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TETRAHEDRON

Synthesis of Both the Enantiomers of Methyl Tuberonate, Natural Methyl β-D-Glucopyranosyloxyjasmonate and Its Epimer

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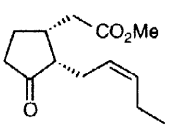
Abstract: Synthesis of both the enantiomers of methyl tuberonate **3**, natural methyl β-D-glucopyranosyloxyjasmonate **6**, and its epimer, methyl β-D-glucopyranosyltuberonate **5** is described. They were synthesized *via* mild deprotection of dichloroacetate and trifluoroacetate by methanolysis from the enantiomerically pure dithiane **9**.

INTRODUCTION



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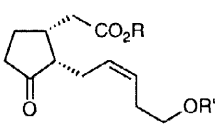
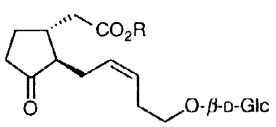


2: R=H, R'=H
3: R=Me, R'=H
4: R=H, R'=β-D-Glc
5: R=Me, R'=β-D-Glc



6: R=Me
7: R=H

Many jasmonoids have been isolated as components of jasmine oil and odor, and plant growth regulators since Demole's discovery of methyl jasmonate in 1962.[1] In 1989, Koda's group isolated tuberonic acid **2** and β-D-glucopyranosyltuberonic acid **4** from *Solanum tuberosum* L. as tuber inducing factors of potato plant.[2] They also isolated methyl β-D-glucopyranosyloxyjasmonate from *Helianthus tuberosus* L. as a similar tuber-inducer and elucidated its structure as **6** in 1993.[3] In 1996, Fujita et al isolated β-D-glucopyranosyloxyjasmonic acid from *Perilla frutescens* and determined its structure as **7** by converting it into its methyl ester derivative **6**.[4]

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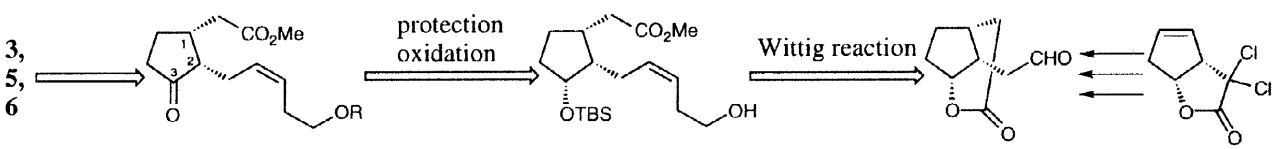
Recently, jasmonoids have been considered not only as perfume but also as plant growth regulators.[5] With the progress of the biological study of jasmonoids, the relation between stereochemistry and bioactivity has been becoming important.[6] Many syntheses of jasmonoids have been reported[7] because of their usefulness in the perfumery industry and their unique biological activity but there were only a little reports of enantiomerically pure synthesis.[8] In our previous paper we described the enantiomerically pure syntheses of methyl epijasmonate **1**[9] and methyl dehydrojasmonate[10] *via* the efficient route. The synthesis of enantioselective jasmonoids should contribute to biological study and determine the absolute configuration. Described herein is synthesis of both the enantiomers of methyl tuberonate **3**,[11] natural methyl β-D-glucopyranosyloxyjasmonate **6** and its epimer **5** by the same strategy.

RESULTS AND DISCUSSION

Synthetic plan.

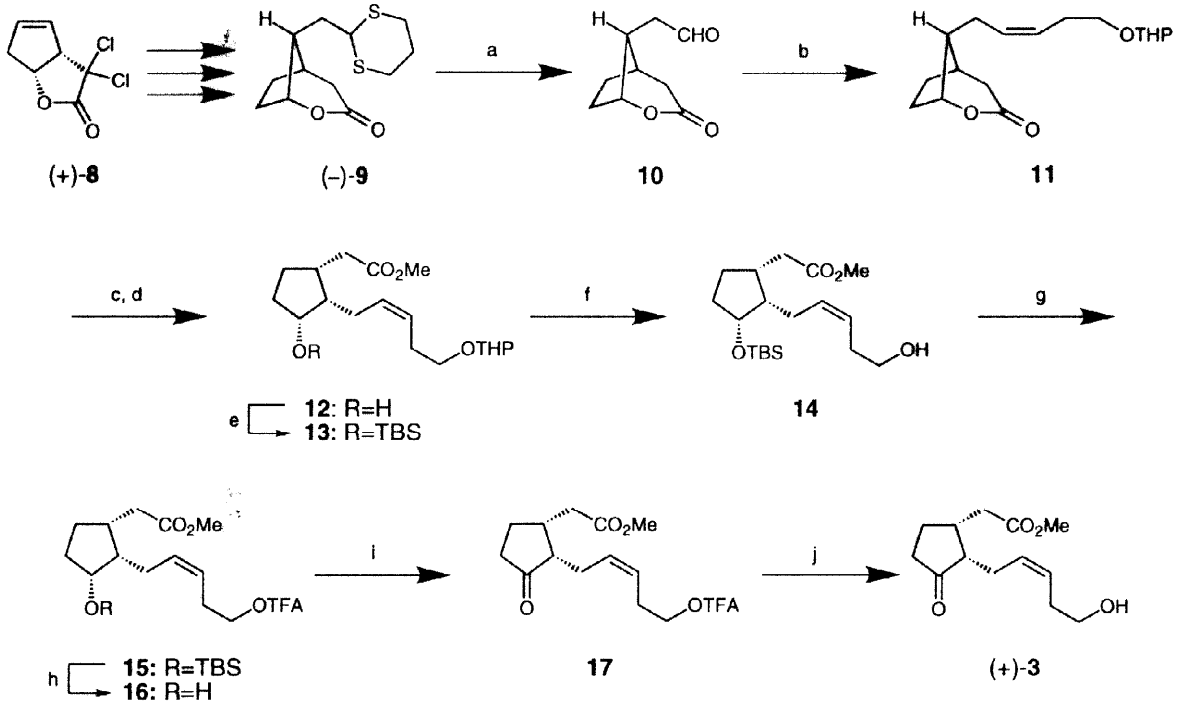
Since the target molecules have two *cis*-substituted groups on the cyclopentanone and C-2 substituent is located adjacent to carbonyl group, they easily epimerize to give more stable *trans*-isomer under both acidic and basic media. So we thought that oxidation of secondary alcohol to cyclopentanone should be done at the final stage of the synthesis and in the case of synthesis of **3** and **5**, it was needed to develop procedure for the removal of protecting group of hydroxy function (**A** to **3** or **5**) after the oxidation step. We chose haloacetyl group as the candidate for the mild deprotection. In the case of **6**, deprotection and isomerization were done at the same time (**A** to **6**). The aldehyde **C** was obtained from the dichlorolactone **8** by our procedure.[9,10] Formation of *cis*-pentenyl side chain by the Wittig reaction should give the common intermediate **B**. And protection of hydroxy function and oxidation should give **A**.



A (R=acyl or tetraacyl glycoside) **B** **C** **8**

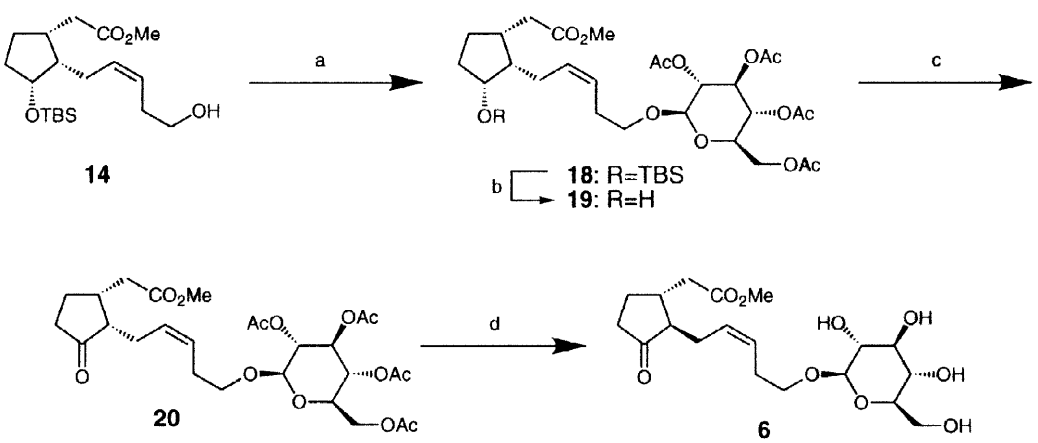
Synthesis of both the enantiomers of methyl tuberonate 3.

The synthesis of methyl tuberonate **3** is shown in **Scheme 1**. We started the synthesis from the enantiomerically pure dithiane **9**, which was the common intermediate for our jasmonoid synthesis and prepared from lactone **8** (99.6%e.e.) by our procedure.[9,10] Hydrolysis of the thioacetal **9** with MeI in phosphate buffer (pH7)-MeCN gave the aldehyde **10**, which was immediately treated with the phosphorane derived from 3-tetrahydropyranyloxypropyltriphenylphosphonium bromide,[12] KHMDS and 18-crown-6 in THF to give a *Z*-olefin **11** (65% from **9**). The stereochemistry of the olefin moiety was proved to be almost 100% *Z*-isomer by ^{1}H-NMR.[13] Alkaline hydrolysis of the bridged lactone moiety of **11** was followed by diazomethane treatment to give a hydroxy ester **12** (99%). The secondary hydroxyl group of **12** was protected as TBS ether to give **13** (99%). In order to remove THP ether thoroughly, it was necessary to treat with 70% acetic acid at 60 °C for 6 hr, and clearly this procedure was shown to be too harsh to retain the *cis*-substituents without epimerization at



Scheme 1

(a)MeI, MeCN-phosphate buffer (pH7), $NaHCO_3$; (b)$Ph_3P^+Br^-CH_2CH_2CH_2OTHP$, KHMDS, 18-c-6, THF, 65% in 2 steps; (c) 2N KOHaq.-MeOH(4:1); (d) CH_2N_2, Et_2O, 99% in 2 steps; (e) TBSCl, imidazole, DMF, 99%; (f) Me_2AlCl, CH_2Cl_2, 78%; (g)TFAA, $NaHCO_3$, DMF; (h) HFaq., MeCN; (i) Dess-Martin reag., CH_2Cl_2, 49% in 3 steps; (j) MeOH, 88%



Scheme 2

(a) tetra-*O*-acetyl α-D-glucopyranosyl bromide, $Hg(CN)_2$, PhH-$MeNO_2$, 72%; (b) HFaq.-MeCN;(c) Dess-Martin reag., CH_2Cl_2, 78% in 2 steps; (d) MeONa, MeOH, 86%

the last step (**A** to **3**). Thus, we had to optimize the deprotection process with proper choice of protecting group. In the case of 1-ethoxyethyl (EE) ether, deprotection was executed under much milder condition with 70% acetic acid at 50 °C for 5 min, but still some epimerization was observed. Next, we tried various acyl groups. In the case of acetate, at least the addition of sodium bicarbonate (catalytic amount) into methanol was essential to remove acetoxy group and even this weakly basic medium caused epimerization almost completely. Therefore, we examined more activated and labile esters, such as monochloroacetate or dichloroacetate, and finally we found trifluoroacetate as the best choice. The optimum procedure is as follows. The selective deprotection of THP ether was completed with Me_2AlCl in CH_2Cl_2 to give the alcohol **14** (78%).[14] The hydroxy group of **14** was protected with trifluoroacetic anhydride and $NaHCO_3$ in DMF to give trifluoroacetate **15**. Deprotection of the TBS group of **15** with 46%HFaq. in MeCN was followed by oxidation with Dess-Martin reagent[15] in CH_2Cl_2 to give the ketone **17** (49% from **14**) without any epimerization at C-2 proton. Finally, deprotection of trifluoroacetyl group of **17** was achieved by stirring the ketone **17** just in pure MeOH (at room temp., 12hr) to give the target compound, (+)-methyl tuberonate (+)-**3** again without any epimerization (88%). The total yield was 21% in 10 steps from (–)-**9**. $[\alpha]_D^{18}$ +33.9 (*c* 0.34, MeOH) In the same manner, the enantiomer, (–)-methyl tuberonate (–)-**3** was synthesized in 31% yields through 10 steps from (+)-**9**.

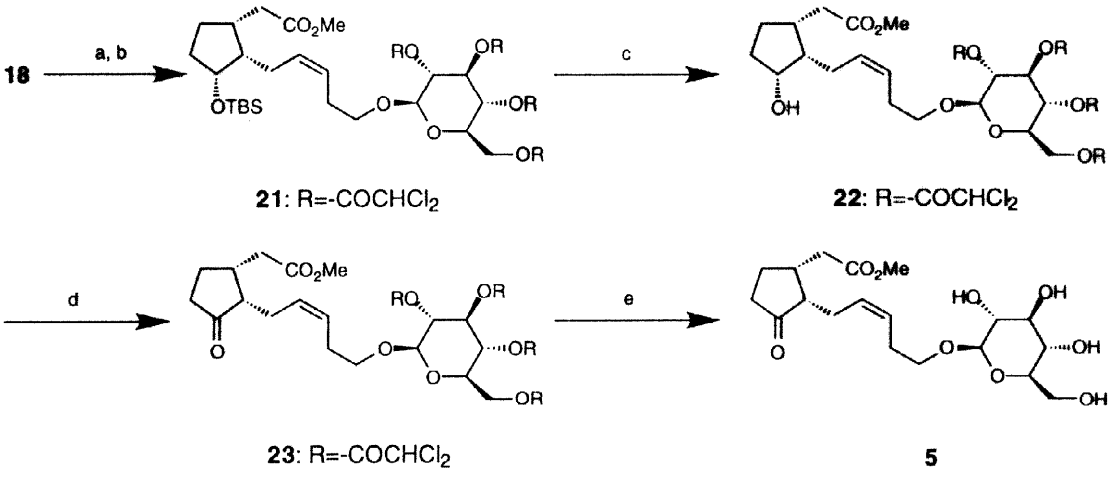
Synthesis of natural methyl β-D-glucopyranosyloxyjasmonate 6

The synthesis of methyl β-D-glucopyranosyloxyjasmonate **6** was executed as follows (**Scheme 2**). Glycosylation of the alcohol **14** was achieved with tetra-*O*-acetyl-α-D-glucopyranosyl bromide and $Hg(CN)_2$ in PhH-$MeNO_2$ to give glycoside **18** (72%).[16] Stereochemistry of the anomeric position was checked by ^{1}H-NMR and it proved that β-glycoside was obtained (J_{H1H2}=8.1Hz). Deprotection of TBS group of **18** with 46% HFaq. in MeCN was followed by oxidation with Dess-Martin reagent in CH_2Cl_2 to give the ketone **20** (78% from **14**) without any epimerization. Finally the deprotection of acetyl group of **20** was achieved with MeONa in MeOH (at r.t., 1hr) to give natural methyl β-D-glucopyranosyloxyjasmonate **6** (86%). The total yield was 22% in 10 steps from (–)-**9**. $[\alpha]_D^{18}$ –51.2 (*c* 0.34, EtOH); Lit[3], $[\alpha]_D^{22}$ –52.5 (*c* 0.08, EtOH)

Synthesis of methyl β-D-glucopyranosyltuberonate 5, epimer of 6.

At first, we tried to deprotect the acetyl groups of **20** under mild condition (KCN or $NaHCO_3$ in MeOH) to obtain the compound **5**, deprotection was occured easily but we obatined only *trans*-isomer, that is, **6** *via* complete epimerization. In order to prevent this epimerization, it was again necessary to explore milder condition using protecting group to be removed easier than acetyl group. In this case, we found dichloroacetate as the best choice. The optimum procedure is as follows (**Scheme 3**). Treatment of **18** with MeONa in MeOH followed by protection with dichroloacetyl chloride and pyridine in CH_2Cl_2 gave tetrakis-*O*-dichloroacetyl glycoside **21**. Removal of TBS group of **21** with 46%HFaq. in MeCN followed by oxidation with Dess-Martin reagent in CH_2Cl_2 gave the ketone **23** (27% from **18**) without any epimerization. Finally, deprotection of dichloroacetyl group of **23** was achieved by stirring **23** in MeOH (at room temp., 24 hr) to give the target compound, methyl β-D-glucopyranosyltuberonate **5**, (86%) without any epimerization. The total yield was 8% in 12 steps from (–)-**9**. $[\alpha]_D^{18}$ –3.22 (*c* 0.27, MeOH)

In conclusion, both the enantiomers of methyl tuberonate **3**, natural methyl β-D-glucopyranosyl-oxyjasmonate **6**, and its epimer, methyl β-D-glucopyranosyltuberonate **5** were efficiently synthesized in completely stereoselective manner from the common intermediate **9**.



Scheme 3

(a) MeONa, MeOH; (b) $CHCl_2COCl$, pyr., CH_2Cl_2; (c) HFaq.-MeCN, 32% in 3 steps; (d) Dess-Martin reag., CH_2Cl_2, 85%; (e) MeOH, 86%

We are investigating the physiological activity of those synthetic substances as a plant growth regulator and the result will be published in due course.

EXPERIMENTAL

Melting points were determined on a YANACO micro melting point apparatus. Infrared spectra were measured with a Jasco IRA-102 or FT/IR-230 spectrometer. ^{1}H-NMR spectra were recorded in $CDCl_3$ or CD_3OD on a JEOL JNM EX-90 or a Bruker AC-300 NMR spectrometer with tetramethylsilane or chloroform or methanol as an internal standard. Mass spectra were recorded with a JASCO JMS-SX102/SX102 tandem mass spectrometer. Optical rotations were measured with a Jasco DIP-1000 polarimeter. Column chromatography was performed on Merck Kieselgel 60, Art No. 7734 or 7754.

(1*R*,5*R*,8*S*)-8-(5-2'-Tetrahydropyranyloxy-*cis*-2-pentenyl)-2-oxabicyclo[3.2.1]octan-3-one (11). To a stirred solution of lactone **9** (1.169 g, 4.52 mmol) in MeCN and phosphate buffer (pH7, 50 ml, 4:1) was added MeI (6.40 g, 45.1 mmol) at 0°C. The mixture was stirred for 8 hr at 40 °C by adding $NaHCO_3$ in portion to neutraize. The reaction mixture was diluted with H_2O and extracted with EtOAc. The extract was washed with satd. $NaHCO_3$ and brine, dried over $MgSO_4$ and concentrated under vacuum. The residue was chromatographed over silica gel to give aldehyde **10** (698 mg, 4.15 mmol). To a solution of **10** (690 mg, 4.10 mmol) in dry THF (10 ml) was added a THF solution (52.5 ml) of 3-tetrahydropyranyloxypropyl-triphenylphosphorane prepared from 3-tetrahydropyranyloxypropyltriphenylphosphonium bromide (5.5 g, 11.3 mmol), KHMDS (5.9 ml, 9.7 mmol, 1.65 mol/l in tol), 18-crown-6 (8.46 g, 32 mmol) and THF (80 ml) at −50 °C under Ar. The mixture was stirred for 1 hr at −50 °C, then poured into ice-water and extracted with Et_2O. The extract was washed with satd. NH_4Claq., satd. $NaHCO_3$aq. and brine, dried over $MgSO_4$ and concentrated under vacuum. The residue was chromatographed over silica gel to give **11** (887 mg, 65%).

Similarly, *ent*-**9** (661 mg, 2.56 mmol) gave *ent*-**11** (565 mg, 75%).

11: $[\alpha]_D^{20}$ –40.4 (*c* 1.00, MeOH); IR ν_{max} (film) 3020(m), 1740(s), 1660(m), 1420(m), 1140(s); ^{1}H-NMR δ(90MHz, $CDCl_3$) 1.48~2.45 (17H, m), 2.78 (1H, m), 3.37~3.55 (2H, m), 3.70~3.91 (2H, m), 4.55~4.66 (2H, m), 5.47~5.65 (2H, m); Anal. calcd for $C_{17}H_{26}O_4$: C, 69.36; H, 8.90. Found: C, 69.07; H, 8.91. *ent*-**11**: $[\alpha]_D^{21}$ +40.1 (*c* 0.90, MeOH); Anal. calcd for $C_{17}H_{26}O_4$: C, 69.36; H, 8.90. Found: C, 69.36; H, 9.00.; IR and ^{1}H-NMR spectra were identical with those of **11**.

Methyl (1*R*,2*S*,3*R*)-3-hydroxy-2-(5-2'-tetrahydopyranyloxy-*cis*-2-pentenyl)-1-cyclopentaneacetate (12). A solution of **11** (1.10 g, 3.74 mmol) in 2N KOHaq.-MeOH (2.5 ml, 4:1) was stirred for 4 hr at room temp. The solution was neutralized with 1N HClaq and extracted with Et_2O. The extract was dried over $MgSO_4$ and the residue was immediately treated with diazomethane in the usual manner and then chromatographed over silica gel to give the hydroxy ester **12** (1.21 g, 99%).

Similarly, *ent*-**11** (251 mg, 0.85 mmol) gave *ent*-**12** (265 mg, 95%).

12: $[\alpha]_D^{19}$ –4.70 (*c* 1.03, MeOH); IR ν_{max} (film) 3490(s), 2946(m), 1738(s), 1652(m), 1120(s); ^{1}H-NMR δ(90MHz, $CDCl_3$) 1.45~2.60 (19H, m), 3.20~4.00 (4H, m), 3.65 (3H, s), 4.13 (1H, m), 4.56 (1H, m), 5.20~5.60 (2H, m); Anal. calcd for $C_{18}H_{30}O_5$: C, 66.23; H, 9.26. Found: C, 65.94; H, 9.19. *ent*-**12**: $[\alpha]_D^{19}$ +4.81 (*c* 1.03, MeOH); Anal. calcd for $C_{18}H_{30}O_5$: C, 66.23; H, 9.26. Found: C, 65.87; H, 9.19.; IR and ^{1}H-NMR spectra were identical with those of **12**.

Methyl (1*R*,2*S*,3*R*)-3-*t*-butyldimethylsilyloxy-2-(5-2'-tetrahydropyranyloxy-*cis*-2-pentenyl)-1-cyclopentaneacetate (13). To a stirred solution of **12** (649 mg, 1.99 mmol) in DMF (25 ml) was added TBSCl (754 mg, 5.0 mmol) and imidazole (1.09 g, 16.0 mmol) at 0 °C. The mixture was stirred at 40 °C over night, then diluted with H_2O and extracted with Et_2O. The extract was washed with 1N HClaq., satd. $NaHCO_3$aq. and brine, dried over $MgSO_4$ and concentrated under vacuum. The residue was chromatographed over silica gel to give **13** (868 mg, 99%).

Similarly, *ent*-**12** (210 mg, 0.64 mmol) gave *ent*-**13** (255 mg, 90%).

13: $[\alpha]_D^{20}$ –6.73 (*c* 1.00, MeOH); IR ν_{max} (film) 2952(s), 1739(s), 1650(m), 1253(s), 1120(s); ^{1}H-NMR δ(300MHz, $CDCl_3$) 0.02 (3H, s), 0.03 (3H, s), 0.88 (9H, s), 1.48~1.91 (11H, m), 2.14 (2H, d, *J*=7.2Hz), 2.33~2.52 (5H, m), 3.35~3.55 (2H, m), 3.64 (3H, s), 3.73 (1H, dt, *J*=9.4, 7.2Hz), 3.87 (1H, m), 4.13 (1H, m), 4.58 (1H, m), 5.33~5.56 (2H, m); Anal. calcd for $C_{24}H_{44}O_5Si$: C, 65.41; H, 10.06. Found: C, 65.52; H, 10.06. *ent*-**13**: $[\alpha]_D^{20}$ +6.34 (*c* 1.05, MeOH); Anal. calcd for $C_{24}H_{44}O_5Si$: C, 65.41; H, 10.06. Found: C, 65.38; H, 9.98; IR and ^{1}H-NMR spectra were identical with those of **13**.

Methyl (1*R*,2*S*,3*R*)-3-*t*-butyldimethylsilyloxy-2-(5-hydroxy-*cis*-2-pentenyl)-1-cyclopentaneacetate (14). To a stirred solution of **13** (771 mg, 1.75 mmol) in CH_2Cl_2 (25 ml) was added Me_2AlCl (3.3 ml, 3.50 mmol, 1.05 mol/l in hexane) at –10°C. The mixture was stirred for 4 hr at room temp., then diluted with H_2O and extracted with EtOAc. The extract was washed with satd. $NaHCO_3$aq. and brine, dried over $MgSO_4$ and concentrated under vacuum. The residue was chromatographed over silica gel to give **14** (485 mg, 78%).

Similarly, *ent*-**13** (250 mg, 0.57 mmol) gave *ent*-**14** (141 mg, 70%).

14: $[\alpha]_D^{18}$ –9.35 (*c* 1.00, MeOH); IR ν_{max} (film) 3450(s), 3020(m), 1740(s), 1650(w), 1255(s), 1170(s),

1040(s); ^{1}H-NMR δ(300MHz, $CDCl_3$) 0.03 (3H, s), 0.04 (3H, s), 0.88 (9H, s), 1.50~2.50 (12H, m), 3.65 (2H, t, *J*=6.8Hz), 3.65 (3H, s), 4.14 (1H, m), 5.37 (1H, dtt, *J*=10.7, 1.5, 7.4Hz), 5.58 (1H, dtt, *J*= 10.7, 7.5, 1.4Hz); Anal. calcd for $C_{19}H_{36}O_4Si$: C, 64.00; H, 10.18. Found: C, 64.04; H, 10.17. *ent*-**14**: $[\alpha]_D^{20}$ +9.37 (*c* 1.00, MeOH); Anal. calcd for $C_{19}H_{36}O_4Si$: C, 64.00; H, 10.18. Found: C, 63.90; H, 10.17.; IR and ^{1}H-NMR spectra were identical with those of **14**.

Methyl (1*R*,2*S*)-2-(5-hydroxy-*cis*-2-pentenyl)-3-oxo-1-cyclopentaneacetate (3). (Methyl Tuberonate). A solution of **14** (24 mg, 0.067 mmol) in DMF (1 ml) was added trifluoroacetic anhydride (44 mg, 0.21 mmol) and $NaHCO_3$ (67 mg, 0.80 mmol) at 0 °C. The mixture was stirred at room temp. over night, then diluted with Et_2O. The organic layer was washed with cold 1/2N HClaq., half satd. $NaHCO_3$aq. and brine, dried over $MgSO_4$ and concentrated under vacuum. The residue was chromatographed over silica gel to give **15** (21 mg). To a stirred solution of **15** (21 mg, 0.046 mmol) in MeCN (1 ml) was added 46%HFaq. (20 mg) at 0 °C. The reaction mixture was stirred for 1 hr at 0 °C, diluted with H_2O and extracted with EtOAc. The extract was washed with half satd. $NaHCO_3$aq. and brine, dried over $MgSO_4$ and concentrated under vacuum. The residue was chromatographed over silica gel to give **16** (12 mg). To a stirred solution of **16** (12 mg, 0.035 mmol) in CH_2Cl_2 (1 ml) was added Dess-Martin periodinate (30 mg, 0.071 mmol) at 0 °C. The reaction mixture was stirred for 40 min. at room temp., diluted with Et_2O and washed with 15% $Na_2S_2O_3$aq., satd. $NaHCO_3$aq. and brine, dried over $MgSO_4$ and concentrated under vacuum. The residue was chromatographed over silica gel to give **17** (11 mg, 49% from **14**).

17: IR ν_{max} (film) 2956(s), 1789 (s) 1733(s), 1221(m), 1154(m); ^{1}H-NMR δ(300MHz, $CDCl_3$) 1.83 (1H, m), 2.00~2.55 (10H, m), 2.85 (1H, m), 3.69 (3H, s), 4.35 (2H, t, *J*=6.8Hz), 5.42 (1H, m), 5.61 (1H, m).

This trifuluoroacetyl ester **17** was so labile that it was immediately used for the next reaction. A solution of **17** (11 mg, 0.033 mmol) in MeOH (150 ml) was stirred at room temp. over night. The reaction mixture was concentrated under vacuum. The residue was chromatographed over silica gel to give (+)-methyl tuberonate **3** (7 mg, 88%).

Similarly, *ent*-**14** (15 mg, 0.044 mmol) gave (–)-methyl tuberonate *ent*-**3**(7 mg, 70%).

3: $[\alpha]_D^{18}$ +33.9 (*c* 0.45, MeOH); IR ν_{max} (film) 3450(s), 3040(m), 1745(s), 1730(s), 1655(m); ^{1}H-NMR δ(300MHz, $CDCl_3$) 1.71 (1H, bs), 1.82 (1H, m), 1.98~2.50 (10H, m), 2.83 (1H, m), 3.65 (2H, t, *J*= 6.3Hz), 3.69 (3H, s), 5.40~5.60 (2H, m); Anal. calcd for $C_{13}H_{20}O_4$: C, 64.98; H, 8.39. Found: C, 64.90; H, 8.50. *ent*-**3**: $[\alpha]_D^{18}$ –33.6 (*c* 0.35, MeOH); Anal. calcd for $C_{13}H_{20}O_4$: C, 64.98; H, 8.39 Found: C, 64.75; H, 8.46.; IR and ^{1}H-NMR spectra were identical with those of **3**.

Methyl (1*R*,2*S*,3*R*)-3-*t*-butyldimethylsilyloxy-2-(5-2',3',4',6'-tetra-*O*-acetyl-β-D-glucopyranosyloxy-*cis*-2-pentenyl)-1-cyclopentaneacetate (18). A solution of **14** (0.89 g, 2.50 mmol) in $MeNO_2$ (50 ml) and PhH(50 ml) was heated at 110 °C and the solvent (80 ml) was removed. To the mixture was added 2',3',4',6'-tetra-*O*-acetyl-α-D-glucopyranosyl bromide (2.07 g, 5.03 mmol) and $Hg(CN)_2$ (1.25 g, 4.95 mmol) at room temp. The mixture was stirred at 80 °C for 4 hr., and then filtered through the celite and the filtrate was concentrated under vacuum. The residue was chromatographed over silica gel to give **18** (1.25 g, 72%).

18: $[\alpha]_D^{18}$ –13.8 (*c* 1.05, MeOH); IR ν_{max} (film) 2954(m), 1758(s), 1655(w), 1225(s), 1170(s), 1039(s); ^{1}H-NMR δ(300MHz, $CDCl_3$) 0.01 (3H, s), 0.02 (3H, s), 0.87 (9H, s), 1.50~2.50 (12H, m), 1.99 (3H, s), 2.00 (3H, s), 2.01 (3H, s), 2.04 (3H, s), 3.47 (1H, dt, *J*=9.3, 7.2Hz), 3.64 (3H, s), 3.67 (1H, m), 3.88

(1H, m), 4.12 (2H, m), 4.25 (1H, dd, *J*=4.5, 12.2Hz), 4.49 (1H, d, *J*=8.1Hz), 4.97 (1H, dd, *J*=8.1, 9.7Hz), 5.07 (1H, t, *J*=9.7Hz), 5.19 (1H, t, *J*=9.7Hz), 5.31 (1H, m), 5.46 (1H, m); HRMS: Calcd for $C_{33}H_{54}O_{13}Si$ (M+) 686.3333, found 686.3384.

Methyl (1*R*,2*S*)-3-oxo-2-(5-2',3',4',6'-tetra-*O*-acetyl-β-D-glucopyranosyloxy-*cis*-2-pentenyl)-1-cyclopentaneacetate (20). To a stirred solution of **18** (32 mg, 0.047 mmol) in MeCN (1 ml) was added 46%HFaq. (20 mg) at 0 °C. The mixture was stirred for 50 min. at 0 °C., diluted with H_2O and extracted with EtOAc. The extract was washed with half satd. $NaHCO_3$aq. and brine, dried over $MgSO_4$ and concentrated under vacuum. The residue was chromatographed over silica gel to give **19** (24 mg). To a stirred solution of **19** (22 mg, 0.038 mmol) in CH_2Cl_2 (1 ml) was added Dess-Martin periodinate (24 mg, 0.056 mmol) at 0°C. The reaction mixture was stirred for 40 min. at room temp., diluted with H_2O and extracted with Et_2O. The extract was washed with 15% $Na_2S_2O_3$aq., satd. $NaHCO_3$aq. and brine, dried over $MgSO_4$ and concentrated under vacuum. The residue was chromatographed over silica gel to give **20** (19 mg, 78% from **18**).

20: $[\alpha]_D^{19}$ +2.16 (*c* 0.90, MeOH); IR ν_{max} (film) 2954(m), 1756(s), 1730(s), 1650(w), 1130(s); ^{1}H-NMR δ(300MHz, $CDCl_3$) 1.82 (1H, m), 1.93~2.49 (10H, m), 2.00 (3H, s), 2.02 (3H, s), 2.04 (3H, s), 2.07 (3H, s), 2.85(1H, m), 3.47 (1H, dt, *J*=9.3, 7.0Hz), 3.69 (3H, s), 3.69 (1H, m), 3.88 (1H, dt, *J*=9.3, 6.5Hz), 4.13 (1H, dd, *J*=2.3, 12.3Hz), 4.27 (1H, dd, *J*=4.6, 12.3Hz), 4.50 (1H, d, *J*=8.1Hz), 4.97 (1H, dd, *J*=9.4, 8.1Hz), 5.07 (1H, t, *J*=9.4Hz), 5.20 (1H, t, *J*=9.4Hz), 5.41 (2H, m); HRMS: Calcd for $C_{27}H_{38}O_{13}$ (M+) 570.2312, found 570.2293.

Methyl (1*R*,2*S*)-2-(5-β-D-Glucopyranosyloxy-*cis*-2-pentenyl)-3-oxo-1-cyclopentaneacetate (6). (Methyl β-D-Glucopyranosyloxyjasmonate) A solution of **20** (12 mg, 0.014 mmol) in MeOH (5 ml) was added NaOMe at 0 °C and stirred at room temp for 1 hr. Amberlyst 15 was added to the reaction mixture and stirred for 5 min at room temp. The reaction mixture was filtered through celite and washed with MeOH. The filtrate was concentrated under vacuum and the residue was chromatographed over silica gel to give **6** (5 mg, 86%).

6: $[\alpha]_D^{18}$ –51.2 (*c* 0.34, EtOH); IR ν_{max} (film) 3895(m), 2927(m), 1740 (s), 1730(s), 1160 (m); ^{1}H-NMR δ(300MHz, CD_3OD) 1.55 (1H, m), 1.95~2.48 (10H, m), 2.73 (1H, dd, *J*=4.0, 14.8Hz), 3.17 (1H, dd, *J*=7.9, 8.6Hz), 3.21~3.40 (3H, m), 3.56 (1H, dt, *J*=9.6, 7.0Hz), 3.67 (1H, m), 3.68 (3H, s), 3.80~3.95 (2H, m), 4.28 (1H, d, *J*=7.9Hz), 5.41 (1H, dt, *J*=10.9, 7.3Hz), 5.52 (1H, dt, *J*=10.9, 7.1Hz); HRMS: Calcd for $C_{19}H_{31}O_9$ (M+H) 403.1968, found 403.1939.

Methyl (1*R*,2*S*)-3-oxo-2-(5-2',3',4',6'-tetrakis-*O*-dichloroacetyl-β-D-glucopyranosyloxy-*cis*-2-pentenyl)-1-cyclopentaneacetate (23). To a solution of **18** (50 mg, 0.088 mmol) in MeOH (2 ml) was added MeONa (5 mg). The mixture was stirred at room temp. for 4 hr. Amberlyst 15 was added to the reaction mixture. The mixture was stirred for 10 min., and then filtered with celite. The filtrate was concentrated under vacuum to give crude tetra-ol (37 mg). To a solution of crude tetra-ol (37 mg) in CH_2Cl_2 (1.5 ml) was added pyridine (0.4 ml) and dichloroacetyl chloride (176 mg, 1.19 mmol) at 0 °C. The mixture was stirred for 4 hr at room temp., then diluted with Et_2O. The organic layer was washed with cold 1/2N HClaq., half satd. $NaHCO_3$aq. and brine, dried over $MgSO_4$ and concentrated under vacuum. The residue was filtrated with silica gel to give crude **21**. To a stirred solution of crude **21** in MeCN (1 ml) was added 46%HFaq. (20 mg) at 0 °C.

The mixture was stirred for 50 min. at 0 °C., diluted with H_2O and extracted with EtOAc. The extract was washed with half satd. $NaHCO_3$aq. and brine, dried over $MgSO_4$ and concentrated under vacuum. The residue was chromatographed over silica gel to give **22** (24 mg, 32% from **18**). **22** was so labile that it was immediately used for next reaction. To a stirred solution of **22** (22 mg, 0.026 mmol) in CH_2Cl_2 (1 ml) was added Dess-Martin periodinate (24 mg, 0.056 mmol) at 0 °C. The mixture was stirred for 40 min. at room temp., diluted with H_2O and extracted with Et_2O. The extract was washed with 15% $Na_2S_2O_3$aq., satd. $NaHCO_3$aq. and brine, dried over $MgSO_4$ and concentrated under vacuum. The residue was chromatographed over silica gel to give **23** (19 mg, 85%).

23: $[\alpha]_D^{18}$+8.97 (*c* 0.43, $CHCl_3$); IR ν_{max} (film) 2955(s), 1768(s), 1731(s), 1160(m); ^{1}H-NMR δ(300MHz, $CDCl_3$) 1.81 (1H, m), 1.95~2.46 (10H, m), 2.84 (1H, m), 3.54 (1H, dt, *J*=9.3, 6.8Hz), 3.70 (3H, s), 3.87 (1H, dt, *J*=9.3, 6.8Hz), 3.96(1H, ddd, *J*=2.4. 4.7, 9.7Hz), 4.40 (1H, dd, *J*=4.7, 12.3Hz), 4.47 (1H, dd, *J*=2.4, 12.3Hz), 4.68 (1H, d, *J*=7.9Hz), 5.14 (1H, dd, *J*=7.9, 9.7Hz), 5.27 (1H, t, *J*=9.7Hz), 5.31~5.57 (2H, m), 5.54 (1H, t, *J*=9.7Hz), 5.87 (1H, s), 5.92(1H, s), 5.95 (1H, s), 6.03 (1H, s); HRMS: Calcd for $C_{27}H_{31}Cl_8O_{13}$ (M+H) 842.9272, found 842.9277.

Methyl (1*R*,2*S*)-2-(5-β-D-glucopyranosyloxy-*cis*-2-pentenyl)-3-oxo-1-cyclopentaneacetate (5). (Methyl β-D-Glucopyranosyltuberonate) A solution of **23** (12 mg, 0.014 mmol) in MeOH (5 ml) was stirred at room temp over night. The reaction mixture was concentrated under vacuum and the residue was chromatographed over silica gel to give **5** (5 mg, 86%).

5: $[\alpha]_D^{18}$–3.22 (*c* 0.27, MeOH); IR ν_{max} (film) 3417(m), 2924(m), 1740 (s), 1732(s), 1645 (w), 1166 (m); ^{1}H-NMR δ(300MHz, CD_3OD) 1.77 (1H, m), 1.95~2.47 (10H, m), 2.75 (m, 1H), 3.11 (1H, t, *J*=8.3Hz), 3.20~3.35 (3H, m), 3.57 (1H, m), 3.62 (1H, m), 3.63 (3H, s), 3.71~3.85 (2H, m), 4.25 (1H, d, *J*=7.7Hz), 5.35~5.53 (2H, m); HRMS: Calcd for $C_{19}H_{31}O_9$ (M+H) 403.1968, found 403.1981.

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