A (**1**).

indicating that the absolute configuration at C-14 was opposite to that of **1**. Furthermore, oxidation of **2** with $NaIO_4$ gave an aldehyde, the spectral data of which were identical to those of the aldehyde (**7**) prepared from **1**. Thus the absolute configuration of trifarienol B was established to be **2**.

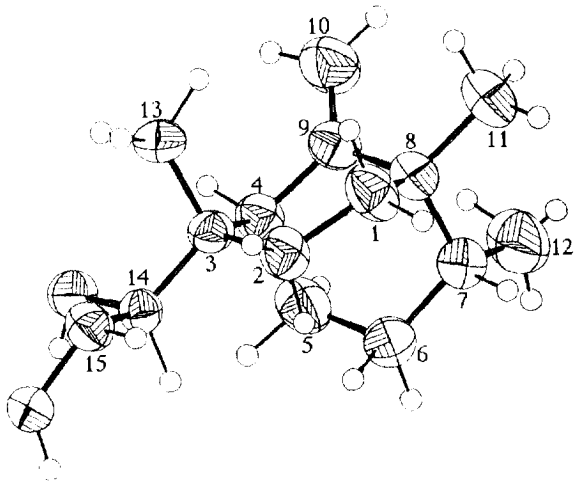

Fig. 3. ORTEP drawing of trifarienol A (**1**).

Trifarienol C (**3**)

Compound **3**, $C_{17}H_{28}O_3$ ($[M]^+$ m/z = 280.2025), showed the presence of a primary acetate group (IR: 1742 cm^{-1}; δ_M2.12, *s*, δ66.9, *t*, 171.5, *s*). The spectral data of **3** were very similar to those of **1**, except for the presence of an acetoxy group, thus establishing that **3** was the C-15 acetate of trifarienol A. Acetylation of **3** gave a diacetate, the spectral data of which were in good accordance with those of the diacetate **6** prepared from **1**. Consequently, the structure of trifarienol C were established as trifarienol A 15-acetate (**3**).

Trifarienol D (**4**)

The ^{1}H- and ^{13}C NMR spectral patterns, as well as the mass spectrum of compound **4**, $C_{17}H_{28}O_3$ ($[M]^+$ m/z = 280.2025), were almost identical with those of trifarienol C (**3**), suggesting that trifarienol D might be its C-4 stereoisomer. This assumption was confirmed by acetylation of **2** to afford an acetate, the spectral data of which were identical in all respects with **4**.

Trifarienol E (**5**)

Compound **5**, $C_{15}H_{24}O_2$ ($[M]^+$ m/z = 236.1750). Its IR and NMR data indicated the presence of a ketone [1703 cm^{-1}; δ_c215.1] and a primary hydroxyl group (3472 cm^{-1}; δ_H4.35, 4.41 each 1H, *d*, J = 18.8 Hz; δ_C64.3, *t*). Its spectral data were very similar to those of trifarienol A (**1**), except for the presence of a ketone group in place of the secondary hydroxyl group. Thus, the structure of the final new sesquiterpene ketol was suggested to be that of the dehydro compound of **1**. Acetylation of **5** gave a mono acetate, $C_{17}H_{26}O_3$ ($[M]^+$ m/z = 278), whose spectral data were identical to those of the product (**10**) derived from trifarienol C (**3**) by oxidation with pyridinium chlorochromate (PCC)-Al_2O_3. This established the stereochemistry of **5** and confirmed that **5** was the 14-dehydro compound of trifarienols A (**1**) and B (**2**).

Sulte *et al.* [13] reported that the marine sponge *Dysidea fragilis* produced upial (**13**), a sesquiterpene aldehyde

lactone with a bicylo[3.3.1]nonane skeleton whose absolute configuration is the same as that of trifarienols, except for the stereochemistry at C-3. They also suggested that this unique sesquiterpenoid might be biosynthesized from a striatane-type sesquiterpene furan found in a different sponge. The absolute configuration of **13**, including C-3, was further confirmed by total synthesis of the enantiomer of **13** [14]. The above biogenetic hypothesis is supported by the co-occurence of the trifarienols **1–5** with the striatane-type sesquiterpenoids, striatol (**11**) and striatene (**12**) in *C. trifaria*. The last two compounds are widespread in the liverworts belonging to the Lejeuneaceae [11]. Previously, we proposed that trifarienols A (**1**) and B (**2**) might be formed *via* **15**, which is an intermediate in the formation of pinguisane-type sesquiterpenoids (Fig. 4) [16]. This route is unlikely to be suitable for the biogenesis of trifaranes. A more plausible biogenetic pathway for the new sesquiterpenoids (**1–5**) found in *C. trifaria* is shown in Fig. 5. β-Monocyclo-nerolidol (**14**), which is also found in *Cheilolejeunea excisula* [11] might be formed from nerolidol (route a). Alternatively, one of the methyl groups at C-4 could migrate to C-5, to give a striatane-type sesquiterpenoids (**11**) from which striatene (**12**) and trifarienols **1–5** might be biosynthesized (route b).

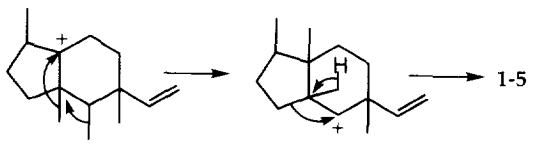

Fig. 4. Previously reported biogenetic pathway for trifarienols [16].

A number of sesquiterpenoids have been isolated from or detected in the Lejeuneaceae and their structures have been elucidated [1–3, 15–18]. Prior to the present study two *Cheilolejeunea* species, *C. excisula* and *C. imbricata*, had been chemically analysed. The former was shown to β-chamigrene, β-caryophyllene, striatene (**12**), striatol (**11**) and β-monocyclo-nerolidol (**14**) while the latter contained striatene (**12**). However, trifaranes were not detected in either species. This is the first reported isolation of trifarane-type sesquiterpenoids, possessing *S* configuration at C-3, from a natural source. It is noteworthy that the marine sponge and the liverwort produce the same trifarane-type sesquiterpenoids and that the former organism biosynthesizes a trifarane with *R* configuration at C-3.

EXPERIMENTAL

Mps: uncorr. Solvents for the spectral measurements were TMS–$CDCl_3$ [^{1}H NMR (200, 400 and 600 MHz),

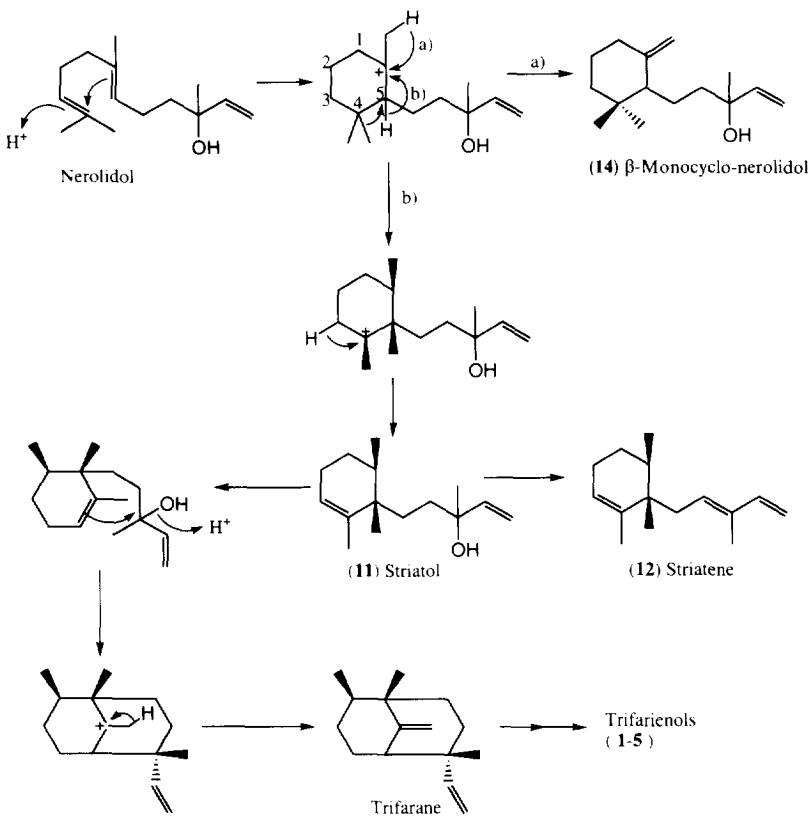

Fig. 5. Biogenetic pathway for striatone-(**11**, **12**) and trifarane-type sesquiterpenoids (**1–5**) found in *Cheilolejeunea trifaria*.

^{13}C NMR (50, 100, 150 MHz)], $CHCl_3$ ($[\alpha]_D$ and CCl_4 or EtOH (CD). GC-MS was carried out as previously reported [19]. TLC: silica gel precoated glass plates with *n*-hexane–EtOAc (4:1, 1:1). Spots were detected by illumination with an UV lamp or by spraying with 30% H_2SO_4, followed by heating at 110°. CC: silica gel 60 (40–60 μm).

Plant materials. Cheilolejeunea trifaria (Reinw. *et al.*) Mizut. was collected by Y. A., T. H. and Mr H. Tanaka on Langkuai island, West Malaysia, in July 1992 and identified by Dr. M. Mizutani. The voucher specimen has been deposited at the Institute of Pharmacognosy, Tokushima Bunri University.

Extraction and isolation. Dried *C. trifaria* (18.75 g) was extracted with Et_2O for 1 week. After filtration and evaporation of the solvent a green viscous oil (1.31 g) was obtained. Analysis of part of this oil by TLC and GC-MS showed the presence of the sesquiterpene hydrocarbons, β-caryophyllene and striatene (**12**) and striatol (**11**) [10, 11] (*R,s* and MS data identical to those of authentic samples). The remaining extract (1.30 g) was chromatographed on silica gel using an *n*-hexane–EtOAc gradient to give 10 frs. Fr. 3 was rechromatographed on Sephadex LH-20 using MeOH–$CHCl_3$ (1:1) and silica gel using *n*-hexane–EtOAc, repeatedly, to give trifarienol A (**1**) (271 mg), trifarienol B (**2**) (73 mg), trifarienol C (**3**) (66 mg), trifarienol D (**4**) (24 mg) and trifarienol E (**5**) (9 mg).

Trifarienol A (**1**). mp 59–60°; $[\alpha]_D$ + 10.2 (*c* 0.63); EIMS *m/z* (rel. int.): 238 ($[M]^+$ (13), 220 (7), 207 (15), 187 (4), 177 (100), 161 (15), 147 (12), 136 (26), 123 (67), 107 (44), 95 (39) 81 (36); HRMS: found: 238.1930; $C_{15}H_{26}O_2$ requires 238.1932); IR ν_{max}^{KBr} cm^{-1}: 3354, 1644, 1454, 1377, 1078, 1011, 983, 924, 882, 756, 673, 538, 403; CD [CCl_4 + Eu(fod)$_3$]: $\Delta\varepsilon_{307}$: +79.8, $\Delta\varepsilon_{282}$: −55.9; ^{1}H and ^{13}C NMR: Tables 1 and 2.

Trifarienol B (**2**). mp 105–105.5°; $[\alpha]_D$–3.6 (*c* 1.62), EIMS *m/z* (rel. int.): 238 ($[M]^+$(9), 220 (6), 207 (14), 189 (24), 177 (100), 161 (16), 123 (49), 107 (40), 95 (35), 81 (32); HRMS: found: 238.1925; $C_{15}H_{26}O_2$ requires 238.1933); IR ν_{max}^{KBr} cm^{-1}: 3383, 2959, 2938, 2886, 1641, 1491, 1406, 1377, 1308, 1221, 1161, 1055, 987, 771, 585, 451: CD [CCl_4 + Eu(fod)$_3$] $\Delta\varepsilon_{304}$: − 53.92, $\Delta\varepsilon_{280}$: + 38.7; ^{1}H and ^{13}C NMR: Tables 1 and 2.

Trifarienol C (**3**). mp 99–100°; $[\alpha]_D$ + 13.0 (*c* 0.53); EIMS *m/z* (rel. int.) 280 ($[M]^+$ (4), 262 (2), 220 (9), 202 (21), 187 (12), 177 (100), 161 (7), 147 (9), 136 (22), 123 (59), 107 (35), 95 (25), 81 (22); HRMS: found: 280.2025; $C_{17}H_{28}O_3$ requires 280.2038); IR ν_{max}^{KBr} cm^{-1}: 3483, 1742, 1644, 1454, 1370, 1246, 1036, 976, 882, 693, 459; ^{1}H and ^{13}C NMR: Tables 1 and 2.

Trifarienol D (**4**). mp 83–85°; $[\alpha]_D$ − 0.24 (*c* 0.42); EIMS *m/z* (rel. int.) 280 ($[M]^+$ (3), 262 (2), 220 (8), 202 (17), 187 (11), 177 (100), 161 (9), 147 (8), 136 (17), 123 (40), 107 (33), 95 (25), 81 (22); HRMS: found: 280.2025; $C_{17}H_{28}O_3$ requires 280.2038; IR ν_{max}^{KBr} cm^{-1}: 3435, 1742, 1644, 1454, 1377, 1044, 986, 883, 606; ^{1}H and ^{13}C NMR: Tables 1 and 2.

Trifarienol E (**5**). an oil; $[\alpha]_D$ + 2.40 (*c* 0.76); EIMS *m/z* (rel. int.) 236 $[M]^+$, (2), 222 (6), 205 (15), 177 (100), 161 (3), 149 (2), 136 (17), 121 (41), 107 (30), 95 (22), 81 (18); HRMS: found: 236.1750; $C_{15}H_{24}O_2$ requires 236.1776; IR ν_{max}^{KBr} cm^{-1}: 3472, 1703, 1644, 1493, 1454, 1408, 1377, 1278, 1167, 1101, 1015, 883, 742, 548, 498, 440, 419; ^{1}H and ^{13}C NMR: Tables 1 and 2.

Acetylation of trifarienol A (**1**). Compound **1** (7 mg) was acetylated with Ac_2O in pyridine (each 1 ml) to give the diacetate **6** (4 mg) as an oil; $[\alpha]_D$ + 45.1 (*c* 1.18); EIMS *m/z* (rel. int.) 322 ($[M]^+$ (7), 262 (9), 202 (57), 187 (31), 177 (56), 161 (11), 147 (29), 123 (100), 107 (41), 95 (28), 81 (25), 69 (8), 55 (12), 43 (54); IR ν_{max}^{KBr} cm^{-1}: 1745, 1643, 1368, 1238, 1030, 885, 603; ^{1}H NMR (200 MHz): δ0.83 (3H, *d*, *J* = 3.8 Hz, H-12), 0.92 (3H, *s*, H-13), 0.95 (3H, *s*, H-11), 1.27 (2H, *m*, H-2, H-6), 1.66 (4H, *m*, H-1, H-1, H-5, H-7), 1.99 (2H, *m*, H-2, H-5), 2.04 (3H, *s*), 2.09 (3H, *s*), 4.03 (1H, *dd*, *J* = 11.9, 9.2 Hz, H-15), 4.41 (1H, *dd*, *J* = 11.9, 2.4 Hz, H-15), 4.63 (1H, *d*, *J* = 2.0 Hz, H-10), 4.78 (1H, *d*, *J* = 2.0 Hz, H-10), 5.25 (1H, *dd*, *J* = 9.2, 2.4 Hz, H-14).

Oxidation of trifarienol A (**1**). To compound **1** (15 mg) in EtOH (5 ml) was added $NaIO_4$ (40 mg) and H_2O (2 ml) and the mixture was allowed to stand for 30 min at room temp. The reaction mixture was then poured into ice water and extracted with Et_2O. The Et_2O layer was dried over $MgSO_4$ to give after evaporation of the solvent, the aldehyde **7** (11 mg) as an oil; $[\alpha]_D$ + 16.5 (*c* 1.12); EIMS *m/z* (rel. int.): 206 ($[M]^+$ (20), 191 (16), 177 (64), 163 (25), 149, (15), 136 (66), 121 (100), 107 (96), 95 (58), 81 (45), 69 (19), 55 (50); IR ν_{max}^{KBr} cm^{-1}; 3080, 2926, 2698, 1726, 1645, 1491, 1452, 1406, 1371, 951, 742, 579, 561, 503, 496, 465, 432; ^{1}H NMR (200 MHz): δ0.83 (3H, *d*, *J* = 7.0 Hz, H-12), 0.95 (3H, *s*, H-11), 1.02 (3H, *s*, H-13), 1.26 (2H, *m*, H-2, H-6), 1.62 (4H, *m*, H-1, H-1, H-5, H-7), 2.28 (2H, *m*, H-2, H-5), 2.54 (1H, *m*, H-4), 4.72 (1H, *d*, *J* = 1.8 Hz, H-10), 4.87 (1H, *d*, *J* = 1.8 Hz, H-10), 9.49 (1H, *s*, 14-H).

Oxidation of trifarienol B (**2**). Compound **2** (15 mg) was oxidized with $NaIO_4$ (40 mg) in EtOH (5 ml) and H_2O (2 ml), as described above, to afford an aldehyde (12 mg) whose spectral data were identical to those of aldehyde **7** prepared from **1**.

Benzoylation of **1** *and* **2**. To compound **1** (4 mg) in CH_2Cl_2 (5 ml) *p*-bromobenzoylchloride (80 mg), dimethylaminopyridine (5.7 mg) and Et_3N (0.2 ml) were added and the mixture stirred for 24 hr. The reaction mixture was directly chromatographed on silica gel using *n*-hexane–EtOAc to give the dibenzoate **8** (11 mg) as an oil: CD (EtOH): $\Delta\varepsilon_{250}$: + 16.13, $\Delta\varepsilon_{233}$: − 5.26. Trifarienol B(**2**) (4 mg) was treated in the same manner as described above to afford the dibenzoate **9** (13 mg) as an oil. CD (EtOH): Δε 250 nm − 15.09, Δε 233 nm + 5.08.

Acetylation of trifarienol C (**3**). Compound **3** (18 mg) was acetylated with Ac_2O in pyridine (each 1 ml) to afford an oily diacetate (18 mg) whose spectral data were superimposable on those of trifarienol A diacetate (**6**).

Acetylation of trifarienol E (**5**). Compound **5** (10 mg) was treated in the same manner as described above to give the monoacetate **10** (8 mg) as an oil; $[\alpha]_D$ + 49.9 (*c* 0.77); EIMS *m/z* (rel. int.): 278 $[M]^+$ (1), 218 $[M^+–AcOH]^+$, (35) 205 (9), 177 (100), 161 (3), 147 (3), 135 (10), 121 (31), 107 (31), 95 (25), 81 (18), 73 (3), 69 (9),

55 (121), 43 (21); ^{1}H NMR (200 MHz): δ0.83 (3H, *d*, J = 7.1 Hz, H-12), 0.95 (3H, *s*, H-11), 1.15 (3H, *s*, H-13), 2.18 (3H, *s*, OAc), 2.42 (1H, *brd*, J = 5.1 Hz, 4-H), 4.71 (1H, *d*, J = 1.8 Hz, 10-H), 4.84 (1H, *d*, J = 17.0 Hz, H-15), 4.89 (1H, *d*, J = 1.8 Hz, H-10), 4.93 (1H, *d*, J = 17.0 Hz, H-15).

Oxidation of trifarienol C (**3**). To compound **3** (10 mg) in *n*-hexane (50 ml) pyridiniumchlorochromate (PCC)–Al_2O_3 (210 mg) was added and the mixture stirred for 3 hr at room temp. The reaction mixture was filtered through a short column packed with silica gel using Et_2O. Evapn of the solvent gave a keto acetate (9.9 mg), the spectral data of which were superimposable on those of trifarienol E mono acetate (**10**).

Single-crystal X-ray diffraction analysis of trifarienol A (**1**). The crystal data for **1** were: monoclinic; space group P21 with a = 1.8538 (4), b = 0.7062 (2), c = 1.8427 (4) nm, b = 9.502 (2), V = 2.4031 nm^3, Z = 8 and μ(Cu Kα) = 5.74 cm^{-1} by Mac Science MXC 18 instrument. Final R value was 0.051 for 3972 reflections. The supplementary data have been deposited at the Cambridge Crystallographic Centre.

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