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Chemical and Chemotaxonomical Studies of Filices. LIII.[1] Chemical Studies on the Constituents of *Dipteris conjugata* REINW.

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Three new *ent*-kaurane-type diterpenes, I, II and III, were isolated from the fronds of *Dipteris conjugata* REINW. Their structures were elucidated as 16β,17-dihydroxy-*ent*-kauran-19-oic acid, 16β,17-dihydroxy-19-nor-*ent*-kauran-18-oic acid and 16β,17,18-trihydroxy-*ent*-kauran-19-oic acid, respectively.

Keywords——*Dipteris conjugata*; Dipteridaceae; fern; *ent*-kaurane; nor-*ent*-kaurane; ^{13}C-NMR; structure elucidation; chemotaxonomy

We have isolated many *ent*-kaurane-type diterpenes from several genera of Pteridaceae.[2] In a continuation of our studies, three new *ent*-kaurane-type diterpenes, I, II and III, were isolated from the fronds of *Dipteris conjugata* REINW. (Japanese name: Yaburegasauraboshi, Dipteridaceae). This is the first time that *ent*-kaurane-type diterpenes have been isolated from a fern belonging to a family other than Pteridaceae. In this paper, we report the structure elucidation of these compounds.

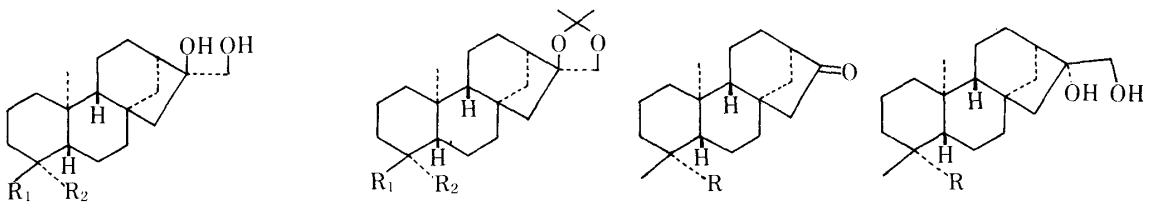
Compound I, colorless needles, mp 285—290 °C, $[\alpha]_D^{25}$ −70° (c=1.0, C_5H_5N), was formulated as $C_{20}H_{32}O_4$ by elemental analysis. Compound I showed infrared (IR) absorption bands due to a carboxyl group (ν_{max}^{KBr}: 3200, 1695 cm^{-1}) and hydroxyl groups (3350, 1175, 1075 cm^{-1}). In the ^{13}C-nuclear magnetic resonance (^{13}C-NMR) spectrum of I in C_5D_5N (Table I), one sp^2-carbon signal and nineteen sp^3-carbon signals were observed. Among them, signals assignable to a carboxyl carbon (δ 180.0 s), a primary and a tertiary carbon bearing a hydroxyl or an ether oxygen (δ 70.4 t, 79.7 s) and two methyl carbons (δ 29.4 q, 16.0 q) were identified. In the ^{1}H-nuclear magnetic resonance (^{1}H-NMR) spectrum of I in C_5D_5N, methylene proton signals corresponding to the signal at δ 70.4 in the ^{13}C-NMR spectrum were observed at δ 3.75 (1H, d, J=11 Hz) and 3.83 (1H, d, J=11 Hz), together with two methyl signals at δ 1.22 (3H, s) and 1.35 (3H, s). Compound I gave a monomethyl ester IV, mp 178—179 °C, $[\alpha]_D^{20}$ −69° (c=0.5, $CHCl_3$), on treatment with methyl iodide and potassium carbonate in acetone and a monoacetonide VIII, mp 268 °C, $[\alpha]_D^{20}$ −71° (c=0.5, $CHCl_3$), on treatment with acetone and sulfuric acid. Based on these results, I was characterized as a tetracyclic diterpene bearing a carboxyl group, a terminal 1,2-glycol system and two tertiary methyl groups. To confirm the structure, I was oxidized with $NaIO_4$, yielding a nor-ketone XIV, mp 238—240 °C, $[\alpha]_D^{20}$ −68° (c=0.9, $CHCl_3$). Compound XIV was identified as 17-nor-16-oxo-*ent*-kauran-19-oic acid by direct comparison with an authentic sample derived from microlepin (XVI).[3] Therefore, the structure of I was considered to be either 16α,17- or 16β,17-

dihydroxy-*ent*-kauran-19-oic acid. Though the former (XVII) and its glucoside have been isolated from several plants,[4] its properties and spectral data were not identical with those of I. In the ^{13}C-NMR spectra, the chemical shifts of the A- and B-ring carbons of I are similar to those of XVII, but the chemical shifts of the C- and D-ring carbons are similar rather to those of 16β,17-dihydroxy-*ent*-kaurane (V)[5] (see Table I). Thus, the structure of I was determined as 16β,17-dihydroxy-*ent*-kauran-19-oic acid.

Table I. ^{13}C Chemical Shifts in C_5D_5N

	I	XVII[5]	V[5]	II	III	$\delta_{III}-\delta_I$
C-1	41.2	41.1	40.6	39.3	40.9	
C-2	19.8	19.8	19.2	20.7	19.4	
C-3	38.6[a]	38.7	42.3	30.9	32.9	−5.7
C-4	43.9	43.9	33.3	45.2	50.4	+6.5
C-5	57.1[b]	57.0	56.2	49.3	51.3	−5.8
C-6	22.5	22.9	20.4	24.4	22.2	
C-7	42.5	42.7	42.3	41.0	42.2	
C-8	43.9	44.9	43.9	43.7	43.7	
C-9	56.7[b]	56.3	57.6	55.1	56.7	
C-10	40.1	40.0	39.6	38.4	39.8	
C-11	19.4	18.9	18.0	19.0	19.4	
C-12	27.6	26.8	27.7	27.4	27.5	
C-13	41.6	45.8	41.9	41.6	41.5	
C-14	38.7[a]	37.8	38.7	38.7	38.5	
C-15	53.4	53.9	53.6	53.3	53.1	
C-16	79.7	81.6	79.7	79.7	79.8	
C-17	70.4	66.4	70.5	70.3	70.3	
C-18	29.4	29.3	33.7	178.9	70.3	+40.9
C-19	180.0	180.1	21.8	—	179.0	−1.0
C-20	16.0	16.0	17.8	15.1	16.1	

a, *b*) Assignments with the same superscript may be reversed, although those given here are preferred.



I: $R_1=CH_3$, $R_2=COOH$
II: $R_1=COOH$, $R_2=H$
III: $R_1=CH_2OH$, $R_2=COOH$
IV: $R_1=CH_3$, $R_2=COOCH_3$
V: $R_1=R_2=CH_3$
VI: $R_1=COOCH_3$, $R_2=H$
VII: $R_1=CH_2OH$, $R_2=COOCH_3$

VIII: $R_1=CH_3$, $R_2=COOH$
IX: $R_1=COOH$, $R_2=H$
X: $R_1=COOCH_3$, $R_2=H$
XI: $R_1=CH_2OH$, $R_2=H$
XII: $R_1=CH_2Cl$, $R_2=H$
XIII: R_1, $R_2=CH_2=$

XIV: R=COOH
XV: $R=CH_2OH$

XVI: $R=CH_2O$-(4-*O*-methyl-β-D-glucosyl)
XVII: R=COOH

Chart 1

Compound II, colorless needles, mp 225—230 °C, $[\alpha]_D^{25}$ −39° ($c=1.0$, C_5H_5N), was formulated as $C_{19}H_{30}O_4$ by elemental analysis, suggesting it to be a nor-diterpene. Compound II showed an IR spectrum similar to that of I and formed a monomethyl ester (VI), mp 87—90 °C, $[\alpha]_D^{25}$ −36° ($c=1.0$, $CHCl_3$), and a monoacetonide (IX), mp 221—222 °C, $[\alpha]_D^{25}$ −35°

($c=2.0$, $CHCl_3$), indicating the presence of a carboxyl and a 1,2-glycol system. The presence of only one methyl group in II was suggested by the ^{1}H-NMR ($\delta_{C_5D_5N}$ 0.95, 3H, s) and ^{13}C-NMR ($\delta_{C_5D_5N}$ 15.1, q) spectra. Further, the ^{13}C-NMR spectrum of II indicated a close relationship between I and II (see Table I), suggesting that the only structural difference between them is the lack of a methyl group at C-4 in II. The chemical correlation of these compounds was achieved as follows. The acetonide of II (IX) was methylated to give a methyl ester X by treatment with methyl iodide and potassium carbonate in acetone. Compound X was reduced to an alcohol XI with $LiAlH_4$ and the hydroxyl group of XI was chlorinated with $SOCl_2$ in pyridine to yield XII. Dehydrochlorination of XII with hexamethyl phosphoryl triamide[6] gave an *exo*-methylene compound XIII, mp 70—71 °C, $[\alpha]_D^{20}$ −122° ($c=1.0$, $CHCl_3$). The properties and spectral data of XIII were identical with those of the main product of oxidative decarboxylation of VIII (acetonide of I) with $Pb(OAc)_4$.[7] The result limited the structure of II to either 16β,17-dihydroxy-18-nor-*ent*-kauran-19-oic acid or 16β,17-dihydroxy-19-nor-*ent*-kauran-18-oic acid. To determine the configuration at C-4, Narayanan's method[8] was applied. As shown in Table II, the C-10 methyl signal of II appeared at almost the same position as that of VI (methyl ester of II)[9] in the ^{1}H-NMR spectrum in C_5D_5N solution, so that the carboxyl group at C-4 was determined to be equatorial. Thus, the structure of II was established as 16β,17-dihydroxy-19-nor-*ent*-kauran-18-oic acid.

TABLE II. ^{1}H Chemical Shifts of the C-10 Methyl Group in I—IV, VI and VII in C_5D_5N

Carboxylic acid	I	II	III
(A)	1.22	0.95	1.25
Methyl ester	IV	VI	VII
(E)	0.93	0.92	1.02
$\delta_A-\delta_E$	+0.29	+0.03	+0.23

Compound III, colorless prisms, mp 265—270 °C, $[\alpha]_D^{20}$ −78° ($c=1.0$, C_5H_5N), was formulated as $C_{20}H_{32}O_5$ by elemental analysis. The IR spectrum of III indicated that the structure of III is analogous to that of I. Compound III formed a monomethyl ester VII, mp 212—217 °C, $[\alpha]_D^{25}$ −35° ($c=0.1$, $CHCl_3$), and a monoacetonide XVIII, mp 267—268 °C, $[\alpha]_D^{20}$ −86° ($c=1.5$, MeOH). A comparison of the ^{1}H-NMR spectrum of III with that of I revealed the presence of one more primary hydroxyl group [$\delta_{C_5D_5N}$ 3.95 (1H, d, $J=10$ Hz), 4.33 (1H, d, $J=10$ Hz)] in place of a methyl group. The ^{13}C-NMR signals of III appeared at almost the same positions as those of I, except for C-3, C-4, C-5, C-18 and C-19 (see Table I). The differences of chemical shifts between I and III indicated the presence of a hydroxyl group at C-18 in III. To confirm the structure of III, XVIII (acetonide of III) was oxidized with CrO_3 in pyridine. The resulting aldehyde (XIX) was too labile to isolate, and underwent decarboxylation to give an aldehyde XX. Further oxidation of XX yielded the acetonide of II (IX). As the decarboxylation of a β-aldehyde-acid such as XIX occurs *via* the enol, the carboxyl group of II was considered to occupy the more energetically favorable equatorial position. This consideration is in accord with the aforementioned results. On the other hand, the presence of an axial carboxyl group at C-4 of III was confirmed by application of Narayanan's method, that is, the methyl proton signal in the ^{1}H-NMR spectrum of III appeared at lower field by 0.23 ppm than that of the methyl ester VII (see Table II). Accordingly, the structure of III was determined as 16β,17,18-trihydroxy-*ent*-kauran-19-oic acid.

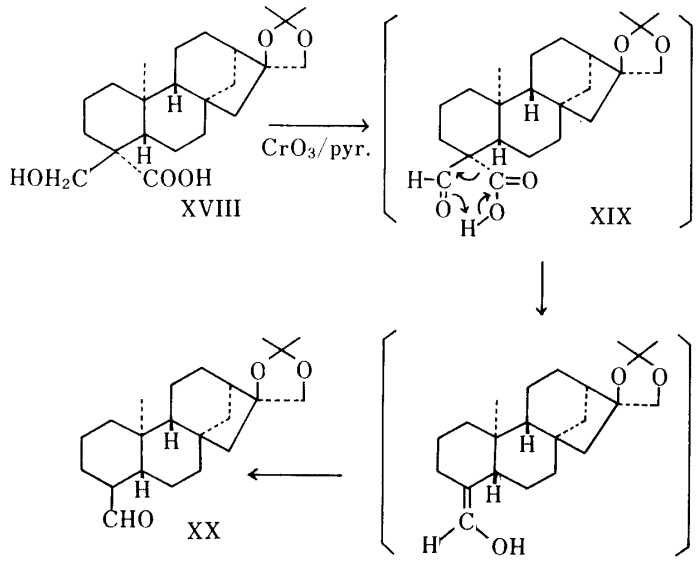


Chart 2

Experimental

The instruments, materials and experimental conditions were the same as described in Part XXXVII[2] of this series.

Isolation Procedure——The air-dried fronds (650 g) of *Dipteris conjugata* REINW., collected in March at Ishigakijima-Island, Okinawa prefecture, were extracted three times with 3 l of methanol under reflux for 6 h. The combined extracts (9 l) and then 10 l of methanol were passed over activated charcoal (70 g) packed in a column of 5 cm diameter. The resulting solution (19 l) was concentrated to a syrup under reduced pressure. The syrup was chromatographed three times on silica gel using $CHCl_3$ and methanol as eluents, yielding 130 mg of I, 120 mg of II and 30 mg of III.

Compound I [=16β,17-Dihydroxy-*ent*-kauran-19-oic Acid]——Colorless needles from MeOH, mp 285—290 °C, $[\alpha]_D^{25}$ −70° (c=1.0, C_5H_5N). IR ν_{max}^{KBr} cm^{-1}: 3350, 3200, 2945, 2845, 1695, 1245, 1175, 1075, 1025, 790. ^{1}H-NMR (100 MHz, in C_5D_5N) δ: 1.22 (3H, s), 1.35 (3H, s), 3.75 (1H, d, J=11 Hz), 3.83 (1H, d, J=11 Hz). MS m/z: 305 ($M^+ - CH_2OH$), 287, 259, 241. *Anal.* Calcd for $C_{20}H_{32}O_4$: C, 71.39; H, 9.59. Found: C, 71.22; H, 9.70.

Compound II [=16β,17-Dihydroxy-19-nor-*ent*-kauran-18-oic Acid]——Colorless needles from MeOH, mp 225—230 °C, $[\alpha]_D^{25}$ −39° (c=1.0, C_5H_5N). IR ν_{max}^{KBr} cm^{-1}: 3370, 2950, 2875, 1725, 1710, 1445, 1215, 1165, 1070, 1035, 925, 700, 670. ^{1}H-NMR (100 MHz, in C_5D_5N) δ: 0.95 (3H, s), 3.70 (1H, d, J=11 Hz), 3.80 (1H, d, J=11 Hz). MS m/z: 291 ($M^+ - CH_2OH$), 273, 245, 227. *Anal.* Calcd for $C_{19}H_{30}O_4$: C, 70.77; H, 9.38. Found: C, 70.75; H, 9.52.

Compound III [=16β,17,18-Trihydroxy-*ent*-kauran-19-oic Acid]——Colorless prisms from MeOH, mp 265—270 °C, $[\alpha]_D^{25}$ −78° (c=1.0, C_5H_5N). IR ν_{max}^{KBr} cm^{-1}: 3350, 2950, 2870, 1695, 1455, 1245, 1030. ^{1}H-NMR (100 MHz, in C_5H_5N) δ: 1.25 (3H, s), 3.74 (1H, d, J=11 Hz), 3.81 (1H, d, J=11 Hz), 3.95 (1H, d, J=10 Hz), 4.33 (1H, d, J=10 Hz). MS m/z: 334 ($M^+ - H_2O$), 321, 303, 285, 257. *Anal.* Calcd for $C_{20}H_{32}O_5$: C 68.15; H, 9.15. Found: C, 68.05; H, 9.31.

Methyl Ester of I (IV)——I (10 mg) was suspended in a mixture of anhydrous acetone (15 ml) and CH_3I (10 ml), and anhydrous K_2CO_3 was added. The mixture was stirred for 5 h under reflux, then cooled. The precipitates were filtered off and the filtrate was evaporated to dryness under reduced pressure. The residue was dissolved in EtOAc. The solution was washed with water, dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The residue was crystallized from benzene to yield 8 mg of IV. Colorless needles, mp 178—179 °C, $[\alpha]_D^{20}$ −69° (c=0.5, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 3400, 2960, 1725, 1715, 1160. ^{1}H-NMR (60 MHz, in C_5D_5N) δ: 0.93 (3H, s), 1.17 (3H, s), 3.50 (1H, d, J=12 Hz), 3.63 (3H, s), 3.90 (1H, d, J=12 Hz). MS m/z: 332 (M^+), 319, 305, 301, 287, 273, 259, 245, 241.

Acetonide of I (VIII)——A suspension of I (80 mg) in anhydrous acetone (50 mg) containing one drop of concentrated sulfuric acid was stirred for 1 h at room temperarure. The resulting solution was poured into ice-water. The products were extracted with ether. The extract was washed with water, dried over anhydrous Na_2SO_4 and concentrated. The residue was crystallized from EtOH to yield 77 mg of V, colorless needles, mp 268 °C, $[\alpha]_D^{20}$ −70° (c=0.5, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 2960, 2860, 1695, 1375, 1250, 1065. ^{1}H-NMR (60 MHz, $CDCl_3$) δ: 0.96 (3H, s), 1.22 (3H, s), 1.37 (6H, s), 3.59 (1H, d, J=7 Hz), 3.83 (1H, d, J=7 Hz). MS m/z: 376 (M^+), 361, 315, 301, 283, 255.

$NaIO_4$ Oxidation of I——$NaIO_4$ (60 mg) was added to a suspension of I (20 mg) in a mixture of MeOH (20 ml) and water (5 ml). The mixture was stirred for 4 h at room temperature. The resulting solution was poured into ice-water and the products were extracted with ether. The extract was washed with water, dried over anhydrous Na_2SO_4

and concentrated. The residue was crystallized from a mixture of benzene and *n*-hexane to yield 12 mg of XIV, colorless prisms, mp 238—240 °C, $[\alpha]_D^{20}$ −68° (*c*=0.9, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 2970, 1730, 1450, 1245, 1155. ^{1}H-NMR (60 MHz, $CDCl_3$) δ: 1.02 (3H, s), 1.26 (3H, s). MS *m/z*: 304 (M^+), 286, 259, 243. This product was found to be identical with an authentic sample derived from microlepin by direct comparison (thin layer chromatography (TLC), IR and mixed fusion).

Conversion of Microlepin (XVI) into XIV——A solution of $NaIO_4$ (500 mg) in water (5 ml) was added to a solution of microlepin (150 mg) in MeOH (30 ml). The mixture was stirred for 5 h at room temperature. The reaction mixture was poured into ice-water and extracted with EtOAc. The extract was washed with water, dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The residue was dissolved in MeOH (20 ml), and 10% HCl (20 ml) was added. The mixture was refluxed for 3 h and poured into ice-water. The products were extracted with ether. The extract was washed with water, dried over anhydrous Na_2SO_4 and concentrated. The residue was crystallized from a mixture of benzene and *n*-hexane to yield 60 mg of XV, colorless needles, mp 155—156 °C, $[\alpha]_D^{25}$ −30° (*c*=2, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 3370, 2950, 1740, 1035, 1005. ^{1}H-NMR (60 MHz, $CDCl_3$) δ: 0.99 (3H, s), 1.09 (3H, s), 3.44 (1H, d, *J*=10 Hz), 3.74 (1H, d, *J*=10 Hz). MS *m/z*: 290 (M^+), 269.

Ten drops of Jones reagent were added to a solution of XV (50 mg) in acetone (15 ml). The mixture was allowed to stand for 1 h at room temperature, then poured into ice-water. The products were extracted with ether. The extract was washed with water, dried over anhydrous Na_2SO_4 and concentrated. The residue was crystallized from a mixture of benzene and *n*-hexane to yield 25 mg of XIV.

Methyl Ester of II (VI)——II (20 mg) was methylated in the same way as I to yield 12 mg of VI, colorless needles from MeOH, mp 87—90 °C, $[\alpha]_D^{25}$ −36° (*c*=1.0, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 3400, 2950, 1740, 1720, 1160, 1065. ^{1}H-NMR (60 MHz, C_5D_5N): 0.92 (3H, s), 3.50 (1H, d, *J*=18 Hz), 3.65 (3H, s), 3.86 (1H, d, *J*=18 Hz). MS *m/z*: 305 ($M^+ - CH_2OH$), 273, 245.

Acetonide of II (IX)——II (180 mg) was suspended in anhydrous acetone (50 ml) containing one drop of concentrated sulfuric acid. The mixture was stirred for 1 h at room temperature. Usual work-up gave 160 mg of IX, colorless prisms from EtOAc, mp 221—222 °C, $[\alpha]_D^{20}$ −65° (*c*=0.6, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 2940, 1705, 1380, 1370, 1230, 1070, 1005. ^{1}H-NMR (100 MHz, $CDCl_3$) δ: 0.96 (3H, s), 1.35 (3H, s), 1.38 (3H, s), 3.60 (1H, d, *J*=8 Hz), 3.83 (1H, d, *J*=8 Hz). MS *m/z*: 362 (M^+), 347, 287.

Methyl Ester of IX (X)——IX (90 mg) was methylated in the same way as I to yield 70 mg of X, colorless needles from EtOH, mp 155—158 °C, $[\alpha]_D^{25}$ −35° (*c*=2.0, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 2925, 2870, 1735, 1380, 1370, 1205, 1160, 1055. ^{1}H-NMR (60 MHz, $CDCl_3$) δ: 0.97 (3H, s), 1.35 (3H, s), 1.37 (3H, s), 3.57 (1H, d, *J*=8 Hz), 3.63 (3H, s), 3.80 (1H, d, *J*=8 Hz). MS *m/z*: 376 (M^+), 361, 301, 241.

$LiAlH_4$ Reduction of X——$LiAlH_4$ (100 mg) was added to a solution of X (70 mg) in absolute ether (15 ml), and the mixture was refluxed for 2 h. After quenching of the reaction with EtOAc and water-saturated ether, the reaction mixture was poured into ice-water and the products were extracted with EtOAc. The extract was washed with water, dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The residue was crystallized from EtOH to yield 55 mg of XI, colorless needles, mp 120—125 °C, $[\alpha]_D^{25}$ −53° (*c*=1.0, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 3350, 2940, 2860, 1385, 1375, 1260, 1150, 1070, 1005. ^{1}H-NMR (60 MHz, $CDCl_3$) δ: 0.98 (3H, s), 1.37 (3H, s), 1.39 (3H, s), 3,66 (1H, d, *J*=12 Hz), 3.47 (1H, d, *J*=12 Hz), 3.58 (1H, d, *J*=8 Hz), 3.85 (1H, d, *J*=8 Hz). MS *m/z*: 348 (M^+), 333, 273, 255.

Conversion of XI to XII——$SOCl_2$ (0.5 ml) was added to a solution of XI (50 mg) in pyridine (3 ml). The mixture was allowed to stand for 30 h at room temperature, then poured into ice-water. The products were extracted with EtOAc. The extract was washed with 10% HCl and water, dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The residue was chromatographed on silica gel using *n*-hexane as an eluent to yield 22 mg of XII, colorless needles from $CHCl_3$, mp 125—127 °C, $[\alpha]_D^{20}$ −29° (*c*=0.4, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 2930, 1380, 1370, 1255, 1070. ^{1}H-NMR (60 MHz, $CDCl_3$) 0.98 (3H, s), 1.38 (3H, s), 1.39 (3H, s), 3.59 (1H, d, *J*=8 Hz), 3.48 (1H, d, *J*=12 Hz), 3.63 (3H, d, *J*=12 Hz), 3.83 (3H, d, *J*=8 Hz). MS *m/z*: 368 (M^+), 366 (M^+), 353, 351, 293, 291.

Dehydrochlorination of XII——A solution of XII (20 mg) in hexamethyl phosphoryl triamide (10 ml) was heated at 200 °C for 6 h. After cooling, the reaction mixture was poured into ice-water and extracted with EtOAc. The extract was washed with water, dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The residue was crystallized from *n*-hexane to yield 9 mg of XIII, colorless needles, mp 70—71 °C, $[\alpha]_D^{20}$ −122° (*c*=1.0, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 3100, 2950, 1650, 1380, 1370, 1065, 890. ^{1}H-NMR (60 MHz, $CDCl_3$) δ: 0.83 (3H, s), 1.38 (3H, s), 1.39 (3H, s), 3.60 (1H, d, *J*=9 Hz), 3.83 (1H, d, *J*=9 Hz), 4.45 (1H, br s), 4.69 (1H, br s). MS *m/z*: 330 (M^+), 315, 255. This product was shown to be identical with the main product of oxidative decarboxylation of VIII by direct comparison.

Oxidative Decarboxylation of VIII——$Pb(OAc)_4$ (100 mg) and $Cu(OAc)_2 \cdot H_2O$ (6 mg) were added to a solution of VIII (60 mg) in anhydrous benzene (15 ml) and pyridine (0.4 ml). The mixture was stirred at reflux under nitrogen for 4 h, then added to 150 ml of EtOAc and 50 ml of water. Ferrous sulfate was added until the aqueous layer was saturated. The EtOAc layer was washed with 10% HCl solution, 10% Na_2CO_3 solution and water, then dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The residue was chromatographed on silica gel impregnated with 20% of $AgNO_3$ (eluate: 30% $CHCl_3$ in *n*-hexane) to yield 12 mg of XII.

Methyl Ester of III (VII)——III (5 mg) was methylated in the same way as I to yield 3 mg of VII, colorless needles from MeOH, mp 212—217 °C, $[\alpha]_D^{20}$ −35° (*c*=0.1, $CHCl_3$). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3400, 2940, 1725, 1225, 1160, 1010. ^{1}H-

NMR (60 MHz, C_5D_5N) δ: 1.02 (3H, s), 3.57 (1H, d, $J=8$ Hz), 3.66 (3H, s), 3.76 (1H, d, $J=12$ Hz), 3.87 (1H, d, $J=8$ Hz), 4.25 (1H, d, $J=12$ Hz). MS *m/z*: 335 ($M^+ - CH_2OH$), 317, 305, 285, 257.

Acetonide of III (XVIII)——III (30 mg) was converted to its acetonide XVIII (26 mg) in the same way as I. Colorless needles from MeOH, mp 267—268 °C, $[\alpha]_D^{20}$ −86° ($c=1.5$, MeOH). IR ν_{max}^{KBr} cm^{-1}: 3370, 3150, 2940, 2875, 1730, 1385, 1375, 1220, 1160, 1050, 1035. ^{1}H-NMR (60 MHz, CD_3OD) δ: 1.01 (3H, s), 1.37 (6H, s), 3.43 (1H, d, $J=10$ Hz), 3.60 (1H, d, $J=8$ Hz), 3.81 (1H, d, $J=10$ Hz), 3.86 (1H, d, $J=8$ Hz). MS *m/z*: 392 (M^+), 377, 317, 299.

Oxidation of XVIII———XVIII (20 mg) was added to a solution of CrO_3 (100 mg) in pyridine (1 ml). The mixture was allowed to stand at room temperarure for 3 h and poured into ice-water. The products were extracted with ether. The extract was washed with water, dried over anhydrous Na_2SO_4 and concentrated. The residue was subjected to preparative layer chromatography (silica gel; solvent system, $CHCl_3$: ether = 2 : 1) to yield 8 mg of XX, colorless needles from *n*-hexane, mp 72—75 °C, $[\alpha]_D^{25}$ −50° ($c=0.4$, $CHCl_3$). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 2940, 1725, 1385, 1375, 1255, 1070. ^{1}H-NMR (60 MHz, $CDCl_3$) δ: 0.98 (3H, s), 1.36 (3H, s), 1.38 (3H, s), 3.58 (1H, d, $J=8$ Hz), 3.83 (1H, d, $J=8$ Hz), 9.40 (1H, d, $J=5$ Hz). MS *m/z*: 346 (M^+), 331, 303, 271, 243.

Oxidation of XX——XX (5 mg) was added to a solution of CrO_3 (100 mg) in pyridine (1 ml), and the mixture was allowed to stand for 10 h at room temperature. Usual work-up gave 2 mg of IX. Its properties and spectral data were identical with those of IX derived from II.

References and Notes

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9) The methyl ester VI was obtained from II by treatment with methyl iodide and potassium carbonate in acetone as the sole product. It was also obtained from II on treatment with CH_2N_2, although the reaction was very slow owing to the poor solubility of II in ether and methanol. These results indicate that there is no change of inversion of the configuration at C-4 of II under the reaction conditions used.