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New Phenylpropanoid Glycerol Glucosides from the Bulbs of *Lilium* Species

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The fresh bulbs of the genus *Lilium* have yielded new phenylpropanoid glycerol glucosides, *epi*-regaloside A (**6b**), *epi*-regaloside C (**7b**) and *epi*-regaloside F (**10b**), as mixtures with the corresponding (2*S*)-regalosides (**6a**, **7a** and **10a**), and regaloside G (**11**). Compounds **6b** and **7b** have been obtained from *Lilium pardarinum*, and **6b**, **10b** and **11** from *L. auratum*. The spectroscopic data and chemical evidence have allowed us to assign the structures of **6b**, **7b**, **10b** and **11** as (2*R*)-1-*O*-*p*-coumaroyl-3-*O*-*β*-D-glucopyranosylglycerol, (2*R*)-1-*O*-caffeoyl-3-*O*-*β*-D-glucopyranosylglycerol, (2*R*)-1-*O*-feruloyl-3-*O*-*β*-D-glucopyranosylglycerol and (2*S*)-1-*O*-feruloyl-2-*O*-*β*-D-glucopyranosylglycerol, respectively. In addition, jatropham and its glucoside have been detected in the fresh bulbs of *L. medeoloides*. Several previously reported compounds have also been obtained and identified.

Keywords——*Lilium pardarinum*; *Lilium auratum*; *Lilium medeoloides*; Liliaceae; phenolic glycerol glucoside; *epi*-regaloside A; *epi*-regaloside C; *epi*-regaloside F; ragaloside G; jatropham

Cinnamic acid derivatives, *p*-coumaric, caffeic and ferulic acids, are widely distributed in higher plants as esters and glycosides.[1] Some medical uses of the bulbs of the genus *Lilium* are described in the literature,[2] and recently, we have reported the occurrence of phenylpropanoid glycosides in lily bulbs[3]; little had previously been known about the phenolic constituents.[4] Regalosides, phenylpropanoid glycerol glucosides, are considered to be the major components of the lily bulbs, and no report has appeared on such compounds from other natural sources. On the other hand, the isolation of jatropham and its glucoside from *L. hansonii*[5a] is of interest from the viewpoint of chemotaxonomy. Jatropham was first isolated from *Jatropha macrorhiza* (Euphorbiaceae) as an antitumor alkaloid[6] and later from *Lilium* spp.[5] We know of no other report on jatropham from a natural source.

As part of a series of chemical studies on the bulbs of the genus *Lilium*, examinations have been made of *L. pardarinum*, *L. auratum* and *L. medeoloides*. *L. pardarinum* is indigenous to North America, growing in damp places, and the bulbs have a bitter taste. *L. auratum* and *L. medeoloides* are indigenous to Japan and are classified on the basis of the flower shapes into the subgenera *Archelirion* and *Martagon*, respectively.[7] We previously isolated phenolic diacylated and monoacylated glycerols from the bulbs of *L. auratum*.[8] The present communication deals with the structural assignment of new phenylpropanoid glycerol glucosides, *epi*-regaloside A (**6b**), *epi*-regaloside C (**7b**) and *epi*-regaloside F (**10b**), obtained as mixtures with the corresponding (2*S*)-regalosides (**6a**, **7a** and **10a**), and regaloside G (**11**). Compounds **6b**, **7b** and **10b** are the first examples of (2*R*)-regalosides. Several known compounds have also been isolated and identified.

Lilium pardarinum

The methanol extract of the fresh bulbs was extracted with chloroform and then with *n*-butanol. Compound **1** was isolated from the chloroform-soluble portion and **2**—**7** from the *n*-

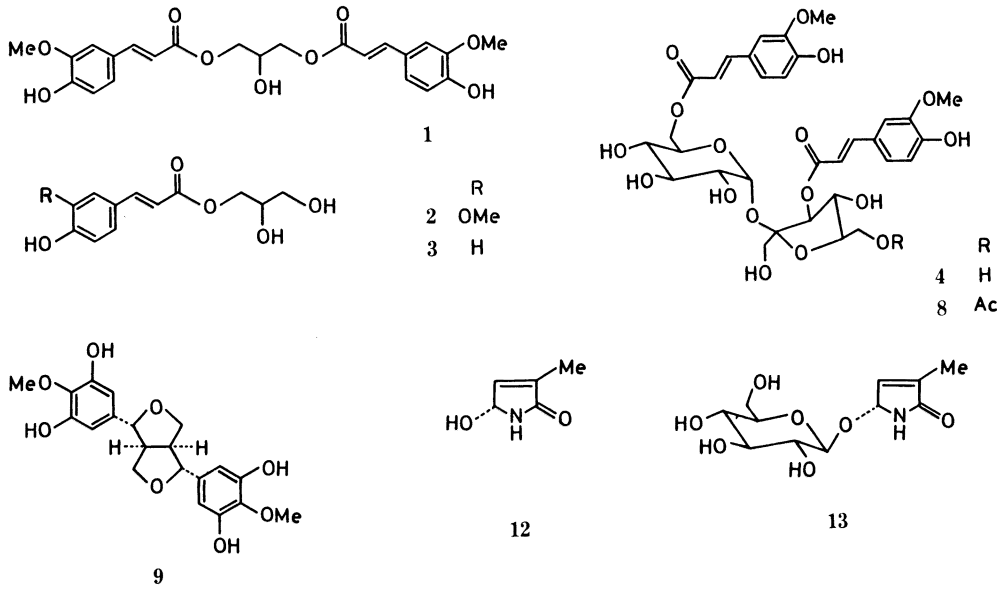


Chart 1

butanol-soluble portion after repeated column chromatography on silica gel and Sephadex LH-20, and preparative thin-layer chromatography (PTLC).

Compound **1** was a phenolic 1,3-disubstituted glycerol and its structure was confirmed to be 1,3-*O*-diferuloylglycerol.[8,9] Compounds **2** and **3** were phenolic monoacylated glycerols and they were identified as 1-*O*-feruloylglycerol and 1-*O*-*p*-coumaroylglycerol, respectively.[8,10] Compounds **4** and **5** exhibited a bitter taste and were shown to be 3,6′-*O*-diferuloylsucrose and (2*S*)-1-*O*-*p*-coumaroyl-2-*O*-*β*-D-glucopyranosylglycerol (regaloside D), respectively, on the basis of the physical and spectroscopic data.[3a,d]

Compound **6** (**6a**, **6b**) was obtained as a pale-yellow amorphous powder. It gave an orange coloration with benzidine reagent. The infrared (IR) spectrum indicated the presence of hydroxyl group(s) (3380 cm^{-1}), a carbonyl group (1680 cm^{-1}), an alkene (1620 cm^{-1}) and an aromatic ring (1595, 1575, 1500 cm^{-1}). The electron impact mass spectrum (EI-MS) displayed a molecular ion peak at *m/z* 400. The proton nuclear magnetic resonance (^{1}H-NMR) spectrum showed the existence of a *p*-coumaroyl residue (δ 7.65 and 6.35, each d, J = 16.0 Hz, *trans* alkene protons; δ 7.46 and 6.81, each d, J = 8.7 Hz, *p*-disubstituted aromatic protons) and glycerol glucoside protons (δ 4.33 – 3.20). The above spectral data are essentially identical with those of regaloside A,[3b] but, two anomeric protons were observed in the ^{1}H-NMR spectra of both **6** (δ 4.31 and 4.30, each d, J = 7.7 Hz in methanol-d_4) and **6** peracetate (**6a**$_1$, **6b**$_1$) (δ 4.56 and 4.55, each d, J = 7.9 Hz in chloroform-d_1), which was prepared with acetic anhydride in pyridine. The corbon-13 nuclear magnetic resonance (^{13}C-NMR) spectrum of **6** also exhibited a duplicated signal pattern of the anomeric carbon (δ 104.8 and 104.7) and the glycerol carbons (δ 66.7 and 66.5, 70.0 and 69.8, and 72.2 and 72.0). When **6** was submitted to alkaline methanolysis with 3% sodium methoxide in methanol, **6** was hydrolyzed to afford methyl *p*-coumarate and a mixture of glycerol glucosides (**6a**$_2$, **6b**$_2$). Gas liquid chromatography (GLC) of the trimethylsilyl (TMS) derivative of the mixture was performed. Two peaks appeared on the chromatogram, as described in the experimental section, and were identified as lilioside D TMS (retention time (t_R); 19.01 min) and lilioside C TMS (t_R; 19.13 min), by coinjection with authentic samples.[11] The ^{1}H-NMR spectrum (400 MHz) of the peracetate (**6a**$_3$, **6b**$_3$) of the mixture supported the results of GLC

examination, and it was possible to assign the signals due to lilioside C hexaacetate (**6a**$_3$) and due to lilioside D hexaacetate (**6b**$_3$) by comparison with authentic spectra. Thus, **6** was characterized as a mixture of (2*S*)-1-*O*-*p*-coumaroyl-3-*O*-*β*-D-glucopyranosylglycerol (regaloside A) (**6a**) and (2*R*)-1-*O*-*p*-coumaroyl-3-*O*-*β*-D-glucopyranosylglycerol (**6b**), and the latter was designated as *epi*-regaloside A. The approximate ratio of regaloside A and *epi*-regaloside A was established to be 8 : 5 from the integrals of the anomeric proton signals in the ^{1}H-NMR spectrum. Efforts to separate the mixture were unsuccessful.

Compound **7** (**7a**, **7b**) was a pale-yellow amorphous powder and was more polar than **6**. It gave a dark green color with ferric chloride reagent as well as an orange coloration with benzidine reagent. The ^{1}H-NMR spectrum was quite similar to that of **6** except in the aromatic region corresponding to the phenylpropanoid moiety, showing a *trans* olefin system (δ 7.59 and 6.29, each d, J=15.9 Hz) and an ABC system arising from the aromatic protons (δ7.05, d, J=2.0 Hz, 6.95, dd, J=8.2, 2.0 Hz and 6.78, d, J=8.2 Hz). In addition, considering the ultraviolet (UV) and ^{13}C-NMR spectra of **7**, the aromatic acid constituting **7** was assumed to be a caffeic acid. The acetyl derivative (**7a**$_1$, **7b**$_1$) of **7** showed a molecular ion peak at *m/z* 710 in the EI-MS, and two anomeric protons (δ4.56 and 4.55, each d, J=7.9 Hz) in the ^{1}H-NMR spectrum. On alkaline methanolysis, **7** afforded methyl caffeate and a mixture of glycerol glucosides, and the latter was subsequently acetylated with acetic anhydride in pyridine to provide a mixture of lilioside C hexaacetate and lilioside D hexaacetate in the ratio of approximately 5 : 4. Accordingly, **7** was assigned as a 5 : 4 mixture of (2*S*)-1-*O*-caffeoyl-3-*O*-*β*-D-glucopyranosylglycerol (regaloside C) (**7a**) and (2*R*)-1-*O*-caffeoyl-3-*O*-*β*-D-glucopyranosylglycerol (**7b**), named *epi*-regaloside C.

Lilium auratum

The methanol extract of the bulbs of *L. auratum* was further investigated after the isolation of phenolic diacylated and monoacylated glycerols,[8] resulting in the isolation of **4**—**6**, **8**—**11**. Compound **8** was characterized on the basis of the IR and ^{1}H-NMR spectra as 6-*O*-acetyl-3,6′-*O*-diferuloylsucrose. Compound **9** was obtained as a white amorphous powder, $[\alpha]_D \pm 0°$ (chloroform), with the molecular formula $C_{22}H_{26}O_8$. The dimeric nature of the molecule was shown by the ^{1}H- and ^{13}C-NMR spectra, in which only half the number of signals expected from the molecular formula appeared. The structure was determined as *dl*-syringaresinol, whose spectral data were identical with literature values.[12] While **9** is a minor component, to our knowledge, there is no report on the isolation of lignan from *Lilium* plants.

Spectral data of **10** (**10a**, **10b**) provided information suggesting a phenylpropanoid glycerol glucoside structure. Dual signal patterns in the ^{1}H- and ^{13}C-NMR spectra could be also observed, as in the case of **6** and **7**. A prominent fragment ion peak at *m/z* 177 in the EI-MS, and ABC signals due to the aromatic protons at δ 7.19 (d, J=1.7 Hz), 7.08 (dd, J=8.2, 1.7 Hz) and 6.81 (d, J=8.2 Hz), and methoxyl protons at 3.89 (s) in the ^{1}H-NMR spectrum confirmed the existence of a feruloyl moiety in **10**. The peracetate (**10a**$_1$, **10b**$_1$) of **10** gave a molecular ion peak at *m/z* 682 in the EI-MS. Alkaline hydrolysis of **10** with 3% sodium methoxide in methanol gave methyl ferulate and a mixture of glycerol glucosides, which was subsequently converted to the corresponding peracetate. The ^{1}H-NMR spectrum proved the acetate to be a mixture of lilioside C hexaacetate and lilioside D hexaacetate in the ratio of approximately 1 : 4. Thus, **10** was determined to be a mixture of (2*S*)-1-*O*-feruloyl-3-*O*-*β*-D-glucopyranosylglycerol (regaloside F) (**10a**) and (2*R*)-1-*O*-feruloyl-3-*O*-*β*-D-glucopyranosylglycerol (**10b**), named *epi*-regaloside F.

The ^{1}H- and ^{13}C-NMR spectra of **11** also exhibited signals typical of a phenylpropanoid glycerol glucoside. The aromatic acid constituting **11** was ferulic acid, which was easily deduced from the EI-MS (*m/z* 177), the ^{1}H-NMR spectrum and the results of alkaline methanolysis. The ^{1}H-NMR spectrum of the hexaacetate (**11a**) of **11** indicated the existence of

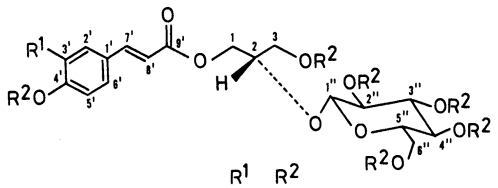
five aliphatic and one aromatic acetoxyl groups, and the EI-MS showed a molecular ion peak at *m/z* 682. The configuration, 2*S*, and the substitution pattern could be assigned from the ^{13}C-NMR spectral data of the glycerol moiety of regaloside D. In conclusion, **11** was shown to be (2*S*)-1-*O*-feruloyl-2-*O*-*β*-D-glucopyranosylglycerol, designated as regaloside G.

Lilium medeoloides

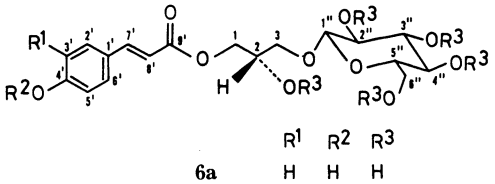
L. medeoloides can be found in the subalpine zone of Japan. We obtained a small amount of the wild bulbs and examined them.

The methanol extract of the bulbs yielded jatropham (**12**) and jatropham 5-*O*-*β*-D-glucopyranoside (**13**) as well as **4**. The specific rotations and the spectral data of **12** and **13** were in good accordance with those of authentic samples isolated previously from *L. hansonii*.[5a)]

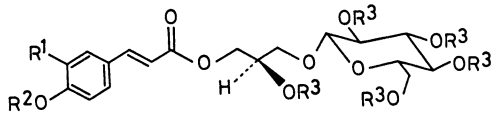
Various regalosides have so far been found in lily bulbs, and the distribution of the regalosides seems to vary corresponding to the species in the genus *Lilium*. *L. henryi* contains regaloside A, methylregaloside A and regaloside C,[3c)] and *L. lancifolium* contains regaloside A and regaloside F,[3d)] in which glucose is attached to a primary hydroxyl group of glycerol and the absolute configuration of the glycerol C-2 is *S*. On the other hand, regalosides detected in *L. longiflorum* (regalosides B, D and E) bear the glucose at the C-2 position on glycerol and have 2*S* configuration.[3d)] *L. regale* yielded regalosides A and B.[3b)] This time, (2*R*)-regalosides, *epi*-regaloside A and *epi*-regaloside C have been detected in *L. pardarinum*, together with regaloside A, regaloside C and regaloside D, and *epi*-regaloside A and *epi*-regaloside F in *L. auratum*, along with regaloside A, regaloside D and regaloside G. *L. medeoloides* is related



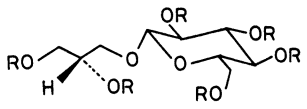
	R^1	R^2
5	H	H
11	OMe	H
11a	OMe	Ac



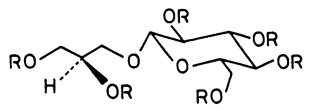
	R^1	R^2	R^3
6a	H	H	H
6a$_1$	H	Ac	Ac
7a	OH	H	H
7a$_1$	OAc	Ac	Ac
10a	OMe	H	H
10a$_1$	OMe	Ac	Ac



	R^1	R^2	R^3
6b	H	H	H
6b$_1$	H	Ac	Ac
7b	OH	H	H
7b$_1$	OAc	Ac	Ac
10b	OMe	H	H
10b$_1$	OMe	Ac	Ac



	R	
6a$_2$	H	lilioside C
6a$_3$	Ac	lilioside C hexaacetate



	R	
6b$_2$	H	lilioside D
6b$_3$	Ac	lilioside D hexaacetate

Chart 2

TABLE I. ^{13}C-NMR Spectral Data for **6** (**6a**, **6b**), **7** (**7a**, **7b**), **10** (**10a**, **10b**), **5** and **11**[a]

Carbon No.	6		7		10		5	11
	6a	6b	7a	7b	10a	10b		
Glycerol moiety								
1	66.7	66.5	66.7	66.5	66.7	66.5	64.8	64.8
2	69.8	70.0	69.8	70.0	69.8	70.0	79.5	79.5
3	72.0	72.2	72.0	72.2	72.0	72.3	63.4	63.4
Phenylpropanoid moiety								
1′	127.2		127.8		127.8		127.2	127.7
2′	131.2		115.0		111.9		131.2	111.9
3′	116.9		146.8		150.8		116.9	150.8
4′	161.3		149.6		149.5		161.3	149.5
5′	116.9		116.6		116.6		116.9	116.6
6′	131.2		123.0		124.2		131.2	124.3
7′	146.8		147.2		147.2		147.0	147.3
8′	115.0		115.3		115.3		115.0	115.3
9′	169.2		169.2		169.1		169.1	169.1
OMe					56.5			56.5
Glucose moiety								
1″	104.7	104.8	104.7	104.8	104.8	104.9	104.2	104.2
2″	75.1		75.1		75.2		75.0	75.1
3″	78.0[b]		78.0[b]		78.1[b]		78.0[b]	78.1[b]
4″	71.6		71.6		71.6		71.6	71.6
5″	77.9[b]		77.9[b]		78.0[b]		77.9[b]	78.0[b]
6″	62.8		62.8		62.8		62.7	62.7

a) Spectra were measured in CD_3OD with a Bruker AM-400 (100.6 MHz) and the chemical shifts were expressed in ppm relative to internal standard, TMS. *b*) Assignments may be interchanged in each column.

taxonomically to *L. hansonii* and both lilies contain jatropham and its glucoside instead of regalosides. These findings seem to provide a basis for dividing the genus *Lilium* into several classes. Additional studies on other lily bulbs would be helpful. Results along this line will be reported in the near future.

Experimental

The following instruments were used for the measurements of the spectral and physical data. IR spectra were recorded on a Hitachi 260-36, a JASCO A-302 or a Perkin-Elmer 1710 FT-IR instrument, UV spectra on a Hitachi 557 spectrometer, and MS on a Hitachi M-80 machine. Optical rotations were measured with a JASCO DIP-4 or a JASCO DIP-360 automatic polarimeter. ^{1}H-NMR spectra were taken with a Varian EM-390 (90 MHz) or a Bruker AM-400 (400 MHz) spectrometer, and ^{13}C-NMR spectra with a Bruker AM-400 (100.6 MHz) spectrometer. Chemical shifts were expressed in ppm (δ) relative to the internal standard, tetramethylsilane (TMS) (s, singlet; d, doublet; dd, doublet of doublets; m, multiplet; br, broad). GLC was performed with a Hitachi G-3000 gas chromatograph equipped with flame ionization detector (FID) and recorded with a Hitachi D-2000 Chromato-Integrator. Fuji Davison silica gel BW-300 and BW-340 (Fuji Davison Co., Ltd.), Yamazen silica gel Y-8012 (Yamazen Co., Ltd.), and Sephadex LH-20 (Pharmacia Fine Chemicals Co., Ltd.) were used for column chromatographies. Thin-layer chromatography (TLC) was carried out on precoated Kieselgel 60 F_{254} (0.25 mm thick, Merck) and PTLC on precoated Kieselgel 60 F_{254} (0.5 mm thick, Merck), and spots were visualized under UV (254 nm) illumination and by spraying the plates with 10% H_2SO_4 solution followed by heating.

Extraction and Isolation——*Lilium pardarinum*: The dormant fresh bulbs of *Lilium pardarinum* (2.5 kg) purchased from Sakata-shubyo Co., Ltd., Kanagawa prefecture, Japan, were cut into pieces and extracted with MeOH under reflux. The MeOH extract on removal of the solvent gave a crude residue, a dark viscous syrup, which was suspended in H_2O, and extracted with $CHCl_3$ and then with *n*-BuOH. Each fraction, after concentration to a small volume, was subjected to column chromatography on silica gel with $CHCl_3$–EtOAc, $CHCl_3$–acetone and

$CHCl_3$–MeOH solvent systems for the $CHCl_3$-soluble fraction, and with $CHCl_3$–MeOH, $CHCl_3$–MeOH–H_2O, EtOAc–acetone, EtOAc–MeOH, EtOAc–MeOH–H_2O, Et_2O–MeOH and Et_2O–MeOH–H_2O systems for the *n*-BuOH-soluble fraction. Sephadex LH-20 column chromatography with MeOH as the eluent and PTLC with EtOAc–MeCOEt–MeOH–H_2O (10 : 10 : 1 : 1) were also applied to purification of the *n*-BuOH-soluble fraction. Compound **1** (52.0 mg) was obtained from the $CHCl_3$-soluble portion, and **2** (13.0 mg), **3** (30.2 mg), **4** (174 mg), **5** (134 mg), **6** (866 mg) and **7** (103 mg) from the *n*-BuOH-soluble portion.

Lilium auratum: Details of the extraction and isolation procedures of *Lilium auratum* (4.1 kg) are described in the previous paper.[8] Compound **9** (8.0 mg) was isolated from the $CHCl_3$-soluble portion and **4** (275 mg), **5** (254 mg), **6** (946 mg), **8** (56.0 mg), **10** (8.3 mg) and **11** (9.4 mg) from the *n*-BuOH-soluble portion.

Lilium medeoloides: The fresh bulbs of *Lilium medeoloides* (10 g) collected at Yamanashi prefecture, Japan, in July 1987 were extracted with MeOH and the MeOH extract was repeatedly subjected to silica gel and Sephadex LH-20 column chromatography to give **12** (0.3 mg) and **13** (20.3 mg) along with **4** as a trace constituent. Compound **4** was identified by TLC comparison with an authentic sample ($CHCl_3$–MeOH (5 : 2), *Rf* 0.59. EtOAc–MeOH (5 : 1), *Rf* 0.64).

A Mixture (6) of (2*S*)-1-*O*-*p*-Coumaroyl-3-*O*-*β*-D-glucopyranosylglycerol (Regaloside A) (6a) and (2*R*)-1-*O*-*p*-Coumaroyl-3-*O*-*β*-D-glucopyranosylglycerol (*epi*-Regaloside A) (6b)——A pale-yellow amorphous powder. $C_{18}H_{24}O_{10}$. $[\alpha]_D^{26}$ −12.1° (*c* = 0.61, MeOH). UV λ_{max}^{MeOH} nm (log ε): 227 (4.09), 300 shoulder (sh) (4.34), 312 (4.39). IR ν_{max}^{KBr} cm^{-1}: 3380 (OH), 2900 (CH), 1680 (C=O), 1620 (CH=CH), 1595, 1575, 1500 (aromatic ring), 1430, 1365, 1320, 1260, 1160, 1065, 1020, 820. EI-MS *m/z* (%): 400 (M^+, weak), 249 (1.6), 238 (1.6), 221 (1.5), 205 (1.7), 163 (21), 147 (20), 145 (28), 121 (22), 103 (100). ^{1}H-NMR (CD_3OD) δ: 7.65 (d, *J* = 16.0 Hz, H-7′), 7.46 (d, *J* = 8.7 Hz, H-2′, -6′), 6.81 (d, *J* = 8.7 Hz, H-3′, -5′), 6.35 (d, *J* = 16.0 Hz, H-8′), 4.31 (d, *J* = 7.7 Hz, H-1″ (**6b**)), 4.30 (d, *J* = 7.7 Hz, H-1″ (**6a**)), 4.31—4.26 (H-1α), 4.23 (dd, *J* = 11.5, 6.1 Hz, H-1β (**6a**)), 4.20 (dd, *J* = 11.4, 6.1 Hz, H-1β (**6b**)), 4.07 (m, H-2), 4.00 (dd, *J* = 10.4, 4.3 Hz, H-3α (**6b**)), 3.96 (dd, *J* = 10.5, 5.2 Hz, H-3α (**6a**)), 3.87 (dd, *J* = 11.9, 1.1 Hz, H-6″α), 3.74—3.61 (H-3β, -6″β), 3.40—3.20 (H-2″, -3″, -4″, -5″). ^{13}C-NMR spectrum: Table I.

Acetylation of 6——A solution of **6** (12.8 mg) in Ac_2O–pyridine was allowed to stand at room temperature overnight. The crude product was chromatographed on silica gel using *n*-hexane–acetone (3 : 1) to give a white amorphous powder (15.6 mg) (**6a**$_1$, **6b**$_1$). IR ν_{max}^{KBr} cm^{-1}: 2960 (CH), 1755, 1715 (C=O), 1635 (CH=CH), 1605, 1510 (aromatic ring), 1435, 1370, 1325, 1230, 1165, 1040, 910, 840. EI-MS *m/z* (%): 652 (M^+, 0.7), 610 (1.1), 429 (3), 355 (5), 331 (35), 305 (81), 263 (26), 189 (39), 169 (82), 147 (100), 109 (32). ^{1}H-NMR ($CDCl_3$) δ: 7.67 (d, *J* = 16.0 Hz, H-7′), 7.55 (d, *J* = 8.5 Hz, H-2′, -6′), 7.14 (d, *J* = 8.5 Hz, H-3′, -5′), 6.39 (d, *J* = 16.0 Hz, H-8′), 5.26 (m, H-2), 5.21 (dd, *J* = 9.4, 9.4 Hz, H-3″ (**6a**$_1$)), 5.20 (dd, *J* = 9.4, 9.4 Hz, H-3″ (**6b**$_1$)), 5.09 (dd, *J* = 9.4, 9.4 Hz, H-4″), 5.02 (dd, *J* = 9.4, 7.9 Hz, H-2″ (**6a**$_1$)), 5.00 (dd, *J* = 9.4, 7.9 Hz, H-2″ (**6b**$_1$)), 4.56 (d, *J* = 7.9 Hz, H-1″ (**6b**$_1$)), 4.55 (d, *J* = 7.9 Hz, H-1″ (**6a**$_1$)), 4.41 (dd, *J* = 12.1, 3.5 Hz, H-1α), 4.32—4.23 (H-1β, -6″α), 4.15 (dd, *J* = 12.3, 2.1 Hz, H-6″β), 4.02 (dd, *J* = 11.0, 4.7 Hz, H-3α (**6b**$_1$)), 4.00 (dd, *J* = 10.9, 5.1 Hz, H-3α (**6a**$_1$)), 3.78—3.68 (H-3β, -5″), 2.32, 2.09, 2.07, 2.03, 2.01 (each s, Ac).

Alkaline Hydrolysis Followed by Acetylation of 6——Hydrolysis of **6** (17.7 mg) with 3% NaOMe in MeOH was carried out at room temperature for 2 h. The reaction solution was passed through a cation exchange resin (Amberlite IR-120B) and the eluate was purified by silica gel column chromatography with $CHCl_3$–MeOH (2 : 1) to yield methyl *p*-coumarate, which was identified by direct comparison with an authentic sample, and a mixture of glycerol glucosides (**6a**$_2$, **6b**$_2$) as a white amorphous powder. IR ν_{max}^{KBr} cm^{-1}: 3411 (OH), 2932 (CH), 1078, 1040. ^{1}H-NMR (C_5D_5N) δ: 5.01 (d, *J* = 7.6 Hz, H-1″ (**6b**$_2$)), 5.00 (d, *J* = 7.6 Hz, H-1″ (**6a**$_2$)), 4.58—3.92 (H-1, -2, -3, -2″, -3″, -4″, -5″, -6″). The mixture (1.0 mg) was converted to the TMS derivatives (Silylating Reagent TMS-HT kit, Tokyo Kasei Kogyo Co., Ltd.) for GLC examination. GLC operating conditions were as follows. Column: a silica capillary column OV-1701 Bonded (25 m × 0.25 mm), Gasukuro Kogyo Inc. Carrier gas: N_2, 0.6 ml/min. Oven temperature: 200—270 °C (initial 2 min hold and then increased at 2.5 °C/min). Lilioside C (**6a**$_2$) and lilioside D (**6b**$_2$) were identified. The mixture (6.0 mg) was acetylated with Ac_2O–pyridine and the crude product was purified by silica gel column chromatography with *n*-hexane–acetone (2 : 1) to give a white amorphous powder (9.5 mg) (**6a**$_3$, **6b**$_3$), which was shown to be a mixture of lilioside C hexaacetate (**6a**$_3$) and lilioside D hexaacetate (**6b**$_3$) in the ratio of approximately 8 : 5. ^{1}H-NMR ($CDCl_3$) δ: 5.20 (dd, *J* = 9.4, 9.4 Hz, H-3′ (**6a**$_3$)), 5.19 (dd, *J* = 9.5, 9.5 Hz, H-3′ (**6b**$_3$)), 5.18 (m, H-2), 5.08 (dd, *J* = 9.5, 9.5 Hz, H-4′ (**6b**$_3$)), 5.07 (dd, *J* = 9.4, 9.4 Hz, H-4′ (**6a**$_3$)), 4.99 (dd, *J* = 9.5, 7.9 Hz, H-2′ (**6b**$_3$)), 4.98 (dd, *J* = 9.4, 7.8 Hz, H-2′ (**6a**$_3$)), 4.54 (d, *J* = 7.9 Hz, H-1′ (**6b**$_3$)), 4.53 (d, *J* = 7.8 Hz, H-1′ (**6a**$_3$)), 4.30 (dd, *J* = 12.0, 3.6 Hz, H-1α (**6a**$_3$)), 4.28 (dd, *J* = 12.0, 4.0 Hz, H-1α (**6b**$_3$)), 4.26 (dd, *J* = 12.3, 4.7 Hz, H-6′α (**6b**$_3$)), 4.25 (dd, *J* = 12.3, 4.8 Hz, H-6′α (**6a**$_3$)), 4.14 (dd, *J* = 12.3, 2.4 Hz, H-6′β), 4.13 (dd, *J* = 12.0, 6.2 Hz, H-1β (**6a**$_3$)), 4.10 (dd, *J* = 12.0, 6.1 Hz, H-1β (**6b**$_3$)), 3.96 (dd, *J* = 10.9, 5.4 Hz, H-3α (**6b**$_3$)), 3.95 (dd, *J* = 10.9, 5.1 Hz, H-3α (**6a**$_3$)), 3.70 (dd, *J* = 10.9, 5.5 Hz, H-3β (**6a**$_3$)), 3.69 (m, H-5′), 3.68 (dd, *J* = 10.9, 5.7 Hz, H-3β (**6b**$_3$)), 2.10, 2.08, 2.07, 2.06, 2.05, 2.02, 2.01, 2.00 (each s, Ac).

A Mixture (7) of (2*S*)-1-*O*-Caffeoyl-3-*O*-*β*-D-glucopyranosylglycerol (Regaloside C) (7a) and (2*R*)-1-*O*-Caffeoyl-3-*O*-*β*-D-glucopyranosylglycerol (*epi*-Regaloside C) (7b)——A pale-yellow amorphous powder. $C_{18}H_{24}O_{11}$. $[\alpha]_D^{30}$ −21.1° (*c* = 0.19, MeOH). UV λ_{max}^{MeOH} nm (log ε): 241 sh (4.02), 300 sh (4.12), 328 (4.32). UV $\lambda_{max}^{MeOH + NaOMe}$ nm: 262, 310, 374. IR ν_{max}^{KBr} cm^{-1} 3400 (OH), 2900 (CH), 1680 (C=O), 1620 (CH=CH), 1595, 1510 (aromatic ring), 1440, 1365, 1275, 1175,

1160, 1110, 1065, 1025. EI-MS *m/z* (%): 163 (10), 145 (17), 103 (74). ^{1}H-NMR (CD_3OD) δ: 7.59 (d, J=15.9 Hz, H-7′), 7.05 (d, J=2.0 Hz, H-2′), 6.95 (dd, J=8.2, 2.0 Hz, H-6′), 6.78 (d, J=8.2 Hz, H-5′), 6.29 (d, J=15.9 Hz, H-8′), 4.31 (d, J=7.7 Hz, H-1″ (**7b**)), 4.30 (d, J=7.7 Hz, H-1″ (**7a**)), 4.31—4.26 (H-1α), 4.23 (dd, J=11.4, 6.1 Hz, H-1β (**7a**)), 4.20 (dd, J=11.4, 6.0 Hz, H-1β (**7b**)), 4.06 (m, H-2), 4.00 (dd, J=10.4, 4.2 Hz, H-3α (**7b**)), 3.96 (dd, J=10.6, 5.2 Hz, H-3α (**7a**)), 3.87 (br d, J=11.8 Hz, H-6″), 3.74—3.62 (H-3β, -6″β), 3.40—3.19 (H-2″, -3″, -4″, -5″). ^{13}C-NMR spectrum: Table I.

Acetylation of 7——Compound **7** (20.0 mg) was acetylated with Ac_2O–pyridine and the crude product was chromatographed on silica gel using *n*-hexane–acetone (3 : 1) to yield a white amorphous powder (20.4 mg) (**7a$_1$**, **7b$_1$**). IR ν_{max}^{KBr} cm^{-1}: 2950 (CH), 1750 (C=O), 1635 (CH=CH), 1500 (aromatic ring), 1420, 1375, 1220, 1670, 1105, 1030, 900. EI-MS *m/z* (%): 710 (M^+, 0.1), 668 (0.8), 626 (3.1), 566 (0.3), 507 (0.3), 446 (0.9), 363 (24), 331 (51), 321 (27), 278 (19), 205 (22), 169 (100), 163 (47), 109 (42). ^{1}H-NMR ($CDCl_3$) δ: 7.63 (d, J=15.9 Hz, H-7′), 7.41 (dd, J=8.3, 1.9 Hz, H-6′), 7.37 (d, J=1.9 Hz, H-2′), 7.23 (d, J=8.3 Hz, H-5′), 6.38 (d, J=15.9 Hz, H-8′), 5.25 (m, H-2), 5.21 (dd, J=9.5, 9.5 Hz, H-3″ (**7a$_1$**)), 5.20 (dd, J=9.5, 9.5 Hz, H-3″ (**7b$_1$**)), 5.09 (dd, J=9.5, 9.5 Hz, H-4″ (**7b$_1$**)), 5.08 (dd, J=9.5, 9.5 Hz, H-4″ (**7a$_1$**)), 5.01 (dd, J=9.5, 7.9 Hz, H-2″ (**7a$_1$**)), 4.99 (dd, J=9.5, 7.9 Hz, H-2″ (**7b$_1$**)), 4.56 (d, J=7.9 Hz, H-1″ (**7b$_1$**)), 4.55 (d, J=7.9 Hz, H-1″ (**7a$_1$**)), 4.40 (dd, J=12.1, 3.6 Hz, H-1α), 4.32—4.23 (H-1β, -6″α), 4.14 (br d, J=12.3 Hz, H-6″β), 4.01 (dd, J=11.1 Hz, 4.7 Hz, H-3α (**7b$_1$**)), 3.99 (dd, J=10.9, 5.1 Hz, H-3α (**7a$_1$**)), 3.77—3.68 (H-3β, -5″), 2.31, 2.30, 2.09, 2.08, 2.06, 2.02, 2.00 (each s, Ac).

Alkaline Hydrolysis Followed by Acetylation of 7——Compound **7** (36.5 mg) was treated with 3% NaOMe in MeOH as described for **6** to yield methyl caffeate and a mixture of glycerol glucosides. The latter was acetylated with Ac_2O–pyridine to give a white amorphous powder (28.0 mg), which was confirmed to be a 5 : 4 mixture of lilioside C hexaacetate and lilioside D hexaacetate by analysis of the ^{1}H-NMR spectrum.

A Mixture (10) of (2*S*)-1-*O*-Feruloyl-3-*O*-β-D-glucopyranosylglycerol (Regaloside F) (10a) and (2*R*)-1-*O*-Feruloyl-3-*O*-β-D-glucopyranosylglycerol (*epi*-Regaloside F) (10b)——A pale-yellow amorphous powder. $C_{19}H_{26}O_{11}$. $[\alpha]_D^{23}$ −15.1° (c=0.35, MeOH). UV λ_{max}^{MeOH} nm (log ε): 235 (4.10), 300 sh (4.20), 323 (4.32). IR ν_{max}^{KBr} cm^{-1}: 3424 (OH), 2927 (CH), 1702 (C=O), 1636 (CH=CH), 1604, 1517 (aromatic ring), 1273, 1165, 1125, 1078, 1034. MS *m/z* (%): 430 (M^+, 3), 296 (3), 279 (5), 268 (22), 251 (6), 205 (7), 194 (17), 177 (66), 164 (15), 163 (14), 145 (26), 103 (80). ^{1}H-NMR (CD_3OD) δ: 7.65 (d, J=15.6 Hz, H-7′), 7.19 (d, J=1.7 Hz, H-2′), 7.08 (dd, J=8.2, 1.7 Hz, H-6′), 6.81 (d, J=8.2 Hz, H-5′), 6.39 (d, J=15.9 Hz, H-8′), 4.31 (d, J=7.8 Hz, H-1″ (**10a**)), 4.30 (d, J=7.7 Hz, H-1″ (**10b**)), 4.31—4.17 (H-1), 4.07 (m, H-2), 4.03—3.93 (H-3α), 3.89 (s, OMe), 3.87 (dd, J=11.9, 1.4 Hz, H-6″α), 3.74—3.60 (H-3β, -6″β), 3.40—3.20 (H-2″, -3″, -4″, -5″). ^{13}C-NMR spectrum: Table I.

Acetylation of 10——A pyridine solution of **10** (4.7 mg) was treated with Ac_2O. Work-up as usual gave a white amorphous powder (3.2 mg) (**10a$_1$**, **10b$_1$**). IR ν_{max}^{KBr} cm^{-1}: 2926 (CH), 1757 (C=O), 1637 (CH=CH), 1602, 1509 (aromatic ring), 1421, 1375, 1231, 1156, 1125, 1038, 906. EI-MS *m/z* (%): 682 (M^+, 2.7), 640 (83), 610 (3), 337 (33), 335 (100), 331 (57), 293 (43), 219 (44). ^{1}H-NMR ($CDCl_3$) δ: 7.65 (d, J=16.0 Hz, H-7′), 7.15—7.10 (H-2′, -6′), 7.06 (d, J=7.9 Hz, H-5′), 6.38 (d, J=16.0 Hz, H-8′). 5.25 (m, H-2), 5.21 (dd, J=9.5, 9.5 Hz, H-3″ (**10a$_1$**)), 5.20 (dd, J=9.5, 9.5 Hz, H-3″ (**10b$_1$**)), 5.09 (dd, J=9.5, 9.5 Hz, H-4″), 5.05–4.98 (H-2″), 4.56 (d, J=8.0 Hz, H-1″ (**10b$_1$**)), 4.55 (d, J=7.8 Hz, H-1″ (**10a$_1$**)), 4.41 (dd, J=12.0, 4.0 Hz, H-1α), 4.32—4.23 (H-1β, -6″α), 4.14 (dd, J=12.3, 2.3 Hz, H-6″β), 4.03 (dd, J=11.0, 4.8 Hz, H-3α (**10b$_1$**)), 4.00 (dd, J=11.0, 4.9 Hz, H-3α (**10a$_1$**)), 3.88 (s, OMe), 3.77—3.68 (H-3β, -5″), 2.33, 2.10, 2.09, 2.06, 2.03, 2.01 (each s, Ac).

Alkaline Hydrolysis Followed by Acetylation of 10——Compound **10** (3.5 mg) was hydrolyzed with 3% NaOMe in MeOH to afford methyl ferulate and a mixture of glycerol glucosides. The mixture was acetylated in the usual manner to provide a white amorphous powder (2.1 mg), which the ^{1}H-NMR spectrum proved to be a 1 : 4 mixture of lilioside C hexaacetate and lilioside D hexaacetate.

(2*S*)-1-*O*-Feruloyl-2-*O*-β-D-glucopyranosylglycerol (Regaloside G) (11)——A pale-yellow amorphous powder. $C_{19}H_{26}O_{11}$. $[\alpha]_D^{23}$ −19.3° (c=0.14, MeOH). UV λ_{max}^{MeOH} nm (log ε): 236 (4.04), 300 sh (4.11), 325 (4.24). IR ν_{max}^{KBr} cm^{-1}: 3426 (OH), 2926, 2854 (CH), 1702 (C=O), 1731 (CH=CH), 1600, 1517 (aromatic ring), 1459, 1430, 1383, 1263, 1161, 1125, 1076, 1033, 846. EI-MS *m/z* (%): 430 (M^+, 4), 296 (4), 279 (4), 268 (26), 251 (10), 194 (20), 177 (75), 164 (26), 145 (28), 136 (23), 135 (32), 103 (100). ^{1}H-NMR (CD_3OD) δ: 7.66 (1H, d, J=15.9 Hz, H-7′), 7.20 (1H, d, J=1.9 Hz, H-2′), 7.09 (1H, dd, J=8.2, 1.9 Hz, H-6′), 6.81 (1H, d, J=8.2 Hz, H-5′), 6.38 (1H, d, J=15.9 Hz, H-8′), 4.48 (1H, d, J=7.8 Hz, H-1″), 4.36 (1H, dd, J=11.7, 4.9 Hz, H-1α), 4.30 (1H, dd, J=11.7, 5.8 Hz, H-1β), 4.05 (1H, m, H-2), 3.89 (3H, s, OMe), 3.86 (1H, dd, J=11.8, 1.2 Hz, H-6″α), 3.73 (2H, d, J=5.0 Hz, H-3), 3.66 (1H, m, H-6″β), 3.41—3.26 (H-3″, -4″, -5″), 3.22 (1H, dd, J=9.0, 7.8 Hz, H-2″). ^{13}C-NMR spectrum: Table I.

Acetylation of 11——Upon acetylation of **11** (2.8 mg) with Ac_2O–pyridine, 4.4 mg of the hexaacetate (**11a**) was obtained as a white amorphous powder. IR ν_{max}^{KBr} cm^{-1}: 2962 (CH), 1758 (C=O), 1638 (CH=CH), 1601, 1510 (aromatic ring), 1421, 1375, 1231, 1177, 1156, 1124, 1038, 985, 906, 834. EI-MS *m/z* (%): 682 (M^+, 2.7), 640 (17), 429 (3), 355 (3), 337 (11), 335 (30), 331 (23), 293 (25), 219 (38), 205 (100). ^{1}H-NMR ($CDCl_3$) δ: 7.67 (1H, d, J=16.0 Hz, H-7′), 7.15 (1H, dd, J=8.1, 1.7 Hz, H-6′), 7.12 (1H, d, J=1.7 Hz, H-2′), 7.07 (1H, d, J=8.1 Hz, H-5′), 6.38 (1H, d, J=16.0 Hz, H-8′), 5.22 (1H, dd, J=9.5, 9.5 Hz, H-3″), 5.08 (1H, dd, J=9.5, 9.5 Hz, H-4″), 5.01 (1H, dd, J=9.5, 8.0 Hz, H-2″), 4.70 (1H, d, J=8.0 Hz, H-1″), 4.35—4.11 (7H, H-1, -2, -3, -6″), 3.89 (3H, s, OMe), 3.72 (1H, m, H-5″), 2.33 (3H, s, arom. Ac), 2.10, 2.08, 2.03, 2.00, 1.99 (each 3H, s, Ac).

Alkaline Hydrolysis of 11——Compound **11** (1.0 mg) was treated with 3% NaOMe in MeOH at room temperature for 1 h. Methyl ferulate and glycerol glucoside were detected in the reaction mixture by TLC.

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