Chemical Components of the Leaves of *Duranta repens* LINN.

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Extracts of the leaves of *Duranta repens* LINN. were found to contain two new iridoids, durantoside IV and durantoside V together with several known compounds, oleanolic acid, ursolic acid, (*E*)-cinnamic acid, β-sitosteryl-3-*O*-β-D-glucopyranoside, (*E*)-*p*-methoxycinnamic acid, KNO_3, KCl, kusaginin, glucose, durantoside I, and durantoside II. Their structures was elucidated on the basis of spectral and chemical evidence. The absolute configuration of durantoside was determined by using the benzoate rule.

Key words *Duranta repens*; iridoid chemistry; iridoid glucoside; durantoside; benzoate rule

There are only two species of *Duranta* genus (Verbenaceae) indigenous to Taiwan: *Duronta repens* LINN. and *D. repens* LINN. *forma alba* (MAST.) MATURDA. The former, a common ornamental and fence tree, has small purple flowers and golden fruit. The leaves of this plant exhibit a strong bitter taste. We have briefly reported the structural elucidation of a new iridoid, durantoside IV pentaacetate (**1a**) (purified by acetylation), from the leaves of *D. repens* LINN.[1] In the present paper we describe in detail our study on the components of the leaves of this plant. The leaves were extracted with hexane, acetone, and ethanol, successively. The hexane extract gave oleanolic (**2**) and ursolic acids (**3**),[2] and β-sitosteryl-3-*O*-β-D-glucopyranoside (**4**)[3] was obtained from the acetone extract. The ethanol extract suspended in water was continuously extracted with ethyl acetate. The water layer yielded two inorganic salts, KNO_3 and KCl, and the organic layer was subjected to chromatography on silica gel. (*E*)-Cinnamic acid, (*E*)-*p*-methoxycinnamic acid, and a fraction containing a strongly bitter substance were isolated. The bitter principle showed a strong hydroxyl absorption in its IR spectrum. This fraction was acetylated and then subjected to chromatography on silica gel to yield glucose pentaacetate, kusaginin nonaacetate (**5b**),[4] durantoside I pentaacetate (**1b**),[5] durantoside I tetraacetate (**1c**),[5] durantoside II tetraacetate (**1d**),[5] durantoside IV pentaacetate (**1a**), and durantoside V tetraacetate (**1e**). Rimpler and Timm[5] reported three iridoid glucosides, durantoside I (**1f**), durantoside II (**1g**), and durantoside III (**1h**), from the same species of plant. Compound **1b** was considered as the product of exhaustive acetylation of durantoside. In this paper, we wish to report the structural elucidation of two new iridoid glucosides **1a** and **1e**, as well as some iridoid chemistry. Further, the absolute configuration of the iridoid structure of durantoside was determined by applying the benzoate rule.

Durantoside IV pentaacetate (**1a**) forms colorless needles, mp 215—217 °C. It was deduced to have the molecular formula $C_{36}H_{42}O_{19}$ on the basis of its elemental analysis. The IR spectrum of **1a** shows bands attributable to phenyl acetate (1755 cm^{-1}), alkyl acetate (1730 cm^{-1}), conjugated ester (1715 cm^{-1}), conjugated double bond (1640, 1630 cm^{-1}), and hydroxyl groups (3540 cm^{-1}), as well as aromatic absorptions (1605, 1500 cm^{-1}). The UV spectrum (λ_{max}^{MeOH} 220.5, 225 nm) and ^{1}H-NMR spectrum (δ 7.29, s, –OCOC=CHO–) suggested the presence of an iridoid structure. The ^{1}H-NMR spectrum (Table 1) of **1a** revealed that it has a *p*-acetoxy-*E*-cinnamolyl group [δ 2.31 (3H, s), 6.46, 7.68 (each 1H, d, J=16.0 Hz), 7.10, 7.57 (each 2H, d, J=8.1 Hz)], a tertiary methyl group [δ 1.21 (3H, s)] on carbon bearing a hydroxyl group, a methylene group [δ 2.47 (2H, d, J=3.5 Hz)], three methine protons [δ 2.97, 5.67 (each 1H, s, H-9, H-1), 4.85 (1H, t, J=3.5 Hz, H-7)], a carbomethoxy group [δ 3.75 (3H, s)], and a β-*O*-tetraacetyl glucopyranosyl group [δ 1.95, 2.00, 2.05, 2.19 (each 3H, s), 3.70 (1H, m), 4.17 (1H, dd, J=10.5, 2.3 Hz), 4.26 (1H, dd, J=10.5, 4.5 Hz), 4.80 (1H, d, J=7.9 Hz, anomeric H), 4.94 (1H, dd, J=9.6, 7.9 Hz), 5.02 and 5.23 (each 1H, t, J=9.6 Hz)]. Hydrogenation of **1a** gave **1i** [λ_{max}^{MeOH} 223 nm; δ 2.80 (4H, m)]. On further reduction with PtO_2 in EtOAc, **1a** afforded **1j** [δ 1.40—1.60 (about 13H, m), 7.29 (1H, s)]. On acetylation with Ac_2O–pyridine at 75 °C for 6 h, **1a** afforded the hexaacetate **1k** [mp 168—170 °C; ν_{max}^{KBr} 3550 cm^{-1}; δ 1.94, 2.00, 2.01, 2.10, 2.10, 2.33 (each 3H, s)]. The remaining tertiary hydroxyl group in **1j** was located at C-5 on the basis of steric hindrance.[6] The tertiary methyl group is located at C-8 for biogenetic reasons.[7] Based on the ^{1}H-NMR signals at δ 2.37 (2H, d, J=3.5 Hz) and 4.65 (1H, t, J=3.5 Hz) in **1j** and corresponding protons in **1a**, as well as the result of double resonance experiments, the partial structure C–CH_2CH(O-COR)–C was confirmed.

When **1a** was allowed to react with NaOMe in MeOH at room temperature, followed by neutralization with excess Amberlite IR-120, methyl *p*-(*E*)-coumarate, three glucosides, **6a**, **7** and **1l** were isolated. If the neutralization was done to pH 6—7, only three hydrolyzed products, methyl *p*-(*E*)-coumarate, **7** and **1l** were recovered. The physical data of **1l** (major product) were in good agreement with those of lamiide.[5,8–10] The pentaacetate **1m** and hexaacetate **1n** prepared from **1l** were identical with lamiide pentaacetate and lamiide hexaacetate.[5,8] Compound **6a** showed a conjugated ester (λ_{max}^{MeOH} 223.5 nm) and additional signals of a new methoxy group [δ 3.53 (3H, s)] together with a signal at δ 5.43 [1H, br s, –O–CH(OMe)–C=C–] instead of at δ 7.29 in **1a**. Compound **6a** could be prepared quantitatively by treating **1l** in MeOH with Amberlite IR-120 at 50—55 °C. A similar result was reported by Scopati and Guiso[8] who used Dewar 50 W

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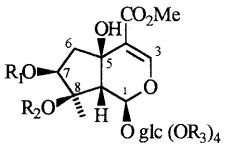


	R_1	R_2	R_3
1a	*p*-AcO–C_6H_4–CH=CH–CO–	H	Ac
1b	C_6H_5–CH=CH–CO–	Ac	Ac
1c	C_6H_5–CH=CH–CO–	H	Ac
1d	*p*-MeO–C_6H_4–CH=CH–CO–	H	Ac
1e	C_6H_5–CH=CH–CO–	H	Ac
1f	C_6H_5–CH=CH–CO–	H	H
1g	*p*-MeO–C_6H_4–CH=CH–CO–	H	H
1h	3,4-$(MeO)_2$–C_6H_3–CH=CH–CO–	H	H
1i	*p*-AcO–C_6H_4–CH_2CH_2–CO–	H	Ac
1j	Cyclohexyl–CH_2CH_2–CO–	H	Ac
1k	*p*-AcO–C_6H_4–CH=CH–CO–	Ac	Ac
1l	H	H	H
1m	Ac	H	Ac
1n	Ac	Ac	Ac
1o	$C_6H_5CH_2CH_2$–CO–	H	Ac

as an acidic catalyst to transform lamiide (**1l**) to **6a**. Compound **7** shows an isolated ester absorption and its ^{1}H-NMR spectrum exhibits signals due to a new methoxyl group (δ 3.47) and two methine protons [δ 3.47 and 4.98 (each 1H, d, J=10.1 Hz, H-4, H-3)]. The formation of **7** occurred through the addition of methoxide to the conjugated double bond of **1l**. Further, **1l** reacted with NaOMe in MeOH to give **7**. The attack of a methoxide ion on **1l** from the less hindered α-side is reasonable.[11] Therefore durantoside pentaacetate can be assigned the formula **1a**.

Durantoside tetraacetate (**1e**), mp 178—180 °C, needles from methanol, has the molecular formula $C_{34}H_{40}O_{17}$ on the basis of elementary analysis. The IR spectrum of **1e** showed bands at 1730, 1720 cm^{-1} (ester group), 1635 cm^{-1} (conjugated double bond), 1600 and 1500 cm^{-1} (phenyl group), and 3530 and 3470 cm^{-1} (hydroxy group). The UV spectrum (λ_{max}^{MeOH} 224 nm) and the ^{1}H-NMR spectrum (δ 7.26, s) suggested the presence of iridoid structure.[12] The presence of a *cis*-cinnamoyl group was indicated by the UV spectrum (λ_{max}^{MeOH} 219, 262 nm) and signals in the ^{1}H-NMR spectrum at δ 5.98 and 7.12 (each 1H, d, J=12.0 Hz). The compound contains four acetyl groups, a tertiary methyl group on carbon bearing a hydroxyl group, a methylene group, three methine protons, and a carbomethoxy moiety, from the ^{1}H-NMR spectrum (Table 1). Hydrogenation of **1e** with 5% Pd–C in EtOAc gave **1o** [mp 176—177 °C, λ_{max}^{MeOH} 228.5 nm; δ 2.84—2.92 (4H, m)], which was also obtained from durantoside I tetraacetate (**1c**) by similar hydrogenation. On catalytic hydrogenation with PtO_2 in EtOAc, compound **1j** was obtained from **1e**. When **1e** was allowed to react with NaOMe in MeOH at room temperature followed by neutralization with Amberlite IR-120 to pH 6—7, methyl (*Z*)-cinnamate, **7** and lamiide (**1l**) were obtained. On reaction with 1 N HCl MeOH solution at room temperature, **1e** afforded four products, methyl (*E*)-cinnamate, **8**, **9a** and **9b**, in addition to glucose. Methyl cinnamate was presumably converted from (*Z*) form to (*E*) form by acidic isomerization. Compound **8** (mp 164—165 °C) has the molecular formula $C_{12}H_{12}O_5$ on the basis of elemental analysis. It shows UV absorption bands at λ_{max}^{MeOH} 223 and 312 nm and IR absorption bands at 1720 and 1700 cm^{-1} (no hydroxyl group absorption). The ^{1}H-NMR data for **8** [δ 2.25, 3.56, 3.81 (each 3H, s, H-10, –OMe, –COOMe), and 5.78, 6.33, 7.91 (each 1H, s, H-1, H-6, H-3)] confirmed the structure. The formation of this compound is illustrated in Chart 1. Compound **9b** showed a conjugated ester group (λ_{max}^{MeOH} 222 nm, 1710 cm^{-1}) and gave ^{1}H-NMR signals at δ 4.78 (1H, d, J=9 Hz, H-1), 3.76 (1H, br d, J=4.5 Hz, H-7), as well as three methoxyl signals [δ 3.51, 3.56, 3.72 (each 3H, s)]. The physical data are in good agreement with the assigned structure. Compound **9a** was considered to be a derivative of **9b** from the similarity of its ^{1}H-NMR spectral pattern to that of **9a**, except for an extra (*E*)-cinnamoyl group [δ 6.39, 7.69 (each 1H, d, J=16.0 Hz)]. The evidence described above is consistent with the assignment of durantoside V tetraacetate as **1e**.

Thus we have found many interesting products from the basic and acidic hydrolysis of **1a** and **1e**. In order to study the mechanism of the formation of these products. We selected the major component, durantoside I tetraacetate (**1c**), for the following reactions. The absolute configurations of two of the products were determined by using the benzoate rule. Hydrolysis of **1c** with 1 N HCl–MeOH at room temperature gave products, methyl (*E*)-cinnamate, **10**, **8**, **11**, **9a**, **9b**, **6b**, and glucose. When **1c** was allowed to react with NaOMe in MeOH at room temperature followed by neutralization with excess Amberlite IR-120, methyl (*E*)-cinnamate, **6a**, **7**, and **1l** were isolated. When the neutralization was done to pH 6—7, only three hydrolytic products, methyl (*E*)-cinnamate, **7**,

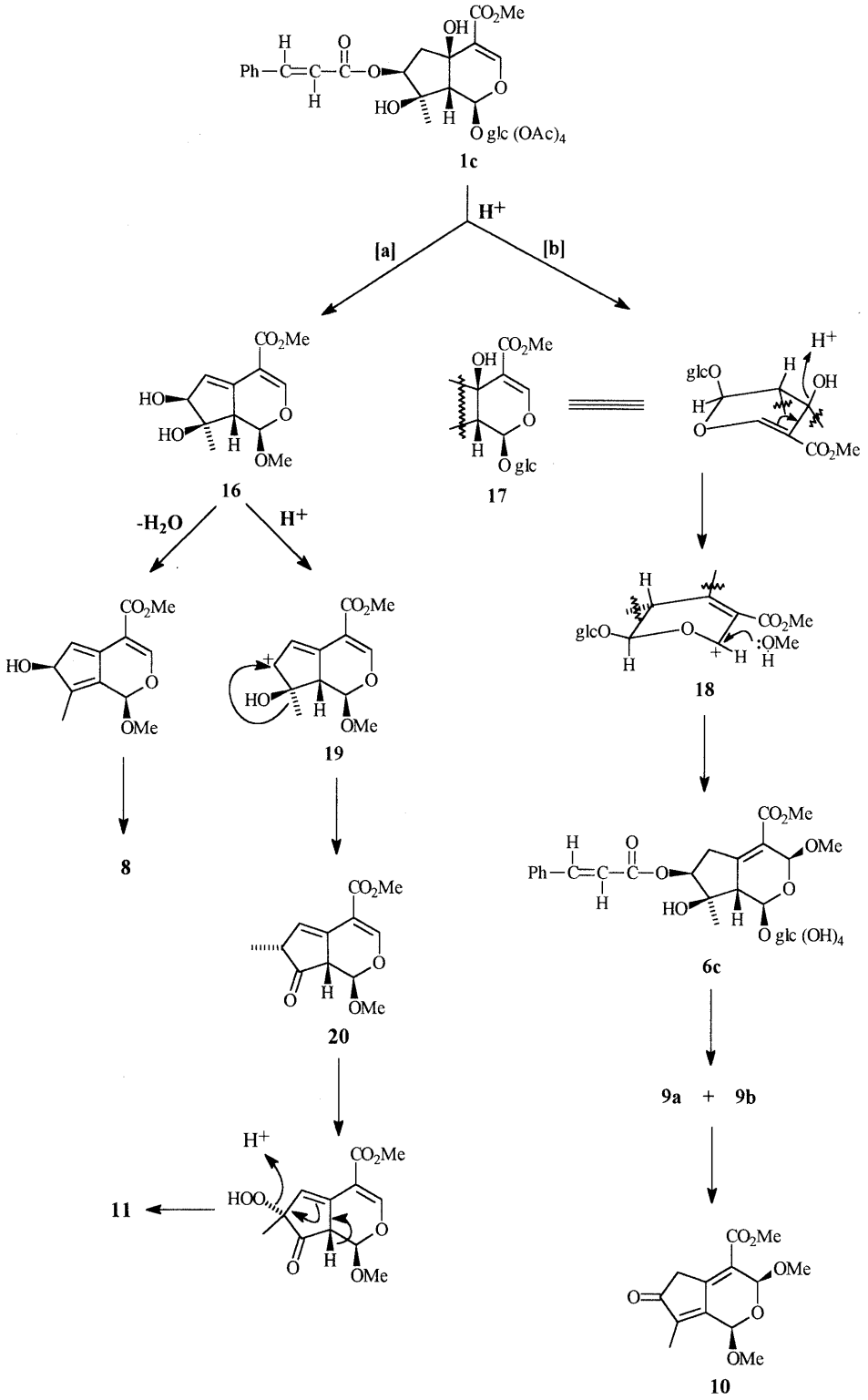
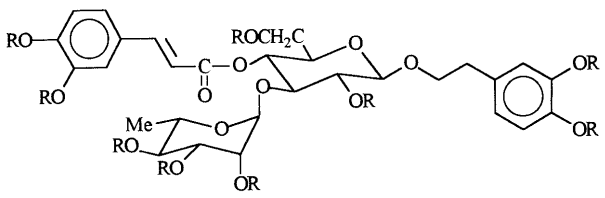


Chart 1

11 were observed. Lamiide (**11**) was hydrolyzed with 1 N HCl in MeOH at room temperature and three products, **11**, **9b**, and **12** were formed. Compound **6b** was considred to be a glycoside with a cinnamoyl group from its spectrum. New signals in the spectrum of **6b** at δ 3.42 (3H, s, –OMe) and 5.15 (1H, br s, H-3) were seen instead of δ 7.34 in **1c**. The tetraacetate **6c** prepared from **6b** by acetylation exhibits H-1 (δ 5.21) and H-9 (δ 3.02) signals with a large coupling constant (8.3 Hz), suggesting that the conversion would also change the conformation of the glucoside residue at C-1 from quasi-axial to quasi-equatorial. The other proton signals in **6c** were seen at δ 2.96 (2H, m, H-6), 5.09 (1H, br d, J = 5 Hz, H-7), 5.27 (1H, br s, H-3). Three methoxyl groups were present in compound **10**, and H-1 (δ 5.57) and H-3 (δ 5.51) both appeared as singlets. Two protons with larger coupling constants at δ 3.20, 3.40 (each 1H, d, J = 16.1 Hz) can be assigned to the vicinal position to carbonyl. The methyl group was attached at the double bond, based on the low field signal at δ 1.91 (3H, s). The product **10** was considered to have been formed from **9b**



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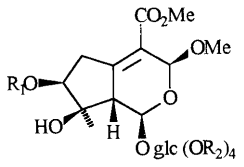
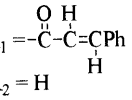
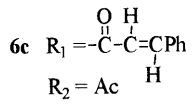
5b R = Ac



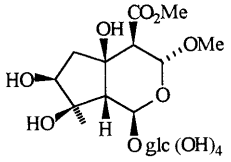
6a $R_1 = R_2 = H$



6b $R_2 = H$



6c $R_2 = Ac$



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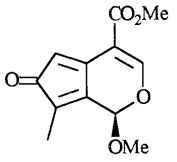

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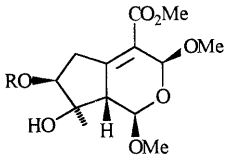
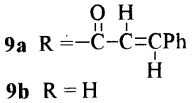
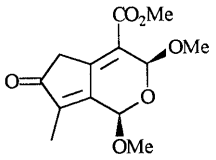




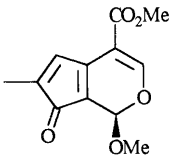
9a R =

9b R = H

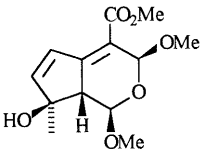
9c R = Bz



10



11



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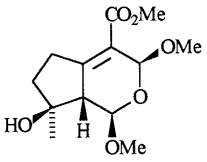
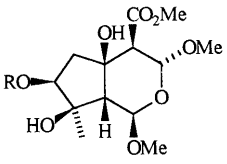
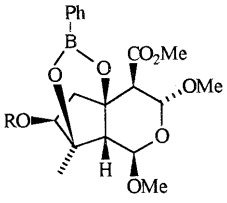


13



14a R = H
14b R = Bz



15a R = H
15b R = Ac

by dehydration and then autooxidization. Compound **11**, an interesting product, is an isomer of **8**. It contains two methoxy and one methyl groups [δ 3.80, 3.53 (each 3H, s), 2.25 (3H, br s)], and three methine protons [δ 5.78, 7.91 (each 1H, H-1, H-3), 6.33 (1H, br s, H-6)]. Irradiation at δ 2.25 simplified the signal at δ 6.33 to be a singlet, and signals between δ 2.25 and 6.33 showed 6.5% NOE. It was considered to be a rearrangement product. Product **12** exhibits UV absorption at λ_{max}^{MeOH} 263 nm (log ε 4.36), IR absorption at 3480 cm^{-1} (OH), and ^{1}H-NMR signals at δ 1.31, 3.52, 3.58, 3.83 (each 3H, s), 2.84 (1H, br d, J = 9.0 Hz, H-9), 4.81 (1H, d, J = 9.0 Hz, H-1), 5.39 (1H, br s, H-3), 6.39, 6.99 (each 1H, d, J = 5.5 Hz, H-6, H-7). Hydrogenation of **12** gave **13**, which shows λ_{max}^{MeOH} 225 nm and signals at δ 1.89, 2.79 (each 2H, m, H-7, H-6). In an attempt to prepare **9b** from **9a**, the latter was treated with NaOMe in MeOH at room temperature, but the products were **12** and (*E*)-cinnamic acid. When **9b** was reacted with equimolar brosyl chloride in dry pyridine at room temperature for 2 h, only **12** was observed. The facile elimination can be ascribed to the fact that the product is a stable conjugated compound.

Compound **1c** afforded glucose, methyl (*E*)-cinnamate, **9a**, **9b**, and **6c** on hydrolysis under the above conditions, but in the dark under a nitrogen atmosphere. Compounds **8**, **10**, and **11** were not observed under this condition. Therefore, **8**, **10**, and **11** are autooxidization products. In order to examine the conformation of the tetrahydropyran

Table 1. ^{1}H-NMR Data for **1a**, **1b**, **1e**, and **1k** (in $CDCl_3$, TMS as Standard)

H	1a	1b	1e	1k
1	5.67 s	5.83 br s	5.49 br s	5.76 s
3	7.29 s	7.33 s	7.36 s	7.32 s
6	2.47 d (3.5)	2.51 d (4.0)	2.35 d (3.4)	2.40 d (4.0)
7	4.85 t (3.5)	5.29 t (4.0)	4.60 t (3.4)	5.37 t (4.0)
9	2.97 s	3.25 br s	2.47 br s	3.23 br s
10	1.21 s	1.43 s	1.05 s	1.44 s
1′	4.80 d (7.9)	4.81 d (8.0)	4.78 s (7.8)	4.82 s (7.9)
2′	4.94 dd (9.6, 7.9)	4.93 dd (9.5, 8.0)	4.90 dd (9.3, 7.8)	4.92 dd (9.4, 7.9)
3′	5.02 t (9.6)	5.03 t (9.5)	5.04 t (9.3)	5.02 t (9.4)
4′	5.23 t (9.6)	5.24 t (9.5)	5.23 t (9.3)	5.23 t (9.4)
5′	3.70 m	3.72 m	3.71 m	3.71 m
6′	4.17 dd (10.5, 2.3)	4.17 dd (10.5, 2.3)	4.17 dd (10.5, 2.3)	4.12 dd (10.5, 2.3)
	4.26 dd (10.5, 4.5)	4.24 dd (10.6, 4.5)	4.27 dd (10.4, 4.6)	4.26 dd (10.5, 4.6)
Phenyl	7.10 d (8.1)	7.30—7.55 m	7.38—7.56 m	7.08 d (8.0)
	7.57 d (8.1)			7.52 d (8.0)
MeO	3.75 s	3.75 s	3.71 s	3.74 s
AcO	1.95 s, 2.00 s, 2.05 s,	1.95 s, 2.04 s, 2.04 s,	1.92 s, 1.97 s, 1.99 s,	1.94 s, 2.00 s, 2.01 s,
	2.19 s, 2.31 s	2.11 s, 2.11 s	2.06 s	2.10 s, 2.10 s, 2.33 s
Olefin	6.46 d (16.0)	6.43 d (16.1)	5.98 d (12.0)	6.33 d (16.2)
	7.68 d (16.0)	7.70 d (16.1)	7.12 d (12.0)	7.69 d (16.2)

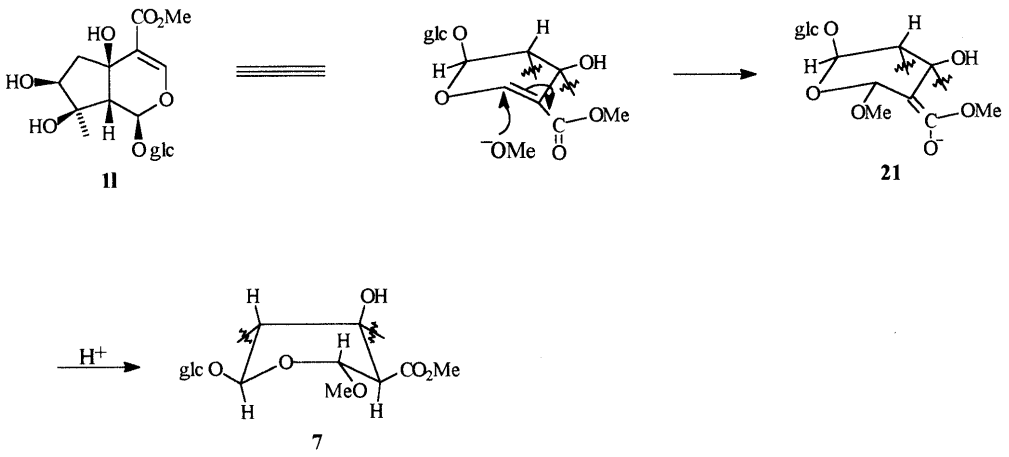


Chart 2

ring in the iridoid compound, **7** was hydrolyzed with 1 N HCl MeOH at room temperature, and **12**, **9b**, **14a** were eluted in that order on chromatography. The last product (major) melted at 144—146 °C and exhibited IR absorption bands at 3440, 3380, 3260 (–OH), and 1730 cm^{-1} (CO_2Me). The ^{1}H-NMR spectrum shows signals at δ 1.23, 3.36, 3.40 and 3.68 (each 3H, s), 1.71 (1H, dd, J=15.1, 3.0 Hz, H_a-6), 2.30 (1H, dd, J=15.0, 6.1 Hz, H_b-6), 2.23, 4.63 (each 1H, d, J=1.5 Hz, H-9, H-1), 3.25, 4.70 (each 1H, d, J=9.1 Hz, H-4, H-3), 3.72 (1H, dd, J=6.1, 3.0 Hz, H-7). Compound **14a** was heated with phenylboric acid in dry benzene in a Dean–Stark apparatus under reflux. The reaction mixture gave **15a** [ν_{max}^{KBr} 3520, 1605, 1500 cm^{-1}, δ 4.51 (1H, t, J=4.2 Hz, H-7), 7.37 (3H, m), and 7.79 (2H, dd, J=7.8, 1.2 Hz)]. On acetylation, **15a** afforded **15b** [no hydroxy absorption; δ 5.07 (1H, dd, J=10.1, 5.2 Hz, H-7), 2.04 (3H, s, CH_3COO–)]. This result indicated that the hydroxyls at C-5 and C-8 are in a *cis* relationship. The benzoate rule was applied to confirm the absolute configuration of C-7. Compounds **9b** (M_D=−291.6) and **14a** (M_D=+34.6) were treated with benzoyl chloride to give **9c** (M_D=−262.7) and **14b** (M_D=+109.6), respectively. The application of the benzoate rule[13] to **9a** or **14a** indicates that the hydroxyl group at C-7 has *S*-configuration. Therefore the structure and absolute configuration of **1a** and **1e** should be as represented in the formula.

The mechanism of the formation of products of methanolysis of **1c** with 1 N HCl–MeOH is considered to be as shown in Chart 1. Compound **1c** undergoes methanolysis then dehydration (path a) to yield methyl (*E*)-cinnamate, α- and β-methyl-*O*-glucoside, and **16**. *Via* path b, **1c** affords only the intermediate **17**, which is protonated and then dehydrated and rearranged to give the carbocation **18**. By coupling with methanol from the less-hindered β-face, the carbocation **18** is converted to **6c**. Compound **6c** is transformed to **9a**, followed by hydrolysis to afford **9b** and methyl (*E*)-cinnamate. After dehydration and autooxidation, **9b** is converted to **10**. Compound **8** is obtained from **16** by dehydration and autooxidation. Dehydration from **16** yields a cation **19**, followed by the migration of the methyl group to form

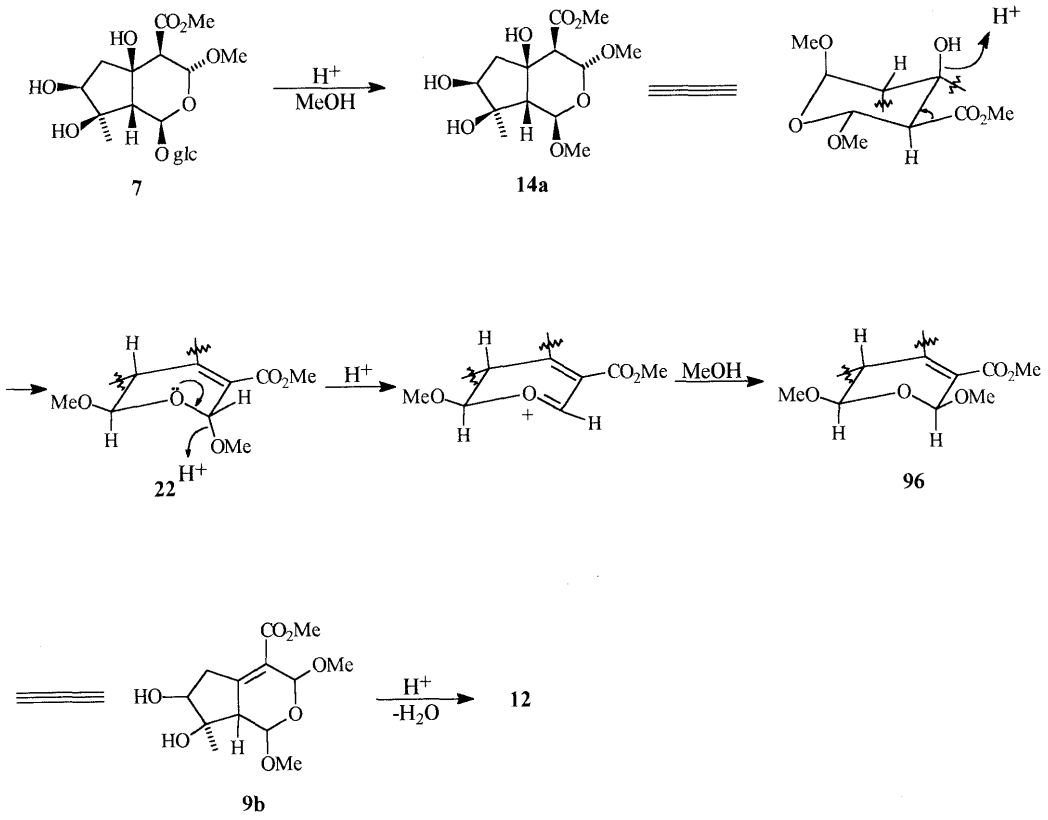


Chart 3

20. Compound **20** is converted to **11** by autooxidation then elimination.

The formation of **7** from **11** is proposed to occur as shown in Chart 2. The attack of a methoxide ion from the less-hindered α-side would give an ion **21**, which affords **7** after protonation. The pathway of formation of **12**, **9b**, and **14a** from **7** is shown in Chart 3. Methanolysis of **7** yields **14a**, which followed by acid dehydration to afford the intermediate **22**. Due to the C-3 methoxy group being in a hindered quasi-axial orientation, **22** is converted to the more stable **9b**. Dehydration of **9b** gives **12**.

Experimental

Melting points were determined on a Yanagimoto micromelting point apparatus without correction. IR spectra were recorded on a JASCO IRA-1 spectrophotometer and UV spectra were determined in methanol solution on a Hitachi 323 recording spectrophotometer. ^{1}H-NMR spectra were run on NEC PS-100 and HL-60 instruments in the indicated solvent with tetramethylsilane (TMS) as an internal standard. Chemical shifts are given in δ-values and coupling constants (*J*) are given in hertz (Hz).

Extraction and Isolation The leaves of *Duranta repens* LINN. (17 kg) were extracted with hexane (110 l × 3), acetone (110 l × 3), and ethanol (110 l × 3), successively. Oleanolic acid (**2**) (0.5 g) was isolated from the hexane extract. The acetone extract yielded three components, oleanolic acid (**2**) (0.72 g), ursolic acid (**3**) (14.15 g), and β-sitosteroyl-3-*O*-β-glucopyranoside (0.34 g), after purification on silica gel chromatography. The whole ethanol extract was evaporated *in vacuo* to about 500 ml, and the amorphous precipitates and mother liquid (fraction A) were separated. Water (200 ml) was added to the combined three amorphous precipitates to give an insoluble fraction and an aqueous solution. The insoluble fraction is a black substance which is soluble in $CHCl_3$ and acetone, but only slightly soluble in ethanol. It was purified by silica gel chromatography but gave no crystalline product. The aqueous layer was extracted with ethyl acetate continuously to obtain an ethyl acetate layer (fraction B) and a water layer. The water layer was evaporated to about 100 ml, and KNO_3 (6 g) crystallized out. On further evaporation of the aqueous filtrate to about 50 ml, KNO_3 (4 g) and KCl (4.7 g) crystallized out in a different crystalline shape. Separation was achieved by a mechanical method. Fraction B (3 g) showed strong hydroxyl absorption in its IR spectrum and a bitter taste. The combined three mother liquids (fraction A) were evaporated to leave a residue, which was taken up in 10 l of water. This aqueous solution was subsequently extracted with ethyl acetate using a glass continuous extraction apparatus. The extract was dried (Na_2SO_4) and the solvent was removed under reduced pressure to leave the crude material (460 g). A part of the crude material (100 g) together with fraction B (3 g) was chromatographed on silica gel (2.3 kg), and (*E*)-cinnamic acid (1.1 g), and (*E*)-*p*-methoxycinnamic acid (0.48 g) were eluted with 1% EtOH in $CHCl_3$. The fractions eluted with 10% EtOH in $CHCl_3$ to 50% EtOH in $CHCl_3$ showed a strong bitter taste and afforded amorphous powder. These bitter substance fractions were separated into four fractions, and each was acetylated with Ac_2O–pyridine overnight at room temperature. Durantoside I pentaacetate (**1b**) (1.8 g), durantoside V tetraacetate (**1e**) (0.95 g), durantoside I tetraacetate (**1c**) (16.5 g), and durantoside II tetraacetate (**1d**) (4.4 g) were purified from the first acetylated fraction. The second acetylated fraction yielded durantoside II tetraacetate (**1d**) (0.2 g) and durantoside IV pentaacetate (**1a**) (0.81 g), and the third acetylated fraction gave kusiginin nonaacetate (**5b**) (6.5 g). The fourth gave α- and β-glucoside pentaacetate (0.72 g). The known compounds were identical with authentic samples or their physical data were consistent with literature values. Durantoside I pentaacetate (**1b**) was considered to be an acetylated product of durantoside I, *i.e.*, an artifact. The physical data of durantoside I pentaacetate (**1b**), durantoside IV pentaacetate (**1a**), an durantoside V tetraacetate (**1e**) were as follows.

Durantoside I Pentaacetate (**1b**): mp 211—212 °C, $[\alpha]^{15}$ −39.2 (c = 1.0, $CHCl_3$). UV λ_{max}^{MeOH} nm (log ε): 218.5 (4.08), 224 (4.08), 282 (4.02). IR ν_{max}^{KBr} cm^{-1}: 3550, 1740, 1715, 1630, 1600, 1505, 1235, 1260, 1080, 1075, 1050. ^{1}H-NMR ($CDCl_3$): Table 1. *Anal.* Calcd for $C_{36}H_{42}O_{19}$: C, 55.51; H, 5.44. Found: C, 55.84; H, 5.49.

Durantoside IV Pentaactate (**1a**): mp 215—217 °C, $[\alpha]^{20}$ −47.9 (c = 1.0, $CHCl_3$. UV λ_{max}^{MeOH} nm (log ε): 220.5 (4.22), 225 (4.22), 280 (4.26). IR ν_{max}^{KBr} cm^{-1}: 3540, 3520, 1755, 1730, 1715, 1640, 1630, 1605, 1500. ^{1}H-NMR ($CDCl_3$): Table 1. *Anal.* Calcd for $C_{36}H_{42}O_{18}$: C, 56.68; H, 5.55. Found: C, 56.35; H, 5.47.

Durantoside V Pentaacetate (**1e**): mp 178—180 °C, $[\alpha]^{22}$ −57.4 (c= 1.0, $CHCl_3$. UV λ_{max}^{MeOH} nm (log ε): 219 (4.19), 224 (4.19), 262 (3.91). IR ν_{max}^{KBr} cm^{-1}: 3530, 3470, 1730, 1720, 1635, 1600, 1500, 1155, 1235, 1060. ^{1}H-NMR ($CDCl_3$): Table 1. *Anal.* Calcd for $C_{34}H_{40}O_{17}$: C, 56.65; H, 5.60. Found: C, 56.34; H, 5.62.

Catalytic Hydrogenation of 1a with Pd–C Compound **1a** (100 mg) was dissolved in 8 ml of EtOAc, then 20 mg of 10% Pd–C was added and the mixture was saturated with H_2. After 12 h, the catalyst was removed by filtration and washed with several times with EtOAc. The combined filtrate and washing yielded a product **1i** (96 mg) [mp 162—163 °C, UV λ_{max}^{MeOH} nm (log ε): 2.23 (4.11). IR ν_{max}^{KBr} cm^{-1}: 3550, 3520, 1745, 1720, 1630, 1600, 1500. ^{1}H-NMR ($CDCl_3$): δ: 1.11, 3.93 (each 3H, s, H-10, –OCH_3), 1.95, 2.00, 2.01, 2.14, 2.27 (each 3H, s, CH_3COO–), 2.34 (2H, d, J=3.5 Hz, H-6), 2.80 (4H, m, –CH_2CH_2–), 2.82, 5.61 (each 1H, br s, H-9, H-1), 3.70 (1H, m, H-5′), 4.10 (1H, dd, J=10.6, 2.5 Hz, H_a-6′), 4.27 (1H, dd, J=10.6, 4.7 Hz, H_b-6′), 4.64 (1H, t, J=3.5 Hz, H-7), 4.7—5.3 (4H, m), 6.97, 7.26 (each 2H, d, J=8.1 Hz, phenyl protons), 7.29 (1H, s, H-3)].

Catalytic Hydrogenation of 1a with PtO_2 Compound **1a** (115 mg) was hydrogenated in EtOAc (8 ml) with PtO_2 (20 mg) as a catalyst. After 25 h, the product **1j** was obtained (110 mg) [mp 168—170 °C. IR ν_{max}^{KBr} cm^{-1}: 3550, 3480, 3360, 1735, 1716, 1640, 1505. ^{1}H-NMR ($CDCl_3$): δ 1.16, 3.75 (each 3H, s, H-10, –OCH_3), 1.96, 2.02, 2.03, 2.11 (each 3H, s, CH_3COO–), 1.40—1.60 (about 13H, m), 2.39 (2H, t, J=7.1 Hz, –CH_2CH_2CO–), 2.37 (2H, d, J=3.5 Hz, H-6), 2.86, 5.61 (each 1H, br s, H-9, H-1), 3.73 (1H, m, H-5′), 4.11 (1H, dd, J=10.5, 2.5 Hz, H_a-6′), 4.25 (1H, dd, J=10.5, 4.6 Hz, H_b-6′), 4.65 (1H, t, J=3.5 Hz, H-7), 4.70—5.30 (4H, m), 7.29 (1H, s, H-3)].

Acetylation of 1a with Ac_2O–Pyridine at 75 °C Compound **1a** (100 mg) was allowed to react with Ac_2O (1 ml) and pyridine (1 ml) at 75 °C for 6 h. Usual work-up gave a hexaacetate **1k** (70 mg) [mp 168—170 °C, IR ν_{max}^{KBr} cm^{-1}: 3560, 1740, 1725, 1635, 1610, 1510. ^{1}H-NMR ($CDCl_3$): Table 1].

Methanolysis of 1a with NaOMe in MeOH Compound **1a** (254 mg) was added to 10 ml of 3% methanolic NaOMe solution and after 5 h at room temperature, the solution was neutralized with Amberlite IR-120 to pH 6—7. The reaction mixture was filtered and evaporated to leave a residue, which was separated by silica gel chromatography to afford methyl (*E*)-coumarate (47 mg), **7** (14 mg), and **1l** (92 mg).

Compound **1a** (404 mg) was also methanolyzed with NaOMe under the same conditions as mentioned above, but neutralized with excess Amberlite IR-120. The reaction mixture was purified by SiO_2 chromatography to afford methyl (*E*)-coumarate (65 mg), **6a** (28 mg),[8] **7** (25 mg), and **1l** (148 mg). Methyl (*E*)-coumarate was identified on the basis of its physical data. Compound **1l** was identical with lamiide.[5,8-10] Acetylation of **1l** (128 mg) with Ac_2O (2 ml) and pyridine (2 ml) at room temperature gave two products, lamiide pentaacetate (**1m**) (mp 198—199 °C) (160 mg)[5,8] and lamiide hexaacetate (**1n**) (17 mg).[5,8] Compound **7**: amorphous. IR ν_{max}^{KBr} cm^{-1}: 3360, 1735, 1080, 1020. ^{1}H-NMR (D_2O): δ 1.29, 3.47, 3.76 (each 3H, s, H-10, –OCH_3, –$COOCH_3$), 1.78 (1H, dd, J=15.3, 3.2 Hz, H_a-6), 2.34 (1H, dd, J=15.3, 6.4 Hz, H_b-6), 2.28 (1H, d, J=7.0 Hz, H-9, the signal of H-1 was obscured by HOD), 3.41, 4.98 (each 1H, d, J=10.0 Hz, H-4, H-3), 3.78 (1H, H-7, obscured by signal of 3.76).

Reaction of Lamiide (1l) with Amberlite IR-120 in MeOH Lamiide (**1l**) (50 mg) was heated at 55 °C for 2 h in 5 ml of MeOH with 100 mg of Amberlite IR-120, then the reaction mixture was filtered and the filtrate was evaporated to leave **6a** (45 mg).[9]

Reaction of Lamiide (1l) with Methanolic NaOMe Lamiide (**1l**) (52 mg) was dissolved in 5 ml of 3% methanolic NaOMe and the solution was left for 3 d at room temperatue. After neutralization with Amberlite IR-120 to pH 6—7, the reaction mixture afforded **7** (37 mg).

Catalytic Hydrogenation of 1e with Pd–C or PtO_2 Compound **1e** (30 mg) was hydrogenated in EtOAc (1 ml) with 10% Pd–C (20 mg) as a catalyst. After 12 h, Compound **1o** was obtained quantitatively. Compound **1o** can be prepared from durantoside I tetraacetate under similar catalytic hydrogenation conditions.[5] Under similar conditions [PtO_2 (60 mg) as catalyst in EtOAc (5 ml)], compound **1e** (175 mg) yielded **1j** (160 mg).

Methanolysis of 1e with NaOMe in MeOH Compound **1e** (250 mg) was added to 3% methanolic NaOMe solution for 5 h under room temperature, and then the mixture was neutralized with Amberlite IR-120 to pH 6—7, filtered and purified by SiO_2 chromatography. Methyl (*Z*)-cinnamate (25 mg), **7** (16 mg), and **1l** (110 mg) were isolated.

Methanolysis of 1e with 1 N HCl Methanol Solution Compound **1e** (298 mg) was added to 11 ml of 1 N HCl MeOH solution at room temperature for 8 d. The reaction mixture was added to 100 ml of H_2O and the solution thus obtained was extracted with EtOAc. The EtOAc layer was washed with $NaHCO_3$, H_2O, and dried (Na_2SO_4). The residue was purified and four products, methyl (*E*)-cinnamate (16 mg), **8** (15 mg), **9a** (46 mg), and **9b** (15 mg) was observed. Compound **8**: mp 164—165 °C. IR ν_{max}^{KBr} cm^{-1}: 3090, 1720, 1700, 1640, 1600, 1145, 1110. *Anal.* Calcd for $C_{12}H_{12}O_5$: C, 61.01; H, 5.12. Found: C, 61.27; H, 5.06. Compound **9a**: amorphous, UV λ_{max}^{MeOH} nm (log ε): 214 (4.14), 218 (4.18), 224 (4.15), 281 (4.23). IR ν_{max}^{KBr} cm^{-1}: 3600, 3005, 1720, 1640, 1580, 1500. ^{1}H-NMR ($CDCl_3$): δ 1.25, 3.55, 3.64, 3.74 (each 3H, s, H-10, –OCH_3, –OCH_3, –$COOCH_3$), 3.01 (1H, br d, J=8.5 Hz, H-9), 3.22 (2H, m, H-6), 4.88 (1H, d, J=8.5 Hz, H-1), 5.03 (1H, br d, J=5.0 Hz, H-7), 5.36 (1H, br s, H-3), 6.39, 7.69 (each 1H, d, J=16.0 Hz), 7.30—7.65 (5H, m, phenyl-H). Compound **9b**: amorphous. UV λ_{max}^{MeOH} nm (log ε): 222 (4.00). IR ν_{max}^{KBr} cm^{-1}: 3600, 1710, 1260, 1125, 1120, 1060. ^{1}H-NMR ($CDCl_3$): δ 1.10, 3.51, 3.54, 3.72 (each 3H, s, H-10, –OCH_3, –OCH_3, –$COOCH_3$), 2.90 (1H, br d, J=9.0 Hz, H-9), 2.94 (2H, m, H-6), 3.76 (1H, br d, J=4.5 Hz, H-7), 4.78 (1H, d, J=9.0 Hz, H-1), 5.28 (1H, br s, H-3). By the decoupling technique, H-3 and H-9 showed homoallylic coupling in compounds **9a** and **9b**. Glucose was isolated from the aqueous layer.

Methanolysis of Durantoside II Tetraacetate (1c) in 1 N HCl MeOH Compound **1c** (560 mg) was added to 12 ml of 1 N HCl MeOH solution, and the reaction mixture was left at room temperature for 20 d. Excess water (50 ml) was added thereto, and the solution thus obtained was extracted with EtOAc. After purification, the organic layer afforded methyl (*E*)-cinnamate (38 mg), **10** (12 mg), **8** (15 mg), **11** (24 mg), **9a** (100 mg), **9b** (30 mg), **6b** (27 mg). Compound **10**: mp 143—145 °C. UV λ_{max}^{MeOH} nm (log ε): 291 (4.31). IR ν_{max}^{KBr} cm^{-1}: 3010, 1715, 1650, 1230, 1065, 1020, 925. ^{1}H-NMR ($CDCl_3$): δ 1.91, 3.61, 3.64, 3.79 (each 3H, s, H-10, –OCH_3, –OCH_3, –$COOCH_3$), 5.57, 5.51 (each 1H, s, H-1, H-3), 3.20, 3.40 (each 1H, d, J=16.1 Hz, H-6). Compound **11**: mp 157—158 °C. UV λ_{max}^{MeOH} nm (log ε): 220 (4.15), 233 (3.78), 280 (3.67), 291 (3.80), 325 (3.88). IR ν_{max}^{KBr} cm^{-1}: 3010, 1720, 1640, 1600, 1580, 1545. *Anal.* Calcd for $C_{12}H_{12}O_5$: C, 61.01; H, 5.12. Found: C, 60.96; H, 5.10. Compound **6b**: amorphous. UV λ_{max}^{MeOH} nm (log ε): 216 (4.06), 224 (4.05), 280 (4.15). IR ν_{max}^{KBr} cm^{-1}: 3400, 1710, 1640, 1600, 1580, 1510. ^{1}H-NMR (D_2O): δ 1.14, 3.42, 3.69 (each 3H, s, H-10, –OCH_3, –$COOCH_3$), 5.15 (1H, br s, H-3), 6.42, 7.69 (each 1H, d, J=16.1 Hz), 7.21—7.40 (5H, m). Compound **6c** [prepared from **6b** by acetylation): amorphous. UV λ_{max}^{MeOH} nm (log ε): 218 (4.42), 224 (4.38), 280 (4.35). IR ν_{max}^{KBr} cm^{-1}: 3560 1740, 1720, 1715, 1605, 1630, 1580, 1505. ^{1}H-NMR ($CDCl_3$): δ 1.21, 3.52, 3.62 (each 3H, s), 2.04, 2.06, 2.06, 2.08 (each 3H, CH_3COO–), 3.02, 5.01 (each 1H, d, J=8.3 Hz, H-9, H-1), 2.96 (2H, m, H-6), 5.09 (1H, br d, J=5.1 Hz, H-7), 5.27 (1H, br s, H-3), 6.45, 7.68 (each 1H, d, J=15.9 Hz), 7.22—7.38 (5H, m), signals of H-1′, -2′, -3′, -4′, -5′, -6′ of β-*O*-glucopyranosyl tetraacetate moiety.

Hydrolysis of Durantoside I Tetraacetate (1c) with NaOMe in MeOH Compound **1c** (306 mg) was added to 10 ml of 3% methanolic NaOMe solution; the mixture was kept for 5 h at room temperature, and then neutralized with Amberlite IR-120 to pH 6—7. The reaction mixture was filtered and evaporated to leave a residue which was separated by silica gel chromatography to yield methyl (*E*)-cinnamate (60 mg), **7** (14 mg), and **1l** (139 mg).

Methanolysis of Lamiide (1l) in 1 N HCl MeOH Lamiide (**1l**) (350 mg) was dissolved in 5 ml of 1 N HCl MeOH and the mixture was left at room temperature for one week. The reaction mixture was added to 50 ml of water, and the whole was extracted with EtOAc (30 ml × 3). Purification afforded **1l** (40 mg), **9b** (25 mg), and **12** (30 mg). Compound **12**: amorphous. IR ν_{max}^{KBr} cm^{-1}: 3480, 1710, 1645, 1580, 1060, 1020.

Hydrogenation of 12 with Pd–C in EtOAc A solution of **12** (40 mg) in 4 ml of EtOAc was added to 10% Pd–C (20 mg) previously suspended in 4 ml of EtOAc and the mixture was saturated with H_2 for 10 h. Usual work-up gave compound **13** (38 mg): amorphous. UV λ_{max}^{MeOH} nm (log ε): 225 (4.04). IR ν_{max}^{KBr} cm^{-1}: 3540, 1715, 1640, 1080, 1020. ^{1}H-NMR ($CDCl_3$): δ 1.17, 3.53, 3.57, 3.73 (each 3H, s), 1.89 (2H, m, H-7), 2.79 (3H, m, H-6, H-9), 4.77 (1H, d, J=9.1 Hz, H-1), 5.33 (1H, br s, H-3).

Reaction of 9a with NaOH in MeOH Compound **9a** (35 mg) was added to 3% methanolic NaOMe solution (4 ml) at room temperature for 2 h. Excess water (50 ml) was poured into the reaction mixture and the whole was extracted with EtOAc (30 ml × 2). Compound **12** (24 mg) was isolated from the organic layer, and cinnamic acid (8 mg) was purified from the aqueous layer.

Reaction of 9b with Brosyl Chloride in Dry Pyridine Compound **9b** (32 mg) was treated with 1.2 equimolar brosyl chloride in dry pyridine at room temperature for 2 h. The only product obtained from the reaction mixture was **12** (20 mg).

Methanolysis of Compound 7 in 1 N HCl MeOH Compound **7** (125 mg) was treated with 5 ml of 1 N HCl MeOH solution at room temperature for 5 d. The reaction mixture was poured into excess water (60 ml), and the aqueous layer was extracted with EtOAc (30 ml × 3). The EtOAc solution was purified to give **12** (5 mg), **9b** (20 mg), and **14a** (48 mg). Compound **14a**: mp 144—146 °C. IR ν_{max}^{KBr} cm^{-1}: 3340, 3380, 3260, 1735, 1340, 1205, 1155, 1030, 1020.

Reaction of 14a with $PhB(OH)_2$ in Dry Benzene A solution of **14a** (28 mg) and $PhB(OH)_2$ (12 mg) in 20 ml of dry benzene was refluxed on Dean–Stark apparatus for 40 min. The reaction mixture was directly subjected to chromatography on SiO_2 to afford **15a** (21 mg). Compound **15a**: amorphous. IR ν_{max}^{KBr} cm^{-1}: 3520, 1735, 1605, 1500, 1340, 1310, 1090, 1020. ^{1}H-NMR ($CDCl_3$): δ 1.50, 3.46, 3.47, 3.77 (each 3H, s), 2.09 (2H, d, J=4.2 Hz, H-6), 2.43, 4.38 (each 1H, d, J=7.3 Hz, H-9, H-1), 2.93, 4.69 (each 1H, d, J=9.0 Hz, H-4, H-3), 4.51 (1H, t, J=4.2 Hz, H-7), 7.37 (3H, m), 7.79 (2H, dd, J=7.8, 1.2 Hz). On acetylation, **15a** (16 mg) gave **15b** (16 mg) [amorphous. IR ν_{max}^{KBr} cm^{-1}: 1735, 1605, 1495, 1340, 1320, 1220, 1150, 1010. ^{1}H-NMR ($CDCl_3$): δ 1.47, 2.04, 3.52, 3.52, 3.78 (each 3H, s), 1.94 (1H, dd, J=16.0, 5.2 Hz, H_a-6), 2.45, 4.33 (each 1H, d, J=8.0 Hz, H-9, H-1), 2.95 (1H, dd, J=16.0, 10.1 Hz, H_b-6), 2.92, 4.67 (each 1H, d, J=8.5 Hz, H-4, H-3), 5.07 (1H, dd, J=10.0, 5.2 Hz, H-7), 7.35 (3H, m), 7.80 (2H, dd, J=7.9, 1.3 Hz)].

Preparation of 9c or 14b from 9b or 14a by Using Benzoyl Chloride A solution of **9b** (20 mg) or **14a** (25 mg) and benzoyl chloride (0.2 ml) in dry pyridine (1 ml) was held at room temperature for 2.5 h, then worked up as usual to yield **9c** (16 mg) or **14b** (20 mg), respectively. Compound **9c**: amorphous. IR ν_{max}^{KBr} cm^{-1}: 3520, 1720, 1600, 1585, 1490. ^{1}H-NMR ($CDCl_3$): δ 1.26, 3.53, 3.60, 3.73 (each 3H, s), 3.06 (1H, br d, J=9.0 Hz, H-9), 3.23 (2H, m, H-6), 4.85 (1H, d, J=9.0 Hz, H-1), 5.07 (1H, br d, J=5.2 Hz, H-7), 5.46 (1H, br s, H-3), 7.42 (3H, m), 7.95 (2H, dd, J=8.1, 1.7 Hz). Compound **14b**: amorphous. IR ν_{max}^{KBr} cm^{-1}: 3500, 1725, 1605, 1585, 1490. ^{1}H-NMR ($CDCl_3$): δ 1.35, 3.28, 3.43, 3.74 (each 3H, s), 1.89 (1H, dd, J=15.5, 7.1 Hz, H_a-6), 2.24 (1H, d, J=2.0 Hz, H-9), 2.98 (1H, dd, J=15.5, 7.1 Hz, H-7), 3.29, 4.71 (each 1H, d, J=8.5 Hz, H-4, H-3), 5.05 (1H, dd, J=8.5, 7.1 Hz), 7.43 (3H, m), 7.96 (2H, dd, J=8.4, 1.6 Hz).

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