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Synthesis of Optically Active Vomifoliol and Roseoside Stereoisomers

Yumiko YAMANO* and Masayoshi ITO*

Kobe Pharmaceutical University; Motoyamakita-machi, Higashinada-ku, Kobe 658–8558, Japan.

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A synthesis of optically active vomifoliol stereoisomers 1—4 and their glucosides, roseoside stereoisomers 5—8, was accomplished *via* α-acetylenic alcohol 11a or 11b effectively prepared by an asymmetric transfer hydrogenation of α,β-acetylenic ketone 10. Simultaneous separation of these stereoisomers by HPLC was also perfomed.

Key words optically active vomifoliol; optically active roseoside; β-D-glucopyranoside; HPLC separation

Vomifoliol [=blumenol A, (6*S*,9*R*)-**1** in Chart 2] and its glucoside, roseoside [(6*S*,9*R*)-**5**], have been isolated[1—7] from various plant sources and they may have been produced[8] biogenetically by oxidative cleavage of carotenoids conjugated double bonds. They were considered[8] to be important precursors in tea and tobacco flavor. Recently, Yoshikawa *et al.* reported[6] that roseoside and its related compounds inhibit the release of histamine.

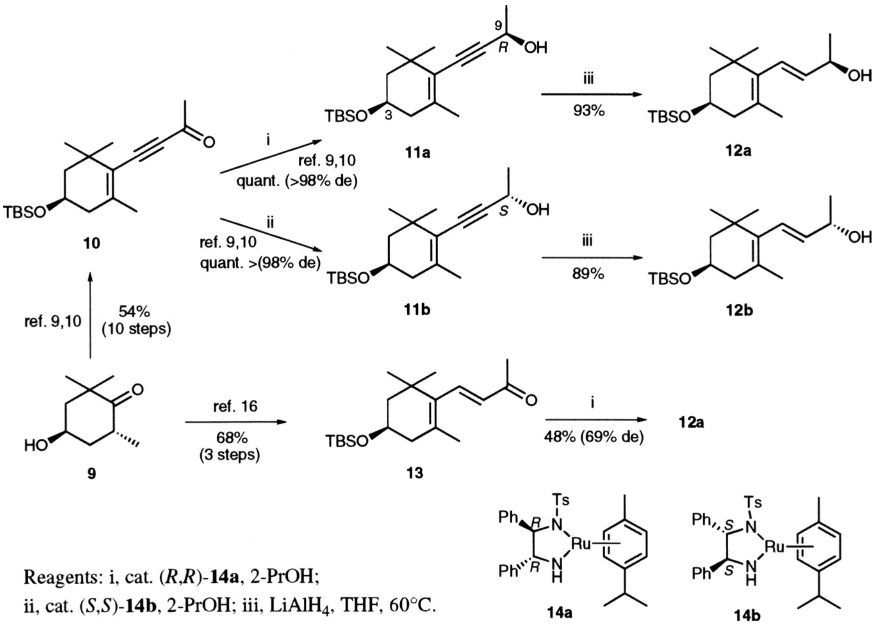
Although most natural roseosides have (6*S*)-configuration, roseoside having (6*R*)-configuration was also isolated[5] by Otsuka *et al.* They pointed out some conflicting physical data had been reported for roseosides from different sources. ^{1}H- and ^{13}C-NMR spectra of these glucosides are so similar to each other that confirmation of their stereochemistries from spectral data is not easy.

Recently, we reported[9,10] stereocontrolled synthesis of optically active 3-hydroxy-7,8-didehydro-β-ionol-glucosides utilizing an asymmetric transfer hydrogenation[11] of α,β-acetylenic ketone **10** (Chart 1) catalyzed by chiral ruthenium complexes as the key step, leading to the confirmation of the natural glucosides stereochemistries. We report here the synthesis of optically active vomifoliol stereoisomers **1**—**4** (Chart 2) and their glucosides, roseoside stereoisomers **5**—**8**, starting from the chiral intermediates **11a** and **11b**. Simultaneous separation of these isomers by HPLC is also reported.

Results and Discussion

Synthesis of Vomifoliol Stereoisomers 1—4 Although vomifoliol has been prepared[12—15] as a diastereomeric mixture, there has been no stereocontrolled synthesis reported so far for the optically active one. In order to synthesize diastereomeric pure vomifoliols **1**—**4** (Chart 2), intermediate allylic alcohols **12a** and **12b** were respectively prepared by reduction of previously prepared diastereomeric pure α-acetylenic alcohols **11a** and **11b**[9,10] with $LiAlH_4$ as shown in Chart 1. We also tried to obtain the allylic alcohols **12a** and **12b** directly by an asymmetric transfer hydrogenation of the α,β-unsaturated ketone **13**[16] using Ru^{II} catalyst **14a** or **14b**[17] and 2-propanol as the hydrogen donor. However, the reaction proceeded very slowly compared to the previously reported[9,10] hydrogenation of the α,β-acetylenic ketone **10** and its stereoselectivity was low (64% de).

Allylic alcohols **12a** and **12b** were then converted into four vomifoliol stereoisomers **1**—**4** as shown in Chart 2. Acetylation of (9*R*)-alcohol **12a** and subsequent epoxidation with MCPBA provided a mixture of *anti*-epoxide **16a** and *syn*-one



Reagents: i, cat. (*R*,*R*)-**14a**, 2-PrOH;
ii, cat. (*S*,*S*)-**14b**, 2-PrOH; iii, $LiAlH_4$, THF, 60°C.

Chart 1

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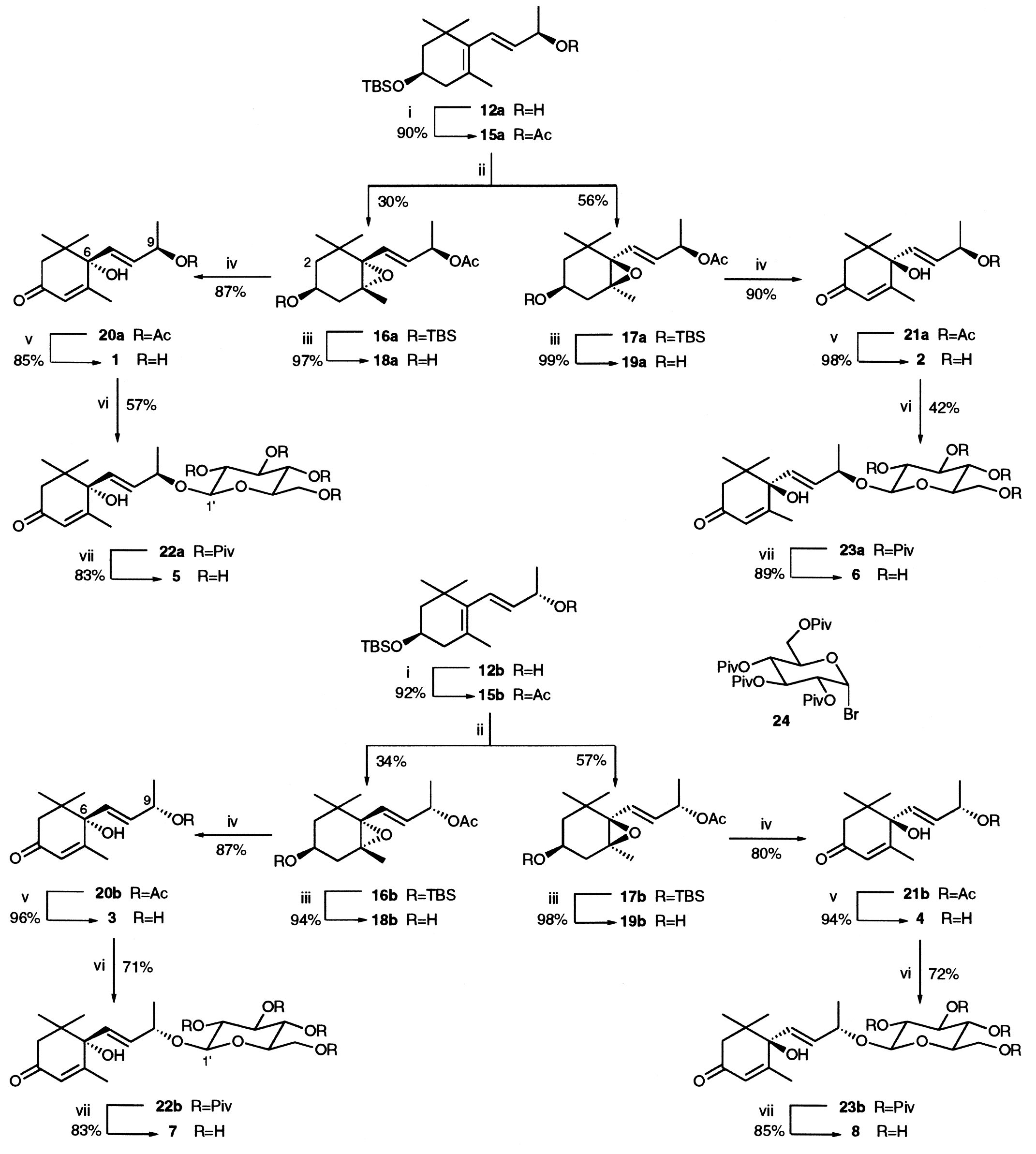
* To whom correspondence should be addressed. e-mail: y-yamano@kobepharma-u.ac.jp



Reagents: i, Ac_2O, Py, DMAP; ii, MCPBA; iii, HF•Py; iv, Dess-Martin periodinane then *p*-TsOH; v, NaOMe-MeOH; vi, **24**, AgOTf, $Me_2NC(O)NMe_2$; vii, LiOH-MeOH.

Chart 2

17a, which was cleanly separated by column chromatography (CC). The relative configurations between the siloxy and the epoxy groups in two isomers were confirmed from chemical shifts for 2-Hs (**16a**: 2-H_{ax} δ 1.22, 2-H_{eq} δ 1.48; **17a**: 2-H_{ax} δ 1.54, 2-H_{eq} δ 1.19) in both isomers on the basis of the empirical rule.[18] These epoxides were then desylilated (HF·Py) to afford alcohols **18a** and **19a**. These alcohols were respectively oxidized with Dess–Martin periodinane followed by treatment with *p*-toluenesulfonic acid (*p*-TsOH) to give γ-hydroxy-α,β-unsaturated ketones **20a** and **21a**. Finally, compounds **20a** and **21a** were deacetylated under basic conditions to provide (6*S*,9*R*)- and (6*R*,9*R*)-vomifoliols **1** and **2**, respectively. (6*S*,9*S*)- and (6*R*,9*S*)-vomifoliol stereoisomers **3** and **4** were also prepared (Chart 2) respectively by a similar method as the preparation of **1** and **2**.

As shown in Fig. 1, CD spectra of synthetic vomifoliol stereoisomers **1**—**4** indicated distinct differences between (6*S*)-isomers and (6*R*)-isomers but showed no differences between diastereomers **1** and **3** as well as **2** and **4**. In addition ^{1}H-NNR spectra of these diastereomers were so similar to each other. Stereochemistries of vomifoliols and roseosides have been hitherto confirmed by comparing their spectral data including optical data with those of authentic sample[19] [(6*S*,6*R*)-blumenol A (=vomifoliol)]. But, the results are not reliable. In order to confirm the stereochemistries of natural vomifoliols, separation of synthetic four isomers by HPLC was investigated. As a result, simultaneous complete separation using a chiral column (CHIRALPAK AD-H; DAICEL) was achieved as shown in Fig. 2.

Synthesis of Roseoside Stereoisomers 5—8 β-Glucosidation[9,10] of vomifoliol stereoisomers **1**—**4** was achieved by using tetra-*O*-pivaloyl (Piv)-β-D-glucopyranosyl bromide

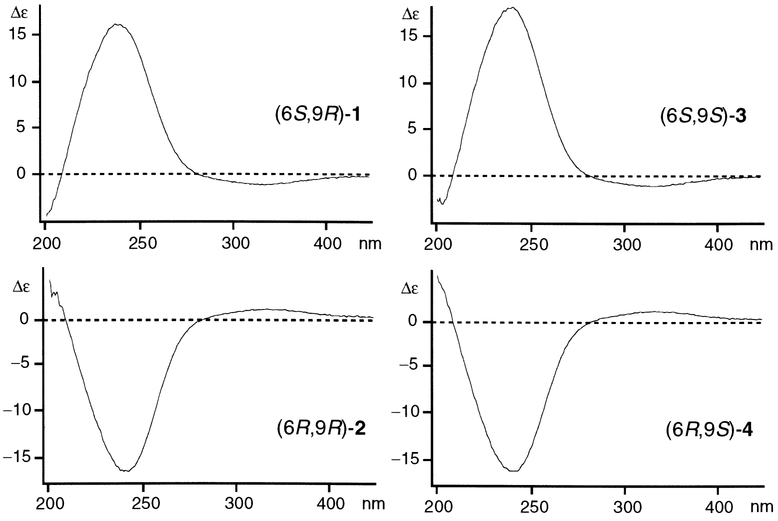


Fig. 1. CD Spectra in MeOH of Vomifoliol Stereoisomers **1**—**4**

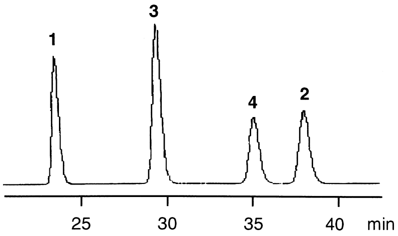


Fig. 2. HPLC Elution Profile of a Vomifoliol Stereoisomers Mixture **1**—**4**

Column: CHIRALPAK AD-H 0.46×25 cm; eluent: ethanol–hexane (7 : 93); temp.: 25 °C; flow rate: 0.7 ml/min; UV detection: 230 nm.

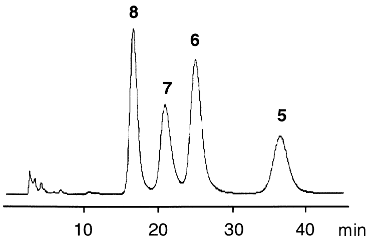


Fig. 3. HPLC Elution Profile of a Roseoside Stereoisomers Mixture **5**—**8**

Column: CHIRALPAK AS 0.46×25 cm; eluent: ethanol–hexane (1 : 9); temp.: 40 °C; flow rate: 1.0 ml/min; UV detection: 230 nm.

Table 1. Characteristic ^{1}H- and ^{13}C-NMR Data for Roseoside Stereoisomers in CD$_3$OD (500 MHz, δ in ppm, J in Hz)

	(6*S*,9*R*)-**5**	(6*R*,9*R*)-**6**	(6*S*,9*S*)-**7**	(6*R*,9*S*)-**8**
7-H	5.86 (m)	5.85 (m)	5.97 (dd, 15.5, 1)	5.97 (d, 15.5)
8-H			5.73 (dd, 15.5, 7.5)	5.70 (dd, 15.5, 8)
9-H	4.42 (m)	4.44 (qdd, 6.5, 3.5, 1.5)	4.53 (quint.-like, 6.5)	4.53 (quint.-like, 7)
9-C$\underline{H}_3$	1.29 (d, 6.5)	1.30 (d, 6.5)	1.29 (d, 6.5)	1.28 (d, 6.5)
1′-H	4.34 (d, 8)	4.33 (d, 8)	4.27 (d, 7.5)	4.31 (d, 8)
C6	80.04	79.97	80.05	79.98
C7	131.58	131.67	133.74, 133.81	134.12
C8	135.33	135.11		133.80
C9	77.32	76.90	74.67	74.70
9-$\underline{C}H_3$	21.22	21.16	22.29	22.22
C1′	102.79	102.59	100.29	100.91

24[20] possessing a sterically bulky acyl group at C-2 position as a glucosyl donor and silver triflate as an activator in the presence of *N*,*N*-tetramethylurea. The acyl groups of **22a**, **b** and **23a**, **b** were removed under basic conditions to give the free alcohols **5**—**8**.

CD spectra of synthetic roseoside stereoisomers **5**—**8** were almost similar to those of their aglycones **1**—**4** shown in Fig. 1. ^{1}H- and ^{13}C-NMR spectra of these isomers were similar to each other, but showed slight differences around C9 as shown in the Table 1. Spectral data of (6*S*,9*R*)- and (6*R*,9*R*)-roseosides isolated[5] from the *Alangium premnifolium* leaves were identical with those of synthetic (6*S*,9*R*)-**5** and (6*R*,9*R*)-**6**, respectively, while corchoinoside C [(6*S*,9*S*)-roseoside] isolated[6] from the *Corchorus olitorius* L. leaves were in accordance with synthetic (6*S*,9*S*)-**7**. In order to facilitate the confirmation of natural glucosides stereochemistries, separation of synthetic four isomers by HPLC was investigated. As a result, simultaneous separation using a chiral column (CHIRALPAK AS; DAICEL) was performed as shown in Fig. 3.

In summary, we have accomplished a synthesis of enantiomerically pure vomifoliol and roseoside stereoisomers **1**—**4** and **5**—**8** and simultaneous separation of these isomers by HPLC. This work must be useful not only in order to confirm the stereochemistries of the natural products but also to clarify their biosynthesis.

Experimental

General Melting points (mp) were measured on a micro melting point apparatus (Yanagimoto) and are uncorrected. UV spectra were recorded on a JASCO Ubest-55 instrument. IR spectra were measured on a Perkin Elmer FT-IR spectrometer, model Paragon 1000. ^{1}H- and ^{13}C-NMR spectra were determined on a Varian Gemini-300 or a Varian VXR-500 superconducting FT-NMR spectrometer and the chemical shifts were referenced to tetramethylsilane. *J*-values are given in Hz. Mass spectra were taken on a Hitachi M-4100 spectrometer. Optical rotations were measured on a JASCO DIP-181 polarimeter ($[\alpha]_D$ values are in units of 10^{-1} deg cm^2 g^{-1}) and CD spectra on a Shimadzu-AVIN 62A DS circular dichroism spectrometer. CC was performed on silica gel (Merck Art. 7734). Short-column chromatography (SCC) was conducted on silica gel (Merck Art. 7739) under reduced pressure. All operations were carried out under nitrogen or argon. Evaporation of the extract or the filtrate was carried out under reduced pressure. Ether refers to diethyl ether, and hexane to *n*-hexane. NMR assignments are given using the carotenoid numbering system.

Reduction of α-Acetylenic Alcohols 11a and 11b A solution of α-acetylenic alcohol **11a**[9,10] (2.74 g, 8.51 mmol) in dry THF (20 ml) was added dropwise to a stirred suspension of $LiAlH_4$ (380 mg, 10 mmol) in dry THF (30 ml) at 0 °C and the mixture was stirred at 60 °C for 1 h. After cooling, the excess of $LiAlH_4$ was decomposed by dropwise addition of water. The mixture was extracted with ether and the extracts were washed with brine and dried. Evaporation of the solvent gave a residue, which was purified by SCC (ether–hexane, 1 : 3) to afford the dienol **12a** (2.56 g, 93%). The compound **12b** was prepared (89%) in the same manner as described above.

12a: A colorless oil. $[\alpha]_D^{26}$ −64.0° (c=0.99, MeOH); IR ($CHCl_3$) cm^{-1}: 3607, 3451 (OH); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.08 (6H, s, SiMe×2), 0.90 (9H, s, *tert*-Bu), 1.00, 1.03 (each 3H, s, *gem*-Me), 1.31 (3H, d, *J*=6.5 Hz, 9-Me), 1.47 (1H, t, *J*=12.5 Hz, 2-H_{ax}), 1.64 (1H, ddd, *J*=12.5, 4, 2 Hz, 2-H_{eq}), 1.66 (3H, s, 5-Me), 2.03 (1H, br dd, *J*=17, 9.5 Hz, 4-H_{ax}), 2.20 (1H, br dd, *J*=17, 6 Hz, 4-H_{eq}), 3.94 (1H, m, 3-H), 4.36 (1H, quint.d, *J*=6.5, 0.5 Hz, 9-H), 5.49 (1H, dd, *J*=16, 6.5 Hz, 8-H), 6.01 (1H, dd-like, *J*=16, 1 Hz, 7-H); EI-MS *m/z*: 324.2479 [Calcd for $C_{19}H_{36}O_2Si$ (M^+) 324.2482].

12b: A colorless oil. $[\alpha]_D^{23}$ −82.0° (c=1.02, MeOH); IR ($CHCl_3$) cm^{-1}: 3607, 3446 (OH); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.08 (6H, s, SiMe×2), 0.90 (9H, s, *tert*-Bu), 1.00, 1.02 (each 3H, s, *gem*-Me), 1.31 (3H, d, *J*=6.5 Hz, 9-Me), 1.47 (1H, t, *J*=12.5 Hz, 2-H_{ax}), 1.64 (1H, ddd, *J*=12.5, 4, 2 Hz, 2-H_{eq}), 1.67 (3H, s, 5-Me), 2.03 (1H, br dd, *J*=17, 9.5 Hz, 4-H_{ax}), 2.20 (1H, br dd, *J*=17, 6 Hz, 4-H_{eq}), 3.94 (1H, m, 3-H), 4.37 (1H, m, 9-H), 5.50 (1H, dd, *J*=16, 6.5 Hz, 8-H), 6.01 (1H, dd-like, *J*=16, 1 Hz, 7-H); EI-MS *m/z*: 324.2498 [Calcd for $C_{19}H_{36}O_2Si$ (M^+) 324.2482].

Asymmetric Transfer Hydrogenation of the Dienone 13 To a solution of the dienone **13**[16] (164 mg, 0.5 mmol) in 2-propanol (5 ml) was added the (R,R)-Ru^{II} catalyst **14a**[17] (30 mg, 0.05 mmol) and the mixture was stirred at r.t. for 24 h. After evaporation of 2-propanol, the residue was purified by CC (ether–hexane, 1 : 4) to provide the (3R,9R)-alcohol **12a** (79 mg, 48%; 69% de) accompanied by the recovered ketone **13** (80 mg, 49%). The optical purity of **12a** was calculated by analytical HPLC (CHIRALPAK AS; DAICEL IND., Ltd., 0.46×25 cm; 2-propanol–hexane, 0.5 : 95.5, 0.6 ml/min; 25 °C; 250 nm detect.).

Acetylation of Dienols 12a and 12b Ac_2O (4 ml) was added to a solution of the dienol **12a** (2.56 g, 7.90 mmol) in pyridine (Py) (16 ml) and the reaction mixture was stirred at r.t. for 3 h, poured into ice-water and extracted with ether. The extracts were washed with aq. 5% HCl, saturated aq. $NaHCO_3$ and brine. Evaporation of the dried extracts gave a residue, which was purified by SCC (ether–hexane, 5 : 95) to afford the acetate **15a** (2.61 g, 90%). The compound **15b** was prepared (92%) in the same manner as described above.

15a: A colorless oil. $[\alpha]_D^{28}$ +6.4° (c=0.94, MeOH); IR ($CHCl_3$) cm^{-1}: 1728 (OAc); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.07 (6H, s, SiMe×2), 0.90 (9H, s, *tert*-Bu), 1.00, 1.01 (each 3H, s, *gem*-Me), 1.34 (3H, d, *J*=6.5 Hz, 9-Me), 1.46 (1H, t, *J*=12.5 Hz, 2-H_{ax}), 1.64 (1H, ddd, *J*=12.5, 3.5, 2 Hz, 2-H_{eq}), 1.65 (3H, s, 5-Me), 2.02 (1H, br dd, *J*=17, 9.5 Hz, 4-H_{ax}), 2.05 (3H, s, OAc), 2.20 (1H, br dd, *J*=17, 6 Hz, 4-H_{eq}), 3.93 (1H, m, 3-H), 5.38 (1H, m, 9-H), 5.41 (1H, dd, *J*=15, 7 Hz, 8-H), 6.06 (1H, dm, *J*=15 Hz, 7-H); EI-MS *m/z*: 366.2582 [Calcd for $C_{21}H_{38}O_3Si$ (M^+) 366.2588].

15b: A colorless oil. $[\alpha]_D^{21}$ −133.9° (c=1.01, MeOH); IR ($CHCl_3$) cm^{-1}: 1727 (OAc); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.07 (6H, s, SiMe×2), 0.90 (9H, s, *tert*-Bu), 0.99, 1.02 (each 3H, s, *gem*-Me), 1.35 (3H, d, *J*=6.5 Hz, 9-Me), 1.46 (1H, t, *J*=12.5 Hz, 2-H_{ax}), 1.64 (1H, ddd, *J*=12.5, 4, 2 Hz, 2-H_{eq}), 1.65 (3H, s, 5-Me), 2.02 (1H, br dd, *J*=17, 10.5 Hz, 4-H_{ax}), 2.04 (3H, s, OAc), 2.19 (1H, br dd, *J*=17, 6 Hz, 4-H_{eq}), 3.93 (1H, m, 3-H), 5.40 (2H, m, 8-H, 9-H), 6.05 (1H, br d, *J*=15 Hz, 7-H); EI-MS *m/z*: 366.2587 [Calcd for $C_{21}H_{38}O_3Si$ (M^+) 366.2588].

Epoxidation of Acetates 15a and 15b A solution of MCPBA (72%, 0.98 g, 4.09 mmol) in CH_2Cl_2 (7 ml) was added dropwise to an ice-cooled solution of the acetate **15a** (1.17 g, 3.20 mmol) in CH_2Cl_2 (15 ml) and the mixture was stirred at r.t. for 1 h. After the reaction was quenched with aq. 10% $Na_2S_2O_3$, CH_2Cl_2 was evaporated off and the organics were extracted with AcOEt. The extracts were washed with saturated aq. $NaHCO_3$ and brine. Evaporation of the dried extracts gave a residue, which was purified by CC (CH_2Cl_2–ether, 97 : 3) to afford the *anti*-epoxide **16a** (369 mg, 30%) and the *syn*-epoxide **17a** (687 mg, 56%). Epoxides **16b** (34%) and **17b** (57%) were prepared in the same manner as described above.

16a: A colorless oil. $[\alpha]_D^{21}$ −7.4° (c=1.08, MeOH); IR ($CHCl_3$) cm^{-1}: 1728 (OAc); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.04 (6H, s, SiMe×2), 0.87 (9H, s, *tert*-Bu), 0.93, 1.10 (each 3H, s, *gem*-Me), 1.15 (3H, s, 5-Me), 1.22 (1H, dd, *J*=13, 10 Hz, 2-H_{ax}), 1.30 (3H, d, *J*=6.5 Hz, 9-Me), 1.48 (1H, ddd, *J*=13, 3.5, 2 Hz, 2-H_{eq}), 1.62 (1H, dd, *J*=14.5, 8 Hz, 4-H_{ax}), 2.04 (3H, s, OAc), 2.22 (1H, ddd, *J*=14.5, 5, 2 Hz, 4-H_{eq}), 3.83 (1H, m, 3-H), 5.37 (1H, quint.d, *J*=6.5, 1 Hz, 9-H), 5.64 (1H, dd, *J*=15.5, 6.5 Hz, 8-H), 5.91 (1H, dd, *J*=15.5, 1 Hz, 7-H); CI-MS *m/z*: 383.2592 [Calcd for $C_{21}H_{39}O_4Si$ (MH^+) 383.2616].

17a: A colorless oil. $[\alpha]_D^{26}$ +61.4° (c=0.91, MeOH); IR ($CHCl_3$) cm^{-1}: 1729 (OAc); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.04 (6H, s, SiMe×2), 0.87 (9H, s, *tert*-Bu), 0.93, 1.11 (each 3H, s, *gem*-Me), 1.15 (3H, s, 5-Me), 1.19 (1H, ddd, *J*=12.5, 4, 2 Hz, 2-H_{eq}), 1.31 (3H, d, *J*=6.5 Hz, 9-Me), 1.54 (1H, t, *J*=12.5 Hz, 2-H_{ax}), 1.83 (1H, dd, *J*=15, 10 Hz, 4-H_{ax}), 2.02 (3H, s, OAc), 2.05 (1H, ddd, *J*=15, 7.5, 2 Hz, 4-H_{eq}), 3.81 (1H, m, 3-H), 5.36 (1H, quint.d, *J*=6.5, 1 Hz, 9-H), 5.64 (1H, dd, *J*=15, 6.5 Hz, 8-H), 5.84 (1H, dd, *J*=15.5, 1 Hz, 7-H); CI-MS *m/z*: 383.2594 [Calcd for $C_{21}H_{39}O_4Si$ (MH^+) 383.2616].

16b: A colorless oil. $[\alpha]_D^{22}$ −104.0° (c=1.01, MeOH); IR ($CHCl_3$) cm^{-1}: 1728 (OAc); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.04 (6H, s, SiMe×2), 0.87 (9H, s, *tert*-Bu), 0.93, 1.08 (each 3H, s, *gem*-Me), 1.16 (3H, s, 5-Me), 1.22 (1H, dd, *J*=13, 10 Hz, 2-H_{ax}), 1.31 (3H, d, *J*=6.5 Hz, 9-Me), 1.48 (1H, ddd, *J*=13, 3.5, 2 Hz, 2-H_{eq}), 1.62 (1H, dd, *J*=15, 9 Hz, 4-H_{ax}), 2.03 (3H, s, OAc), 2.22 (1H, ddd, *J*=15, 5, 2 Hz, 4-H_{eq}), 3.83 (1H, m, 3-H), 5.37 (1H, quint.d, *J*=6.5, 1 Hz, 9-H), 5.63 (1H, dd, *J*=15.5, 6.5 Hz, 8-H), 5.92 (1H, dd, *J*=15.5, 1 Hz, 7-H); CI-MS *m/z*: 383.2593 [Calcd for $C_{21}H_{39}O_4Si$ (MH^+) 383.2616].

17b: A colorless oil. $[\alpha]_D^{22}$ –38.7° (c=1.09, MeOH); IR ($CHCl_3$) cm^{-1}: 1728 (OAc); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.04 (6H, s, SiMe×2), 0.87 (9H, s, *tert*-Bu), 0.94 (3H, s, 1-Me), 1.13, 1.14 (each 3H, s, 1-Me, 5-Me), 1.19 (1H, ddd, *J*=12.5, 4, 2 Hz, 2-H_{eq}), 1.30 (3H, d, *J*=6.5 Hz, 9-Me), 1.54 (1H, t, *J*=12.5 Hz, 2-H_{ax}), 1.83 (1H, dd, *J*=15, 10 Hz, 4-H_{ax}), 2.04 (3H, s, OAc), 2.05 (1H, ddd, *J*=15, 7.5, 2 Hz, 4-H_{eq}), 3.82 (1H, m, 3-H), 5.36 (1H, quint.d, *J*=6.5, 1 Hz, 9-H), 5.65 (1H, dd, *J*=15.5, 6.5 Hz, 8-H), 5.85 (1H, dd, *J*=15.5, 1 Hz, 7-H); CI-MS *m/z:* 383.2626: [Calcd for $C_{21}H_{39}O_4Si$ (MH^+) 383.2616].

Desilylation of Compounds 16a, b and 17a, b HF·Py (2.5 ml) was added to a solution of the silyl ether **16a** (758 mg, 1.98 mmol) in THF (10 ml) at 0 °C. After being stirred at 0 °C for 15 min, the reaction mixture was diluted with ether. The organic layer was washed successively with brine, saturated aq. $NaHCO_3$ and brine. Evaporation of the dried solution gave a residue, which was purified by SCC (acetone–hexane, 1 : 3) to afford the 3-hydroxy compound **18a** (517 mg, 97%). The compounds **19a** (99%), **18b** (94%) and **19b** (98%) were prepared in the same manner as described above.

18a: A colorless oil. $[\alpha]_D^{21}$ −11.9° (c=1.01, MeOH); IR ($CHCl_3$) cm^{-1}: 3608, 3467 (OH), 1728 (OAc); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.95, 1.12 (each 3H, s, *gem*-Me), 1.18 (3H, s, 5-Me), 1.22 (1H, dd, *J*=13, 11 Hz, 2-H_{ax}), 1.31 (3H, d, *J*=6.5 Hz, 9-Me), 1.60 (1H, ddd, *J*=13, 3.5, 2 Hz, 2-H_{eq}), 1.60 (1H, dd, *J*=14, 9 Hz, 4-H_{ax}), 2.05 (3H, s, OAc), 2.35 (1H, ddd, *J*=14, 5, 2 Hz, 4-H_{eq}), 3.88 (1H, m, 3-H), 5.37 (1H, quint.d, *J*=6.5, 1 Hz, 9-H), 5.65 (1H, dd, *J*=15.5, 6.5 Hz, 8-H), 5.91 (1H, dd, *J*=15.5, 1 Hz, 7-H); CI-MS *m/z*: 269.1753 [Calcd for $C_{15}H_{25}O_4$ (MH^+) 269.1752].

19a: A colorless oil. $[\alpha]_D^{24}$ +68.7° (c=1.03, MeOH); IR ($CHCl_3$) cm^{-1}: 3604, 3468 (OH), 1729 (OAc); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.98, 1.11 (each 3H, s, *gem*-Me), 1.18 (3H, s, 5-Me), 1.32 (3H, d, *J*=6.5 Hz, 9-Me), 1.33 (1H, ddd, *J*=12.5, 4, 1.5 Hz, 2-H_{eq}), 1.57 (1H, dd, *J*=12.5, 11 Hz, 2-H_{ax}), 1.86 (1H, dd, *J*=15, 9 Hz, 4-H_{ax}), 2.03 (3H, s, OAc), 2.18 (1H, ddd, *J*=15, 6.5, 1.5 Hz, 4-H_{eq}), 3.85 (1H, m, 3-H), 5.37 (1H, quint.d, *J*=6.5, 1 Hz, 9-H), 5.66 (1H, dd, *J*=15.5, 6.5 Hz, 8-H), 5.84 (1H, dd, *J*=15.5, 1 Hz, 7-H); CI-MS *m/z*: 269.1755 [Calcd for $C_{15}H_{25}O_4$ (MH^+) 269.1752].

18b: A colorless oil. $[\alpha]_D^{22}$ −137.5° (c=0.90, MeOH); IR ($CHCl_3$) cm^{-1}: 3608, 3640 (OH), 1728 (OAc); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.95, 1.09 (each 3H, s, *gem*-Me), 1.18 (3H, s, 5-Me), 1.21 (1H, dd, *J*=13, 10.5 Hz, 2-

H_{ax}), 1.32 (3H, d, J=6.5 Hz, 9-Me), 1.60 (1H, ddd, J=13, 3.5, 2 Hz, 2-H_{eq}), 1.60 (1H, dd, J=14, 9 Hz, 4-H_{ax}), 2.03 (3H, s, OAc), 2.35 (1H, ddd, J=14, 5, 2 Hz, 4-H_{eq}), 3.87 (1H, m, 3-H), 5.37 (1H, quint.d, J=6.5, 1 Hz, 9-H), 5.65 (1H, dd, J=15.5, 6.5 Hz, 8-H), 5.92 (1H, dd, J=15.5, 1 Hz, 7-H); CI-MS *m/z*: 269.1754 [Calcd for $C_{15}H_{25}O_{34}$ (MH^+) 269.1752].

19b: A colorless oil. $[\alpha]_D^{22}$ −65.3° (c=1.21, MeOH); IR ($CHCl_3$) cm^{-1}: 3601, 3462 (OH), 1732 (OAc); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.98 (3H, s, 1-Me), 1.13, 1.14 (each 3H, s, 1-Me, 5-Me), 1.31 (3H, d, J=6.5 Hz, 9-Me), 1.33 (1H, ddd, J=12.5, 3.5, 1.5 Hz, 2-H_{eq}), 1.57 (1H, dd, J=12.5, 11 Hz, 2-H_{ax}), 1.86 (1H, dd, J=15, 9 Hz, 4-H_{ax}), 2.05 (3H, s, OAc), 2.18 (1H, ddd, J=15, 7, 1.5 Hz, 4-H_{eq}), 3.86 (1H, m, 3-H), 5.37 (1H, quint.d, J=6.5, 1 Hz, 9-H), 5.66 (1H, dd, J=15.5, 6.5 Hz, 8-H), 5.87 (1H, dd, J=15.5, 1 Hz, 7-H); CI-MS *m/z*: 269.1743 [Calcd for $C_{15}H_{25}O_4$ (MH^+) 269.1752].

Synthesis of Enones 20a, b and 21a, b Dess–Martin periodinane (1.06 g, 2.50 mmol) was added to a stirred solution of the 3-hydroxy compound **18a** (517 mg, 1.93 mmol) in CH_2Cl_2 (20 ml) at r.t. Stirring was continued for an additional 1.5 h. After CH_2Cl_2 was evaporated off, the resulting solids were washed with ether and filtered off. The filtrate was concentrated. The residue was purified by SCC (acetone–hexane, 1 : 3) to afford the corresponding ketone. This was dissolved in benzene (15 ml) and p-TsOH·H_2O (25 mg, 0.13 mmol) was added to it. After being stirred at r.t. for 17 h, the reaction mixture was diluted with ether. The organic layer was washed successively with saturated aq. $NaHCO_3$ and brine. Evaporation of the dried solution gave a residue, which was purified by SCC (acetone–hexane, 1 : 3) to give the enone **20a** (446 mg, 87% from **18a**). The compounds **21a** (90%), **20b** (96%) and **21b** (94%) were prepared in the same manner as described above.

20a: Colorless needles (ether–hexane). mp 91—93 °C; $[\alpha]_D^{23}$ +208.8° (c=1.07, MeOH); UV λ_{max}(EtOH) nm: 236; IR ($CHCl_3$) cm^{-1}: 3604, 3480 (OH), 1729 (OAc), 1661 (conj. CO), 1627 (C=C); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 1.00, 1.08 (each 3H, s, *gem*-Me), 1.33 (3H, d, J=6.5 Hz, 9-Me), 1.89 (3H, d, J=1 Hz, 5-Me), 2.05 (3H, s, OAc), 2.25, 2.44 (each 1H, d, J=17 Hz, 2-H_2), 5.38 (1H, m, 9-H), 5.79 (2H, m, 7-H, 8-H), 5.92 (1H, quint., J=1 Hz, 4-H); EI-MS *m/z*: 266.1518 [Calcd for $C_{15}H_{22}O_4$ (M^+) 266.1517]. *Anal.* Calcd for $C_{15}H_{22}O_4$: C, 67.64; H, 8.33. Found: C, 67.67; H, 8.31.

21a: Colorless needles (ether–hexane). mp 92—93 °C; $[\alpha]_D^{23}$ −120.8° (c=1.01, MeOH); UV λ_{max}(EtOH) nm: 236; IR ($CHCl_3$) cm^{-1}: 3605, 3468 (OH), 1731 (OAc), 1662 (conj. CO), 1627 (C=C); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 1.00, 1.08 (each 3H, s, *gem*-Me), 1.33 (3H, d, J=6.5 Hz, 9-Me), 1.89 (3H, d, J=1 Hz, 5-Me), 2.05 (3H, s, OAc), 2.25, 2.40 (each 1H, dd, J=17 Hz, 2-H_2), 5.38 (1H, m, 9-H), 5.78 (2H, m, 7-H, 8-H), 5.92 (1H, br s, J=1 Hz, 4-H); EI-MS *m/z*: 266.1511 [Calcd for $C_{15}H_{22}O_4$ (M^+) 266.1517]. *Anal.* Calcd for $C_{15}H_{22}O_4$: C, 67.64; H, 8.33. Found: C, 67.68; H, 8.25.

20b: Colorless needles (ether–hexane). mp 91—92 °C; $[\alpha]_D^{23}$ +117.1° (c=0.98, MeOH); EI-MS *m/z*: 266.1529 [Calcd for $C_{15}H_{22}O_4$ (M^+) 266.1517]. *Anal.* Calcd for $C_{15}H_{22}O_4$: C, 67.64; H, 8.33. Found: C, 67.50; H, 8.21. UV, IR and ^{1}H-NMR spectra were identical with compound **21a**.

21b: Colorless needles (ether–hexane). mp 91—92 °C; $[\alpha]_D^{23}$ −221.6° (c=1.00, MeOH); EI-MS *m/z*: 266.1523 [Calcd for $C_{15}H_{22}O_4$ (M^+) 266.1517]. *Anal.* Calcd for $C_{15}H_{22}O_4$: C, 67.64; H, 8.33. Found: C, 67.46; H, 8.25. UV, IR and ^{1}H-NMR spectra were identical with compound **20a**.

Methanolysis of Compounds 20a, b and 21a, b A solution of NaOMe (0.5 M in MeOH; 1.65 ml; 0.83 mmol) was added to a solution of the acetate **20a** (440 mg, 1.65 mmol) in MeOH (15 ml) at r.t. and the mixture was stirred at r.t. for 1.5 h. To this mixture was added Dowex 50W-X8 (H^+) (1.2 g) and stirring continued at r.t. for a further 15 min. After Dowex was filtered off, the filtrate was evaporated to give a residue, which was purified by SCC (acetone–hexane, 1 : 2) to give the alcohol **1** [(6*S*,9*R*)-vomifoliol] (315 mg, 85%). The compounds **2** (98%), **3** (96%) and **4** (94%) were prepared in the same manner as described above.

(6*S*,9*R*)-Vomifoliol **1**: Colorless needles (acetone–hexane). mp 107—109 °C; $[\alpha]_D^{24}$ +214.1° (c=0.64, MeOH); UV λ_{max}(EtOH) nm: 237; CD (c=0.0021, MeOH) $\Delta\varepsilon$ (λ nm): −2.5 (205), 0 (209), +16.3 (241), 0 (290), −0.9 (320), 0 (370); IR ($CHCl_3$) cm^{-1}: 3606, 3453 (OH), 1662 (conj. CO); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 1.02, 1.08 (each 3H, s, *gem*-Me), 1.29 (3H, d, J=6.5 Hz, 9-Me), 1.90 (3H, s, 5-Me), 2.23, 2.44 (each 1H, d, J=17.5 Hz, 2-H_2), 4.40 (1H, qd, J=6.5, 5 Hz, 9-H), 5.78 (1H, d, J=16 Hz, 7-H), 5.85 (1H, dd, J=16, 5 Hz, 8-H), 5.90 (1H, br s, 4-H); CI-MS *m/z*: 225.1494 [Calcd for $C_{13}H_{21}O_3$ (MH^+) 225.1490]. *Anal.* Calcd for $C_{13}H_{20}O_3$: C, 69.61; H, 8.99. Found: C, 69.54; H, 9.25.

(6*R*,9*R*)-Vomifoliol **2**: A colorless oil. $[\alpha]_D^{23}$ −195.8° (c=0.95, MeOH); UV λ_{max}(MeOH) nm (ε): 237 (11,500); UV λ_{max}(EtOH) nm: 237; CD (c=0.0019, MeOH) $\Delta\varepsilon$ (λ nm): +2.8 (205), 0 (209), −17.2 (242), 0 (290), +0.9 (320), 0 (370); IR ($CHCl_3$) cm^{-1}: 3607, 3442 (OH), 1661 (conj. CO); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 1.00, 1.07 (each 3H, s, *gem*-Me), 1.30 (3H, d, J=6.5 Hz, 9-Me), 1.91 (3H, s, 5-Me), 2.23, 2.45 (each 1H, d, J=17 Hz, 2-H_2), 4.41 (1H, quint.-like, J=6 Hz, 9-H), 5.77 (1H, d, J=15.5 Hz, 7-H), 5.87 (1H, dd, J=15.5, 5 Hz, 8-H), 5.90 (1H, br s, 4-H); CI-MS *m/z*: 225.1491 [Calcd for $C_{13}H_{21}O_3$ (MH^+) 225.1490].

(6*S*,9*S*)-Vomifoliol **3**: A colorless oil. $[\alpha]_D^{23}$ +197.8° (c=0.80, MeOH); CD (c=0.0021, MeOH) $\Delta\varepsilon$ (λ nm): −2.5 (205), 0 (209), +16.5 (241), 0 (287), −0.9 (320), 0 (370); CI-MS *m/z*: 225.1491 [Calcd for $C_{13}H_{21}O_3$ (MH^+) 225.1490]. UV, IR and ^{1}H-NMR spectra were identical with compound **2**.

(6*R*,9*S*)-Vomifoliol **4**: Colorless needles (acetone–hexane). mp 108—109 °C; $[\alpha]_D^{24}$ −205.2° (c=0.80, MeOH); CD (c=0.0019, MeOH) $\Delta\varepsilon$ (λ nm): +2.6 (205), 0 (209), −16.5 (241), 0 (290), +0.9 (320), 0 (370); CI-MS *m/z*: 225.1476 [Calcd for $C_{13}H_{21}O_3$ (MH^+) 225.1490]. *Anal.* Calcd for $C_{13}H_{20}O_3$: C, 69.61; H, 8.99. Found: C, 69.75; H, 9.11. UV, IR and ^{1}H-NMR spectra were identical with compound **1**.

***β*-Glucosidation of Alcohols 1—4** To a stirred suspension of tetra-*O*-pivaloyl-*α*-D-glucosyl bromide **24**[20] (1.75 g, 3.13 mmol), (6*S*,9*R*)-alcohol **1** (350 mg, 1.46 mmol), *N*,*N*-tetramethylurea (0.67 ml, 5.6 mmol) and powdered molecular sieves 4 Å (4.5 g) in dry CH_2Cl_2 (20 ml) was added AgOTf (1.20 g, 4.7 mmol) at 0 °C. After being stirred at 0 °C for 20 min and r.t. for 1.5 h, the reaction was quenched with saturated aq. $NaHCO_3$. The reaction mixture was diluted with AcOEt and filtered through Celite. The organic layer of the filtrate was washed with brine, dried and evaporated to give a residue which was purified by CC (CH_2Cl_2–hexane–acetone, 4 : 4 : 1) to afford the *β*-glucoside **22a** (610 mg, 57%) as a colorless foam. The compounds **23a** (42%), **22b** (83%) and **23b** (85%) were prepared in the same manner as described above.

22a: $[\alpha]_D^{24}$ +56.8° (c=0.99, MeOH); UV λ_{max}(EtOH) nm: 237; IR ($CHCl_3$) cm^{-1}: 3515 (OH), 1740 (COO), 1662 (conj. CO), 1624 (C=C); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 1.03, 1.09 (each 3H, s, *gem*-Me), 1.11, 1.15, 1.16, 1.23 (each 9H, s, *tert*-Bu×4), 1.21 (3H, d, J=6.5 Hz, 9-Me), 1.88 (3H, d, J=1 Hz, 5-Me), 2.24, 2.44 (each 1H, d, J=17 Hz, 2-H_2), 3.65 (1H, ddd, J=10, 4, 2 Hz, 5′-H), 3.94 (1H, dd, J=12.5, 4 Hz, 6′-H), 4.26 (1H, qd, J=6.5, 5 Hz, 9-H), 4.38 (1H, dd, J=12.5, 2 Hz, 6′-H), 4.61 (1H, d, J=8 Hz, 1′-H), 5.00 (1H, dd, J=9.5, 8 Hz, 2′-H), 5.14 (1H, t, J=9.5 Hz, 4′-H), 5.30 (1H, t, J=9.5 Hz, 3′-H), 5.74 (1H, d, J=15.5 Hz, 7-H), 5.80 (1H, dd, J=15.5, 5 Hz, 8-H), 5.88 (1H, br s, 4-H); SI-MS *m/z*: 745.4141 [Calcd for $C_{39}H_{62}O_{12}Na$ (M^++Na) 745.4136].

23a: $[\alpha]_D^{28}$ −64.8° (c=0.94, MeOH); UV λ_{max}(EtOH) nm: 236; IR ($CHCl_3$) cm^{-1}: 3603, 3524 (OH), 1740 (COO), 1662 (conj. CO), 1626 (C=C); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.98, 1.07 (each 3H, s, *gem*-Me), 1.11, 1.14, 1.15, 1.23 (each 9H, s, *tert*-Bu×4), 1.22 (3H, d, J=6.5 Hz, 9-Me), 1.90 (3H, d, J=1 Hz, 5-Me), 2.24, 2.42 (each 1H, d, J=17 Hz, 2-H_2), 3.68 (1H, ddd, J=10, 4.5, 2 Hz, 5′-H), 3.98 (1H, dd, J=12.5, 4.5 Hz, 6′-H), 4.31 (1H, qd, J=6.5, 4.5 Hz, 9-H), 4.33 (1H, dd, J=12.5, 2 Hz, 6′-H), 4.62 (1H, d, J=8 Hz, 1′-H), 5.01 (1H, dd, J=9.5, 8 Hz, 2′-H), 5.14 (1H, t, J=9.5 Hz, 4′-H), 5.31 (1H, t, J=9.5 Hz, 3′-H), 5.75 (1H, d, J=15.5 Hz, 7-H), 5.83 (1H, dd, J=15.5, 4.5 Hz, 8-H), 5.89 (1H, br s, 4-H); SI-MS *m/z*: 745.4137 [Calcd for $C_{39}H_{62}O_{12}Na$ (M^++Na) 745.4136].

22b: $[\alpha]_D^{24}$ +63.3° (c=0.77, MeOH); UV λ_{max}(EtOH) nm: 236; IR ($CHCl_3$) cm^{-1}: 3604, 3528 (OH), 1740 (COO), 1664 (conj. CO), 1623 (C=C); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 0.99, 1.08 (each 3H, s, *gem*-Me), 1.11, 1.15, 1.16, 1.21 (each 9H, s, *tert*-Bu×4), 1.29 (3H, d, J=6.5 Hz, 9-Me), 1.94 (3H, d, J=1 Hz, 5-Me), 2.28, 2.41 (each 1H, d, J=17 Hz, 2-H_2), 3.61 (1H, ddd, J=10, 6.5, 2 Hz, 5′-H), 4.02 (1H, dd, J=12, 6.5 Hz, 6′-H), 4.22 (1H, dd, J=12, 2 Hz, 6′-H), 4.36 (1H, quint.-like, J=6.5 Hz, 9-H), 4.53 (1H, d, J=8 Hz, 1′-H), 4.99 (1H, dd, J=9.5, 8 Hz, 2′-H), 5.09 (1H, t, J=9.5 Hz, 4′-H), 5.26 (1H, t, J=9.5 Hz, 3′-H), 5.65 (1H, dd, J=16, 5.5 Hz, 8-H), 5.71 (1H, d, J=16 Hz, 7-H), 5.92 (1H, br s, 4-H); SI-MS *m/z*: 745.4128 [Calcd for $C_{39}H_{62}O_{12}Na$ (M^++Na) 745.4136].

23b: $[\alpha]_D^{27}$ −53.1° (c=1.04, MeOH); UV λ_{max}(EtOH) nm: 235; IR ($CHCl_3$) cm^{-1}: 3605, 3514 (OH), 1740 (COO), 1665 (conj. CO), 1626 (C=C); ^{1}H-NMR δ (300 MHz, $CDCl_3$): 1.04, 1.10 (each 3H, s, *gem*-Me), 1.11, 1.14, 1.16, 1.22 (each 9H, s, *tert*-Bu×4), 1.27 (3H, d, J=6.5 Hz, 9-Me), 1.89 (3H, d, J=1 Hz, 5-Me), 2.26 (1H, dd, J=17, 0.5 Hz, 2-H), 2.40 (1H, d, J=17 Hz, 2-H), 3.65 (1H, ddd, J=10, 6, 2 Hz, 5′-H), 4.04 (1H, dd, J=12.5, 6 Hz, 6′-H), 4.22 (1H, dd, J=12.5, 2 Hz, 6′-H), 4.37 (1H, quint.-like, J=6.5 Hz, 9-H), 4.59 (1H, d, J=8 Hz, 1′-H), 4.98 (1H, dd, J=9.5, 8 Hz, 2′-H), 5.09 (1H, t, J=9.5 Hz, 4′-H), 5.28 (1H, t, J=9.5 Hz, 3′-H), 5.58 (1H, dd, J=16, 7.5 Hz, 8-H), 5.72 (1H, d, J=16 Hz, 7-H), 5.91 (1H, br s, 4-H); SI-MS *m/z*: 745.4136 [Calcd for $C_{39}H_{62}O_{12}Na$ (M^++Na) 745.4136].

Methanolysis of Tetrapivalates 22a, b and 23a, b To a solution of the tetrapivalate **22a** (320 mg, 044 mmol) in MeOH (15 ml) was added LiOH·H_2O (47 mg, 1.12 mmol) and the mixture was stirred at r.t. for 24 h. To this mixture was added Dowex 50W-X8 (H^+) (1.5 g) and stirring continued at r.t. for a further 15 min. After Dowex was filtered off, the filtrate was evaporated to give a residue, which was purified by SCC (CH_2Cl_2–MeOH, 85 : 15) to yield the pentaol **5** [(6*S*,9*R*)-roseoside] (135 mg, 83%) as a colorless foam. The compounds **6** (89%), **7** (83%) and **8** (85%) were prepared in the same manner as described above.

(6*S*,9*R*)-Roseoside **5**: $[\alpha]_D^{19}$ +109.4° (c=0.96, MeOH); UV λ_{max} (MeOH) nm (ε): 237 (11600); UV λ_{max} (EtOH) nm: 237; CD (c=0.0032, MeOH) $\Delta\varepsilon$ (λ nm): −3.2 (205), 0 (210), +16.1 (241), 0 (297), −0.7 (323), 0 (360); ^{1}H-NMR δ (500 MHz, CD_3OD): 1.03, 1.04 (each 3H, s, *gem*-Me), 1.29 (3H, d, J=6.5 Hz, 9-Me), 1.92 (3H, d, J=1.5 Hz, 5-Me), 2.15, 2.52 (each 1H, d, J=17 Hz, 2-H_2), 3.17 (1H, dd, J=9, 8 Hz, 2′-H), 3.22 (1H, m, 5′-H), 3.25 (1H, t, J=9 Hz, 4′-H), 3.33 (1H, t, J=9 Hz, 3′-H), 3.62 (1H, dd, J=12, 5.5 Hz, 6′-H), 3.85 (1H, dd, J=12, 2.5 Hz, 6′-H), 4.34 (1H, d, J=8 Hz, 1′-H), 4.42 (1H, m, 9-H), 5.86 (2H, m, 7-H, 8-H), 5.87 (1H, quint.-like, J=1.5 Hz, 4-H); ^{13}C-NMR δ (125 MHz, CD_3OD) 19.59 (5-CH_3), 21.22 (9-CH_3), 23.47 (1-CH_3), 24.73 (1-CH_3), 42.47 (C1), 50.74 (C2), 62.88 (C6′), 71.70 (C4′), 75.29 (C2′), 77.32 (C9), 78.08 (C5′), 78.16 (C3′), 80.04 (C6), 102.79 (C1′), 127.22 (C4), 131.58 (C7), 135.33 (C8), 167.29 (C5), 201.23 (C3); SI-MS *m*/*z*: 409.1850 [Calcd for $C_{19}H_{30}O_8Na$ (M^++Na) 409.1836].

(6*R*,9*R*)-Roseoside **6**: $[\alpha]_D^{27}$ −116.0° (c=0.79, MeOH); UV λ_{max} (EtOH) nm: 237; CD (c=0.0036, MeOH) $\Delta\varepsilon$ (λ nm): +2.4 (205), 0 (209), −16.0 (241), 0 (283), +0.9 (320), 0 (370); ^{1}H-NMR δ (500 MHz, CD_3OD): 1.00, 1.03 (each 3H, s, *gem*-Me), 1.30 (3H, d, J=6.5 Hz, 9-Me), 1.92 (3H, d, J=1 Hz, 5-Me), 2.16, 2.51 (each 1H, d, J=17 Hz, 2-H_2), 3.16 (1H, dd, J=9, 8 Hz, 2′-H), 3.20 (1H, ddd, J=9, 5.5, 2.5 Hz, 5′-H), 3.29 (1H, t, J=9 Hz, 4′-H), 3.33 (1H, t, J=9 Hz, 3′-H), 3.65 (1H, dd, J=12, 5.5 Hz, 6′-H), 3.81 (1H, dd, J=12, 2.5 Hz, 6′-H), 4.33 (1H, d, J=8 Hz, 1′-H), 4.44 (1H, qdd, J=6.5, 3.5, 1.5 Hz, 9-H), 5.85 (2H, m, 7-H, 8-H), 5.88 (1H, quint., J=1 Hz, 4-H); ^{13}C-NMR δ (125 MHz, CD_3OD): 19.74 (5-CH_3), 21.16 (9-CH_3), 23.43 (1-CH_3), 24.60 (1-CH_3), 42.46 (C1), 50.78 (C2), 62.62 (C6′), 71.45 (C4′), 75.24 (C2′), 76.90 (C9), 77.97 (C5′), 78.03 (C3′), 79.97 (C6), 102.59 (C1′), 127.11 (C4), 131.67 (C7), 135.11 (C8), 167.36 (C5), 201.26 (C3); SI-MS *m*/*z*: 409.1839 [Calcd for $C_{19}H_{30}O_8Na$ (M^++Na) 409.1836].

(6*S*,9*S*)-Roseoside **7**: $[\alpha]_D^{25}$ +74.0° (c=0.96, MeOH); UV λ_{max} (EtOH) nm: 237; CD (c=0.0037, MeOH) $\Delta\varepsilon$ (λ nm): −3.9 (205), 0 (210), +17.4 (241), 0 (290), −0.8 (320), 0 (367); ^{1}H-NMR δ (500 MHz, CD_3OD): 1.01, 1.04 (each 3H, s, *gem*-Me), 1.29 (3H, d, J=6.5 Hz, 9-Me), 1.94 (3H, d, J=1 Hz, 5-Me), 2.17, 2.61 (each 1H, d, J=17 Hz, 2-H_2), 3.14 (1H, ddd, J=8.5, 6, 2.5 Hz, 5′-H), 3.19 (1H, dd, J=8.5, 7.5 Hz, 2′-H), 3.24 (1H, t, J=8.5 Hz, 4′-H), 3.28 (1H, t, J=8.5 Hz, 3′-H), 3.63 (1H, dd, J=12, 6 Hz, 6′-H), 3.85 (1H, dd, J=12, 2.5 Hz, 6′-H), 4.27 (1H, d, J=7.5 Hz, 1′-H), 4.53 (1H, quint.-like, J=6.5 Hz, 9-H), 5.73 (1H, dd, J=15.5, 7.5 Hz, 8-H), 5.87 (1H, quint, J=1 Hz, 4-H), 5.97 (1H, dd, J=15.5, 1 Hz, 7-H); ^{13}C-NMR δ (125 MHz, CD_3OD): 19.60 (5-CH_3), 22.29 (9-CH_3), 23.52 (1-CH_3), 24.74 (1-CH_3), 42.47 (C1), 50.80 (C2), 62.88 (C6′), 71.72 (C4′), 74.67 (C9), 75.00 (C2′), 78.25 (C5′), 78.41 (C3′), 80.05 (C6), 100.29 (C1′), 127.17 (C4), 134.74, 133.81 (C7, C8), 167.15 (C5), 201.30 (C3); SI-MS *m*/*z*: 409.1835 [Calcd for $C_{19}H_{30}O_8Na$ (M^++Na) 409.1836].

(6*R*,9*S*)-Roseoside **8**: $[\alpha]_D^{26}$ −157.5° (c=0.80, MeOH); UV λ_{max} (EtOH) nm: 237; CD (c=0.0038, MeOH) $\Delta\varepsilon$ (λ nm): +4.2 (205), 0 (211), −17.3 (240), 0 (285), +0.9 (320), 0 (370); ^{1}H-NMR δ (500 MHz, CD_3OD): 1.04, 1.05 (each 3H, s, *gem*-Me), 1.28 (3H, d, J=6.5 Hz, 9-Me), 1.92 (3H, d, J=1 Hz, 5-Me), 2.18, 2.54 (each 1H, d, J=17 Hz, 2-H_2), 3.19 (1H, m, 5′-H), 3.19 (1H, dd, J=9, 8 Hz, 2′-H), 3.24 (1H, t, J=9 Hz, 4′-H), 3.29 (1H, t, J=9 Hz, 3′-H), 3.63 (1H, dd, J=12, 6 Hz, 6′-H), 3.87 (1H, dd, J=12, 2 Hz, 6′-H), 4.31 (1H, d, J=8 Hz, 1′-H), 4.53 (1H, quint.-like, J=7 Hz, 9-H), 5.70 (1H, dd, J=15.5, 8 Hz, 8-H), 5.86 (1H, br s, 4-H), 5.95 (1H, d, J=15.5 Hz, 7-H); ^{13}C-NMR δ (125 MHz, CD_3OD): 19.39 (5-CH_3), 22.22 (9-CH_3), 23.47 (1-CH_3), 24.84 (1-CH_3), 42.36 (C1), 50.66 (C2), 62.90 (C6′), 71.76 (C4′), 74.70 (C9), 75.00 (C2′), 78.12 (C5′), 78.25 (C3′), 79.98 (C6), 100.91 (C1′), 127.20 (C4), 133.80 (C8), 134.12 (C7), 166.90 (C5), 201.09 (C3); SI-MS *m*/*z*: 409.1830 [Calcd for $C_{19}H_{30}O_8Na$ (M^++Na) 409.1836].

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References

1) Galbraith M. N., Horn D. H. S., *J. Chem. Soc., Chem. Commun.*, **1972**, 113—114 (1972).
2) Takasugi M., Anetai M., Katsui N., Masamune T., *Chem. Lett.*, **1973**, 245—248 (1973).
3) Bhakuni D. S., Joshi P. P., Uprety H., Kapil R. S., *Phytochemistry*, **13**, 2541—2543 (1974).
4) Achenbach H., Waibel R., Raffelsberger B., Addae-Mensah I., *Pytochemistry*, **20**, 1591—1595 (1981).
5) Otsuka H., Yao M., Kamada K., Takeda Y., *Chem. Pharm. Bull.*, **43**, 754—759 (1995).
6) Yoshikawa M., Shimada H., Saka M., Yoshizumi S., Yamahara J., Matsuda H., *Chem. Pharm. Bull.*, **45**, 464—469 (1997).
7) Murai Y., Kashimura S., Tamezawa S., Hashimoto T., Takaoka S., Asakawa Y., Kiguchi K., Murai F., Tagawa M., *Planta Med.*, **67**, 480—481 (2001).
8) Wahlberg I., Eklund A.-M., "Carotenoids Volume 3: Biosynthesis and Metabolism," Chap. 4, ed. by Britton G., Liaaen-Jensen S., Pfander H., Birkhäuser Verlag, Basel, 1998, pp. 195—216.
9) Yamano Y., Watanabe Y., Watanabe N., Ito M., *Chem. Pharm. Bull.*, **48**, 2017—2018 (2000).
10) Yamano Y., Watanabe Y., Watanabe N., Ito M., *J. Chem. Soc., Perkin Trans. 1*, **2002**, 2833—2844 (2002).
11) Matsumura K., Hashiguchi S., Ikariya T., Noyori R., *J. Am. Chem. Soc.*, **119**, 8738—8739 (1997).
12) Heckman R. A., Roberts D. L., *Tetrahedron Lett.*, **1969**, 2701—2704 (1969).
13) Demole E., Enggist P., *Helv. Chim. Acta*, **57**, 2087—2091 (1974).
14) Mayer H., *Pure Appl. Chem.*, **51**, 535—564 (1979).
15) Ito N., Etoh T., Hagiwara H., Kato M., *J. Chem. Soc., Perkin Trans. 1*, **1997**, 1571—1579 (1997).
16) Yamano Y., Tode C., Ito M., *J. Chem. Soc., Perkin Trans. 1*, **1998**, 2569—2581 (1998).
17) Haack K.-J., Hashiguchi S., Fujii A., Ikariya T., Noyori R., *Angew. Chem., Int. Ed. Engl.*, **36**, 285—288 (1997).
18) Yamano Y., Ito M., *J. Chem. Soc., Perkin Trans. 1*, **1993**, 1599—1610 (1993).
19) Weiss G., Koreeda M., Nakanishi K., *J. Chem. Soc., Chem. Commun.*, **1973**, 565—566 (1973).
20) Kunz H., Harreus A., *Liebigs Ann. Chem.*, **1982**, 41—48 (1982).