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SESQUITERPENE ARYL ESTERS FROM *ARMILLARIA TABESCENS*

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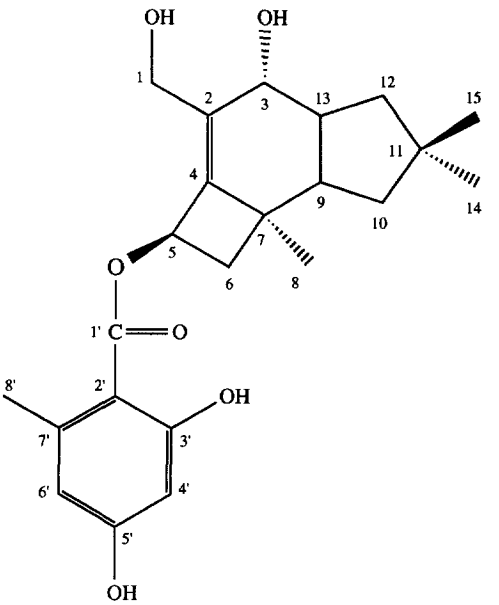
Key Word Index—*Armillaria tabescens*; Basidiomycete; sesquiterpene aryl esters; melleolides.

Abstract—Five new sesquiterpene aryl esters based on the $\Delta^{2,3}$-protoilludane skeleton were isolated from *Armillaria tabescens* grown in culture. These were characterized as 4-dehydro-14-hydroxydihydromelleolide, 4-dehydro-dihydromelleolide, 14-hydroxydihydromelleolide, 13-hydroxy-4-methoxymelleolide and 5β,10α-dihydroxy-1-orsellinate-dihydromelleolide. The structures of these compounds was established by collective NMR techniques. Copyright © 1997 Elsevier Science Ltd

INTRODUCTION

The pathogenic basidiomycete *Armillaria* causes root disease in softwood and hardwood plantations, orchards, horticultural crops, amenity planting, ornamental shrubs and herbaceous plants [1]. Some 20 species are recognised worldwide with virulence varying between species and within strains of the same species [2]. A series of biologically active protoilludane sesquiterpene aryl esters have been isolated from different strains of the fungus. These comprise two major structural types, represented by armillyl orsellinate (**1**) [3] and melleolide (**2**) [4]. As part of an ongoing investigation of strains from different species of this basidiomycete, we have isolated 12 sesquiterpene aryl esters from cultures of a N. American isolate of the species *A. tabescens* (Scop.: Fr.) Emel. The N. American strains of this species are similar in morphology but are intersterile and of greater pathogenicity than their European counterparts. This has led to the proposal of a distinct species, *A. monadelpha* for the N. American *A. tabescens* [1].



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RESULTS AND DISCUSSION

Fractionation of a chloroform–methanol–water extract of the mycelium of an *A. tabescens* CBS 137.32 culture by a combination of gel chromatography on Sephadex LH-20 (MeOH) and column chromatography on silica gel afforded three new (**3–5**) and seven previously known (**1–2**, **6–10**) sesquiterpene aryl esters.

The molecular formula of **3**, $C_{23}H_{30}O_6$, was established by elemental analysis and EIMS. The base peak at *m/z* 151 in the EIMS spectrum was indicative of the orsellinate ester. The IR spectrum of **3** showed a chelated ester carbonyl band at 1646 cm^{-1} and a hydroxyl band at 3431 cm^{-1}. The ^1H NMR spectrum indicated one aromatic methyl at δ 2.40, and two *meta* coupled aromatic protons at δ 6.26 and 6.25. This in conjunction with ^{13}C NMR data (Table 1) for the presence of an ester carbonyl atom (δ 172.03) and a tetrasubstituted benzene ring confirmed the presence of the orsellinate ester [5].

The structure of the sesquiterpenoid moiety was established using collective NMR techniques. The ^1H NMR spectrum showed signals due to two aliphatic

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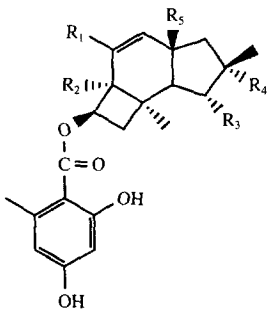
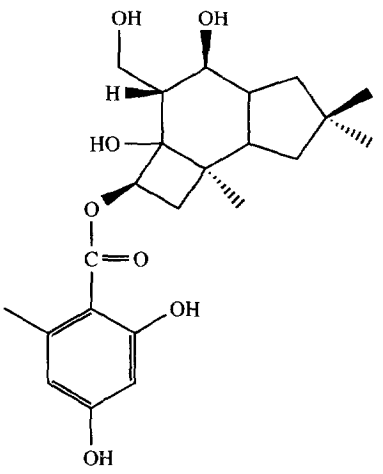


	R_1	R_2	R_3	R_4	R_5
2	CHO	OH	H	H	H
3	CH_2OH	H	H	CH_2OH	H
4	CH_2OH	OH	H	H	H
5	CHO	OCH_3	H	H	OH
6	CHO	OCH_3	H	H	H
7	CHO	H	H	H	H
8	CH_2OH	H	H	H	H
9	CH_2OH	OH	OH	H	H
11	CH_2OH	OH	H	CH_2OH	H



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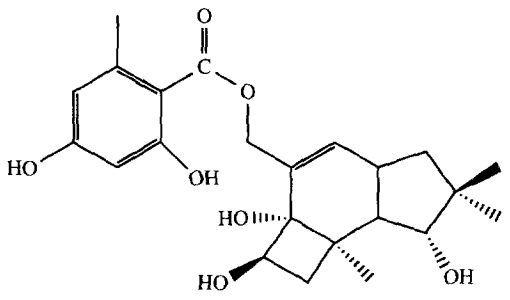

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methyl groups (δ 1.04, 1.29). The appearance of a singlet at δ 3.31 (2H) indicated that one of the two germinal methyl groups (CH_3-14, -15) of **3** had undergone hydroxylation. Signals due to an allylic primary alcohol (δ 3.85, 3.77, $2 \times d$, H-1A and H-1B) and a vinylic proton at δ 5.67 were evident. A resonance at δ 2.90 (*s*, 1H, H-4) indicated that hydroxyl substitution at C-4 was absent in **3** relative to melleolide (**2**). The germinally coupled doublets (2H, δ 1.74, 1.64, $2 \times dd$, J = 13.5, 1.4 Hz) were consistent with a methylene group at C-12 coupled to adjacent proton at C-13. Irradiation at H-5 (δ 5.78, *dd*, J = 8.2, 15.7 Hz) in decoupling experiments collapsed the doublets of H-6α and H-6β (δ 2.18 and 2.17) to give simple doublets (J = 8.0 Hz). This irradiation also collapsed the doublet at δ 2.90 (H-4) to a singlet. Analysis at 500 MHz led to the resolution of the H-10 methylene protons (1.20, *dd*, J = 12.3 Hz, H-10β and 1.27, *d*, J = 12.3 Hz, H-10α). NOE difference experiments (Table 2) established the relative configuration of **3** which was in agreement with that previously reported for these compounds [6]. Irradiation of the methylene at δ 3.25 gave an NOE enhancement to H-12α and H-10α indicating the α positioning of this group at C-11.

The ^{13}C NMR spectrum was in agreement with that of melleolide (**2**) with two olefinic carbons (δ 128.8, 135.8, *s*, C-3 and C-2, respectively), but with an alcohol function at C-1 (δ 65.8, *t*, -CH_2OH), a methine carbon at C-4 (δ 37.8, *d*) and a triplet resonance at δ 72.38 (C-14). The downfield shift experienced by C-14 and C-11 ($\Delta\,\delta$ 40.78, α effect and $\Delta\,\delta$ 6.26, β effect, respectively) and the upfield shifts of C-10 and C-15 are in agreement with a C-14 hydroxy substituent. The structure of **3** was thereby concluded to be 4-dehydro-14-hydroxydihydromelleolide.

The molecular formula of **4**, $C_{23}H_{30}O_4$, was determined by CI mass spectrometry and supported by elemental analysis. The ^1H and ^{13}C NMR data of **4** were practically identical to that recorded for **3** except for the presence of three aliphatic methyl groups (δ 0.99, 1.00 and 1.25) in the ^1H NMR rather than two. Signals for four methyl groups at δ 24.03 (*q*, C-8′), 26.9 (*q*, C-8), 32.18 (*q*, C-14) and 32.25 (*q*, C-15) were evident in the ^{13}C NMR spectrum and this established that **4** lacked the hydroxylation at C-14 present in **3**. The sesquiterpenoid moiety as determined by ^1H–^1H COSY, NOE difference and decoupling experiments was otherwise found to be identical to **3**, and **4** was therefore concluded to be 4-dehydodihydromelleolide.

Compound **5** proved to be a crystalline solid whose molecular formula, $C_{24}O_{30}O_7$, was established by mass spectrometry. The CIMS base peak at m/z 151, the carbonyl resonance in the IR spectrum (1651 cm^{-1}, chelated ester) and comparison of spectral parameters

Table 1. ^{13}C NMR spectral data for compounds **3–5** and **11–12**

C	3*	4†	5*	11‡	12‡
1	65.8 *t*	66.3 *t*	193.6 *d*	64.5 *t*	67.0 *t*
2	135.8 *s*	133.5 *s*	133.7 *s*	135.6 *t*	130.7 *s*
3	128.8 *d*	130.0 *d*	153.5 *d*	132.6 *t*	139.9 *d*
4	43.9 *d*	43.1 *d*	81.7 *s*	77.7 *s*	76.9 *s*
5	71.1 *d*	70.6 *d*	72.6 *d*	77.0 *d*	74.2 *d*
6	37.8 *t*	38.6 *t*	32.9 *t*	33.7 *t*	36.4 *t*
7	33.4 *s*	32.7 *s*	36.2 *s*	39.7 *s*	35.5 *s*
8	24.3 *q*	26.9 *q*	20.8 *q*	22.1 *q*	21.9 *q*1
9	45.7 *d*	45.4 *d*	50.5 *d*	44.8 *d*	47.5 *d*
10	39.2 *t*	41.8 *t*	44.9 *t*	37.6 *t*	82.4 *d*
11	44.2 *s*	37.7 *s*	39.8 *s*	44.5 *s*	43.2 *s*
12	43.6 *t*	47.9 *t*	58.1 *t*	43.5 *t*	45.5 *t*
13	39.7 *d*	39.2 *d*	77.3 *s*	39.8 *d*	36.0 *d*
14	72.4 *t*	32.3 *q*	29.8 *q*	72.4 *t*	24.4 *q*
15	27.4 *q*	32.2 *q*	30.9 *q*	27.1 *q*	29.1 *q*
1′	172.0 *d*	171.1 *s*	171.3 *s*	172.0 *s*	172.5 *s*
2′	105.2 *s*	105.2 *s*	105.3 *s*	105.5 *s*	105.4 *s*
3′	166.5 *s*	165.2 *s*	166.5 *s*	166.1 *s*	166.0 *s*
4′	101.6 *d*	101.3 *d*	101.7 *d*	101.6 *d*	101.4 *d*
5′	163.3 *s*	160.9 *s*	163.9 *s*	163.7 *s*	162.8 *s*
6′	112.4 *d*	111.6 *d*	112.3 *d*	112.5 *d*	112.0 *d*
7′	144.8 *s*	144.0 *s*	144.3 *s*	144.6 *s*	144.5 *s*
8′	27.7 *q*	24.0 *q*	24.6 *s*	24.3 *q*	24.8 *q*
4-C-OCH_3	—	—	54.3 *q*	—	—

*CD_3COCD_3; †$CDCl_3$; ‡$CD_3COCD_3 + CD_3OD$.

Table 2. Connectivities established by NOE difference experiments for compounds **3–5**

Proton irradiated	3	4	5
H-3	-	H-1 (3.1) H-12α (4.6) H_3-14 (3.6)	H-1 (9.59), H-12α (1.89)
H-9	-	H-13 (6.0) H-1 (4.8) H-3 (4.8)	H-10β (1.72)
H_3-8	H-5 (3.70)	H-5 (2.5) H-4 (2.5) H-6α (2.5)	H-5 (5.81), H-6α (2.49) 4-OMe (3.25)
H_3-14	H-12α (1.42) H-10α (1.98) H_3-15 (2.53)	H-3 (0.5) H-12α (1.2)	H-12α (1.89) H-15 (1.18) H-8′ (2.27)
H_3-15	H-12β (5.2) H_3-15 (1.38)	H-9 (1.5), H-12β (1.6) H-3 (1.0)	H-12β (2.03)
H_3-8′	H-4′, H-6′ (6.92)	-	H-4′ (6.21) H-6′ (6.21)

with **3** and **4** indicated another orsellinate sesquiterpenoid. ^1H NMR signals at δ 9.59 (CHO) and 7.04 (*d*, J = 1.1, H-3) showed the presence of an α,β unsaturated aldehyde group. Also signals at δ 4.60, 9.15 and 11.58 which disappeared upon addition of D_2O indicated hydroxyl substitution. The appearance of H-9 as a double doublet at δ 2.43 (J = 7.0, 13.0 Hz) split by the H-10 protons and of H-12α as a doublet (*d* 1.89, J = 14.0 Hz) and H-12β as a double doublet (J = 2, 14.0 Hz), indicated hydroxyl substitution at C-13. The presence of methoxy substitution at position 4 was deduced from comparison of the ^1H and ^{13}C NMR data of **4** with those of 4-methoxymelleolide [7]. NOE difference experiments showed connectivities between CH_3-8 and OCH_3-4, H-5, and H-6α. This, in addition to the absence of a correlation between CH_3-8 and H-9, indicated that the 4-methoxy group was in the α position with the aromatic ester *trans* to CH_3-8 and *cis* to H-9. Compound **5** was thereby established as 13-hydroxy-4-methoxymelleolide.

Five other protoilludane sesquiterpene aryl esters were isolated from the mycelial extract of this basidiomycete. Analysis of their spectral data led to their identification as armillyl orsellinate (**1**) [3], melleolide (**2**) [4], 4-methoxymelleolide (**6**) [7], 4-dehydromelleolide (**7**) [8], dihydromelleolide (**8**) [9] and 10α-hydroxydihydromelleolide (**9**) [6] all of which were previously isolated from cultures of *A. mellea*.

The culture broth obtained on filtration of the mycelium of strains CBS 137.32 was extracted successively with hexane and ethyl acetate. Fractionation of the ethyl acetate extract on Sephdex LH-20 (MeOH) followed by column chromatography on silica gel led to the isolation of two new sesquiterpene aryl esters, (**11–12**).

$C_{23}H_{30}O_7$ was established as the molecular formula of **11** which was supported by elemental analysis. Comparison of MS, IR and NMR data with those of **3–10** indicated another orsellinate sesquiterpenoid.

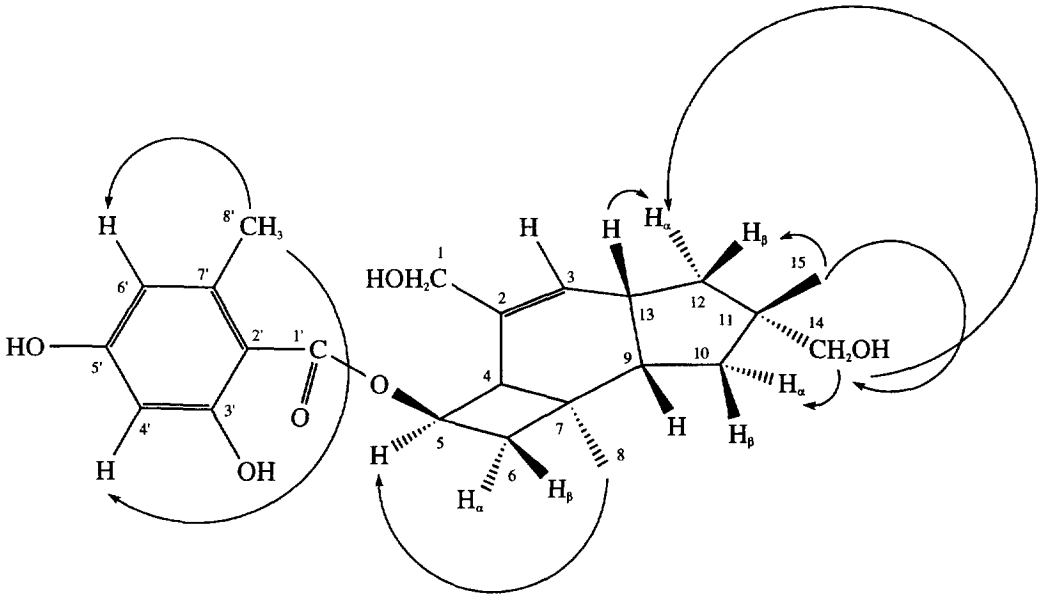


Fig. 1.

The ^{1}H NMR spectrum showed the characteristic signal due to an allylic alcohol at δ 3.98 and 4.27 (2 × *ddd*, H-1A and H-1B) and a vinylic proton at δ 5.74 (*dd*, H-3). The presence of a signal for only one of the germinal methyl groups in the ^{1}H spectrum and appearance of a triplet resonance at δ 72.37 in the ^{13}C NMR was indicative of hydroxyl substitution at C-14 as in **3**. This hydroxylation at C-14 accounts for the downfield shifts of C-14 and C-11 ($\Delta \geqslant \delta$ 40.77, α effect and 6.88, β effect, respectively) and the upfield shift of C-10 and C-15 ($\Delta\ \delta$ 4.1 and 4.0 respectively, γ effect) relative to the ^{13}C resonances recorded for 4-dehydodihydromelleolide (**4**) (Table 1). The remaining ^{1}H and ^{13}C NMR data of **11** resembled that of **3** in all respects except for the absence of a signal corresponding to H-4 in the proton spectrum. The appearance of C-4 in the ^{13}C spectrum at δ 77.7 indicated hydroxylation at this position. This led to the characterization of **11** as 14-hydroxydihydromelleolide. ^{1}H–^{1}H COSY and NOESY experiments confirmed this assignments and the expected relative stereochemistry (Fig. 1).

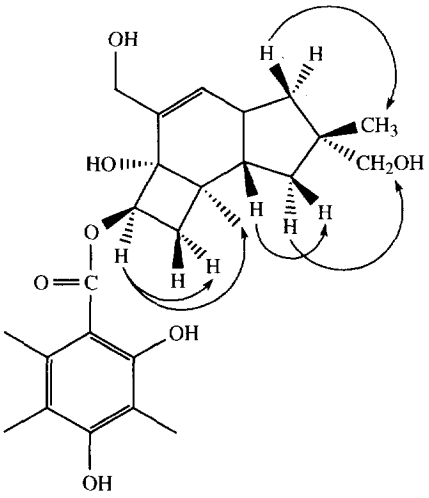
A molecular formula of $C_{23}H_{30}O_7$ was established for **12** by EIMS and elemental analysis. The presence of the orsellinate ester was deduced from IR bands at 1646 (chelated ester carbonyl) and 3413 cm^{-1} (hydroxyl band) in addition to a base peak at *m/z* 151 in the EIMS spectrum and characteristic ^{1}H and ^{13}C NMR resonances.

Analysis of the spectral data relating to the sesquiterpenoid moiety indicated a similar structure to that of 10α-hydroxydihydromelleolide (**9**) [6] with the presence of three aliphatic methyl groups (δ 1.35, 1.02, 0.96; CH_3-8, CH_3-14, CH_3-15, respectively) and hydroxylation at C-10 (δ 3.35, *d*, J = 3.6 Hz). The signals for the C-1 protons of **12** appear at δ 4.93 and 5.08 while those for 10-α-hydroxydihydromelleolide resonate at δ 4.12. Further comparison of the H-5 resonance of **12** (δ 4.38) with that of 10α-hydroxydihydromelleolide (δ 5.66) indicated an identical sesquiterpenoid moiety for both compounds with a variation in the position of orsellinate ester linkage. This is linked through C-5 for 10α-hydroxydihydromelleolide and through C-1 for 12. This was confirmed by ^{1}H–^{1}H COSY and NOESY experiments. A NOESY correlation (Fig. 2) observed between CH_3-8 and 10-OH indicating the hydroxy to be in the α position. The small coupling constant observed between H-9 and H-10, J = 3.9 Hz, indicates that they are *cis*, confirming the α position of the 10 hydroxyl. A NOESY correlation between H-13 and 5-OH indicated that the hydroxyl at C-5 is β oriented. Correlations between H-3 and H-1A, H-1B with CH_3-8′ further corroborates the C-1 orsellinate structure. The recorded ^{13}C NMR resonances were in agreement with this assignment and the structure of **12** was concluded to be 5β,10α-dihydroxy-1-orsellinate-dihydromelleolide. This was further confirmed by comparison of its spectral data with that of armellide A, a C-1 orsellinate protoilludane sesquiterpene ester isolated from cultures of the southern hemisphere species *A. novae-zelandiae* [9].

EXPERIMENTAL

General. Mps: uncorr; ^{1}H NMR (270 and 500 MHz) and ^{13}C NMR (67.8 MHz): TMS as int. standard. CC: Merck Keiselgel $PF60_{254\&360}$ and Sephadex LH-20.

Isolation and purification of metabolites. A strain of *Armillaria tabescens* was grown on potato dextrose broth (Difco) in 80 × 1 l Roux flasks. The mycelia were harvested (after 30 days growth at 21°) by filtration and macerated in 2 × 500 ml MeOH. This was extracted into 3 × 600 ml $CHCl_3$–MeOH–H_2O



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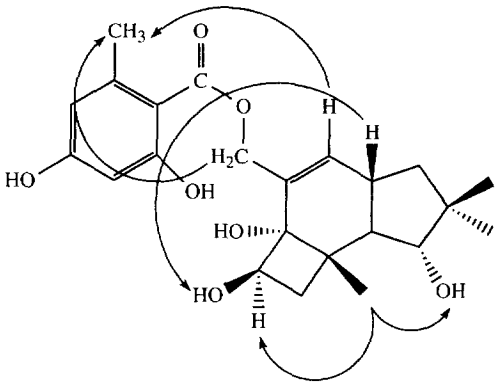

12

Fig. 2.

(13:7:4). The organic layer yielded the crude mycelium extract (6.43 g) which was chromatographed on Sephadex LH-20 (MeOH) to yield five fractions. Fraction 2 (2.94 g) was further separated by CC on Sephadex (MeOH) followed by purification on a silica gel column with $CHCl_3$–MeOH (100:1) to give 4-dehydro-14-hydroxydihydromelleolide (**3**) (5.2 mg). Fractions 3, 4 and 5 were combined (3.42 g) and were subject to open CC on silica gel using a gradient of $CHCl_3$–MeOH (100:1–10:1) to yield six subfractions. Further successive purification of these subfractions on silica gel with $CHCl_3$–MeOH (100:1) and n-hexane–EtOAc (2:1) followed by repeated elution on Sephadex LH-20 for purification led to the isolation of armillyl orsellinate (**1**) (154 mg), melleolide (**2**) (66 mg), 4-dehydrodihydromelleolide (**4**) (50 mg), 13-hydroxy-4-methoxymelleolide (**5**) (14 mg), 4-methoxymelleolide (**6**) (66 mg), 4-dehydromelleolide (**7**), (40 mg), dihydromelleolide (**8**) (238 mg), 10α-hydroxydihydromelleolide (**9**) (100 mg) and armillane (**10**) (30 mg). The culture broth was extracted with 4 × 600 ml n-hexane, then with 4 × 800 ml EtOAc. The EtOAc extract was evaporated yielding a brown oil (1.86 g) which was chromatographed on Sephadex LH-20 with CH_3OH as solvent to give three fractions. Fractions 2 and 3 were combined and subject to extensive open CC on silica gel with $CHCl_3$–MeOH (50:1–10:1) and n-hexane–EtOAc (2:1). After purification by repeated elution on silica gel this led to the isolation of 14-hydroxydihydromelleolide (**11**) (55 mg) and 5β,10α-dihydroxy-1-orsellinatedhydromelleolide (**12**) (6.2 mg). 4-dehydro-14-hydroxydihydromelleolide (**3**) (5.2 mg) and 10α-hydroxydihydromelleolide (**9**) (27.4 mg) previously found in the mycelial extract were also isolated by this route.

4-*Dehydro*-14-*hydroxydihydromelleolide* (**3**). Mp 193–195°, $[\alpha]_D^{22}$ +137.8° (*c* 0.32, Me_2CO_3). Found: C 68.79; H, 6.5 $C_{23}H_{30}O_6$ requires C, 68.66; H, 7.46. IR ν_{max}^{KBr} cm^{-1}: 3431, 1646, 1585, 1382, 846; EIMS *m/z* (% rel. int.): 384 $[M\text{-}H_2O]^+$ (0.05), 190 (10.1), 159 (18.3), 151 (100); ^1H NMR (CD_3COCD_3): δ 1.04 (3H, *s*, H_3C-15), 1.22 (2H, *d*, *J* = 9.5 Hz, H-10α, β), 1.29 (3H, *s*, H_3C-8), 1.64 (1H, *dd*, *J* = 7.6, 13.5 Hz, H-12β), 1.74 (1H, *dd*, *J* = 1.4, 13.5 Hz, H-12α), 2.12 (1H, *m*, H-9), 2.17 (1H, *dd*, *J* = 2.5, 8.0 Hz, H-6β), 2.18 (1H, *d*, *J* = 8.16 Hz, H-6α), 2.40 (3H, *s*, H_3C-8′), 2.81 (1H, *m*, H-13), 2.90 (1H, *d*, *J* = 7.8 Hz, H-4), 3.31 (2H, *s*, H_2C-14), 3.77 (1H, *dd*, *J* = 6.7, 12.7 Hz, H-1B), 3.85 (1H, *dd*, *J* = 6.7, 12.7 Hz, H-1A), 5.67 (1H, *s*, H-3), 5.78 (1H, *dd*, *J* = 8.2, 15.7 Hz, H-5), 6.25 (1H, *dd*, *J* = 0.8, 2.5 Hz, H-6′), 6.26 (1H, *dd*, *J* = 0.84, 2.5 Hz, H-4′), 11.60 (1H, *brd*, HO-3′); ^1H NMR (CD_3COCD_3, 500 MHz): δ 1.06 (3H, *s*, H_3C-15), 1.20 (1H, *dd*,*J* = 12.3, 12.3 Hz, H-10α), 1.27 (1H, *d*, *J* = 12.3 Hz, H-10β), 1.31 (3H, *s*, H_3C-8), 1.67 (1H, *dd*, *J* = 8.1, 13.3 Hz, H-12β), 1.76 (1H, *dd*, *J* = 1.3, 13.3 Hz, H-12α), 2.0–2.2 (1H, *m*, H-9), 2.1–2.2 (2H, *m*, H-6α, H-6β), 2.40 (3H, *s*, H_3C-8′), 2.81 (1H, *m*, H-13), 2.90 (1H, *hidden*, H-4), 3.25 (2H, *s*, H_2C-14), 3.83 (2H, *ABq*, *J* = 13.2 Hz, H-1A, B), 5.80 (1H, *dd*, *J* = 8.3, 16.1 Hz, H-5), 6.24 (1H, *d*, *J* = 2.4 Hz, H-6′), 6.27 (1H, *d*, *J* = 2.4 Hz, H-4′); ^{13}C NMR: Table 1.

4-*Dehydrodihydromelleolide* (**4**). Mp 115–117° (decomposition), $[\alpha]_D^{22}$ +80.5° (*c* 2.8, $CHCl_3$). Found: C, 71.20; H, 7.91. $C_{23}H_{30}O_5$ requires C, 71.48; H, 7.82. IR ν_{max}^{KBr} (cm^{-1}): 3400, 1641, 1587, 1457, 1382, 836; EIMS *m/z* (% rel. int.): 386 $[M]^+$ (0.01), 368 $[M-H_2O]^+$ (0.1), 355 $[M-CH_2OH]^+$ (0.03), 342 $[M-CO_2]^+$ (0.2), 324 (0.05), 218 (1.4), 201 (1.9), 168 (0.9), 151 (100); CIMS *m/z* (% rel. int.): 387 $[M+H]^+$ (1.9), 369 $[M+H-H_2O]^+$ (4.6), 342 $[M-CO_2]^+$ (1.9), 219 (22.2), 201 (23.0), 169 (22.2), 151 (100); ^1H NMR δ: 0.99 (3H, *s*, CH_3-15), 1.00 (3H, *s*, CH_3-14), 1.08 (1H, *dd*, *J* = 12.4, 12.4 Hz, H-10α), 1.25 (3H, *s*, CH_3-8), 1.35 (1H, *dd*, *J* = 7.0, 12.5 Hz, H-10β), 1.52 (1H, *dd*, *J* = 1.4, 13.2 Hz, H-12α), 1.84 (1H, *dd*, *J* = 8.4, 13.2 Hz, H-12β), 2.07 (1H, *ddd*, *J* = 7.0, 7.0, 12.5 Hz, H-9), 2.14 (1H, *d*, *J* = 8.2 Hz, H-6β), 2.15 (1H, *dd*, *J* = 2.0, 7.5 Hz, H-6α), 2.37 (3H, *s*, CH_3-8′), 2.77 (1H,

m, H-13), 2.89 (1H, *ddd*, $J = 2.0, 2.0, 7.6$ Hz, H-4), 3.91 (1H, *d*, $J = 1.4$ Hz, H-1A), 3.96 (1H, *d*, $J = 1.4$ Hz, H-1B), 5.68 (1H, *brd*, *s*, H-3), 5.74 (1H, *ddd*, $J = 7.5, 7.6, 8.2$ Hz, H-5), 6.15 (1H, *d*, $J = 2.5$ Hz, H-6′), 6.22 (1H, *d*, $J = 2.5$ Hz, H-4′), 11.49 (1H, *brd*, *s*, OH-3′); ^{13}C NMR: Table 1.

13-*Hydroxy*-4-*methoxymelleolide* (**5**). Mp 205–206°, $[\alpha]_D^{20} + 51.15°$ (*c* 1.18, MeOH). IR ν_{max}^{KBr} (cm^{-1}): 3298, 1673, 1651, 1625, 1448, 1256; HR-EIMS *m/z* (% rel. int.): 430.222 $[M]^+$ (0.15), 412.19 $[M-H_2O]^+$ (1.5), 386.197 $[M-CO_2]^+$ (0.1), 279.160 $[M-151]^+$ (0.3), 262.166 $[M-168]^+$ (60), 244.150 $[262.166-H_2O]^+$ (5.1), 236.128 $[262.166-C_2H_2]^+$ (20.1), 218.136 $[236.128-H_2O]^+$ (29), 207.136 $[C_7H_7O_2]^+$ (15), 168.041 $[C_8H_8O_4]^+$ (12), 151.041 $[C_8H_7O_3]^+$ (100); EIMS *m/z* (% rel. int.): 430 $[M]^+$ (0.14), 279 $[M-151]^+$ (0.5), 262 [M-168]$^+$ (2.8), 151 (100); ^{1}H NMR (CD_3COCD_3):δ 0.98 (3H, *s*, CH_3-14), 1.18 (3H, *s*, CH_3-15), 1.23 (3H, *s*, CH_3-8), 1.26 (1H, *dd*, $J = 13.0, 13.0$ Hz, H-10α), 1.72 (1H, *ddd*, $J = 2.0, 7.0, 12.0$ Hz, H-10β), 1.89 (1H, *d*, $J = 14.0$ Hz, H-12α), 1.93 (1H, *dd*, $J = 8.7, 12.0$ Hz, H-6β), 2.49 (1H, *dd*, $J = 9.0, 11.2$ Hz, H-6α), 3.25 (3H, *s*, OCH_3-4), 4.60 (1H, *s*, OH-13), 5.81 (1H, *dd*, $J = 8.7, 9.0$ Hz, H-5), 6.21 (2H, *s*, H-4′, H-6′), 7.04 (1H, *d*, $J = 1.1$ Hz, H-3), 9.15 (1H, *s*, OH-5′), 9.59 (1H,*s*, CHO), 11.58 (1H, *s*, OH-3′); ^{13}C NMR: Table 1.

14-*Hydroxydihydromelleolide* (**11**). Mp 208–210°, $[\alpha]_D^{20} + 54.46°$ (*c* 3.61, MeOH). Found C, 65.72; H, 7.36; $C_{23}H_{30}O_7$ requires C, 66.01; H, 7.22. IR ν_{max}^{KBr} (cm^{-1}): 3436, 1634, 1385, 1258, 844; EIMS *m/z* (% rel. int.): 400 $[M-H_2O]^+$ (21.1), 382 $[M-2H_2O]^+$ (10.5), 356 $[M-H_2O-CO_2]^+$ (10.2), 338 (9.3), 249 (0.8), 232 (5.0), 215 (1.0), 206 (19.9), 168 (0.4), 151 (100); CIMS *m/z* (% rel. int.): 401 $[M+H]^+ - H_2O$ (0.4), 383 $[M+H]^+ - 2H_2O$ (33.0), 357 $[M+H]-H_2O-CO_2]^+$ (0.2), 251 (37.0), 2.33 (100), 151 (78.0); ^{1}H NMR ($CD_3COCD_3 + CD_3OD$): δ 1.03 (3H, *s*, CH_3-15), 1.26 (3H, *s*, CH_3-8) 1.29 (1H, *dd*, $J = 7.3, 12.4$ Hz, H-10β), 1.44 (1H, *dd*, $J = 12.4, 12.5$ Hz, H-10α), 1.70 (2H, *dd*, $J = 7.3, 12.5$ Hz, H-12α, β), 1.70 (1H, *dd*, H-6β), 1.96 (1H, *dd*, $J = 8.7, 11.0$ Hz, H-6α), 2.22 (1H, *ddd*, $J = 7.0, 7.0, 12.5$ Hz, H-9), 2.37 (3H, *s*, CH_3-8′), 2.79 (1H, *m*, H-13), 3.27 (2H, *s*, H-15, A, B), 3.98 (1H, *ddd*, $J = 1.4, 1.5, 13.2$ Hz, H-1A), 4.27 (1H, *ddd*, $J = 1.4, 2.5, 13.2$ Hz, H-1B), 5.59 (1H, *dd*, $J = 8.72, 8.72$ Hz, H-5), 5.74 (1H, *dd*, $J = 1.0, 1.4$ Hz, H-3), 6.15 (1H, *dd*, $J = 0.8, 2.4$ Hz, H-6′), 6.18 (1H, *dd*, $J = 0.6, 2.5$ Hz, H-4′); ^{13}C NMR: Table 1.

5β,10α-*Dihydroxy*-1-*orsellinatedihydromelleolide* (**12**). Mp 205–207° $[\alpha]_D^{20} - 16.15°$ (*c* 0.39, MeOH). Found: C, 65.74; H, 7.41. $C_{23}H_{30}O_7$ requires C, 66.01; H, 7.21%. IR ν_{max}^{KBr} (cm^{-1}): 3413, 1646. 1462, 1446, 1262; EIMS *m/z* (% rel. int.): 400 $[M-H_2O]^+$ (4.3), 382 $[M-2H_2O]^+$ (4.3), 374 $[M-CO_2]^+$ (9.8), 356 $[M-CO_2-H_2O]^+$ (21.3), 338 $[356-H_2O]^+$ (8.3), 250 (20.1), 232 (4.1), 206 (8.2), 168 (9.5), 151 (63.0), 134 (100); ^{1}H NMR ($CD_3COCD_3 + CD_3OD$): δ 0.96 (3H, *s*, CH_3-15), 1.02 (3H, *s*, CH_3-14), 1.25 (3H, *s*, CH_3-8), 1.41 (1H, *dd*, $J = 1.4, 10.6$ Hz, H-6β), 1.48 (1H, *d*, $J = 11.5$ Hz, H-12α), 1.81 (1H, *dd*, $J = 8.1, 10.4$ Hz, H-6α), 1.91 (1H, *dd*, $J = 9.8, 12.9$ Hz, H-12β), 2.27 (1H, *dd*, $J = 3.9, 9.6$ Hz, H-9), 2.52 (3H, *s*, CH_3-8′), 2.91 (1H, *m*, H-13), 3.35 (1H, *d*, $J = 3.6$ Hz, OH-10), 3.49 (1H, *s*, OH-4), 3.58 (1H, *dd*, $J = 3.9, 3.9$ Hz, H-10β), 4.09 (1H, *brd*, $J = 6.8$ Hz, OH-5), 4.38 (1H, *ddd*, $J = 4.6, 8.4$ Hz, H-5α), 4.93 (1H, *ddd*, $J = 1.4, 1.6, 12.7$ Hz, H-1A), 5.08 (1H, *brd*, $J = 12.7$ Hz, H-1B), 5.93 (1H, *dJ* = 2.5 Hz, H-3), 6.22 (1H, *d*, $J = 2.2$ Hz, H-4′), 6.24 (1H, *dd*, $J = 0.56, 2.25$ Hz. H-6′), 11.67 (1H, *s*, OH-3′).

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