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Sesquiterpene Glycosides and Phenylpropanoid Esters from *Phonus arborescens* (*Carthamus arborescens*)

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The *tert*-butylmethyl ether extract of the aerial parts of *Phonus arborescens* (L.) G. López (*Carthamus arborescens* L.) afforded three new sesquiterpene glycosides, 10-epi-γ-eudesmol β-D-fucopyranoside (**1**), 10-epi-γ-eudesmol 2′-*O*-acetyl-β-D-fucopyranoside (**2**), and 4,5-dioxo-10-epi-4,5-seco-γ-eudesmol 2′-O-acetyl-β-D-fucopyranoside (**3**), together with two new phenylpropanoid esters, 3-(3,4-dihydroxyphenyl)propyl myristate (**4**) and 3-(3,4-dihydroxyphenyl)propyl palmitate (**5**) in addition to a series of known compounds. The structures of the new compounds were established by spectroscopic and chemical methods.

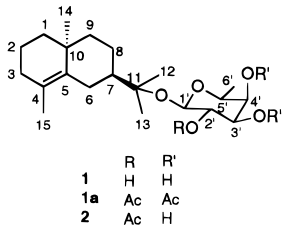
Introduction

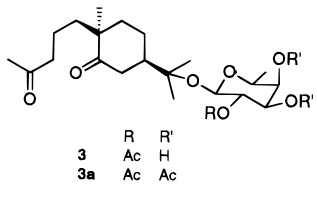
Continuing our study of the chemical composition of medicinal plants found in the Spanish South-East and North Africa,[1−4] we present here the results obtained in the study of *Phonus arborescens* (L.) G. López *(Carthamus arborescens* L.) (Fam. Compositae, tribe Cynereae), a perennial plant which grows in the South of Spain and Northeast Africa.

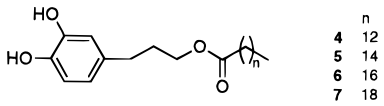
Results and Discussion

Chromatographic separations of the ether extract of the aerial parts of *Phonus arborescens* (L.) G. López (*Carthamus arborescens* L.) led to the isolation of three new sesquiterpene glycosides, 10-epi-γ-eudesmol β-D-fucopyranoside (**1**), 10-epi-γ-eudesmol 2′-*O*-acetyl-β-D-fucopyranoside (**2**), and 4,5-dioxo-10-epi-4,5-seco-γ-eudesmol 2′-*O*-acetyl-β-D-fucopyranoside (**3**), plus two new phenylpropanoid esters, 3-(3,4-dihydroxyphenyl)-propyl myristate (**4**) and 3-(3,4-dihydroxyphenyl)propyl palmitate (**5**). The known compounds, 3-(3,4-dihydroxyphenyl)propyl stearate (**6**),[5] 3-(3,4-dihydroxyphenyl)-propyl arachidate (**7**),[5] pinocembrin,[6,7] 5,7-dihydroxy-6-methoxyflavone,[8,9] 5-hydroxy-6,7-dimethoxyflavone,[9,10] shiromool,[11] and germacra-1(10),4-dien-6β-ol[12] also were isolated and identified by comparison of their physical and spectroscopic data with those reported in the literature.

Compound **1**, a colorless liquid, is the major component of the extract. Its molecular formula $C_{21}H_{36}O_5$ was deduced from its HRCIMS ($[M + 1]^+$, *m/z* 369.2552). Its IR spectrum showed hydroxyl group (3398 and 1063 cm^{-1}) and double bond (1652 cm^{-1}) absorptions. The proton-noise-decoupled ^{13}C-NMR and DEPT spectra showed signals of five oxygenated methines and of a methyl geminal to oxygen corresponding to a deoxy sugar moiety, whereas the rest of the signals indicated that **1** contained four methyl groups, six methylene groups, a methine group, and four quaternary carbons (one oxygenated and two olefinic) corresponding to a







sesquiterpene moiety. Furthermore, the chemical shift of the methyls in the ^{1}H-NMR spectrum at δ 1.63, 1.22, 1.19, and 1.04 (one on a double bond, two on an oxygenated carbon, and the other nonfunctionalized) allowed us to propose an eudesmane skeleton with a double bond at C-4 and an oxygenated function at C-11 for the sesquiterpene moiety.

The ^{1}H- and ^{13}C-NMR spectroscopic data of the triacetylated derivative **1a**, obtained by acetylation of **1** with Ac_2O/Pyr, indicated that **1** contained a β-fucopyranose moiety. This was deduced from the following ^{1}H-NMR spectrum data: the anomeric proton appears at δ 4.62 (J = 7.9 Hz), the protons H-2′, H-3′, H-4′, and H-5′ appear at δ 5.15 (dd, $J_{1'-2'}$ = 7.8 Hz, $J_{2'-3'}$ = 10.4 Hz), 5.02 (dd, $J_{2'-3'}$ = 10.4 Hz, $J_{3'-4'}$ = 3.5 Hz), 5.21 (dd, $J_{3'-4'}$ = 3.5 Hz, $J_{4'-5'}$ = 1.0 Hz), and 3.76 (dq, $J_{4'-5'}$ = 1.0 Hz, $J_{5'-6'}$ = 6.3 Hz), respectively, and the presence of a methyl doublet at δ 1.18 (J = 6.5 Hz, CH_3-6′). The equatorial orientation of H-4′ was determined by the values of $J_{3'-4'}$ and $J_{4'-5'}$. In the ^{13}C-NMR spectrum, the chemical shifts of the six carbons (see the Experimental Section) are in agreement with that identification.[13] In order to confirm the structure of **1** and to establish its stereochemistry, the glycoside was hydrolyzed in acid medium (HOAc−H_2O−dioxane). Once the crude product was fractionated, the aqueous fraction yielded, by acetylation with Ac_2O/Pyr, a mixture (5:1) of β- and α-D-fucopyranose tetraacetate. This ratio was obtained from the ^{1}H-NMR spectrum data, and the D configuration was determined on the basis of the posi-

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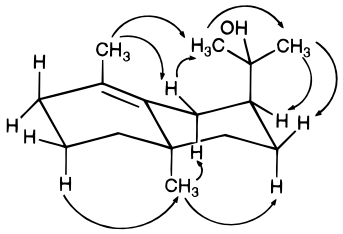
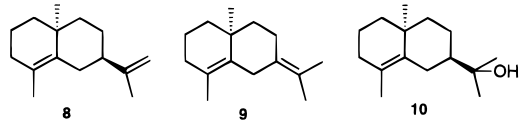
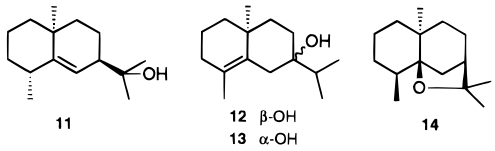


Figure 1. NOESY correlations for **10**.

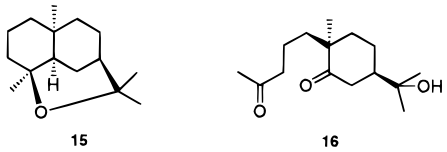
tive value of its optical rotation.[14] From the organic fraction, the alcohols **10**−**13** together with the hydrocarbons **8** and **9** were isolated by CC, with **10** being the major component.



8 **9** **10**



11 **12** β-OH **13** α-OH **14**

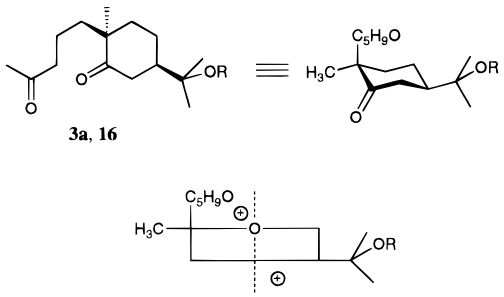


15 **16**

Compounds **8** and **9** were isolated as a mixture and identified by comparison with published spectroscopic data,[15,16] and their presence as hydrolytic products confirmed the eudesmane skeleton of **1**.

The IR and ^{1}H- and ^{13}C-NMR spectra indicated that the alcohol **10** had the structure of 4-eudesmen-11-ol. Its relative stereochemistry and the conformation of the bicyclic system were established by NOESY experiment, following unequivocal assignment of the ^{1}H-NMR signals by ^{1}H−^{1}H and ^{1}H−^{13}C COSY experiments, showing the major correlations in Figure 1. The equatorial orientation of H-7 is corroborated by the values of the coupling constants $J_{6\beta-7} = 2.9$ Hz and $J_{6\alpha-7} = 2.9$ Hz.[17] Furthermore, the oxymercuration of **10** with mercuric acetate in THF−H_2O mixture (1:1), followed by reduction of the intermediate mercury complex with $NaBH_4$ in alkaline medium, gave **14** and **15**. The formation of **14** and **15** confirmed the *trans* relationship between the methyl group at C-10 and the 2-propanol moiety at C-7.[18]

Ozonolysis of **10** led to the formation of the diketone **16**. The ^{1}H-NMR signals of **16** were assigned unequivocally by COSY, DQF-COSY, and HETCOR experiments. The correlation observed between H-14 and H-9α, H-9β, H-2a, H-2b, and H-1a in its NOESY spectrum determined an equatorial orientation for Me-14 (δ 21.8 ppm). The chemical shift of C-1 (18.0 ppm) can be explained by a *cis*-diaxial interaction between this methylene and



3a, **16**

Figure 2. Octant Projection of **3a**, **16**.

the protons H-8β and H-6β, which requires a β-axial orientation of the 4-oxopentyl chain. These data corroborate the conformational change which originated in the cyclohexane ring during the ozonolysis reaction.

The absolute configuration of C-7 and C-10 of **16** was determined as *R* and *S*, respectively, from the positive Cotton effect observed in its CD spectrum (Figure 2). Given that the transformations which lead from **1** to **16** via **10** do not modify the configuration in C-7 and C-10, the same absolute configurations were assigned to these carbons in **1**.

The structures of alcohols **11**−**13** were deduced from the ^{1}H- and ^{13}C-NMR data by comparison with those of **10**.

The IR and ^{1}H- and ^{13}C-NMR spectroscopic data of **2** were very similar to those of **1**, with the difference being the presence of an acetate group in **2** [^{1}H-NMR δ 1.99, and ^{13}C-NMR δ 170.1 and 21.2]. The acetate group in C-2′ was localized based on the value of the chemical shift of H-2′ (4.89 ppm) in ^{1}H-NMR and the values of the coupling constants ($J_{2'-1'} = 7$ Hz, $J_{2'-3'} = 9.4$ Hz), which indicate a *trans* relationship between the proton on the carbon holding the acetate group and both vicinal protons. The stereochemistry of C-7 and C-10 was the same as in **1**, since the acetylation of **2** with Ac_2O/Pyr also gave rise to **1a**.

Compound **3** showed hydroxyl (3402 cm^{-1}), acetate (1742 cm^{-1}), and ketone (1702 cm^{-1}) group absorptions in its IR spectrum. The molecular formula $C_{23}H_{38}O_8$ was deduced from its HRCIMS ([M + 1]$^+$, *m*/*z* 443.2649). The ^{1}H- and ^{13}C-NMR spectroscopic data are, in part, similar to those of **2**. The signals of the sugar moiety showed that a moiety of 2′-*O*-acetyl-β-D-fucopyranose was present in **3**. The rest of the signals established a seco-eudesmane structure[19,20] for the aglycon. So, a methyl singlet assignable to methyl ketone was observed at δ 2.12 in the ^{1}H-NMR spectrum, and the ^{13}C-NMR spectrum indicated the presence of two keto groups at δ 214.8 and 208.0, one of which being assignable to the cyclohexanone carbonyl group. The acetylation of **3** with Ac_2O/Pyr yielded the triacetate **3a**, whose production by ozonolysis of **1a** confirmed the structure of **3**. The CD spectrum of **3a** showed a positive Cotton effect which allowed determination of the absolute configuration of C-7 and C-10 as *R* and *S*, respectively (Figure 2). Since the transformation of **3** into **3a** does not alter the configuration in C-7 and C-10, the same absolute configurations were assigned to these carbons in **3**.

Compounds **4**−**7** were identified as a mixture which could not be separated. Hydroxyl group (3394 cm^{-1}) and ester group (1736 cm^{-1}) absorptions were observed in the IR spectrum. The comparison of the ^{1}H-NMR

spectroscopic data with those described for 3-(3,4-dihydroxyphenyl)propyl stearate and 3-(3,4-dihydroxyphenyl)propyl arachidate[5] allowed us to propose structures of 3-(3,4-dihydroxyphenyl)propanol esterified with saturated lineal chain acids of $n = 12-18$ for **4**−**7**. The saponification of **4**−**7** with 10% KOH/MeOH and subsequent silylation of the acid fraction with BSTFA allowed the identification of the TMS derivatives of myristic, palmitic, stearic, and arachidic acids by GC−MS analysis. The neutral fraction was constituted of 3-(3,4-dihydroxyphenyl)propanol,[21] whose triacetylated derivative showed an $[M]^+$ at *m/z* 294.

Experimental Section

General Experimental Procedures. Optical rotations were measured on a 141 Perkin-Elmer polarimeter. IR spectra were recorded on a 983G Perkin-Elmer spectrometer. High-resolution MS were determined on an Autospec-Q VG-Analytical (FISONS) mass spectrometer, and low-resolution MS were determined on a 5988A Hewlett-Packard mass spectrometer. NMR spectra were recorded on Bruker ARX 400 or Bruker AMX 300 spectrometers (δ values given in ppm relative to internal TMS and *J* values in Hz). GC−MS analyses were carried out in a Hewlett-Packard 5890A using an ionization voltage of 70 eV. The GC conditions were as follows: HP-1 capillary column (25 m × 0.32 mm) packed with methyl silicone, temperature programmed from 120 to 220 °C at 5 °C min^{-1}, 220 to 280 °C at 3 °C min^{-1}, and 10 min hold at 280 °C, injector temperature 260 °C, detector temperature 180 °C, He at 25 mL min^{-1}. Column chromatography was carried out using silica gel 60 Chromagel (35−70 μm), eluting with mixtures of hexane/*tert*-butylmethyl ether, *tert*-butylmethyl ether/ethyl acetate, and ethyl acetate/methanol of increasing polarity. Analytical TLC was performed on layers of silica gel Merck 60G of 0.25 mm thickness, using a 7% phosphomolybdic acid solution (EtOH) to visualize the spots.

Plant Material. *P. arborescens* (L.) G. López (*C. arborescens* L.) was collected in the Alhamilla Mountain Range (Almeria, Spain) in May 1994 and identified by Prof. J. Molero, Professor Titular of the Department of Vegetable Biology, University of Granada. A voucher specimen (GDA 9968) is available for inspection at the herbarium of the Faculty of Pharmacy of the University of Granada.

Extraction and Isolation. The air-dried aerial parts (2.2 kg) of *P. arborescens* (L.) G. López were submerged in *tert*-butylmethyl ether for 6 min. Removal of the solvent under vacuum gave 41.5 g of residue, which was chromatographed on a Si gel column, affording germacra-1(10),4-dien-6β-ol (764 mg), pinocembrin (870 mg), a mixture of 3-(3,4-dihydroxyphenyl)-propyl myristate (**4**), palmitate (**5**), and stearate (**6**), plus arachidate (**7**) (417 mg), shiromool (87 mg), 5,7-dihydroxy-6-methoxyflavone (391 mg), 5-hydroxy-6,7-dimethoxyflavone (388 mg), 7-epi-γ-eudesmol 2′-*O*-acetyl-β-D-fucopyranoside (**2**) (5.4 g), 7-epi-γ-eudesmol β-D-fucopyranoside (**1**) (7.4 g), and 4,5-dioxo-10-epi-4,5-seco-γ-eudesmol 2′-*O*-acetyl-β-D-fucopyranoside (**3**) (92 mg). The acetyl derivatives were obtained by acetylation with Ac_2O in pyridine.

7-Epi-γ-eudesmol β-D-fucopyranoside (1) was obtained as a colorless syrup: $[\alpha]^{20}_D$ −27.1° (*c* 1, $CHCl_3$); IR (film) ν max 3398 (OH), 2933, 1652 (C=C), 1448, 1368, 1216, 1170, 1132, 1063, 997, 755 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 4.36 (1H, d, $J_{1'-2'} = 6.6$ Hz, H-1′), 3.57 (4H, m, H-2′−H-5′), 2.54 (1H, dd, $J_{6\alpha-7} = 3.8$ Hz, $J_{6\alpha-6\beta} = 15.1$, H-6α), 1.63 (3H, br s, Me-15), 1.29 (3H, d, $J_{6'-5'} = 6.5$ Hz, Me-6′), 1.22 and 1.19 (6H, 2s, Me-12, Me-13), 1.04 (3H, s, Me-14); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 134.7 (s, C-4), 124.9 (s, C-5), 97.2 (d, C-1′), 81.2 (s, C-11), 74.1 (d, C-4′), 72.1 (d, C-3′), 71.7 (d, C-2′), 70.3 (d, C-5′), 44.4 (d, C-7), 38.8, 38.3 (2t, C-1, C-6), 34.2 (s, C-10), 32.2 (t, C-3), 26.8, 26.2 (2q, C-12, C-13), 24.8 (t, C-9), 23.3 (q, C-15), 21.9 (t, C-8), 19.7 (q, C-14), 19.1 (t, C-2), 16.6 (q, C-6′); EIMS (70 eV) *m/z* 222 $[M - C_6H_{10}O_4]^+$ (12), 204 (62), 189 (100), 161 (90), 133 (76), 119 (23), 105 (57), 91 (80), 59 (68); CIMS (CH_4) *m/z* 369 $[M + 1]^+$ (2), 368 (8), 351 (1), 292 (1.5), 206 (49), 205 (100), 203 (75), 189 (29), 149 (44), 123 (16); HRCIMS (CH_4) *m/z* 369.2552 (calcd for $C_{21}H_{37}O_5$ 369.2562).

Acetylation of Compound 1. To a solution of **1** (100 mg) in 1 mL of pyridine was added Ac_2O (1 mL), and the mixture was kept at room temperature for 12 h. After the usual workup **1a** (126 mg) was isolated.

Compound 1a was obtained as a colorless syrup: $[\alpha]^{20}_D$ −4.3° (*c* 1, $CHCl_3$); IR (film) ν max 2976, 2936, 2867, 1754 (CO acetate), 1660, 1645 (C=C), 1457, 1436, 1369, 1250, 1225, 1172, 1144, 1129, 1074, 1021, 756 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 5.21 (1H, dd, $J_{4'-5'} = 1.0$ Hz, $J_{4'-3'} = 3.5$ Hz, H-4′), 5.15 (1H, dd, $J_{2'-1'} = 7.8$ Hz, $J_{2'-3'} = 10.4$ Hz, H-2′), 5.02 (1H, dd, $J_{3'-4'} = 3.5$ Hz, $J_{3'-2'} = 10.4$ Hz, H-3′), 4.62 (1H, d, $J_{1'-2'} = 7.8$ Hz, H-1′), 3.76 (1H, dq, $J_{5'-4'} = 1$ Hz, $J_{5'-6'} = 6.3$ Hz, H-5′), 2.40 (1H, dd, $J_{6\alpha-7} = 5.1$ Hz, $J_{6\alpha-6\beta} = 15.6$ Hz, H-6α), 2.17, 2.02, 1.98 (9H, 3s, 3 $COCH_3$), 1.59 (3H, br s, Me-15), 1.21, 1.12 (6H, 2s, Me-12, Me-13), 1.18 (3H, d, $J_{6'-5'} = 6.3$ Hz, Me-6′), 1.03 (3H, s, Me-14); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 170.8, 170.3, 169.2 (3s, 3 *C*OCH_3), 134.1 (s, C-4), 124.9 (s, C-5), 95.3 (d, C-1′), 81.3 (s, C-11), 71.8 (d, C-4′), 70.5 (d, C-3′), 69.4 (d, C-2′), 68.7 (d, C-5′), 44.2 (d, C-7), 39.0 (t, C-1), 38.2 (t, C-6), 34.0 (s, C-10), 32.2 (t, C-3), 27.0, 25.6 (2q, C-12, C-13), 24.7 (t, C-9), 22.7 (q, C-15), 21.8 (t, C-8), 20.9, 20.8, 20.7 (3q, 3 CO*C*H_3), 19.7 (q, C-14), 19.2 (t, C-2), 16.3 (q, C-6′); EIMS (70 eV) *m/z* 273 (4), 204 (100), 189 (31), 161 (34), 149 (25), 123 (7), 111 (10), 81 (6), 55 (4), 43 (42); CIMS (CH_4) *m/z* 495 $[M + 1]^+$ (0.5), 494 (1), 376 (1), 315 (1.5), 289 (3), 273 (77), 205 (100), 204 (96), 189 (19), 161 (22), 149 (31).

Hydrolysis of Compound 1. Glycoside **1** (4.43 g) was hydrolyzed in 124 mL of dioxane−H_2O−HOAc (1:1:2) at 80 °C for 14 h. EtOAc and H_2O were added, and the aqueous layer was evaporated under reduced pressure and treated with excess Ac_2O−pyridine, to yield α- and β-D-fucopyranose tetraacetate. Of the organic layer **8** plus **9** (481 mg), **10** (766 mg), **11** (30 mg), **12** (81 mg), and **13** (11 mg) were isolated by silica gel CC, eluting with mixtures of hexane/*tert*-butylmethyl ether of increasing polarity.

Compound 10 was obtained as an oil: $[\alpha]^{20}_D$ −55.8° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$, 300 MHz) δ 2.69 (1H, br dd, $J_{6\alpha-7} = 2.9$ Hz, $J_{6\alpha-6\beta} = 14.9$ Hz, H-6α), 2.10 (1H, dd, $J_{6\beta-7} = 2.9$ Hz, $J_{6\beta-6\alpha} = 14.9$ Hz, H-6β), 1.92 (2H, m, H-3α, H-3β), 1.68 (4H, m, H-9β, H-8β, H-8α, H-2α), 1.66 (3H, br s, Me-15), 1.55 (1H, m, H-2β), 1.39 (1H, br t, $J_{1\beta-2} = 3.9$ Hz, H-1β), 1.33 (1H, br dd, $J_{1\alpha-2\alpha} = 3.7$ Hz, $J_{1\alpha-2\beta}$, = 11.8 Hz, H-1α), 1.29 (1H, br t, $J_{9\alpha-8} = 4.1$ Hz, H-9α), 1.23, 1.17 (6H, 2s, Me-12, Me-13), 1.07 (3H,

s, Me-14). The IR, EIMS, and ^{13}C NMR data were in agreement with those of the literature.[17]

Compound 11 was obtained as a colorless syrup: $[\alpha]^{20}_D$ −17.1° (*c* 0.66, $CHCl_3$); IR (film) *ν* max 3402 (OH), 2967, 2924, 1652 (C=C), 1457, 1375, 1150, 916 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) *δ* 5.30 (1H, dt, J_{6-4} = 1.9 Hz, J_{6-7} = 5.6 Hz, H-6), 1.20, 1.18 (6H, 2s, Me-12, Me-13), 0.95 (3H, s, Me-14), 0.85 (3H, d, J_{15-4} = 6.6 Hz, Me-15); ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* 144.7 (s, C-5), 118.6 (d, C-6), 72.7 (s, C-11), 44.3 (d, C-7), 41.3 (d, C-4), 38.9 (t, C-9), 38.7 (s, C-10), 32.5, 31.2 (2t, C-3, C-1), 27.7, 27.4 (2t, C-2, C-8), 27.5, 26.3 (2q, C-12, C-13), 18.0 (q, C-14), 15.8 (q, C-15); EIMS (70 eV) *m/z* 222 $[M]^+$ (5), 204 (50), 189 (50), 161 (100), 149 (28), 135 (25), 123 (40), 119 (55), 107 (39), 93 (38), 59 (91), 43 (40).

Compound 12 was obtained as a colorless syrup: $[\alpha]^{20}_D$ −7.9° (*c* 0.63, $CHCl_3$); IR (film) *ν* max 3486 (OH), 2929, 1650 (C=C), 1466, 1369, 1257, 1216, 1169, 1139, 1053, 1010, 969, 858 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) *δ* 2.42 (1H, dd, $J_{6\alpha-7}$ = 2.4 Hz, $J_{6\alpha-6\beta}$ = 14.0 Hz, H-6α), 1.62 (3H, br s, Me-15), 1.00 (3H, s, Me-14), 0.96, 0.95 (6H, 2d, *J* = 6.9 Hz, Me-12, Me-13); ^{13}C NMR ($CDCl_3$, 75 MHz) *δ* 130.9 (s, C-5), 128.8 (s, C-4), 74.8 (s, C-7), 40.1 (t, C-1), 37.8 (d, C-11), 37.6 (t, C-9), 34.1 (t, C-6), 33.8 (t, C-3), 29.7 (s, C-10), 29.3 (t, C-8), 24.1 (q, C-15), 19.5 (q, C-14), 19.2 (t, C-2), 17.3, 17.0 (2q, C-12, C-13); EIMS (70 eV) *m/z* 222 $[M]^+$ (6), 204 (1), 179 (7), 123 (100), 91 (6), 43 (10).

Compound 13 was obtained as a colorless syrup: $[\alpha]^{20}_D$ −16.0° (*c* 1, $CHCl_3$); IR (film) *ν* max 3422 (OH), 2959, 1652 (C=C), 1457, 1375, 1121, 996, 947 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) *δ* 2.76 (1H, dd, $J_{6\alpha-7}$ = 2.9 Hz, $J_{6\alpha-6\beta}$ = 13.5 Hz, H-6α), 1.61 (3H, br s, Me-15), 1.07 (3H, s, Me-14), 0.92, 0.82 (6H, 2d, *J* = 6.9 Hz, Me-12, Me-13); ^{13}C NMR ($CDCl_3$, 75 MHz) *δ* 132.6 (s, C-5), 126.8 (s, C-4), 75.6 (s, C-7), 44.2 (d, C-11), 39.9 (t, C-1), 38.3 (t, C-6), 37.1 (t, C-9), 32.9, 32.8 (2t, C-3, C-8), 29.9 (s, C-10), 25.1 (q, C-15), 19.7 (q, C-14), 19.0 (t, C-2), 16.6; 16.1 (2q, C-12, C-13); EIMS (70 eV) *m/z* 222 $[M]^+$ (7), 204 (2), 179 (8), 123 (100), 91 (7), 43 (14).

Oxymercuration−Demercuration of Compound 10. Mercuric acetate (257 mg) and **10** (179 mg) were dissolved in a mixture of THF (6 mL) and H_2O (2 mL). After 6 h at room temperature, 19.2 mg of $NaBH_4$ dissolved in 1.6 mL of 3 N NaOH was added, and the reaction mixture was kept at room temperature for 1 h. After the usual workup **14** (50 mg) and **15** (22 mg) were isolated by silica gel CC, eluting with hexane/*tert*-butylmethyl ether 98:2.

Compound 14 was obtained as a colorless oil: $[\alpha]^{20}_D$ −51.1° (*c* 1, $CHCl_3$); IR (film) *ν* max 2968, 2927, 2860, 1427, 1380, 1144, 1019, 997, 887 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) *δ* 2.07 (^1H, dd, $J_{6\alpha-7}$ = 4.6 Hz, $J_{6\alpha-6\beta}$ = 11.9 Hz, H-6α), 1.79 (1H, m, H-4), 1.37, 1.15 (6H, 2s, Me-12, Me-13), 0.99 (3H, s, Me-14), 0.88 (3H, d, J_{15-4} = 6.6 Hz, Me-15); ^{13}C NMR ($CDCl_3$, 75 MHz) *δ* 87.3 (s, C-5), 81.1 (s, C-11), 43.8 (d, C-7), 38.7 (s, C-10), 38.1 (t, C-6, C-9), 36.1 (t, C-1), 33.4 (t, C-3), 32.2 (d, C-4), 30.3, 23.5 (2q, C-12, C-13), 25.1 (t, C-8), 23.0 (q, C-14), 21.4 (t, C-2), 15.7 (q, C-15); EIMS (70 eV) *m/z* 222 $[M]^+$ (8), 207 (100), 189 (28), 164 (14), 149 (25), 137 (58), 109 (43), 95 (24), 81 (24), 69 (30), 55 (40), 41 (50).

Compound 15: ^1H NMR ($CDCl_3$, 300 MHz) *δ* 2.27 (1H, dd, $J_{6\alpha-7}$ = 5.3 Hz, $J_{6\alpha-6\beta}$ = 13.8 Hz, H-6α), 1.30, 1.26, 1.22 (9H, 3s, Me-12, Me-13, Me-15), 0.99 (3H, s, Me-14); ^{13}C NMR ($CDCl_3$, 75 MHz) *δ* 74.6 (s, C-11), 72.9 (s, C-4), 44.6 (d, C-5), 42.8 (d, C-7), 42.2 (t, C-9), 41.0 (t, C-1), 32.1 (t, C-3), 31.0, 29.7, 29.1 (3q, C-12, C-13, C-15), 29.4 (t, C-6), 25.2 (t, C-8), 22.1 (t, C-2), 17.8 (q, C-14); EIMS (70 eV) *m/z* 207 $[M - Me]^+$ (100), 189 (24), 164 (7), 149 (29), 133 (9), 123 (13), 109 (81), 95 (13), 93 (14), 81 (19), 43 (37).

Ozonolysis of Compound 10. A slow O_3/O_2 mixture was bubbled for 1 h through a stirred solution of **10** (120 mg) in CH_2Cl_2 (10 mL) at −78 °C. The mixture was flushed with argon and after addition of Me_2S (1 mL) was kept at room temperature for 12 h and then evaporated under vacuum. The crude product was column chromatographed. Elution with hexane/*tert*-butylmethyl ether 50:50 yielded **16** (85 mg).

Compound 16 was obtained as a colorless syrup: $[\alpha]^{20}_D$ +68.4° (*c* 0.53, $CHCl_3$); IR (film) *ν* max 3406 (OH), 2967, 1700 (CO ketone), 1463, 1376, 1248, 1166, 1127, 1027, 951, 926 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) *δ* 2.40 (4H, m, H-3, H-6), 2.09 (3H, s, H-15), 1.87 (1H, dt, $J_{9\beta-8}$ = 3.1 Hz, $J_{9\beta-9\alpha}$ = 13.6 Hz, H-9*β*), 1.72 (1H, br t, *J* = 3.3 Hz, H-2a), 1.70 (2H, m, H-8), 1.64 (1H, m, H-7), 1.55 (1H, m, H-1a), 1.44 (1H, m, H-9α), 1.32 (1H, br dd, J_1 = 3.3 Hz, J_2 = 12.5 Hz, H-2b), 1.25 (1H, m, H-1b), 1.20, 1.19 (6H, 2s, H-12, H-13), 0.99 (3H, s, H-14); ^{13}C NMR ($CDCl_3$, 75 MHz) *δ* 215.8 (s, C-5), 208.3 (s, C-4), 72.0 (s, C-11), 50.1 (d, C-7), 47.9 (s, C-10), 43.6 (t, C-3), 39.9 (t, C-6), 38.4 (t, C-9), 36.9 (t, C-2), 29.9 (q, C-15), 27.5, 27.2 (2q, C-12, C-13), 21.8 (q, C-14), 21.6 (t, C-8), 18.0 (t, C-1); EIMS (70 eV) *m/z* 239 $[M - CH_3]^+$ (0.7), 221 (2), 196 (14), 178 (12), 170 (16), 152 (15), 136 (10), 135 (34), 112 (68), 111 (68), 95 (13), 84 (11), 81 (17), 69 (20), 59 (62), 43 (100).

7-Epi-*γ*-eudesmol 2′-*O*-acetyl-*β*-D-fucopyranoside (2) was obtained initially as a syrup, which slowly crystallizes: mp 110−112 °C; $[\alpha]^{20}_D$ +2.6° (*c* 1, $CHCl_3$); IR (film) *ν* max 3430 (OH), 2929, 1745 (CO acetate), 1652 (C=C), 1456, 1369, 1239, 1167, 1134, 1063, 998, 753 cm^{-1}; ^1H NMR ($(CD_3)_2CO$, 300 MHz) *δ* 4.89 (1H, dd, $J_{2'-1'}$ = 8.0 Hz, $J_{2'-3'}$ = 9.4 Hz, H-2′), 4.57 (^1H, d, $J_{1'-2'}$ = 7.9 Hz, H-1′), 3.89, 3.82 (2H, 2 br s, 2OH), 3.66 (3H, m, H-3′, H-4′, H-5′), 2.46 (1H, dd, $J_{6\alpha-7}$ = 5.1 Hz, $J_{6\alpha-6\beta}$ = 15.5 Hz, H-6α), 1.99 (3H, s, $COCH_3$), 1.58 (3H, br s, Me-15), 1.22 (3H, d, $J_{6'-5'}$ = 6.5 Hz, Me-6′), 1.17, 1.15 (6H, 2s, Me-12, Me-13), 1.02 (3H, s, Me-14); ^{13}C NMR ($(CD_3)_2CO$, 75 MHz) *δ* 170.1 (s, *C*OCH_3), 134.9 (s, C-4), 125.1 (s, C-5), 95.8 (d, C-1′), 80.6 (s, C-11), 73.5, 73.2 (2d, C-2′, C-4′), 72.6 (d, C-3′), 70.6 (d, C-5′), 45.0 (d, C-7), 39.6, 38.8 (2t, C-1, C-6), 34.5 (s, C-10), 32.7 (t, C-3), 27.2, 25.7 (2q, C-12, C-13), 25.4 (t, C-9), 23.2 (q, C-15), 22.8 (t, C-8), 21.2 (q, CO*C*H_3), 19.8 (q, C-14), 19.7 (t, C-2), 16.9 (q, C-6′); CIMS (CH_4) *m/z* 411 $[M + 1]^+$ (0.6), 410 (2), 245 (0.6), 206 (27.5), 205 (100), 203 (41), 189 (61), 171 (17), 149 (24), 43 (10); HRICMS (CH_4) *m/z* 411.2754 (calcd for $C_{23}H_{39}O_6$ 411.2746).

4,5-Dioxo-10-epi-4,5-seco-*γ*-eudesmol 2′-*O*-acetyl-*β*-D-fucopyranoside (3) was obtained as a colorless syrup: $[\alpha]^{20}_D$ + 19.5° (*c* 1, $CHCl_3$); IR (film) *ν* max 3402 (OH), 2930, 1742 (CO acetate), 1702 (CO ketone), 1448, 1369, 1241, 1168, 1136, 1063, 998, 751 cm^{-1}; ^1H NMR ($(CD_3)_2CO$, 400 MHz) *δ* 4.93 (1H, dd, $J_{2'-1'}$ = 7.9 Hz, $J_{2'-3'}$ = 8.7 Hz, H-2′), 4.58 (1H, d, $J_{1'-2'}$ = 7.9 Hz, H-1′), 3.77 (3H, m, H-3′, H-4′, H-5′), 2.46 (2H, t, J_{3-2} = 6.7 Hz, H-3), 2.27 (1H, dd, $J_{6\alpha-7}$ = 3.0 Hz, $J_{6\alpha-6\beta}$ = 11.7 Hz, H-6α), 2.06, 2.02 (6H, 2s, $COCH_3$, Me-15), 1.23 (3H,

d, $J_{6'-5'}$ = 6.5 Hz, Me-6′), 1.21, 1.18 (6H, 2s, Me-12, Me-13), 0.91 (3H, s, Me-14); ^{13}C NMR ($(CD_3)_2CO$, 100 MHz) δ 214.8 (s, C-5), 208.0 (s, C-4), 170.2 (s, *C*OCH$_3$), 96.0 (d, C-1′), 78.6 (s, C-11), 73.4, 73.0 (2d, C-2′, C-4′), 72.6 (d, C-3′), 70.8 (d, C-5′), 50.4 (d, C-7), 48.3 (s, C-10), 43.6 (t, C-3), 39.8, 39.2 (2t, C-6, C-9), 36.8 (t, C-2), 29.8 (q, C-15), 25.4 (q, C-14), 23.1, 22.0 (2q, C-12, C-13), 21.9 (t, C-8), 21.2 (q, CO*C*H$_3$), 18.6 (t, C-1), 16.9 (q, C-6′); CIMS (CH_4) *m/z* 443 $[M + 1]^+$ (1), 265 (2), 255 (12), 237 (33), 231 (3), 219 (21), 201 (8), 189 (53), 177 (8), 171 (21), 129 (14), 111 (21), 85 (27), 59 (41), 43 (100); HRCIMS (CH_4) *m/z* 443.2649 (calcd for $C_{23}H_{39}O_8$ 443.2644).

Acetylation of Compound 3. Following the same procedure described for **1**, compound **3** (50 mg) was acetylated to yield **3a** (52 mg).

Compound 3a was obtained as a colorless syrup: $[\alpha]^{20}_D$ +42.2° (*c* 0.7, $CHCl_3$); IR (film) ν max 2934, 1749 (CO acetate), 1703 (CO ketone), 1458, 1368, 1250, 1225, 1171, 1145, 1127, 1072, 971 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 5.20 (1H, dd, $J_{4'-5'}$ = 1.1 Hz, $J_{4'-3'}$ = 3.5 Hz, H-4′), 5.14 (1H, dd, $J_{2'-1'}$ = 7.7 Hz, $J_{2'-3'}$ = 10.5 Hz, H-2′), 5.00 (1H, dd, $J_{3'-4'}$ = 3.5 Hz, $J_{3'-2'}$ = 10.5 Hz, H-3′), 4.57 (1H, d, $J_{1'-2'}$ = 7.7 Hz, H-1′), 3.74 (1H, dq, $J_{5'-4'}$ = 1.1 Hz, $J_{5'-6'}$ = 6.4 Hz, H-5′), 2.43 (2H, t, J_{3-2} = 7.0 Hz, H-3), 2.37 (1H, br d, $J_{6\alpha-6\beta}$ = 11.0 Hz, H-6α), 2.17, 2.11, 2.02, 1.96 (12H, 4s, 3COCH$_3$, Me-15), 1.18 (3H, d, $J_{6'-5'}$ = 6.5 Hz, Me-6′), 1.21, 1.17 (6H, 2s, Me-12, Me-13); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 215.7 (s, C-4), 208.5 (s, C-5), 170.8, 170.3, 169.3 (3s, 3*C*OCH$_3$), 95.6 (d, C-1′), 78.9 (s, C-11), 71.6 (d, C-4′), 70.4 (d, C-3′), 69.2, 69.0 (2d, C-2′, C-5′), 49.6 (d, C-7), 47.9 (s, C-10), 43.7 (t, C-3), 39.4 (t, C-6), 38.2 (t, C-9), 36.3 (t, C-2), 29.9 (q, C-15), 25.1 (q, C-14), 23.4, 21.7 (2q, C-12, C-13), 21.2 (t, C-8), 20.9, 20.8, 20.7 (3q, 3CO*C*H$_3$), 18.2 (t, C-1), 16.3 (q, C-6′); CIMS (CH_4) *m/z* 527 $[M + 1]^+$ (11), 442 (4), 347 (1), 289 (1), 274 (20), 273 (100), 265 (13), 238 (23), 237 (99), 219 (35), 153 (37), 111 (19), 83 (16).

Ozonolysis of Compound 1a. Following the same procedure described for **10**, compound **1a** (60 mg) was ozonized to yield a crude product which, after column chomatography, afforded **3a** (48 mg).

3-(3,4-Dihydroxyphenyl)propyl myristate, palmitate, stearate, and arachidate (4−7) were obtained as an oily mixture: IR (film) ν max 3394 (OH), 2920, 2851, 1736 (CO ester), 1638, 1513, 1466, 1368, 1282, 1175, 1114 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 6.76 (1H, d, *J* = 8.0 Hz, H-5), 6.70 (1H, d, *J* = 2.0 Hz, H-2), 6.59 (1H, dd, J_1 = 2.0 Hz, J_2 = 8.0 Hz, H-6), 4.06 (2H, t, *J* = 6.5 Hz, H-9), 2.56 (2H, t, *J* = 7.5 Hz, H-7), 2.29 (2H, t, *J* = 7.5 Hz, H-2′), 1.89 (2H, tt, J_1 = 6.5 Hz, J_2 = 7.5 Hz, H-8), 1.60 (2H, m, H-3′), 1.25 (2*x*H, br s, $(CH_2)_x$), 0.88 (3H, t, *J* = 6.8 Hz, Me); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 174.2 (s, C-1′), 143.7 (s, C-4), 141.8 (s, C-3), 134.3 (s, C-1), 120.8 (d, C-6), 115.5, 115.4 (2d, C-2, C-5), 63.6 (t, C-9), 34.4 (t, C-2′), 32.0 (t, *C*H$_2$CH$_2$CH$_3$), 31.5 (t, C-7), 30.4 (t, C-8), 29.7, 29.5, 29.4, 29.3, 29.2 (5t, $(CH_2)_x$), 25.1 (t, C-3′), 22.7 (t, CH$_2$*C*H$_2$CH$_3$), 14.1 (q, Me).

Hydolysis of Compounds 4−7. A mixture of **4−7** (98 mg) was dissolved in 2 N KOH in MeOH (5 mL). The solution was kept at room temperature for 12 h. After most of the MeOH was removed and diluted with H_2O (50 mL), the solution was extracted with Et_2O, yielding 3-(3,4-dihydroxyphenyl)propanol[24] (17 mg). The residual aqueous solution was acidified with 2 N HCl (pH 2) and extracted with Et_2O, giving a mixture of myristic, palmitic, stearic, and arachidic acids (42 mg). Pyridine (20 mL) and BSTFA (40 mL) were added to 2 mg of the acid mixture, and it was maintained at 110 °C for 30 min obtaining the TMSi derivatives, which were identified by GC-MS analysis.

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