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# Structure and Synthesis of Miyaginin, a *p*-Allylphenyl Glycoside from *Lespedeza thunbergii* forma *macrantha*

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The structure of miyaginin previously reported as *p*-vinylphenyl *O*-D-xylosyl-(1→6)-D-glucoside without stereochemical assignment of two glycosidic linkages was reinvestigated by spectral and chemical means and shown to be revised as *p*-allylphenyl *O*-$\beta$-D-xylopyranosyl-(1→6)-$\beta$-D-glucopyranoside (*p*-allylphenyl $\beta$-primeveroside). In order to confirm the revised structure, an unambiguous synthesis of miyaginin was performed.

Miyaginin was first isolated from *Lespedeza thunbergii* (Miyaginohagi in Japanese) and its structure was reported to be *p*-vinylphenyl *O*-D-xylosyl-(1→6)-D-glucoside (**1**) without configurational assignment of two glycosidic linkages.[1] In connection with the carcinogenicity of bracken, *Pteridium aquilinum* var. *latiusculum*, we have examined the constituents of a carcinogenic fraction obtained from the aqueous extract of bracken and isolated a new *p*-hydroxystyrene glycoside, ptelatoside-A (**4**).[2] While the planar structure of ptelatoside-A (**4**) was the same as the previously assigned structure[1] of miyaginin (structure **1**), both compounds were found to be different by comparison of the spectral and physical properties.

In order to establish the complete structure of miyaginin we have isolated miyaginin from *Lespedeza thunbergii* forma *macrantha* [Kehagi in Japanese, a wild type of Miyaginohagi (*L. thunbergii*)] and reinvestigated the structure by chemical and spectral means. As the result the structure of miyaginin previously reported as **1** was shown to be revised to *p*-allylphenyl *O*-$\beta$-D-xylopyranosyl-(1→6)-$\beta$-D-glucopyranoside (*p*-allylphenyl $\beta$-primeveroside) (**2**). We describe the details of structural determination of miyaginin (**2**) and its unambiguous synthesis.

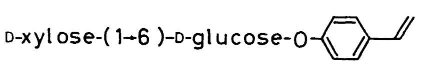
## Results and Discussion

*Isolation of Miyaginin (2).* The ethanolic extract of *L. thunbergii* forma *macrantha* dissolved in water was washed successively with hexane, ether, and ethyl acetate. The aqueous layer was then extracted repeatedly with 1-butanol. The 1-butanol extract was chromatographed on silica gel and then alumina to give crude miyaginin (**2**). Further purification with preparative HPLC afforded pure miyaginin (**2**) (0.07% yield based on dried plant material), mp 215—216 °C, $[\alpha]^{21}_{D}$ −81.0°. Spectral (UV, IR, and $^{1}$H NMR) and physical (mp and $[\alpha]_{D}$) properties of miyaginin (**2**) were identical with those of the authentic sample[1] isolated previously from *L. thunbergii*. Although, in search for miyaginin (**2**), we have examined the constituents of the ethanolic extract of *L. thunbergii* collected in the botanical garden of Tohoku University, **2** was not detected.

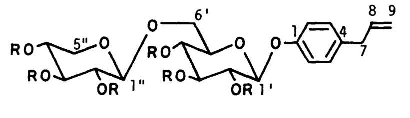
*Structure of Miyaginin (2).* The molecular formula of miyaginin (**2**) was determined to be $C_{20}H_{28}O_{10}$ based on the elemental analysis of **2** and the hexaacetate **3** coupled with FAB-MS of **2**. The spectral data of miyaginin (**2**) suggested the presence of a *p*-(substituted oxy)allylbenzene moiety in **2**: $^{1}$H NMR $\delta$=5.00 (2H, m, H-9), 5.96 (1H, ddt, $J$=17.6, 9.5, and 6.4 Hz, H-8), and 7.07 (4H, m, aromatic protons); $^{13}$C NMR $\delta$=156.0 (s, C-1), 117.9 (d, C-2 and 6), 130.6 (d, C-3 and 5), 135.7 (s, C-4), 39.6 (t, C-7), 138.8 (d, C-8), and 116.4 (t, C-9); UV 221 ($\varepsilon$ 9900), 272 (1200), and 279 nm (1000).

On acidic methanolysis miyaginin (**2**) afforded an aglycone, *p*-allylphenol (chavicol)(**5**)[3,13] and a mixture of methyl glycosides of D-xylose and D-glucose. After acetylation followed by chromatographic separation the methyl glycosides were identified as methyl 2,3,4-tri-*O*-acetyl-$\alpha$-D-xylopyranoside and methyl 2,3,4,6-tetra-*O*-acetyl-$\alpha$-D-glucopyranoside, respectively by comparison with authentic specimens. The aglycone, *p*-allylphenol (**5**) was identified by comparison of the spectral data with those of the authentic sample, the synthesis of which is described later and also by conversion into the known 3,5-dinitrobenzoate **6**.[4] Acetylation of miyaginin (**2**) gave the corresponding hexaacetate **3** as colorless needles, mp 163—164 °C, spectral and physical properties of which were identical with those of the authentic sample.[1] The signals at $\delta$=68.9 (t, C-6′), 101.6 (d, $^{1}J_{CH}$=164 Hz, C-1′), and 104.2 (d, $^{1}J_{CH}$=163 Hz, C-1″) in the $^{13}$C NMR spectrum of miyaginin (**2**) and the signals at $\delta$=4.89 (1H, d, $J$=7.9 Hz, H-1′), 4.38 (1H, d, $J$=6.8 Hz, H-1″), and 3.50—3.80 (2H, m, H-6′) in the $^{1}$H NMR spectrum of the hexaacetate **3** suggested the sugar moiety of miyaginin to be represented as $\beta$-D-xylopyranosyl-(1→6)-$\beta$-D-glucopyranosyl ($\beta$-primeverosyl). The structure of miyaginin was therefore determined to be *p*-allylphenyl $\beta$-primeveroside (**2**). In order to confirm the structure of miyaginin, the unambiguous synthesis of **2** was performed as described below.

*Synthesis of Miyaginin (2).* *p*-Allylphenol (**5**) was previously reported to be synthesized from allylbenzene in very low yield.[13] In the present study we have executed a new synthesis of **5** in 80% overall yield starting from commercially available 3-(4-hydroxyphenyl)-1-propanol (**7**). The alcohol **7** was converted by the procedure developed by Sharpless[5] into the selenide **8** in quantitative yield. Oxidation of **8** with hydrogen peroxide and subsequent elimination of *o*-nitrobenzeneselenenic acid from the resulting selenoxide gave *p*-allylphenol (**5**) in 80% yield. Glycosylation of **5** with penta-*O*-acetyl-$\beta$-D-glucopyranose under the Helferich's conditions[6] gave *p*-allylphenyl 2,3,4,6-tetra-*O*-acetyl-$\beta$-D-glucopyranoside-(**9**)[7] in 56% yield. Methanolysis of **9** with sodium methoxide in

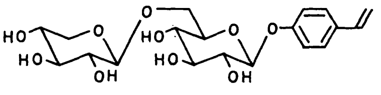


1

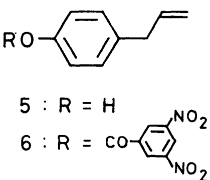


2 : R=H

3 : R=Ac

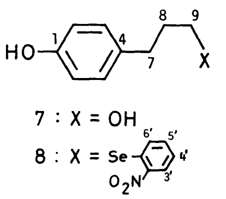


4



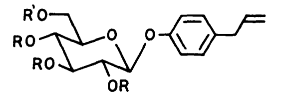
5 : R = H

6 : R = CO-



7 : X = OH

8 : X = Se-



9 : R = R' = Ac

10 : R = R' = H

11 : R = Ac, R' = H

methanol afforded *p*-allylphenyl *β*-D-glucopyranoside (**10**), a natural glucoside previously isolated from *Pinus contorta*,7) in 84% yield. The glucoside **10** was then converted to *p*-allylphenyl 2,3,4-tri-*O*-acetyl-*β*-D-glucopyranoside (**11**) in 40% overall yield by the following three-step sequence;8) (i) tritylation with trityl chloride–pyridine, (ii) acetylation with acetic anhydride–pyridine, (iii) detritylation with aqueous acetic acid. Glycosylation of **11** with 2,3,4-tri-*O*-acetyl-*α*-D-xylopyranosyl bromide under the Helferich's conditions9) gave miyaginin hexaacetate (**3**) in 88% yield. The physical and spectral properties of synthetic **3** were identical with those of the authentic sample derived from natural miyaginin (**2**) in all respects. Finally, methanolysis of **3** with sodium methoxide in methanol afforded *p*-allylphenyl *β*-primeveroside (**2**), colorless needles, mp 211.5—213 °C, $[\alpha]_D^{14}$ −81.6 °in 89% yield. The physical and spectral properties as well as chromatographic mobilities of synthetic **2** were completely identical with those of natural miyaginin in all respects. Thus, the structure of miyaginin was unambiguously established to be *p*-allylphenyl *O*-*β*-D-xylopyranosyl-(1→6)-*β*-D-glucopyranoside (*p*-allylphenyl *β*-primeveroside) (**2**).

So far, there have been known a few *p*-allylphenyl glycosides in nature: *p*-allylphenyl rutinoside,10) *p*-allylphenyl *O*-*α*-L-arabinofuranosyl-(1→6)-*β*-D-glucopyranoside,11) *p*-allylphenyl *O*-[3-*C*-(hydroxymethyl)-*β*-D-erythrofuranosyl]-(1→6)-*β*-D-glucopyranoside (furcatin),12) and *p*-allylphenyl *β*-D-glucopyranoside (**10**).7) *p*-Allylphenol (**5**) itself was also isolated from the plant, *Viburnum japonicum*.3)

## Experimental

Boiling point and melting points were uncorrected. Optical rotations were measured with a JASCO DIP-4 or a JASCO DIP-181 digital polarimeter. IR and UV spectra were recorded on a JASCO model IR-S spectrophotometer and a JASCO UVIDEC-510 spectrophotometer, respectively. $^1$H and $^{13}$C NMR spectra were measured at 90 MHz and 22.5 MHz, respectively with a JEOL FX-90QE spectrometer: the chemical shifts are given in δ using $Me_4Si$ as internal standard except for the $^{13}$C-chemical shifts measured in $D_2O$, which are reported in ppm downfield from $Me_4Si$ by assigning the resonance from internal dioxane to 67.4 ppm. Mass spectra and the fast atom bombardment mass spectrum (FAB-MS) were taken on a Hitachi RMU-6C mass spectrometer and a JEOL JMS-DX300 mass spectrometer, respectively. For column chromatography Fuji-Davison silica gel (BW-820 MH) and Merck neutral alumina (Aluminiumoxid 90, activity II-III) were used. Preparative thin layer chromatography (TLC) was carried out using Merck silica gel $PF_{254}$. A high performance liquid chromatography (HPLC) was performed with a JASCO TRI ROTAR-II apparatus equipped with a UV detector (JASCO UVIDEC-100-II) set at 221 nm.

*Isolation of Miyaginin (2).* The air-dried and chopped leaves and stems (278 g) of *L. thunbergii* forma *macrantha* collected in the Higashiyama botanical garden (Nagoya city) in June, 1983, were immersed in ethanol (2.4 L) at room temperature for 10 d. The ethanol extract was concentrated to dryness under reduced pressure. The residue (20 g) was diluted with water (200 mL) and the mixture was washed successively with hexane (10×200 mL), ether (7×200 mL), and ethyl acetate saturated with water (19×100 mL). The aqueous layer was then extracted with 1-butanol saturated with water (5×100 mL). The 1-butanol layer was concentrated to dryness under reduced pressure. The residue (2.6 g) was chromatographed on silica gel (55 g). Elution with chloroform–methanol (4:1) gave a fraction (0.5 g) containing **2**, which was subsequently chromatographed on alumina (20 g) with methanol–water (9:1) to afford crude **2** (320 mg). Further purification by preparative HPLC on Develosil ODS-5 (250×10 mm I.D.) using ethanol–water (30:70) (flow rate, 3 mL/min) afforded **2** (retention time, 12.4 min) as an amorphous powder (208 mg, 0.07% based on dried plant material). Recrystallization from aqueous acetone gave **2** as colorless needles, mp 215—216 °C (lit,1) mp 212—214 °C); $[\alpha]_D^{21}$ −81.0° (*c* 1.0, $H_2O$) [lit,1) $[\alpha]_D^{20}$ −86.25° (*c* 2.0, $H_2O$)]; UV (MeOH) 221 (ε 9900), 272 (1200), and 279 nm (1000); IR (KBr) 3440, 1636, 1610, 1511, 1231, 1100, 1075, 1038, and 908 cm$^{-1}$; $^1$H NMR ($CD_3OD$) δ=4.32 (1H, d, *J*=7.3 Hz, H-1″), 5.00 (2H, m, H-9), 5.96 (1H, ddt, *J*=17.6, 9.5, and 6.4 Hz, H-8), and 7.07 (4H, m, aromatic protons); $^{13}$C NMR ($D_2O$) δ=39.6 (t, C-7), 65.9 (t, C-5″), 68.9 (t, C-6′), 69.9 (d), 70.1 (d), 73.8 (d), 75.8 (d), 76.5 (d), 101.6 (d, $^1J_{CH}$=164 Hz, C-1′), 104.2 (d, $^1J_{CH}$=163 Hz, C-1″), 116.4 (t, C-9), 117.9 (d, C-2 and 6), 130.6 (d, C-3 and 5), 135.7 (s, C-4), 138.8 (d, C-8), and 156.0 (s, C-1); FAB-MS *m/z* 451 ($M^+$+Na), 429 ($M^+$+1), 427 ($M^+$−1). Found: C, 55.18; H, 6.74%. Calcd for $C_{20}H_{28}O_{10}\cdot 1/2H_2O$: C, 54.91; H, 6.68%.

*Acetylation of 2.* A solution of **2** (40 mg) in acetic anhydride (2 mL) and pyridine (2 mL) was stirred at room temperature for 2 h. The mixture was evaporated under reduced pressure and the residue was purified by column chromatography on silica gel (30 g) with benzene–ether (3:1) to give miyaginin hexaacetate (**3**). Recrystallization from methanol gave pure **3** (30 mg) as colorless needles, mp 163—164 °C (lit,1) mp 164—165 °C); $[\alpha]_D^{21}$ −46.4° (*c* 0.41, $CHCl_3$); UV (MeOH) 220 (ε 10800), 272 (1000), and 278 nm (800); IR ($CHCl_3$) 3050, 1760, 1635, 1604, 1508, 1220, 1052, 986, and 907 cm$^{-1}$; $^1H$ NMR ($C_6D_6$) $\delta$=1.58 (3H, s, $COCH_3$), 1.65 (3H, s, $COCH_3$), 1.72 (6H, s, 2×$COCH_3$), 1.74 (6H, s, 2×$COCH_3$), 2.89 (1H, dd, *J*=11.7 and 8.8 Hz, H-5″), 3.26 (2H, d, *J*=6.6 Hz, H-7), 3.50 (2H, m, H-5′ and 6′), 3.80 (1H, m, H-6′), 3.87 (1H, dd, *J*=11.7 and 5.1 Hz, H-5″), 4.38 (1H, d, *J*=6.8 Hz, H-1″), 4.89 (1H, d, *J*=7.9 Hz, H-1′), 5.00—5.60 (complex pattern), 5.94 (1H, ddt, *J*=17.2, 9.3, and 6.6 Hz, H-8), 7.00 and 7.17 (2H each, AA′BB′ system, aromatic protons); $^{13}C$ NMR ($CDCl_3$) $\delta$=20.5 (q, 6×$CO\underline{C}H_3$), 39.3 (t, C-7), 62.0 (t, C-5″), 67.5 (t, C-6′), 68.9 (d, 2C), 70.7 (d), 71.3 (d), 71.5 (d), 72.8 (d), 73.8 (d), 99.3 (d, $^1J_{CH}$=163 Hz, C-1′), 100.4 (d, $^1J_{CH}$=161 Hz, C-1″), 115.6 (t, C-9), 116.8 (d, C-2 and 6), 129.8 (d, C-3 and 5), 135.0 (s, C-4), 137.5 (d, C-8), 155.4 (s, C-1), 169.2, 169.3, 169.4, 169.7, 169.8, and 170.0 (s each, 6×$COCH_3$). Found: C, 56.35; H, 6.05%. Calcd for $C_{32}H_{40}O_{16}$: C, 56.46; H, 5.92%.

*Methanolysis of Miyaginin (**2**).* To a solution of **2** (41 mg) in methanol (3 mL) was added concd $H_2SO_4$ (0.09 mL) and the mixture was refluxed for 14 h. After cooling, the mixture was neutralized with a saturated aqueous $NaHCO_3$ solution and concentrated. The residue was diluted with water (2 mL) and the mixture was extracted with chloroform (3×20 mL); the aqueous layer was saved for further experiment. The chloroform layer was dried ($Na_2SO_4$) and concentrated under reduced pressure to give an oily residue, which was purified by preparative TLC ($CHCl_3$–MeOH, 4:1), affording *p*-allylphenol (**5**) as colorless oil (9 mg). The $^1H$ NMR spectrum of **5** (see the experimental section of synthesis of **5**) was identical with that of the authentic sample. For identification **5** was converted with 3,5-dinitrobenzoyl chloride in pyridine to the corresponding *p*-allylphenyl 3,5-dinitrobenzoate **6**, mp 102.5—103 °C (benzene–hexane) (lit,4) mp 103.5—104.5 °C). The aqueous layer obtained after extraction of the aglycone **5** described above was concentrated under reduced pressure and the residue (*ca.* 200 mg) was treated with acetic anhydride (2 mL) and pyridine (2 mL) at room temperature for 14 h. The mixture was concentrated under reduced pressure to dryness. The residue was diluted with chloroform and the insoluble materials were removed by filtration and washed with chloroform. The filtrate and washings were combined and concentrated under reduced pressure to afford a syrup, which was purified by preparative TLC (hexane–EtOAc, 1:1) to give methyl 2,3,4-tri-*O*-acetyl-α-D-xylopyranoside (9.3 mg) and methyl 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranoside (13 mg). Methyl 2,3,4-tri-*O*-acetyl-α-D-xylopyranoside (ether–hexane): mp 82—83 °C; $[\alpha]_D^{24}$ +122° (*c* 0.26, $CHCl_3$); $^1H$ NMR ($C_6D_6$) $\delta$=1.70, 1.74, 1.78, and 3.06 (3H each, s), 3.41 (1H, dd, *J*=10.9 and 10.8 Hz), 3.66 (1H, dd, *J*=10.9 and 6.5 Hz), 4.79 (1H, d, *J*=3.6 Hz), 4.89 (1H, dd, *J*=10.2 and 3.6 Hz), 5.00 (1H, ddd, *J*=10.8, 10.1, and 6.5 Hz), and 5.65 (1H, dd, *J*=10.2 and 10.1 Hz). Methyl 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranoside (ether–hexane): mp 63.5—64.5 °C; $[\alpha]_D^{24}$ +129° (*c* 0.24, $CHCl_3$); $^1H$ NMR ($C_6D_6$) $\delta$=1.70, 1.75, 1.76, 1.79, and 3.04 (3H each, s), 3.80 (1H, ddd, *J*=9.9, 4.3, and 2.7 Hz), 4.00 (1H, dd, *J*=11.9 and 2.7 Hz), 4.24 (1H, dd, *J*=11.9 and 4.3 Hz), 4.86 (1H, d, *J*=3.7 Hz), 4.96 (1H, dd, *J*=9.9 and 3.7 Hz), 5.18 (1H, dd, *J*=9.9 and 9.0 Hz), and 5.70 (1H, dd, *J*=9.9 and 9.0 Hz); these data were identical with those of the authentic samples derived from D-xylose and D-glucose, respectively.

*Preparation of* p-*Allylphenol (**5**).* To a stirred solution of 3-(4-hydroxyphenyl)-1-propanol (**7**) (1.0 g, 6.6 mmol) and *o*-nitrophenyl selenocyanate (1.93 g, 8.46 mmol) in anhydrous tetrahydrofuran (50 mL) was added tributylphosphine (3.2 mL, 12.8 mmol) at room temperature under nitrogen. After stirring for 5 h, the mixture was diluted with ether and the insoluble materials were removed by filtration and washed with ether. The filtrate and washings were combined and concentrated under reduced pressure to afford a brown syrup, which was purified by column chromatography on silica gel (150 g) using cyclohexane–ether (2:1) to give a crystalline selenide **8** (2.4 g, quantitative yield), mp 45—47 °C (without recrystallization); UV (MeOH) 226 (ε 13900), 255 (13600), 275 (sh, 7600), and 389 nm (3600); IR ($CHCl_3$) 3630, 3380, 1613, 1594, 1570, 1514, and 1334 cm$^{-1}$; $^1H$ NMR ($CDCl_3$) $\delta$=2.08 (2H, quintet, *J*=7.2 Hz, H-8), 2.72 and 2.88 (2H each, t, *J*=7.2 Hz, H-7 and 9), 6.74 and 7.04 (2H each, AA′BB′ system, H-2, 3, 5, and 6), 7.36 (3H, m, H-4′, 5′, and 6′), and 8.24 (1H, br d, *J*=7.2 Hz, H-3′); MS (70 eV) *m/z* (rel intensity) 337 ($M^+$, $C_{15}H_{15}NO_3{}^{80}Se$; 26), 202 (13), 186 (18), 133 (97), and 107 (100). Found: *m/z* 337.0195. Calcd for $C_{15}H_{15}NO_3{}^{80}Se$: M, 337.0217.

To a stirred solution of **8** (2.2 g, 6.5 mmol) in tetrahydrofuran (50 mL) was added dropwise a 30% hydrogen peroxide solution (6.8 mL, 65 mmol) at room temperature. After stirring at 40 °C for 3.5 h, the mixture was extracted with ether (4×30 mL). The ethereal extracts were washed with 1 M (1 M=1 mol dm$^{-3}$) $Na_2S_2O_3$ (5×15 mL) and a saturated NaCl solution, dried ($Na_2SO_4$), and evaporated. The residue was purified by column chromatography on silica gel (40 g) with ether–hexane (1:3) to give a crude oil (863 mg) of **5**. By the same procedure described above 937 mg of oily **5** was obtained from 2.20 g of the selenide **8**. The combined crude oil (1800 mg) was distilled to afford pure **5** (1.40 g, 80%) as a colorless liquid, bp 100.5—101.5 °C/7.5 mmHg (1 mmHg≈133.322 Pa) (lit,13) bp 105—110 °C/11 mmHg); $^1H$ NMR ($CDCl_3$) $\delta$=3.31 (2H, br d, *J*=6.8 Hz, H-7), 4.84 (1H, br s, OH), 5.02 (2H, m, H-9), 5.95 (1H, ddt, *J*=17.3, 9.4, and 6.8 Hz, H-8), 6.75 and 7.05 (2H each, AA′BB′ system, aromatic protons).

p-*Allylphenyl 2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranoside (**9**).* A mixture of penta-*O*-acetyl-β-D-glucopyranose (512 mg, 1.31 mmol), *p*-allylphenol (**5**) (370 mg, 2.76 mmol), acetic anhydride (0.12 mL, 1.3 mmol), and anhydrous *p*-toluenesulfonic acid (12 mg, 0.07 mmol) was stirred at 100—110 °C for 50 min under reduced pressure (20 mmHg). After cooling, the mixture was diluted with benzene (20 mL) and washed successively with water (3 mL), 0.25 M NaOH (15 mL), and water (10 mL). The benzene layer was dried ($Na_2SO_4$) and evaporated under reduced pressure to give a residue, which was chromatographed on silica gel (20 g) with benzene–ether (5:1), affording crude crystals of **9**. Recrystallization from methanol afforded **9** (337 mg, 56%) as colorless needles, mp 141—142 °C (lit,7) mp 136—138 °C); $[\alpha]_D^{16}$ −21.1° (*c* 0.78, $CHCl_3$); IR (Nujol) 1756, 1640, 1610, 1590, 1514, 1230, 1043, 990, and 910 cm$^{-1}$; $^1H$ NMR ($C_6D_6$) $\delta$=1.68, 1.69, 1.72, and 1.73 (3H each, s, 4×$COCH_3$), 3.15 (2H, d, *J*=6.5 Hz, H-7), 3.20 (1H, m, H-5′), 3.94 (1H, dd, *J*=12.3 and 2.6 Hz, H-6′), 4.18 (1H, dd, *J*=12.3 and 4.8 Hz, H-6′), 4.82 (1H, d, *J*=7.7 Hz, H-1′), 4.97 (2H, m, H-9), 5.00—5.60 (3H, complex pattern), 5.82 (1H, ddt, *J*=17.6, 9.0, and 6.5 Hz, H-8), and 6.95 (4H, s, aromatic protons).

p-*Allylphenyl β-D-Glucopyranoside (**10**).* To a stirred solution of **9** (100 mg, 0.22 mmol) in anhydrous methanol (2 mL) was added a solution of 1 M sodium methoxide in methanol (0.04 mL) at room temperature under nitrogen. After stirring for 2 h, the mixture was neutralized by adding ion-exchange resin, Amberlite IRC-50 (260 mg). The resin was removed by filtration and washed with methanol. The filtrate and washings were combined and concentrated to afford an amorphous powder. Purification by column chromatography on silica gel (20 g) with chloroform–methanol (6:1) gave **10** (54 mg, 84%) as a colorless solid, which was recrystallized from water to give crystalline **10**, mp 149—150 °C (lit,12) mp 148—149 °C); $[\alpha]_D^{15}$ −56.3° (*c* 0.39, MeOH) [lit,[12] $[\alpha]_D^{20}$ −61.8° (*c* 0.275, MeOH)]; UV (MeOH) 222 (ε 6800), 273 (900), and 279 nm (700); IR (KBr) 3350, 1633, 1610, 1590, 1507, 1230, and 910 cm$^{-1}$; $^1$H NMR ($CD_3COCD_3$) δ=3.32 (2H, d, *J*=6.6 Hz, H-7), 4.91 (1H, d, *J*=7.0 Hz, H-1′), 5.00 (2H, m, H-9), 5.96 (1H, ddt, *J*=16.9, 10.1, and 6.6 Hz, H-8), 6.97 and 7.12 (2H each, AA′BB′ system, aromatic protons).

p-*Allylphenyl 2,3,4-Tri-*O*-acetyl-β-*D*-glucopyranoside (11).* A solution of **10** (51 mg, 0.17 mmol) and trityl chloride (147 mg, 0.527 mmol) in anhydrous pyridine (1 mL) was stirred at 100 °C for 7 h. After cooling, acetic anhydride (0.5 mL) was added to the mixture. The mixture was stirred for additional 4.5 h at room temperature and concentrated under reduced pressure. The residue was diluted with 80% acetic acid (3 mL) and the mixture was stirred at 100 °C for 30 min and then at room temperature for several hours. The crystalline precipitates in the mixture were removed by filtration and washed with 75% methanol (20 mL). The combined filtrate and washings were concentrated under reduced pressure to leave a solid, which was purified by column chromatography on silica gel (20 g) with benzene-ether (2:1) to give crude **11**. Recrystallization from ether-hexane afforded **11** (29 mg, 40% overall yield) as colorless needles, mp 79—80 °C; $[\alpha]_D^{12}$ −9.40° (*c* 0.24, $CHCl_3$); UV (MeOH) 221 (ε 10400), 272 (1300), and 278 nm (1000); IR ($CHCl_3$) 3400, 3040, 1760, 1638, 1607, 1510, 1220, 993, and 910 cm$^{-1}$; $^1$H NMR ($C_6D_6$) δ=1.57, 1.61, and 1.73 (3H each, s, $3\times COCH_3$), 3.15 (2H, br d, *J*=6.4 Hz, H-7), 3.15 (1H, m, H-5′), 3.40 (2H, m, H-6′), 4.80—5.60 (6H, complex pattern), 5.86 (1H, ddt, *J*=17.8, 9.2, and 6.4 Hz, H-8), 6.94 (4H, s, aromatic protons); $^{13}$C NMR ($CDCl_3$) δ=20.5 (q, $3\times CO\underline{C}H_3$), 39.3 (t, C-7), 61.3 (t, C-6′), 68.7 (d), 71.4 (d), 72.8 (d), 74.4 (d), 99.2 (d, $^1J_{CH}$=162 Hz, C-1′), 115.7 (t, C-9), 116.8 (d, C-2 and 6), 129.7 (d, C-3 and 5), 135.0 (s, C-4), 137.3 (d, C-8), 155.2 (s, C-1), 169.2, 169.8, and 170.2 (s each, $3\times \underline{C}OCH_3$); MS (70 eV) *m/z* (rel intensity) 422 (M$^+$, 1), 331 (14), 289 (91), 229 (100), 187 (35), 169 (72), 134 (84), 127 (98), and 109 (71). Found: C, 59.12; H, 6.29%. Calcd for $C_{21}H_{26}O_9$: C, 59.71; H, 6.20%.

*Miyaginin Hexaacetate (3).* A solution of **11** (43 mg, 0.10 mmol), 2,3,4-tri-*O*-acetyl-α-D-xylopyranosyl bromide (100 mg, 0.29 mmol), mercury(II) bromide (91 mg, 0.25 mmol), and mercury(II) cyanide (64 mg, 0.25 mmol) in dry acetonitrile (3 mL) was stirred at room temperature under nitrogen in the dark. After stirring for 5 h, the mixture was concentrated under reduced pressure. The residue was dissolved in chloroform (20 mL) and the insoluble materials were removed by filtration and washed with chloroform. The filtrate and washings were combined and washed with a saturated KBr solution, until washings showed no coloration with an aqueous ammonium sulfide solution. The chloroform layer was dried ($Na_2SO_4$) and concentrated under reduced pressure to leave a syrup. Purification by column chromatography on silica gel (25 g) with benzene-ether (3:1) gave **3** (60 mg, 88%) as a colorless solid. Recrystallization from methanol gave **3** as colorless needles, mp 163—164 °C; $[\alpha]_D^{21}$ −44.9° (*c* 0.55, $CHCl_3$). The physical (mp and $[\alpha]_D$) and spectral (IR, UV, $^1$H NMR, and $^{13}$C NMR) properties of synthetic **3** were identical with those of **3** derived from natural miyaginin (**2**).

*Miyaginin (2).* Methanolysis of **3** (23 mg, 0.034 mmol) was performed by essentially the same procedure as described in the preparation of **10**. The crude product was purified by column chromatography on silica gel (20 g) with chloroform-methanol (4:1) to give **2** (13 mg, 89%) as an amorphous solid. Recrystallization from aqueous acetone afforded crystalline **1** as colorless needles, mp 211.5—213 °C; $[\alpha]_D^{14}$ −81.6° (*c* 0.36, $H_2O$). The physical (mp and $[\alpha]_D$) and spectral (UV, IR, $^1$H NMR, and $^{13}$C NMR) properties and chromatographic mobilities of synthetic **2** were completely identical with those of natural **2** in all respects.

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