Sesterterpenoids and Diterpenoids of the Wax Excreted by a Scale Insect, *Ceroplastes pseudoceriferus*

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A new sesterterpene, (2*Z*,6*Z*,10*E*)-cericerene-15,24-diol (**1**), and its 30-hydroxytriacontanoate (**2**) were isolated from the wax exuded by the scale insect *Ceroplastes pseudoceriferus*, together with the acetates and 30-hydroxytriacontanoates of 3,15-dihydroxy- and 15,20-dihydroxylabda-7,13-diene (**3**−**6**). The absolute configurations of the labdadiene alcohols were antipodal to the ordinary labdanes isolated from terrestrial plants.

The scale insects, harmful creatures of 6−9 mm size infesting many orchard trees, exude waxy secretions, as a result of which they are protected from predators. The chemical components of the scale insects have been extensively studied, and unique sesterterpenes and diterpenes have been isolated from the wax.[1]

We have studied the chemical components of the wax excreted by the scale insect *Ceroplastes pseudoceriferus* Green (Coccidea), collected at the campus of this university and have characterized one new sesterterpene and several new diterpenoids. This report deals with the structure elucidation of these new compounds and the absolute configuration determination of the diterpenoids.

Results and Discussion

The scale insect, *C. pseudoceriferus*, which feeds on the host *Laurus nobilis* L. (Lauraceae) (a laurel), was collected in 1996. The wax and the insect body were soaked in chloroform, and the chloroform-soluble material was separated from the insect debris. The evaporated residue was methylated with diazomethane in diethyl ether and was fractionated by repeated chromatography on Si gel to yield two new sesterterpenoids (**1** and **2**), four diterpenoids (**3**, **4**, **6**, and **7**), and the methyl esters of three diterpenes (**9**, **11**, and **13**).

The ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **1** showed signals of a methyl attached to a carbon carrying a hydroxyl group at δ 1.12 (s); four olefinic methyls at 1.55, 1.62, 1.64, and 1.68 (each 3H, s); olefinic protons at 5.01−5.40 (4H); and hydroxymethyl protons as a doublet (δ 4.06 and 4.23, both 1H, d, J = 11.6 Hz). The ^{13}C NMR spectrum confirmed the presence of four olefinic bonds (δ 124.6, 125.9, 126.4, 129.2, 131.6, 134.1, 134.2, and 136.4). Further analysis of the COSY, HSQC, and HMBC spectra suggested that **1** had a structure very similar to that of cericerene-15,24-diol (see Figure 1).[2] However, there are significant differences in the NMR properties between **1** and cericerene-15,24-diol. The NOESY spectrum carried out on **1** revealed that the three olefins on the ring had 2*Z*, 6*Z*, and 10*E* configurations, contrary to the 2*E*, 6*E*, and 10*E* configurations of cericerene-15,24-diol. Accordingly, **1** was named (2*Z*,6*Z*,10*E*)-cericerene-15,24-diol. The absolute configuration at C-14 has not been clarified.

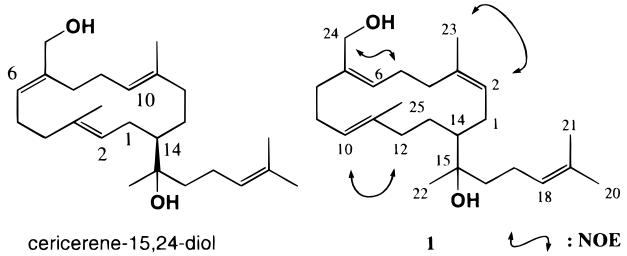

Figure 1. The structure of cericerene-15,24-diol and the new compound (**1**). The arrows on **1** show the NOEs found in the NOESY spectrum.

The ^{1}H NMR spectrum of **2** was similar to that of **1** except for a large envelope due to aliphatic methylene protons (δ 1.20−1.27, br s) and the signals of the methylene protons bearing a hydroxyl group (δ 3.63, t, J = 6.6 Hz), as well as the methylene protons adjacent to a carbonyl group (δ 2.30, t, J = 7.7 Hz). The HOHAHA spectrum of **2** suggested that these protons were in the same proton network, and that a long-chain hydroxy fatty acid was linked to **1**. The hydroxy fatty acid must be condensed with the OH-24 group of **1**, because CH_2-24 appeared at δ_H 4.62 as an AB quartet in the ^{1}H NMR spectrum.

The chain length of the hydroxy fatty acid was determined by GC−MS. The ester **2** was treated with sodium methoxide in MeOH, followed by acetylation (Ac_2O/pyridine), and the product containing the ω-acetoxy fatty acid methyl ester was subjected to GC−MS. In the GC, three peaks in the ratio of 20:2:3 appeared, the MS of which showed parent peaks ($M^+ - CH_3O$) at m/z 493, 465, and 437, respectively. From these data, it was concluded that the hydroxy fatty acid moiety of the sesterterpenoid ester **2** consisted of 30-acetoxytriacontanoic, 28-acetoxyoctacosanoic, and 26-acetoxyhexacosanoic acids, in a 20:2:3 ratio.

The ^{1}H NMR spectrum of **3** showed three sharp singlets due to angular methyls (δ 0.74, 0.84, 0.95), two broad singlets of olefinic methyls (δ 1.68, 1.69), as well as signals assignable to two olefinic protons (δ 5.31, t, J = 7.1 Hz, 5.38, br s), methylene protons (δ 4.57, d, J = 7.0 Hz), and a methine proton bearing a hydroxyl group (δ 3.22, dd, J = 10.8, 4.8 Hz). Additional data, including the ^{13}C NMR, COSY, HSQC, and HMBC spectra, led to a labda-7,13-diene-3,15-diol framework for this compound. The presence of a large methylene signal (δ 1.21−1.32, br s) together with a hydroxymethyl signal (δ 3.62, t, J = 6.6 Hz) and a

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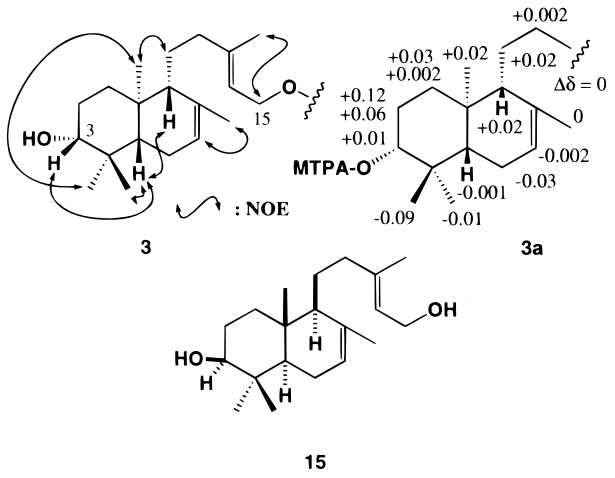


Figure 2. The structure of **3** and **15**. The arrows on **3** indicate the NOEs found in the NOESY spectrum. The numbers on **3a** correspond to the Δδ values obtained from the ^{1}H chemical shifts of (*R*)- and (*S*)-MTPA esters of **3**.

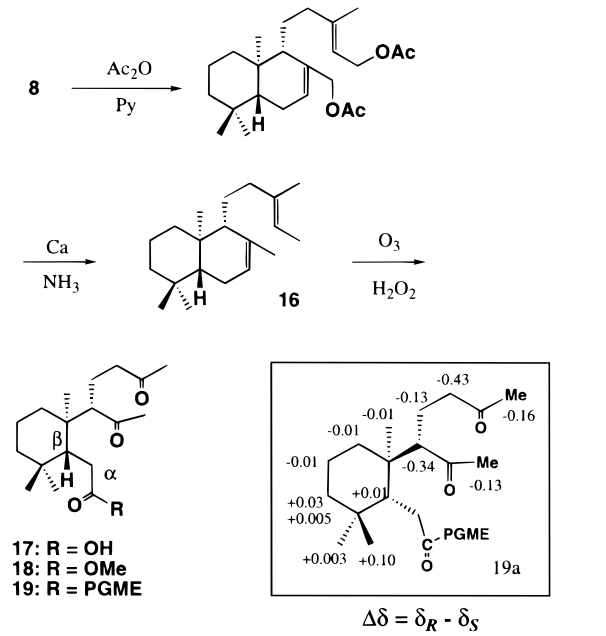


Figure 3. Chemical reactions transforming **8** and **17**. The numbers on **19a** correspond to the Δδ values obtained from the ^{1}H chemical shifts of the (*R*)- and (*S*)-MTPA esters of (**19**).

methylene triplet (δ 2.28, t, J = 7.5 Hz) suggested that a hydroxy fatty acid was linked to either OH-3 or OH-15. The downfield shift of CH_2-15 (δ 4.57) indicated that the hydroxy acid is connected to OH-15. The relative configuration of the ring substituents of **3** was determined by analyzing the NOESY spectrum. This stereochemistry is the same as (−)-labda-7,13-diene-3,15-diol (**15**), which was isolated by Naya et al.[2]

The absolute configuration of **3** was determined by the modified Mosher's method.[3] Esterification of **3** with (*R*)- and (*S*)-MTPA acids yielded the respective di-MTPA esters. The Δδ values ($\delta_S - \delta_R$) are shown in structure **3a** (see Figure 2). The positive and negative Δδ values are oriented on the right and left sides of the MTPA plane, which indicated the *R* configuration of OH-3. Because the relative configuration of **3** has been elucidated, the absolute configuration of this compound was determined as shown in the structure (**3**). Interestingly, the absolute configuration thus determined is enantiomeric to that of **15**.

The similar NMR analysis of **4** revealed that the hydroxy fatty acid moiety at C-15 was replaced by an acetoxy group in this compound. Hydrolysis (KOH−MeOH−H_2O) of **3** and **4** afforded an identical labda-7,13-diene-3,15-diol (**5**). The optical rotation of **5**, $[\alpha]^{25}_D$ +5.9°, is opposite in sign to that of **15**, $[\alpha]^{25}_D$ −2.1°, which confirmed the present result of the modified Mosher's method. The difference of the absolute values between these two values might be due to the presence of the enantiomer in the sample of **15**. Our compound (**5**) has been confirmed to be enantiomerically pure, because the ^{1}H NMR spectra of the (*R*)- and (*S*)-MTPA esters of **3** indicated the complete absence of the enantiomer. It should be noted that the enantiomer of **15** was found from the scale insect *Ceroplastes ceriferus* Anderson living on *Diospyros kaki* Thunb.[2]

The ^{1}H NMR spectrum of **6** showed three methyl groups at δ 0.74, 0.84, and 0.87 (each 3H, s); an olefinic methyl at δ 1.70 (3H, s); a hydroxymethyl at δ 3.97, 4.13 (each 1H, d, J = 12.0 Hz); another hydroxymethyl (δ 4.57, 2H, d, J = 7.0 Hz) adjacent to an olefinic proton (δ 5.35, 1H, br t, J = 7.0 Hz); and the other olefinic proton at δ 5.75 (1H, br s), together with the signals ascribable to an ω-hydroxy fatty acid chain [δ 1.21−1.36, (br s), 3.62, (t, J = 6.6 Hz), 2.28 (t, J = 7.5 Hz)]. These properties and the 2D NMR analysis gave the labda-7,13-diene-15,20-diol structure **6**. The relative stereochemistry of the substituents was deduced by analyzing the NOESY spectrum, which showed the following NOEs: 17-Me ↔ 18-Me, 19-Me ↔ 5-H, 5-H ↔ 9-H, 17-Me ↔ 11-H_2, 15-H_2 ↔ 16-Me.

The hydroxy fatty acid moiety of both **3** and **6** was composed of 30-hydroxytriacontanoic acid and 32-hydroxydotriacontanoic acid (94:6), which was confirmed by mass spectroscopy in the same way as described for **2**.

The structure of **7** was deduced from its NMR data, and eventually confirmed by hydrolysis to **8**, which was identical with the product derived from **6**. The optical rotation of **8**, $[\alpha]^{25}_D$ −9.9°, when obtained from both **6** and **7**, was identical, showing that they had the same absolute configuration. Although the enantiomer of **8** is known, the reported chiroptical property, $[\alpha]^{25}_D$ −2.2°, did not agree with our data. Therefore, we focused on establishing the absolute configuration of **8** obtained in this work.

Because **8** does not possess a secondary hydroxyl group, the modified Mosher's method was not appropriate. Very recently we have developed a new method using phenylglycine methyl ester (PGME)[4] that can determine the absolute configuration of carboxylic acids having a chiral center at the β-position (β-chiral carboxylic acids). The outline of this extended PGME method is described in Figure 4. The PGME amide of a β-chiral carboxylic acid [A] exists in the most stable conformation [B]. The acid is condensed with commercially available (*R*)- and (*S*)-PGME, the proton chemical shifts of each diastereomer are assigned, and the absolute configuration is assigned using the model [C; $\Delta\delta = \delta_R - \delta_S$] in a manner similar to the modified Mosher's method.

The hydrolysate **8**, prepared from **6** and **7**, was acetylated to give a diacetate. Reductive deacetoxylation (Ca/NH_3) produced the diene (**16**). Ozonolysis of **16** in MeOH at −78 °C and subsequent workup with H_2O_2 afforded a β-chiral carboxylic acid **17**, which was identified as its methyl ester **18**. The β-chiral carboxylic acid **17** was condensed with (*R*)- and (*S*)-PGME, and the Δδ values were calculated for each diastereomer of **19**. The results are shown in **19a** (see Figure 3). The systematic arrangement of positive and negative Δδ values was observed, and these findings led to the absolute configuration of **19**, and, therefore, of **8**, as shown in their structures. The absolute configuration thus

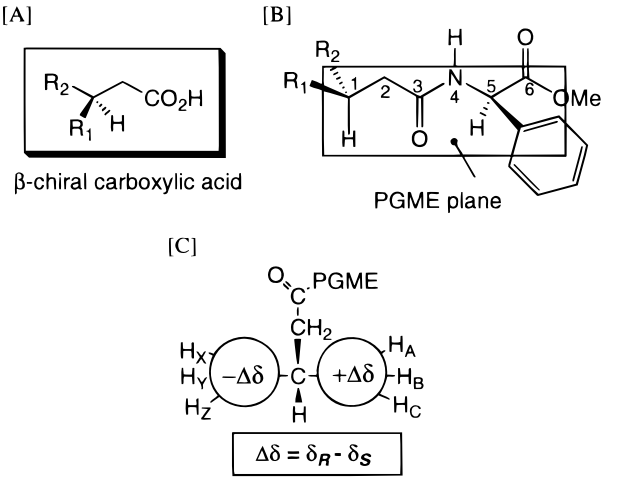


Figure 4. An outline of the extended PGME method to elucidate the absolute configuration of *β*-chiral carboxylic acids [A]. The most stable conformation [B] of a PGME amide is drawn. The absolute configuration of [A] can be determined by using [C] in a similar way with the modified Mosher's method.

determined is compatible with that of **6** and **7**, verifying the use of the extended PGME method to this *β*-chiral carboxylic acid.

Abietic acid (**9**) was isolated as its methyl ester **10**. The structure was confirmed by comparison of its ^{1}H and ^{13}C NMR properties with the reported data. The absolute configuration of **10** was identical with methyl (−)-abietate, because its specific rotation ([α]$^{25}_D$ −56.7°) was in good agreement with the reported value, −61° ($CHCl_3$).[5]

Neoabietic acid (**11**)[6] and 15-hydroxyabieteic acid (**13**)[7] were also isolated as their methyl esters, **12** and **14**. Although their structures were confirmed by comparison of their NMR properties with those of the reported data, their absolute configuration could not be determined because of the limited quantity available.

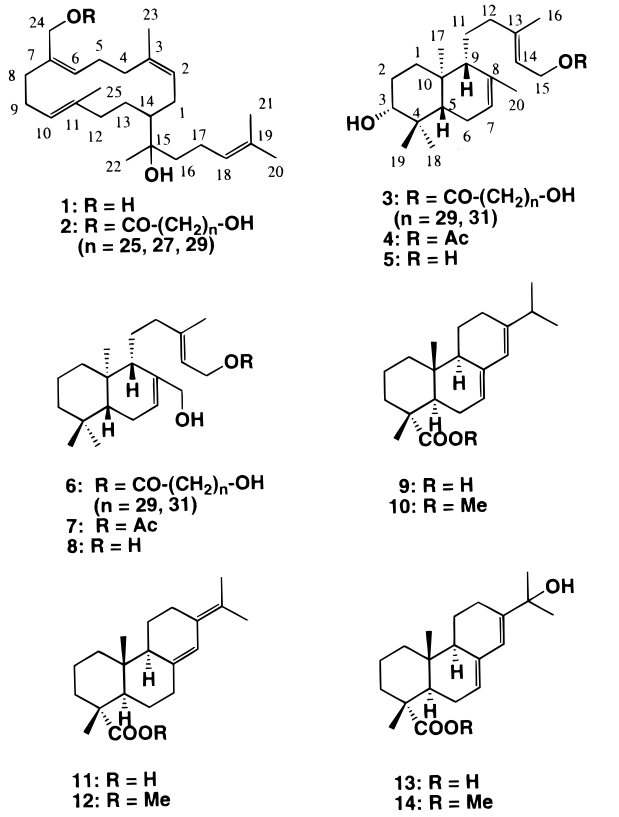
It is quite interesting that the abietic acid (**9**) obtained from the insect wax is antipodal to the labdanes **3**, **4**, **6**, and **7**, which are present in the same wax. Considering that the present labdanes have absolute configurations opposite those produced by terrestrial plants, we may assume that the present labdanes have been biosynthesized by the scale insect. The abietic acid (**9**), which has the common absolute configuration, may be simply excreted by the insect without digestion of the plant ingredient. An attempt to isolate the labdane and abietane diterpenes from the laurel was fruitless, because it resulted in inseparable mixtures of terpenoids and glycerides.

Experimental Section

General Experimental Procedures. ^{1}H NMR and ^{13}C NMR spectra were recorded on Hitachi R-90H and Bruker ARX-400 NMR spectrometers. Chemical shifts are reported in parts per million (ppm) relative to $CHCl_3$ (δ 7.25), and coupling constants are given in Hertz. The specific rotations were measured on a JASCO DIP-370 instrument. MS were recorded on JEOL JMS−SX102A and JEOL JMS-AM150 mass spectrometers. All reagents were commercially available and used without purification.

Animal Material. The scale insect *C. pseudoceriferus* Green (155.3 g: voucher specimen preserved in this laboratory), feeding on the host *Laurus nobilis*, was collected at the campus of Tokushima University in November 1996.

Extraction and Isolation. Whole insect bodies were soaked in $CHCl_3$ (500 mL) overnight with occasional shaking. The solid residues were filtered off and the filtrate washed with H_2O. The $CHCl_3$ layer was concentrated on a rotary



evaporator to give a residue (63.9 g), which was subjected to Si gel (Merck, Kieselgel 60) column chromatography eluted by EtOAc−hexane (0, 10, 30, 50, 70, 90, and 100% EtOAc). The fractions containing terpenoids (by NMR) were esterified with excess diazomethane in diethyl ether, and the methylated fractions were again separated by Si gel flash column chromatography (1:6 EtOAc−hexane) and were finally purified by HPLC (Hibar RT250−25, LiChrosorb Si60) (1:8 EtOAc−hexane) to give compounds **1** (11.7 mg), **2** (5.7 mg), **3** (47.7 mg), **4** (146.3 mg), **5** (15.4 mg), **6** (8.3 mg), **7** (5.2 mg), **8** (18.4 mg), **9** (4.7 mg), **12** (1 mg), and **14** (1 mg).

(2*Z*,6*Z*,10*E*)-Cericerene-15,24-diol (1): [α]$_D$ −51.5° (*c* 0.09, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 1.12 (3H, s, H-22), 1.20 (1H, m, H-13a), 1.48 (3H, m, H-14, H-16), 1.55 (3H, s, H-25), 1.62 (3H, s, H-21), 1.64 (3H, s, H-23), 1.68 (3H, s, H-20), 1.63−1.81 (2H, m, H-1a, H-13b), 2.00−2.17 (8H, m, H-4a, H-8a, H-9, H-12, H-17), 2.28−2.35 (5H, m, H-1b, H-4b, H-5, H-8b), 4.06 (1H, d, J = 11.6 Hz, H-24a), 4.23 (1H, d, J = 11.6 Hz, H-24b), 5.01 (1H, t, J = 7.0 Hz, H-10), 5.12 (2H, m, H-6, H-18), 5.40 (1H, t, J = 7.7 Hz, H-2); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 15.4 (q, C-25), 17.6 (q, C-21), 22.1 (t, C-17), 22.1 (q, C-23), 23.6 (q, C-22), 24.3 (t, C-9), 24.5 (t, C-4), 25.6 (q, C-20), 28.1 (t, C-13), 29.0 (t, C-1) 30.2 (t, C-5), 35.1 (t, C-8), 38.9 (t, C-12), 39.7 (t, C-16), 47.2 (d, C-14), 60.0 (t, C-24), 75.7 (s, C-15), 124.6 (d, C-18), 125.9 (d, C-10), 126.4 (d, C-2), 129.2 (d, C-6), 131.6 (s, C-19), 134.1 (s, C-7), 134.2 (s, C-3), 136.4 (s, C-11); GC−MS *m*/*z* 356 [$M^+ - H_2O$] (8), 325 (4), 109 (75), 81 (100), 55 (63); HREIMS *m*/*z* 374.3172 (calcd for $C_{25}H_{42}O_2$, 374.3185).

24-(*ω*-Hydroxy fatty acid) ester (2) of 1: [α]$^{25}_D$ +9.5° (*c* 0.07, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 1.13 (3H, s, H-22), 1.20−1.27 (51H, m, CH_2), 1.46−1.51 (3H, m, H-14, H-16), 1.54 (3H, s, H-25), 1.53−1.56 (2H, quint, J = 7.6 Hz, CH_2), 1.59−1.62 (2H, quint, J = 7.0 Hz, CH_2), 1.62 (6H, s, H-21, H-23), 1.68 (3H, s, H-20), 1.68−1.73 (1H, m, H-13a), 1.75−1.83 (1H, dt, J = 7.6 Hz, 13.7 Hz, H-1a), 1.99−2.15 (8H, m, H-4a, H-8a, H-9, H-12, H-17), 2.20−2.23 (1H, m, H-8b), 2.27−2.31 (2H, t, J = 7.7 Hz, CH_2), 2.31−2.37 (4H, m, H-1b, H-4b, H-5), 3.61−3.64 (2H, t, J = 6.6 Hz, CH_2OH), 4.58−4.66 (2H, d, J = 11.9 Hz, H-24), 5.00 (1H, t, J = 7.0 Hz, H-10), 5.11 (1H, t, J = 7.0 Hz, H-18), 5.20 (1H, t, J = 7.4 Hz, H-6), 5.39 (1H, t, J = 7.6 Hz, H-2); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 15.3 (q, C-25), 17.6

(q, C-21), 22.0 (t, C-17), 22.1 (q, C-23), 24.0 (q, C-22), 24.4 (t, C-9), 24.8 (t, C-4), 24.9 (t), 25.6 (q, C-20), 25.6 (t), 28.3 (t, C-13), 29.1 (t), 29.2 (t), 29.3 (t), 29.4 (t), 29.5 (t), 29.6 (t), 30.0 (t, C-5), 32.7 (t), 34.3 (t), 35.8 (t, C-8), 39.1 (t, C-12), 39.6 (t, C-16), 47.3 (d, C-14), 61.5 (t, C-24), 63.0 (t), 75.5 (s, C-15), 124.6 (d, C-18), 125.5 (d, C-10), 126.3 (d, C-2), 131.6 (s, C-7, C-19), 132.0 (d, C-6), 134.0 (s, C-3), 134.5 (s, C-11), 173.9 (s, *C*O_2); FABMS showed no distinct peaks above *m*/*z* 400.

Methanolysis of 2 Followed by Acetylation. Into a 20-mL two-necked flask were placed **2** (1.6 mg; 1.3 mmol), sodium methoxide (1.0 mg; 18.5 mmol), and dry MeOH (5 mL). The mixture was stirred at room temperature for 2 h under argon. The reaction mixture was acidified with 12 M HCl, extracted with EtOAc, and dried over Na_2SO_4. The hydrolyzed product was directly treated with acetic anhydride (0.2 mL) and pyridine (0.2 mL) at room temperature for 2 h, and the mixture was concentrated to give a mixture of ω-acetoxy fatty acid methyl esters (0.3 mg): ^{1}H NMR ($CDCl_3$, 90 MHz) δ 1.25 (br s, CH_2), 2.02 (3H, s, CH_3CO_2), 3.65 (3H, s, OCH_3), 4.04 (t, J = 7 Hz, AcOCH_2); GC−MS, see text.

15-(ω-Hydroxy fatty acid) ester (3) of (−)-labda-7,13-diene-3,15-diol: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.74 (3H, s, H-17), 0.84 (3H, s, H-18), 0.95 (3H, s, H-19), 1.06−1.12 (1H, td, J = 4.8 Hz, 12.9 Hz, H-1a), 1.15−1.19 (1H, dd, J = 6.5 Hz, 10.5 Hz, H-5), 1.21−1.32 (52H, m, CH_2), 1.48−1.65 (8H, m, CH_2), 1.68 (3H, s, H-20), 1.69 (3H, s, H-16), 1.83−1.88 (1H, dt, J = 3.5 Hz, 13.3 Hz, H-1b), 1.91−1.99 (3H, m, H-6, H-12a), 2.18−2.25 (1H, br td, J = 4.5 Hz, 10.5 Hz, H-12b), 2.27 (2H, t, J = 7.5 Hz, CH_2), 3.20−3.24 (1H, dd, J = 4.8 Hz, 10.8 Hz, H-3), 3.62 (2H, t, J = 6.6 Hz, CH_2OH), 4.57 (2H, d, J = 7.0 Hz, H-15), 5.32 (1H, t, J = 7.1 Hz, H-14), 5.38 (1H, br s, H-7); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 13.5 (q, C-17), 14.9 (q, C-18), 16.4 (q, C-16), 21.9 (q, C-20), 23.4 (t, C-6), 24.9 (t), 25.3 (t, C-11), 25.6 (t), 27.3 (t, C-2), 27.8 (q, C-19), 29.0 (t), 29.2 (t), 29.3 (t), 29.4 (t), 29.5 (t), 29.6 (t), 32.7 (t), 34.3 (t), 36.5 (s, C-4), 37.1 (t, C-1), 38.6 (s, C-10), 41.8 (t, C-12), 49.5 (d, C-5), 54.2 (d, C-9), 61.0 (t, C-15), 62.9 (t), 79.0 (d, C-3), 118.6 (d, C-14), 122.1 (d, C-7), 134.9 (s, C-8), 142.3 (s, C-13), 173.8 (s, *C*O_2).

(*R*)-MTPA Ester of 3. Into a 10-mL two-necked flask were placed **3** (2.3 mg; 2.9 mmol), (*R*)-MTPA acid (8.4 mg; 15.6 mmol), 2,4,6-trinitrochlorobenzene (4.3 mg; 7.8 mmol), and dry pyridine (distilled from CaH_2) (0.1 mL). The mixture was stirred at room temperature for 22 h. Aqueous $NaHCO_3$ (5%) and Et_2O were added to the reaction mixture, and it was stirred for 1 h until the yellow precipitate of pyridine picrate formed. The ether layer was washed with H_2O until the yellow color of the ethereal solution was no longer detected, and with saturated aqueous Cu(II) sulfate and H_2O. After drying the organic layer over Na_2SO_4, concentration of the solution, and purification of the residue by preparative TLC (20% EtOAc in hexane), the (*R*)-MTPA ester (**10**, 3.4 mg, 91%) was obtained: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.76 (3H, s, H-17), 0.87 (3H, s, H-18), 0.89 (3H, s, H-19), 1.17−1.22 (1H, m, H-1a), 1.22−1.33 (53H, m, CH_2), 1.46−1.51 (2H, m, H-11), 1.59−1.66 (2H, m, H-2a, H-9), 1.69 (3H, s, H-20), 1.70 (3H, s, H-16), 1.74−1.78 (1H, br dq, H-2b), 1.87−1.93 (1H, dt, J = 3.4 Hz, 13.2 Hz, H-1b), 1.93−1.98 (3H, m, H-6, H-12a), 2.19−2.24 (1H, br dt, H-12b), 2.27−2.31 (2H, t, J = 7.2 Hz, CH_2), 3.51 (3H, s, OCH_3), 3.55 (3H, s, OCH_3), 4.27−4.34 (2H, m, CH_2), 4.58 (2H, d, J = 6.8 Hz, H-15), 4.68−4.72 (1H, dd, J = 4.2 Hz, 11.6 Hz, H-3), 5.33 (1H, br t, J = 6.4 Hz, H-14), 5.38 (1H, br s, H-7) 7.37−7.41 (6H, m, Ar−H), 7.50−7.54 (4H, m, Ar−H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 13.5 (q, C-17), 16.0 (q, C-18), 16.4 (q, C-16), 21.9 (q, C-20), 23.1 (t, C-6), 23.4 (t, C-2), 24.9 (t), 25.6 (t, C-11), 27.8 (q, C-19), 28.2 (t), 29.0 (t), 29.1 (t), 29.2 (t), 29.3 (t), 29.4 (t), 29.5 (t), 34.3 (t), 36.3 (s, C-10), 36.6 (t, C-1), 37.5 (s, C-4), 41.7 (t, C-12), 49.6 (d, C-5), 53.9 (d, C-9), 55.2 (q, OCH_3), 55.3 (q, OCH_3), 61.0 (t, C-15), 66.5 (t), 84.4 (d, C-3), 118.7 (d, C-14), 121.8 (d, C-7), 127.2 (d, Ar−C), 127.5 (d, Ar−C), 128.3 (d, Ar−C), 129.4 (d, Ar−C), 129.5 (d, Ar−C), 132.2 (s, Ar−C), 132.3 (s, Ar−C), 135.0 (s, C-8), 142.1 (s, C-13), 166.3 (s, *C*O_2), 166.5 (s, *C*O_2), 173.8 (s, *C*O_2).

(*S*)-MTPA Ester of 3. The procedure was the same as described above. From 1.1 mg of **3**, 0.8 mg (62%) of the (*S*)-MTPA ester were obtained: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.78 (3H, s, H-17), 0.80 (3H, s, H-19), 0.86 (3H, s, H-18), 1.18−1.34 (53H, m, CH_2), 1.47−1.49 (1H, m, H-11), 1.57−1.64 (2H, m, CH_2), 1.69 (3H, s, H-20), 1.70 (3H, s, H-16), 1.73−1.77 (1H, br dd, H-2a), 1.80−1.84 (1H, m, H-2b), 1.88−2.00 (3H, m, H-1a, H-6a, H-12a), 2.19−2.27 (1H, br td, H-12b), 2.27−2.31 (2H, t, J = 7.5 Hz, CH_2), 3.54 (3H, s, OCH_3), 3.56 (3H, s, OCH_3), 4.27−4.34 (2H, m, CH_2), 4.58 (2H, d, J = 7.0 Hz, H-15), 4.71−4.75 (1H, dd, J = 4.3 Hz, 11.6 Hz, H-3), 5.31−5.35 (1H, t, J = 7.0 Hz, H-14), 5.38 (1H, br s, H-7) 7.38−7.40 (6H, m, Ar−H), 7.50−7.55 (4H, m, Ar−H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 13.5 (q, C-17), 15.9 (q, C-18), 16.4 (q, C-16), 21.9 (q, C-20), 23.1 (t), 23.7 (t, C-6), 24.9 (t, C-11), 25.6 (t, C-2), 27.4 (q, C-19), 28.2 (t), 29.0 (t), 29.1 (t), 29.2 (t), 29.3 (t), 29.4 (t), 29.5 (t), 31.8 (s, C-10), 34.3 (t), 36.3 (s, C-4), 36.7 (t, C-1), 41.7 (t, C-12), 49.6 (d, C-5), 53.9 (d, C-9), 55.3 (q, OCH_3), 60.9 (t, C-15), 66.5 (t), 84.2 (d, C-3), 118.8 (d, C-14), 121.8 (d, C-7), 127.2 (d, Ar−C), 128.2 (d, Ar−C), 128.3 (d, Ar−C), 129.4 (d, Ar−C), 129.5 (d, Ar−C), 132.3 (s, Ar−C), 132.6 (s, Ar−C), 134.9 (s, C-8), 142.1 (s, C-13), 166.0 (s, *C*O_2), 166.5 (s, *C*O_2), 173.8 (s, *C*O_2).

15-Acetate (4) of labda-7,13-diene-3,15-diol: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.75 (3H, s, H-17), 0.84 (3H, s, H-18), 0.87 (3H, s, H-19), 1.12 (1H, td, J = 4.7 Hz, 13.0 Hz, H-1a), 1.18 (1H, dd, J = 6.5 Hz, 10.4 Hz, H-5), 1.27−1.32 (1H, m, H-11a), 1.49−1.66 (4H, m, H-2, H-9, H-11b), 1.65 (3H, s, H-20), 1.66 (3H, s, H-16), 1.86 (1H, dt, J = 3.4 Hz, 13.3 Hz, H-1b), 1.96−2.00 (3H, m, H-6, H-12a), 2.05 (3H, s, CH_3CO_2), 2.19−2.26 (1H, br td, H-12b), 3.21−3.25 (1H, dd, J = 4.8 Hz, 11.0 Hz, H-3), 4.57 (2H, d, J = 7.0 Hz, H-15), 5.33 (1H, t, J = 6.7 Hz, H-14), 5.39 (1H, br s, H-7); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 13.5 (q, C-17), 14.9 (q, C-18), 16.4 (q, C-16), 20.9 (q, *C*H_3CO_2), 21.9 (q, C-20), 23.4 (t, C-6), 25.3 (t, C-11), 27.3 (t, C-2), 27.8 (q, C-19), 36.5 (s, C-10), 37.1 (t, C-1), 38.6 (s, C-4), 41.8 (t, C-12), 49.5 (d, C-5), 54.1 (d, C-9), 61.3 (t, C-15), 79.0 (d, C-3), 118.4 (d, C-14), 122.1 (d, C-7), 134.9 (s, C-8), 142.5 (s, C-13), 171.0 (s, *C*O_2); HREIMS *m*/*z* 348.2611 (calcd for $C_{22}H_{36}O_3$, 348.2664).

(+)-Labda-7,13-diene-3,15-diol (5) from 3. A solution of **3** (28.3 mg; 23.3 mmol) in 9:1 MeOH−H_2O (20 mL) containing 10% KOH was stirred at room temperature for 1 h. The reaction mixture was extracted with diethyl ether. The ethereal layer was dried over Na_2SO_4, and the ether was removed to give **5** (5.7 mg, 76%): $[\alpha]^{25}_D$ +5.68° (*c* 0.15, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 90 MHz) δ 0.76 (3H, s, H-17), 0.84 (3H, s, H-18), 0.95 (3H, s, H-19), 1.69 (6H, br s, H-16, H-20), 3.14−3.33 (1H, br dd, H-3), 4.11−4.16 (2H, br d, H-15), 5.28−5.47 (2H, m, H-7, H-14).

(+)-Labda-7,13-diene-3,15-diol (5) from 4. Into a 30-mL flask was placed 14.6 mg (11.6 mmol) of **4** in a 10% solution of KOH in 9:1 MeOH−H_2O (10 mL). The mixture was stirred at room temperature for 1 h. The reaction mixture was extracted with diethyl ether. After drying the ether layer over Na_2SO_4 and concentration, **5** (5.4 mg, 49%) was obtained: $[\alpha]^{25}_D$ +5.89° (*c* 0.14, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 90 MHz) δ 0.74 (3H, s, H-17), 0.83 (3H, s, H-18), 0.95 (3H, s, H-19), 1.67 (6H, br s, H-16, H-20), 3.14−3.31 (1H, br dd, H-3), 4.09−4.16 (2H, br d, H-15), 5.30−5.45 (2H, m, H-7, H-14).

15-(ω-Hydroxy fatty acid) ester (6) of labda-7,13-diene-15,20-diol: $[\alpha]^{25}_D$ −12.0° (*c* 0.78, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.74 (3H, s, H-17), 0.85 (3H, s, H-18), 0.87 (3H, s, H-19), 0.91−0.98 (1H, td, J = 3.8 Hz, 13.0 Hz, H-1a), 1.12−1.17 (1H, br td, H-3), 1.18−1.21 (1H, t, J = 6.1 Hz, H-5), 1.21−1.36 (53H, m, CH_2), 1.39−1.43 (1H, br dt, H-3b), 1.43−1.47 (1H, m, H-2a), 1.50−1.61 (3H, m, H-2b, H-11), 1.70 (3H, s, H-16), 1.81−2.07 (4H, m, H-1b, H-6, H-9), 2.26−2.30 (2H, t, J = 7.5 Hz, CH_2), 2.31−2.34 (1H, br td, H-12), 3.62 (2H, t, J = 6.6 Hz, CH_2OH), 3.97 (1H, d, J = 12.2 Hz, H-20a), 4.13 (1H, d, J = 12.0 Hz, H-20b), 4.57 (2H, d, J = 7.0 Hz, H-15), 5.35 (1H, br t, J = 7.0 Hz, H-14), 5.75 (1H, br s, H-7); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 13.5 (q, C-17), 16.5 (q, C-16), 18.7 (t, C-2), 21.7 (q, C-18), 23.6 (t, C-6), 24.9 (t, C-11), 25.6 (t), 29.1 (t), 29.2 (t), 29.3 (t), 29.4 (t), 29.5 (t), 29.6 (t), 32.7 (t), 32.9 (s, C-4), 33.0 (q, C-19), 34.3 (t), 36.6 (s, C-10), 39.0 (t, C-1), 41.0 (t, C-12), 42.1 (t, C-3), 49.8 (d, C-5), 51.4 (d, C-9), 61.0 (t, C-15), 62.9 (t), 65.8 (t, C-20), 119.0 (d, C-14), 125.5 (d, C-7), 139.2 (s, C-8), 142.5 (s, C-13), 173.8 (s, *C*O_2); FABMS, no peaks above *m*/*z* 400.

15-Acetate (7) of labda-7,13-diene-15,20-diol: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.74 (3H, s, H-17), 0.86 (3H, s, H-18), 0.88 (3H, s, H-19), 0.90−0.98 (1H, td, J = 3.5 Hz, 13.0 Hz, H-1a), 1.12 (1H, br t, J = 11.4 Hz, H-3a), 1.18−1.22 (1H, dd, J = 4.8 Hz, 12.1 Hz, H-9), 1.31−1.36 (1H, m, H-6a), 1.40−1.51 (3H, m, H-2, H-3b), 1.54−1.57 (1H, m, H-6b), 1.71 (3H, s, H-16), 1.82−1.85 (2H, m, H-1b, H-5), 1.91−1.94 (1H, br d, H-11a), 2.02−2.08 (2H, m, H-11b, H-12a), 2.04 (3H, s, C*H*$_3$CO$_2$), 2.28−2.37 (1H, m, H-12b), 3.96−4.00 (1H, br dd, J = 3.3 Hz, 12.0 Hz, H-20a), 4.11−4.16 (1H, br dd, J = 5.9 Hz, 11.8 Hz, H-20), 4.57 (2H, d, J = 7.1 Hz, H-15), 5.36 (1H, t, J = 6.0 Hz, H-14), 5.75 (1H, br s, H-7); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 13.5 (q, C-17), 16.5 (q, C-16), 18.7 (t, C-2), 20.9 (q, *C*H$_3$CO$_2$), 21.7 (q, C-19), 23.6 (t, C-6), 24.9 (t, C-11), 32.9 (s, C-4), 33.0 (q, C-18), 36.6 (s, C-10), 38.9 (t, C-1), 40.9 (t, C-12), 42.1 (t, C-3), 49.8 (d, C-5), 51.4 (d, C-9), 61.3 (t, C-15), 65.9 (t, C-20), 118.3 (d, C-14), 125.6 (d, C-7), 139.2 (s, C-8), 142.6 (s, C-13), 171.0 (s, *C*O$_2$); HREIMS *m*/*z* 348.2656 (calcd for $C_{22}H_{36}O_3$, 348.2664).

(−)-Labda-7,13-diene-15,20-diol (8). Hydrolysis of **6** with 10% KOH in 9:1 MeOH−H_2O afforded 91% yield of **8**: $[\alpha]^{25}_D$ −9.9° (c 0.07, $CHCl_3$); ^{1}H NMR (90 MHz, $CDCl_3$) δ 0.72 (3H, s, H-17), 0.83 (6H, br s, H-18, H-19), 1.64 (3H, br s, H-16), 4.15 (4H, br t, H-15, H-20), 5.38 (1H, br t, H-14), 5.67 (1H, br s, H-7); GC−MS *m*/*z* 306 $[M]^+$ (2), 286 (16), 244 (40), 148 (37), 119 (33), 81 (70), 55 (78), 43 (100); hydrolysis of **7** afforded the same product with $[\alpha]^{25}_D$ −10.9° (*c* 0.13, $CHCl_3$).

(−)-Abietic acid methyl ester (10): $[\alpha]^{25}_D$ −56.7° (*c* 0.41, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.81 (3H, s, H-18), 0.99 (3H, d, J = 6.9 Hz, H-17), 1.00 (3H, d, J = 6.8 Hz, H-16), 1.14−1.22 (2H, m, H-1a, H-11a), 1.24 (3H, s, H-19), 1.53−1.61 (3H, m, H-2, H-6a), 1.72−1.81 (3H, m, H-3a, H-6b, H-11b), 1.84−1.87 (1H, br d, H-1b), 1.91−1.95 (1H, br d, H-9), 2.03−2.08 (4H, m, H-3b, H-12, H-5), 2.21 (1H, sept, J = 6.8 Hz, H-15), 3.61 (3H, s, CO$_2$C*H*$_3$), 5.35 (1H, br s, H-7), 5.76 (1H, br s, H-14); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 13.9 (q, C-18), 16.9 (q, C-19), 18.0 (t, C-2), 20.7 (q, C-17), 21.3 (q, C-16), 22.4 (t, C-11), 25.6 (t, C-3), 27.4 (t, C-12), 34.5 (s, C-10), 34.8 (d, C-15), 37.1 (t, C-6), 38.3 (t, C-1), 45.1 (d, C-5), 46.5 (s, C-4), 50.9 (d, C-9), 51.7 (q, CO$_2$*C*H$_3$), 120.5 (d, C-7), 122.3 (d, C-14), 135.5 (s, C-8), 145.2 (s, C-13), 178.9 (s, C-20).

Neoabietic acid methyl ester (12): ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.77 (3H, s, H-18), 1.10−1.15 (2H, m, H-1a, H-6a), 1.19 (3H, s, H-19), 1.33−1.38 (1H, dt, J = 3.7 Hz, 13.2 Hz, H-11a), 1.44−1.48 (1H, dd, J = 5.0 Hz, 12.7 Hz, H-6b), 1.50−1.61 (3H, m, H-2, H-3), 1.69 (3H, s, H-16), 1.73 (3H, s, H-17), 1.70−1.79 (3H, m, H-1b, H-11b, H-12a), 1.82−1.88 (1H, br t, H-12b), 1.91−1.94 (1H, dd, J = 2.5 Hz, 12.5 Hz, H-5), 1.95−1.97 (1H, m, H-9a), 2.16−2.24 (1H, br d, H-7a), 2.29−2.33 (1H, br dd, H-7b), 2.48−2.53 (1H, dt, J = 4.2 Hz, 14.1 Hz, H-9b), 3.65 (3H, s, CO$_2$C*H*$_3$), 6.18 (1H, br s, H-14); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 15.2 (q, C-18), 16.9 (q, C-19), 18.1 (t, C-2), 19.6 (q, C-17), 20.2 (q, C-16), 22.2 (t, C-11), 24.8 (t, C-6), 25.7 (t, C-12), 35.5 (t, C-7), 36.9 (t, C-3), 37.7 (s, C-10), 38.4 (t, C-1), 47.5 (s, C-4), 48.9 (d, C-5), 51.4 (d, C-9), 51.8 (q, CO$_2$*C*H$_3$), 122.0 (d, C-14), 123.3 (s, C-15), 128.2 (s, C-13), 138.4 (s, C-8), 179.3 (s, C-20).

15-Hydroxyabieteic acid methyl ester (14): ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.79 (3H, s, H-20), 1.13−1.21 (4H, m, H-1a, H-6, H-11a), 1.25 (3H, s, H-19), 1.31 (3H, s, H-17), 1.33 (3H, s, H-16), 1.55−1.62 (3H, m, H-2, H-3a), 1.73−1.77 (1H, m, H-3b), 1.81−1.89 (2H, m, H-1b, H-11b), 1.92−1.96 (1H, br d, H-5), 2.03−2.09 (2H, m, H-9, H-12a), 2.28−2.33 (1H, br dt, H-12b), 3.62 (3H, s, CO$_2$C*H*$_3$), 5.46 (1H, br s, H-7), 6.05 (1H, br s, H-14); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 13.9 (q, C-19), 16.9 (q, C-18), 18.0 (t, C-2), 22.4 (t, C-11), 25.5 (t, C-12), 25.7 (t, C-6), 28.5 (q, C-16), 28.6 (q, C-17), 34.4 (s, C-10), 37.0 (t, C-3), 38.2 (t, C-1), 44.9 (d, C-9), 46.5 (s, C-4), 50.6 (d, C-5), 51.8 (q, CO$_2$*C*H$_3$), 122.3 (d, C-14), 122.9 (d, C-7), 134.9 (s, C-13), 144.5 (s, C-8), 178.9 (s, C-20).

Labda-7,15-diene. Acetic anhydride (0.5 mL) was added to a solution of **8** (32.5 mg) in pyridine (0.5 mL), and the reaction mixture was allowed to stand at room temperature for 4 h. The excess reagent and pyridine were removed in vacuo to yield 35.5 mg (86%) of the diacetate: ^{1}H NMR ($CDCl_3$, 90 MHz) δ 0.76 (3H, s, H-17), 0.86 (6H, br s, H-18, H-19), 1.69 (3H, br s, H-16), 2.03 (6H, br s, C*H*$_3$CO$_2$), 4.54 (4H, br d, H-15, H-20), 5.32 (1H, br t, H-14), 5.80 (1H, br s, H-7).

The diacetate (35.5 mg) in dry THF (1.0 mL) was placed in a two-necked flask equipped with a stirrer and a dropping funnel. The flask was cooled with a mixture of dry ice and acetone. Ammonia was introduced from the dropping funnel into the flask to concentrate it into liquid (ca. 10 mL), then calcium (98 mg) was added. The mixture was stirred for 30 min. The excess of calcium was destroyed by dropwise addition of aqueous NH_4Cl (0.2 mL), and the ammonia was allowed to evaporate. After warming to room temperature, the product was taken up in Et_2O and dried over Na_2SO_4. The organic layer was concentrated to give an oily residue (42.4 mg). Purification by preparative TLC (50% EtOAc in hexane) gave 18.2 mg (73%) of **16**: ^{1}H NMR ($CDCl_3$, 90 MHz) δ 0.75 (3H, s, H-17), 0.87 (6H, br s, H-18, H-19), 1.60 (9H, br s, H-15, H-16, H-20), 5.02−5.44 (2H, m, H-7, H-14); HREIMS *m*/*z* 274.2670 (calcd for $C_{20}H_{34}$, 274.2661).

Ozonolysis of 16. To a solution of **16** (20.4 mg) in MeOH (1.0 mL) cooled to −78 °C, ozone gas was bubbled in for 5 min. After addition of H_2O_2 (1.0 mL), acetic acid (0.5 mL), and 1 drop of 12 M HCl, and after stirring for 20 h, the reaction mixture was extracted with H_2O and Et_2O. The ether extract was washed with 5% $NaHCO_3$. The aqueous layer was acidified to pH 2 with 12 M HCl, and the acidic material was taken up in diethyl ether. Drying the ethereal solution over Na_2SO_4 and concentration afforded the carboxylic acid (**17**, 17.1 mg, 74%): ^{1}H NMR ($CDCl_3$, 90 MHz) δ 0.92 (3H, s, H-17), 0.97 (6H, br s, H-18, H-19), 2.05 (3H, s, H-16), 2.08 (3H, s, H-20).

Methyl Ester of 17. The β-chiral carboxylic acid (**17**, 1.6 mg) was methylated with an excess of diazomethane in diethyl ether at room temperature for 1 h. The excess of diazomethane was destroyed by dropwise addition of acetic acid. The organic layer was concentrated on a rotary evaporator to give a crude methyl ester (2.1 mg). Purification by preparative TLC (20% EtOAc in hexane) gave 1.0 mg (56%) of the methyl ester **18**: ^{1}H NMR ($CDCl_3$, 90 MHz) δ 0.93 (3H, s, H-17), 0.96 (6H, br s, H-18, H-19), 2.05 (3H, s, H-16), 2.08 (3H, s, H-20), 3.33 (3H, s, OC*H*$_3$); GC−MS *m*/*z* $[M]^+$ (7), 324 (7), 235 (8), 197 (50), 181 (26), 128 (98), 123 (94), 43 (100); HREIMS *m*/*z* 324.2336 (calcd for $C_{19}H_{32}O_4$, 324.2301).

(*S*)-PGME Amide (19) of 17. To a stirred solution of carboxylic acid (**17**) (9.4 mg, 0.031 mmol) and (*S*)-PGME (7.6 mg, 0.038 mmol) in dry DMF (0.5 mL), were successively added *1H*-benzotriazol-*1*-yloxytripyrrolidinophosphonium hexafluorophosphate (19.7 mg, 0.038 mmol), 1-hydroxybenzotriazole (5.1 mg, 0.038 mmol), and triethylamine (12.8 mL) at 0 °C. After the mixture was stirred at room temperature for 4 h, EtOAc was added, and the resulting solution was successively washed with 5% HCl, saturated $NaHCO_3$ solution, and brine. The organic layer was dried over anhydrous Na_2SO_4 and concentrated to give a residue (15.1 mg), which was purified by preparative TLC (20% EtOAc in hexane) to afford the (*S*)-PGME amide (**19**) (0.6 mg, 3.8%): ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.79 (3H, s, H-19), 0.89 (3H, s, H-18), 0.91 (3H, s, H-17), 1.09−1.19 (1H, m, H-3a), 1.30−1.36 (1H, m, H-3b), 1.38−1.50 (4H, m, H-1, H-2), 1.82−1.90 (4H, m, H-11, H-12), 2.00−2.02 (1H, t, J = 4.8 Hz, H-5), 2.08 (3H, s, H-16), 2.17 (3H, s, H-20), 2.23−2.27 (2H, dd, J = 4.8 Hz, 12.0 Hz, H-6), 2.54−2.57 (1H, dd, J = 2.8 Hz, 11.6 Hz, H-9), 3.72 (3H, s, CO$_2$C*H*$_3$), 5.54−5.56 (1H, d, J = 7.2 Hz, C$_a$-H), 6.52−6.54 (1H, d, J = 7.2 Hz, NH), 7.31−7.38 (5H, m, Ar−H).

(*R*)-PGME Amide (19) of 17. Condensation of (*R*)-PGME (5.4 mg, 0.027 mmol) with **17** (7.0 mg, 0.021 mmol) in a similar way as described above gave a residue (11.3 mg), which was purified by preparative TLC (20% EtOAc in hexane) to afford the (*R*)-PGME amide (**19**) (2.3 mg, 21%): ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.89 (9H, s, H-17, H-18, H-19), 1.18−1.23 (1H, m, H-3a), 1.38−1.51 (5H, m, H-1, H-2, H-3b), 1.65−1.79 (4H, m, H-8, H-9), 1.92 (3H, s, H-16), 2.01−2.03 (1H, t, J = 4.4 Hz, H-5), 2.05 (3H, s, H-20), 2.20−2.24 (1H, br dd, H-7), 2.24−2.27 (2H, dd, J = 4.0 Hz, 8.8 Hz, H-6), 3.71 (3H, s, CO$_2$C*H*$_3$), 5.51−5.53 (1H, d, J = 6.8 Hz, C$_a$-H), 6.71−6.73 (1H, d, J = 6.8 Hz, NH), 7.29−7.40 (5H, m, Ar−H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 17.9 (t, C-2), 20.5 (q, C-17), 21.7 (t, C-11), 22.7 (q, C-18),

29.5 (q, C-16), 32.6 (t, C-1), 33.7 (q, C-19), 33.8 (t, C-6), 34.1 (q, C-20), 34.8 (s, C-10), 40.2 (s, C-4), 41.4 (t, C-3), 41.8 (t, C-12), 44.5 (d, C-5), 52.8 (q, OCH_3), 56.5 (d), 59.5 (d, C-9), 127.3 (d, Ar−C), 128.4 (d, Ar−C), 128.9 (d, Ar−C), 137.1 (s, Ar−C), 171.4 (s, CO_2), 172.4 (s, *C*ONH), 208.4 (s, C-13), 213.1 (s, C-8).

References and Notes

(1) (a) Miyamoto, F.; Naoki, H.; Takemoto, T.; Naya, Y. *Tetrahedron* **1979**, *35*, 1913−1917. (b) Kusumi, T.; Kinoshita, T.; Fujita, K.; Kakisawa, H. *Phyto* **1979**, 1129−1132.
(2) Miyamoto, F.; Naoki, H.; Naya, Y.; Nakanishi, K. *Tetrahedron* **1980**, *36*, 3481−3487.
(3) (a) Dale, J. A.; Mosher, H. S. *J. Am. Chem. Soc.* **1973**, *95*, 512−519. (b) Ohtani, I.; Kusumi, T.; Kashman, Y.; Kakisawa, H. *J. Am. Chem. Soc.* **1991**, *113*, 4092−4096.
(4) (a) Nagai, Y.; Kusumi, T. *Tetrahedron Lett.* **1995**, *36*, 1853−1856. (b) Yabuuchi, Y.; Ooi, T.; Kusumi, T.; *Chirality* **1997**, *9*, 550−555. (c) Yabuuchi, T.; Kusumi, T.; *J. Org. Chem.*, submitted. As a preliminary report, see Yabuuchi, T.; Ooi, T.; Kusumi, T. 41st Symposium on the Chemistry of Terpenes, Essential Oils and Aromatics (Iwate, Japan, 10−12 October 1997), Summary Paper 2I08 (p 251).
(5) Tabacik, C.; Poisson, C. *Phytochemistry* **1971**, *10*, 1639−1645.
(6) Schuller, W. H.; Lawrence, R. V. *J. Am. Chem. Soc.* **1961**, *83*, 2563−2570.
(7) Carman, R. M.; Marty, R. A. *Aust. J. Chem.* **1970**, *23*, 1457−1464.

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