Tannins and Related Compounds. LXXXVII.¹⁾ Isolation and Characterization of Four New Hydrolyzable Tannins from the Leaves of *Mallotus repandus*

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A chemical examination of the leaves of *Mallotus repandus* (WILLD.) MUELLER-ARG. (Euphorbiaceae) has led to the isolation of four new hydrolyzable tannins, named repandusin (10), repandusinic acids A (11a) and B (14a) (as monopotassium salts) and mallotin (15), together with glucogallin (1), eugenin (2), corilagin (3), punicafolin (4), geraniin (5), furosin (6), mallotinic acid (7), mallotusinic acid (8) and brevifolin carboxylic acid (9). Based on the chemical and spectroscopic evidence, repandusin was assigned the structure (10) in which brevifolin carboxylic acid is attached to the C-4 position of the glucose moiety in mallotinic acid, while repandusinic acids A and B were characterized as 1-*O*-galloyl-3,6-(*R*)-hexahydroxydiphenyl-(11a) and 1-*O*-galloyl-3,6-(*R*)-valoneayl-4-*O*-(4'-dehydrochebuloyl)- β -D-glucoses (14a), respectively. Similarly, mallotin was found to have the structure (15) possessing a new acid, mallotic acid, linked to the C-2 position of the corilagin moiety.

Keywords *Mallotus repandus*; Euphorbiaceae; repandusin; repandusinic acid A; repandusinic acid B; mallotin; hydrolyzable tannin; dehydrochebulic acid; mallotic acid

In previous papers,²⁾ we reported on the isolation and characterization of a series of hydrolyzable tannins from the bark and leaves of *Mallotus japonicus* (THUNB.) MUELLER-ARG. (Euphorbiaceae). In continuing our chemical studies on tannins and related compounds in the plants of the genus *Mallotus*, we next examined the leaves of *Mallotus repandus* (WILLD.) MUELLER-ARG., which is distributed in South-east Asia and northern Australia. In Taiwan the leaves have been used as an anti-inflammatory drug. Although diterpenoids,³⁾ triterpenoids,⁴⁾ bergenin⁵⁾ and cyano- γ -pyridone⁶⁾ have been reported to occur in this plant, no chemical examination of the polyphenolic ingredients has yet been done. This paper deals with the isolation and characterization of thirteen tannins and related compounds (1—11, 14 and 15), including four new hydrolyzable tannins named repandusin (10), repandusinic acids A (11a) and B (14a) (as monopotassium salts) and mallotin (15), from this plant material.

The aqueous acetone extract of the leaves, collected in Taiwan, was repeatedly chromatographed over Sephadex LH-20 (H₂O-MeOH, EtOH-H₂O, 60% aqueous MeOH, acetone-H₂O, etc.), MCI-gel CHP 20P (H₂O-MeOH) and Bondapak C₁₈/Porasil B (H₂O-MeOH) to yield compounds

1—11, 14 and 15. Among them, nine were found to be known hydrolyzable tannins and related compounds, which were identified as glucogallin (1),⁷⁾ eugenin (2),⁸⁾ corilagin (3),⁹⁾ punicafolin (4),⁹⁾ geraniin (5),¹⁰⁾ furosin (6),^{2c)} mallotinic acid (7),^{2c)} mallotusinic acid (8)^{2c)} and brevifolin carboxylic acid (9)¹¹⁾ by direct comparisons of their physical and spectral data with those of authentic samples or by spectral examinations.

Repandusin (10) was obtained as a tan amorphous powder, $[\alpha]_D -44.4^\circ$ (acetone), C₄₇H₃₂O₃₀·6H₂O. Examination of the proton and carbon-13 nuclear magnetic resonance (¹H- and ¹³C-NMR) spectra indicated the presence of one galloyl group (δ 7.22, 2H, s), one valoneayl group (δ 6.56, 6.67 and 7.20, each 1H, s) and a sugar moiety (¹³C-NMR: Table I). In addition, the ¹H-NMR spectrum showed typical aliphatic ABX-type signals [δ 2.71 (dd, $J=2, 19$ Hz), 3.00 (dd, $J=8, 19$ Hz) and 4.69 (dd, $J=2, 8$ Hz)], together with one aromatic singlet (δ 7.44, 1H).

When heated in aqueous solution, 10 produced two major hydrolysates, which were found to be identical with mallotinic acid (7) and brevifolin carboxylic acid (9), thus confirming the constitution of the acyl groups, as well as the locations of the galloyl and valoneayl ester groups in the

Chart 1

TABLE 1. ^{13}C -NMR Spectral Data for Compounds **10**, **11**, **11a**, **14** and **15**

	10^{a)}	11^{b)}	11a^{b)}	14^{b)}	15^{b)}
Glucose					
C-1	94.2	94.8	94.8	94.7	91.3
C-2	71.7	68.8	70.0	69.8	71.7
C-3	74.2	70.6	71.1	71.8	72.9
C-4	66.6	64.2	75.3	64.7	61.7
C-5	75.0	73.6	74.0	74.5	76.5
C-6	64.5	64.2	64.5	64.4	64.6
Galloyl					
C-1	120.6	120.0	120.3	120.1	120.1
C-2,6	110.7 (2C)	110.7 (2C)	110.5 (2C)	110.8 (2C)	110.5 (2C)
C-3,5	145.9 (2C)	145.7 (2C)	146.0 (2C)	146.2 (2C)	146.3 (2C) ^{e)}
C-4	139.6 ^{c)}	139.3 ^{c)}	139.3 ^{c)}	140.0 ^{c)}	139.8
2,4-Acyl group					
C-1'	193.7	173.5	171.1	173.4	174.7
C-2'	149.7	81.1	79.0	81.1	81.8
C-3'	147.9	35.9	35.1	36.0	51.4
C-4'	41.6	144.8 ^{d)}	141.2	145.0 ^{d)}	88.7
C-5'	37.9	135.3	131.8	135.3	38.6
C-6'	172.1	174.7	167.8	174.5	170.5
C-7'		169.3 ^{e)}	168.8 ^{e)}	172.3	171.5
C-1''	115.1	116.3	116.2	116.3	116.1
C-2''	116.0	117.4	117.9	117.5	122.3
C-3''	110.1	109.2	109.0	109.1	112.7
C-4''	140.4 ^{c)}	145.2 ^{d)}	145.1 ^{d)}	145.2 ^{d)}	146.3
C-5''	139.8 ^{c)}	139.9 ^{c)}	139.6 ^{c)}	139.5 ^{c)}	135.8
C-6''	143.0	143.9	143.4	144.0	147.5
3,6-Acyl group					
C-1	115.7	115.5	115.5	116.8	115.9
C-2	125.1	125.1	125.3	124.6	125.4
C-3	107.6	108.4	108.3	108.4	108.2
C-4	145.1 ^{d)}	145.2 ^{d)}	145.3 ^{d)}	145.2 ^{d)}	146.0 ^{c)}
C-5	136.5	136.5 ^{c)}	136.5 ^{c)}	136.6	136.6 ^{d)}
C-6	145.4 ^{d)}	145.2 ^{d)}	145.3 ^{d)}	146.1 ^{d)}	146.0 ^{c)}
C-1'	118.4	116.5	116.7	118.1	116.1
C-2'	125.1	124.8	125.0	124.2	125.1
C-3'	108.3	110.1	110.0	108.8	109.8
C-4'	146.7	144.8 ^{d)}	144.9 ^{d)}	146.9	145.3 ^{c)}
C-5'	138.0 ^{c)}	137.2 ^{c)}	137.2 ^{c)}	137.6 ^{c)}	137.0 ^{d)}
C-6'	145.1 ^{d)}	144.8 ^{d)}	144.9 ^{d)}	144.7 ^{d)}	144.9 ^{c)}
C-1''	143.5			142.5	
C-2''	115.1			115.8	
C-3''	109.5			111.9	
C-4''	140.4 ^{c)}			140.0 ^{c)}	
C-5''	138.0 ^{c)}			137.3 ^{c)}	
C-6''	139.8 ^{c)}			139.3 ^{c)}	
-COO-	160.9	166.3 ^{e)}	165.1 (2C) ^{e)}	166.2	165.0
	165.2	166.4 ^{e)}	165.8 ^{e)}	166.3	165.6
	166.9	167.4 ^{e)}	167.0 ^{e)}	167.4	167.3
	166.1	167.8 ^{e)}		167.5	168.5
	167.8			168.8	

a) Measured in acetone- d_6 . b) Measured in acetone- d_6 +D₂O. c—e) Assignments may be interchanged in each column.

glucose moiety.

The ^1H -NMR spectrum of **10** exhibited an upfield sugar signal at δ 3.95 (d, $J=6$ Hz), which could be assigned to H-2 on the basis of spin-decoupling experiments, i.e., irradiation of the anomeric doublet at δ 6.10 caused a change of this signal into a singlet. Taking the chemical shift of the H-2 signal into account, the C-2 position is concluded to be free from an acyl group. In addition, since the H-4 signal appeared lowfield (δ 5.55), the brevifolin carboxylic acid moiety is considered to be located at the C-4 position. Although there are two possibilities for the connection of the brevifolin carboxylic acid moiety in **10** (through an aliphatic ester or an aromatic ester bond), comparison of

Chart 2

the ^{13}C -NMR spectra of **9** and **10** indicated that the aliphatic carboxyl group is connected to the C-4 position. Namely, among thirteen carbon signals arising from the brevifolin carboxylic acid moiety in **10**, only the aliphatic carboxyl signal (δ 172.1) was found to be shifted upfield as compared with that (δ 174.9) of **9**. Based on these findings, the structure of repandusin was represented by the formula **10**.

Compounds **11**, a tan amorphous powder, $[\alpha]_D +19.8^\circ$ (H₂O-acetone), and **14**, a tan amorphous powder, $[\alpha]_D +20.3^\circ$ (H₂O-MeOH), were sparingly soluble in most organic solvents such as ethyl acetate, acetone and methanol, but were freely soluble in water. Elemental analyses, coupled with fast atom bombardment mass spectroscopy (FAB-MS) [**11**: positive FAB-MS m/z : 1009 ($M+H$)⁺, negative FAM-MS m/z : 969 ($M-K$)⁻; **14**: positive FAB-MS m/z : 1177 ($M+H$)⁺, negative FAB-MS m/z : 1137 ($M-K$)⁻], established their molecular formulae, C₄₁H₂₉KO₂₈·9/2H₂O and C₄₈H₃₃KO₃₃·6H₂O, respectively, where one potassium atom is present.

On acidification with hydrochloric acid, **11** liberated the acid (repandusinic acid A) (**11a**). The ^1H -NMR spectrum of **11a** showed, besides signals due to a galloyl group (δ 7.15, 2H, s) and a 4,4',5,5',6,6'-hexahydroxydiphenoyl (HHDP) group (δ 6.70 and 6.85, each 1H, s), two methine doublets (δ 5.32 and 5.56) coupled with each other ($J=2$ Hz) and two overlapped singlets at δ 7.13. In addition, the spectrum exhibited lowfield sugar signals at δ 4.69 (1H, dd, $J=8$, 11 Hz), 4.88 (1H, br d, $J=3$ Hz), 5.60 (1H, br d, $J=3$ Hz) and 6.23 (1H, d, $J=4$ Hz), which were readily assignable to the glucose H-6, H-3, H-4 and H-1, respectively, based on ^1H - ^1H shift correlation spectroscopy (COSY). The absence of the H-2 signal at low field suggested that the C-2 hydroxyl group is not acylated.

Methylation of **11a** with dimethyl sulfate and potassium carbonate in dry acetone afforded the corresponding tetradecamethylate (**11b**) [field-desorption mass spectrum (FD-MS) m/z : 1166 (M^+)], while on prolonged methylation, partial solvolysis took place to yield an acid ester (**11c**) and a dexamethyl ether (**11d**). The ^1H -NMR spectrum of **11c** was correlated with that of chebulic acid hexamethylate (**12**),¹²⁾ showing signals due to six methoxyl groups (δ 3.65, 3.68, 3.69, 3.79, 3.87 and 3.94), two methines [δ 5.32 (d, $J=2$ Hz), δ 5.49 (d, $J=2$ Hz)] and an aromatic proton (δ 7.36, s), but differed in showing the presence of an olefinic proton (δ 6.88, s) instead of a methine and a methylene occurring in

Chart 3

Chart 4

12. The electron-impact mass spectrum (EI-MS) of **11c**, which exhibited the M^+ ion peak at m/z 438, two mass units less than that of **12**, was consistent with the hexamethyl dehydrochebulic acid structure. On the other hand, **11d** was identified as the decamethyl ether of corilagin (**3**)¹³ by physical and spectral comparisons.

On hydrogenation over palladium-carbon (Pd-C), **11a** afforded two products (**11e** and **11f**), of which **11e** was found to be identical with neochebulagic acid, obtainable by hot water treatment of chebulagic acid (**13**).¹⁴ Thus, the absolute configurations of the C-2' and C-3' atoms in **11a** were shown to be in the *S*-series. On the other hand, the geometrical isomerism of the double bond was concluded to be *Z*, based on the fact that irradiation of the benzylic H-3' signal (δ 5.52) caused the enhancement of the olefinic H-5' signal (δ 7.02) in the nuclear Overhauser effect (NOE) difference spectrum (Fig. 1). Consequently, **11a** was con-

cluded to be 1-*O*-galloyl-3,6-(*R*)-HHDP-4-*O*-(4'-dehydrochebuloyl)- β -D-glucose. The potassium atom was concluded to be located at the C-6' carboxyl group on the basis of the lowfield shift (δ 135.3) of the neighboring C-5' resonance in the ^{13}C -NMR spectrum of **11**, as compared with that in **11a** (δ 131.8).

The 1H - and ^{13}C -NMR spectra of **14** were similar to those of **11**, except for the presence of a valoneayl group (1H -NMR: δ 6.75, 6.90 and 7.14, each 1H, s; ^{13}C -NMR: Table I) in place of the HHDP group. On prolonged heating in a mixture of dimethyl sulfate and potassium carbonate in dry acetone, **14** afforded hexamethyl 4-dehydrochebulic acid (**11c**) and mallotinic acid tridecamethylate (**14b**).¹³ Since the olefinic C-5' signal in the dehydrochebuloyl ester group is similarly observed to be shifted downfield (δ 135.3) in the ^{13}C -NMR spectrum of **14**, the potassium atom is concluded to be located at the C-6' carboxyl group, thus establishing the structure of **14** to be 1-*O*-galloyl-3,6-(*R*)-valoneayl-4-*O*-(4'-dehydrochebuloyl)- β -D-glucose monopotassium salt.

Mallotin (15), a tan amorphous powder, $[\alpha]_D^{25} -55.5^\circ$ (MeOH), $C_{41}H_{30}O_{28} \cdot 5H_2O$, showed, in the 1H -NMR spectrum, signals arising from a galloyl group (δ 7.16, 2H, s), an HHDP group (δ 6.71 and 6.97, each 1H, s) and a sugar moiety. In addition, signals due to an isolated methylene (δ 3.20 and 3.28, each 1H, d, $J=16$ Hz), two

Chart 5

Fig. 1. 1H -NMR Spectrum (a) and NOE Difference Spectrum (b) of **11b** in $CDCl_3$

mutually coupled methines (δ 5.13 and 5.21, each 1H, d, $J=2$ Hz) and an aromatic proton (δ 7.27, 1H, s) were observed. The chemical shifts and coupling patterns of the sugar signals were almost identical with those found in 1,2-di-*O*-galloyl-3,6-(*R*)-HHDP- β -D-glucose.^{2c)} On methylation with dimethyl sulfate and potassium carbonate in dry acetone, **15** afforded the tridecamethylate (**15a**) [FD-MS m/z : 1152 (M^+)]. Subsequent acetylation of **15a** yielded the monoacetate (**15b**) [FD-MS m/z : 1194 (M^+)]. The location of the acetyl group in **15b** was indicated to be at the glucose C-4 position by the 1H -NMR lowfield shift of the H-4 signal (δ 4.58 in **15a**; δ 5.58 in **15b**). Thus, the glucose C-4 hydroxyl group was concluded to be not esterified in **15**. On

the other hand, treatment of **15** with diazomethane caused partial solvolysis to give corilagin nonamethylate (**15c**) and an acid methyl ester (**15d**). The formation of **15c** confirmed the locations of the galloyl and HHDP ester groups and also the atropisomerism of the HHDP ester group in **15**. Consequently, the acid ester (**15d**) is regarded as being located at the glucose C-2 position.

The 1H -NMR spectrum of **15d** showed five methoxyl signals (δ 3.66–4.01), together with methylene [δ 3.14 and 3.40 (each 1H, d, $J=17$ Hz)] and methine [δ 4.96 and 5.07 (each 1H, d, $J=2$ Hz)] signals. Owing to the small amount of the sample available, the ^{13}C -NMR spectrum of **15d** could not be measured, but the ^{13}C -NMR spectrum of **15**

Chart 6

Chart 7

clearly indicated the presence of a methylene (δ 38.6), a benzylic methine (δ 51.4), an oxygen-bearing methine (δ 81.8), an oxygen-bearing quaternary carbon (δ 88.7), a penta-substituted aromatic ring (δ 112.7, 116.1, 122.3, 135.8, 146.3 and 147.5) and four carboxyl groups (δ 165.0, 170.5, 171.5 and 174.7) in the C-2 acyl group. The ^1H - ^{13}C long-range COSY spectrum (Fig. 2)^{2c)} of **15** showed a long-range coupling between the carboxyl carbon signal at δ 165.0 and an aromatic singlet at δ 7.27. Since this carboxyl carbon signal was shown to be further coupled with the glucose H-2 signal, the aromatic carboxyl group is concluded to be connected to the glucose C-2 position. In addition, the spectrum showed similar long-range couplings of the methylene proton signals (δ 3.20 and 3.28) with the quaternary carbon signal (δ 88.7) and with the carboxyl carbon signal (δ 170.5), and correlations between two methine doublets and carbon signals (δ 5.13 and δ 171.5, 174.7; δ 5.21 and δ 51.4, 174.7). These spectral observations

led us to formulate a fragment structure (A) for the C-2 acyl group.

Taking into account the negative FAB-MS [m/z 969 ($\text{M}-\text{H})^-$] of **15** and EI-MS [m/z 424 (M^+)] of **15d**, two of the three aliphatic carboxyl groups should exist in a lactone form. The EI-MS of **15d** showed the fragment peak at m/z 351, which corresponded to the loss of a CH_2COOMe ion from the molecule, indicating that the carboxyl group adjacent to the methylene does not participate in the formation of a lactone ring. Based on these findings, the structure of the C-2 acyl group (we now propose the name, mallotic acid for this acid) was concluded to be as shown in **15**. Thus, mallotin was characterized as 1-*O*-galloyl-2-*O*-mallotoyl-3,6-(*R*)-HHDP- β -D-glucose (**15**). The stereostructure of the mallotoyl group still remains to be determined.

In conclusion, our chemical examination has shown that hydrolyzable tannins, possessing 2,4- and/or 3,6-bridged

Fig. 2. ^1H - ^{13}C Long-Range Shift Correlation Spectrum of **15** in Acetone- d_6 ($J_{\text{CH}} = 10 \text{ Hz}$)

acyl group(s) attached to the glucose moiety with $^1\text{C}_4$ or an intermediate skew boat conformation predominate in the leaf extract of *M. repandus*. Taking into account the co-occurrence of geraniin (**5**) as the major tannin, as well as mallotusinic acid (**8**), in this plant material, the new acyl groups of repandusin (**10**), repandusinic acids A (**11a**) and B (**11b**) and mallotin (**15**) are considered to be biosynthetically derived from the dehydrohexahydroxydiphenoyl group. The presence of diverse acyl groups at the glucose C-2 and/or C-4 position(s) is another characteristic feature of the tannins in this plant.

Experimental

Details of the instruments and chromatographic conditions used throughout this work are the same as described in the previous paper,¹⁵ except for the following. High-performance liquid chromatography (HPLC) was conducted on a Toyo Soda apparatus equipped with an SP-8700 solvent delivery system and a UV-8 model II spectrophotometer.

Isolation of Tannins The air-dried leaves (1.4 kg) of *Mallotus repandus* (collected in Taiwan) were extracted with 80% aqueous acetone at room temperature. The acetone was removed by evaporation under reduced pressure (ca. 40°C), and the resulting precipitates, consisting mainly of chlorophylls, were removed by filtration. The filtrate was further concentrated and applied to a column of Sephadex LH-20. Elution with H_2O containing increasing amounts of MeOH gave four fractions; I (31 g), II (49 g), III (23 g) and IV (37 g). Fraction I was repeatedly chromatographed over MCI-gel CHP 20P with H_2O -MeOH and then over Sephadex LH-20 with EtOH to afford brevifolin carboxylic acid (**9**) (11 mg) and repandusinic acid A monopotassium salt (**11**) (89 mg). Fraction II was rechromatographed over MCI-gel CHP 20P with H_2O -MeOH, Bondapak

C_{18} /Porasil B with H_2O -MeOH and Sephadex LH-20 with various solvent systems (60% aqueous MeOH, EtOH- H_2O , acetone- H_2O , etc.) to give glucogallin (**1**) (50 mg), corilagin (**3**) (205 mg), repandusinic acid B monopotassium salt (**14**) (30 mg) and mallotin (**15**) (83 mg). On similar chromatographies, fraction III yielded furosin (**6**) (309 mg) and mallotinic acid (**7**) (475 mg), while fraction IV gave eugenin (**2**) (22 mg), punicafolin (**4**) (209 mg), geraniin (**5**) (6.0 g), mallotusinic acid (**8**) (285 mg) and repandusin (**10**) (92 mg).

Brevifolin Carboxylic Acid (9) A yellow crystalline powder (H_2O -MeOH), mp $> 300^\circ\text{C}$, $[\alpha]_D^{25} - 3.0^\circ$ ($c = 0.4$, H_2O -acetone). Anal. Calcd for $\text{C}_{13}\text{H}_8\text{O}_8 \cdot 1/2\text{H}_2\text{O}$: C, 51.83; H, 2.99. Found: C, 52.02; H, 3.38. Negative FAB-MS m/z : 291 ($\text{M}-\text{H}^-$), 247 ($\text{M}-\text{COOH}^-$). ^1H -NMR (acetone- $d_6 + \text{D}_2\text{O}$) ppm: 2.58 (1H, d, $J = 19 \text{ Hz}$, H-5), 3.09 (1H, dd, $J = 7, 19 \text{ Hz}$, H-5), 4.56 (1H, dd, $J = 7 \text{ Hz}$, H-4), 7.45 (1H, s, H-3'). ^{13}C -NMR (acetone- $d_6 + \text{D}_2\text{O}$) ppm: 38.4 (C-4), 42.1 (C-5), 109.4 (C-3'), 114.8 (C-1'), 116.4 (C-2'), 140.0 (C-5'), 140.9 (C-3), 144.3 (C-6'), 147.2 (C-4'), 150.2 (C-2), 161.7 (C-7'), 174.9 (C-6), 194.7 (C-1).

Repandusin (10) A tan amorphous powder, $[\alpha]_D^{25} - 44.4^\circ$ ($c = 1.0$, acetone). Anal. Calcd for $\text{C}_{47}\text{H}_{32}\text{O}_{30} \cdot 6\text{H}_2\text{O}$: C, 47.64; H, 3.72. Found: C, 47.96; H, 3.74. Negative FAB-MS m/z : 1075 ($\text{M}-\text{H}^-$). ^1H -NMR (acetone- d_6) ppm: 2.71 (1H, dd, $J = 2, 19 \text{ Hz}$, H-5'), 3.00 (1H, dd, $J = 8, 19 \text{ Hz}$, H-5'), 3.95 (1H, d, $J = 6 \text{ Hz}$, H-2), 4.23 (1H, dd, $J = 8, 12 \text{ Hz}$, H-6), 4.43 (1H, dd, $J = 6, 12 \text{ Hz}$, H-6), 4.61 (1H, dd, $J = 6, 8 \text{ Hz}$, H-5), 4.69 (1H, dd, $J = 2, 8 \text{ Hz}$, H-4'), 4.74 (1H, d, $J = 3 \text{ Hz}$, H-3), 5.55 (1H, d, $J = 3 \text{ Hz}$, H-4), 6.10 (1H, d, $J = 6 \text{ Hz}$, H-1), 6.56, 6.67, 7.20 (each 1H, s, valoneoyl H), 7.22 (2H, s, galloyl H), 7.44 (1H, s, H-3'). ^{13}C -NMR: Table I.

Treatment of 10 with Hot Water A solution of **10** (5 mg) in H_2O (5 ml) was heated on a boiling water-bath for 2 h. The reaction mixture was directly analyzed by HPLC and thin layer chromatography (TLC) to detect **7** and **9**.

a) HPLC: Column, Nucleosil 5 C_{18} ; solvent, 10–25% MeCN–50 mM NaH_2PO_4 (gradient system); flow rate, 0.7 ml/min; t_R 19.7 min for **9** and t_R 23.2 min for **7**. b) TLC (silica gel): Solvent, benzene-ethyl formate-formic acid (1 : 7 : 1); R_f 0.29 for **9** and R_f 0.50 for **7**. c) TLC (Avicel SF cellulose): Solvent, 2% AcOH; R_f 0.21 for **9** and R_f 0.41 for **7**.

Repandusinic Acid A Monopotassium Salt (11) A tan amorphous powder, $[\alpha]_D^{25} + 19.8^\circ$ ($c = 0.5$, H_2O -acetone). Anal. Calcd for $\text{C}_{41}\text{H}_{29}\text{KO}_8 \cdot 9/2\text{H}_2\text{O}$: C, 45.18; H, 3.49. Found: C, 45.15; H, 3.43. Positive FAB-MS m/z : 1009 ($\text{M}+\text{H}^+$). Negative FAB-MS m/z : 1007 ($\text{M}-\text{H}^-$) 969 ($\text{M}-\text{K}^+$). ^1H -NMR (acetone- $d_6 + \text{D}_2\text{O}$) ppm: 6.28 (1H, d, $J = 3 \text{ Hz}$, H-1), 6.75, 6.85 (each 1H, s, HHDP-H), 6.99 (1H, s, H-5'), 7.15 (1H, s, H-3'), 7.17 (2H, s, galloyl H). ^{13}C -NMR: Table I. Treatment of **11** (20 mg) in 1 N HCl (1.5 ml), followed by chromatography over Sephadex LH-20 with MeOH, gave repandusinic acid A (**11a**) (15 mg) as a tan amorphous powder, $[\alpha]_D^{25} - 54.3^\circ$ ($c = 0.9$, MeOH). Anal. Calcd for $\text{C}_{41}\text{H}_{30}\text{O}_{28} \cdot 7/2\text{H}_2\text{O}$: C, 47.63; H, 3.58. Found: C, 47.80; H, 4.03. Negative FAB-MS m/z : 969 ($\text{M}-\text{H}^-$). ^1H -NMR (acetone- $d_6 + \text{D}_2\text{O}$) ppm: 4.23 (1H, d, $J = 4 \text{ Hz}$, H-2), 4.29 (1H, dd, $J = 8, 11 \text{ Hz}$, H-6), 4.60 (1H, dd, $J = 7, 8 \text{ Hz}$, H-5), 4.69 (1H, dd, $J = 8, 11 \text{ Hz}$, H-6), 4.88 (1H, br d, $J = 3 \text{ Hz}$, H-3), 5.32 (1H, d, $J = 2 \text{ Hz}$, H-2'), 5.56 (1H, d, $J = 2 \text{ Hz}$, H-3'), 5.60 (1H, br d, $J = 3 \text{ Hz}$, H-4), 6.23 (1H, d, $J = 4 \text{ Hz}$, H-1), 6.70, 6.85 (each 1H, s, HHDP-H), 7.13 (2H, s, H-5' and H-3'), 7.15 (2H, s, galloyl H). ^{13}C -NMR: Table I.

Methylation of 11a a) A mixture of **11a** (50 mg), dimethyl sulfate (0.3 ml) and anhydrous potassium carbonate (0.5 g) in dry acetone (10 ml) was refluxed for 2 h with stirring. After removal of inorganic salts by filtration, the filtrate was concentrated to a syrup, which was chromatographed over silica gel. Elution with benzene-acetone (17 : 3) furnished **11b** (26 mg) as a white amorphous powder, $[\alpha]_D^{25} - 80.5^\circ$ ($c = 0.8$, CHCl_3). Anal. Calcd for $\text{C}_{55}\text{H}_{38}\text{O}_{28} \cdot \text{H}_2\text{O}$: C, 55.74; H, 5.07. Found: C, 55.98; H, 5.09. FD-MS m/z : 1166 (M^+). ^1H -NMR (CDCl_3) ppm: 3.70–3.97 (42H in total, OMe), 5.39 (1H, d, $J = 4 \text{ Hz}$, H-2'), 5.52 (1H, d, $J = 4 \text{ Hz}$, H-3'), 6.39 (1H, br s, H-1), 6.58, 6.86 (each 1H, s, HMDP⁽⁶⁾-H), 7.02 (1H, s, H-5'), 7.21 (2H, s, trimethoxybenzoyl H), 7.45 (1H, s, H-3'). b) A mixture of **11a** (30 mg), dimethyl sulfate (0.3 ml) and anhydrous potassium carbonate (0.5 g) in dry acetone (5 ml) was refluxed for 3 h with stirring. The reaction mixture was worked up in the same way as described above to give **11c** (6 mg) and **11d** (14 mg). **11c**: A yellow syrup, $[\alpha]_D^{25} + 145.3^\circ$ ($c = 1.5$, CHCl_3). Anal. Calcd for $\text{C}_{20}\text{H}_{22}\text{O}_{11}$: C, 54.79; H, 5.02. Found: C, 54.44; H, 5.12. EI-MS m/z : 438 (M^+), 406, 379, 319. ^1H -NMR (CDCl_3) ppm: 3.66, 3.74, 3.76, 3.79, 3.90, 3.91 (each 3H, s, OMe), 5.24 (1H, d, $J = 2 \text{ Hz}$, H-2), 5.58 (1H, d, $J = 2 \text{ Hz}$, H-3), 6.90 (1H, s, H-5), 7.45 (1H, s, H-3'). **11d**: Colorless needles (MeOH), mp 135 – 137°C , $[\alpha]_D^{25} - 163.8^\circ$ ($c = 0.6$, CHCl_3). ^1H -NMR (CDCl_3) ppm: 3.13 (3H, s, OMe), 3.70–3.97 (27H in total, OMe), 6.58, 6.86 (each 1H, s, HMDP-H), 6.57 (1H, br s, H-1), 7.22 (2H, s, trimethoxybenzoyl H).

Hydrogenation of 11a 11a (25 mg) was hydrogenated over Pd-C (3 mg) in EtOH (10 ml) under a hydrogen atmosphere for 10 h. After removal of the catalyst by filtration, the filtrate was evaporated under reduced pressure. The residue was purified by Kusano packed column ODS chromatography with H₂O-MeOH (1:0—2:3) to give 11e (7 mg) and 11f (9 mg). 11e: A tan amorphous powder, $[\alpha]_D^{25} -72.6^\circ$ ($c=0.5$, MeOH). Anal. Calcd for C₄₁H₃₂O₂₈·5H₂O: C, 46.33; H, 3.95. Found: C, 45.98; H, 3.84. Negative FAB-MS m/z : 971 (M-H)⁻. ¹H-NMR (acetone-*d*₆+D₂O) ppm: 2.43 (1H, dd, $J=4$, 17 Hz, H-5'), 2.97 (1H, dd, $J=10$, 17 Hz, H-5'), 3.97 (1H, d, $J=9$ Hz, H-3'), 4.98 (1H, brs, H-3), 5.50 (1H, s, H-2'), 5.76 (1H, brd, $J=3$ Hz, H-4), 6.28 (1H, d, $J=4$ Hz, H-1), 6.75, 6.89 (each 1H, s, HHDP-H), 7.13 (1H, s, H-3''), 7.16 (2H, s, galloyl H). 11f: A tan amorphous powder, $[\alpha]_D^{25} -72.6^\circ$ ($c=0.5$, MeOH). ¹H-NMR (acetone-*d*₆+D₂O) ppm: 2.43 (1H, d, $J=18$ Hz, H-5'), 2.94 (1H, dd, $J=6$, 18 Hz, H-5'), 4.23 (1H, d, $J=3$ Hz, H-3'), 4.98 (1H, brs, H-3), 5.31 (1H, s, H-2'), 5.73 (1H, brs, H-4), 6.26 (1H, d, $J=3$ Hz, H-1), 6.77, 6.89 (each 1H, s, HHDP-H), 7.16 (2H, s, galloyl H), 7.17 (1H, s, H-3'').

Partial Hydrolysis of 13 A solution of 13 (500 mg) in H₂O (15 ml) was heated on a boiling-water bath for 16 h. The reaction mixture was directly applied to a column of MCI-gel CHP 20P. Elution with H₂O-MeOH (1:0—0:1) furnished 11e (184 mg).

Repandusinic Acid B Monopotassium Salt (14) A tan amorphous powder, $[\alpha]_D^{20} +20.3^\circ$ ($c=0.7$, H₂O-MeOH). Anal. Calcd for C₄₈H₃₃KO₃₃·6H₂O: C, 44.86; H, 3.50. Found: C, 44.41; H, 3.32. Positive FAB-MS m/z : 1177 (M+H)⁺. Negative FAB-MS m/z : 1137 (M-K)⁻. ¹H-NMR (acetone-*d*₆+D₂O) ppm: 4.17 (1H, d, $J=3$ Hz, H-2), 4.27 (1H, dd, $J=7$, 10 Hz, H-6), 4.64 (1H, t, $J=7$ Hz, H-5), 4.73 (1H, dd, $J=7$, 10 Hz, H-6), 4.82 (1H, brs, H-3), 4.93 (1H, brs, H-2'), 5.48 (1H, brs, H-3'), 5.52 (1H, brs, H-4), 6.22 (1H, d, $J=3$ Hz, H-1), 6.75, 6.90, 7.14 (each 1H, s, valoneayl H), 6.96, 6.97 (each 1H, s, H-5' and H-3''), 7.20 (2H, s, galloyl H). ¹³C-NMR: Table I.

Methylation of 14 A mixture of 14 (30 mg), dimethyl sulfate (0.3 ml) and anhydrous potassium carbonate (0.3 g) in dry acetone (5 ml) was refluxed for 3 h with stirring. The reaction mixture was worked up in the same way as described for 11a to give 11c (5 mg) and 14b (8 mg). 14b: A white amorphous powder, $[\alpha]_D^{25} -68.9^\circ$ ($c=0.6$, CHCl₃). ¹H-NMR (CDCl₃) ppm: 3.53—4.12 (39H in total, OMe), 6.40, 6.83, 7.21 (each 1H, s, aromatic H), 6.23 (1H, brs, H-1), 7.25 (2H, s, trimethoxybenzoyl H).

Mallotin (15) A tan amorphous powder, $[\alpha]_D^{20} -55.5^\circ$ ($c=0.9$, MeOH). Anal. Calcd for C₄₁H₃₀O₂₈·5H₂O: C, 46.42; H, 3.77. Found: C, 46.74; H, 3.84. Negative FAB-MS m/z : 969 (M-H)⁻. ¹H-NMR (acetone-*d*₆) ppm: 3.20 (1H, d, $J=16$ Hz, H-5'), 3.28 (1H, d, $J=16$ Hz, H-5'), 4.26 (1H, dd, $J=4$, 8 Hz, H-6), 4.54 (1H, brs, H-4), 4.60 (2H, m, H-5 and H-6), 4.96 (1H, brs, H-3), 5.13 (1H, d, $J=2$ Hz, H-3'), 5.21 (1H, d, $J=2$ Hz, H-2'), 5.41 (1H, brd, $J=5$ Hz, H-2), 6.63 (1H, d, $J=5$ Hz, H-1), 6.71, 6.97 (each 1H, s, HHDP-H), 7.16 (2H, s, galloyl H), 7.27 (1H, s, H-3''). ¹³C-NMR: Table I.

Methylation of 15 A mixture of 15 (45 mg), dimethyl sulfate (0.3 ml) and anhydrous potassium carbonate (0.3 g) in dry acetone (5 ml) was refluxed for 1 h with stirring. The reaction mixture was worked up in the same way as described for 11a to yield 15a (21 mg) as a white amorphous powder, $[\alpha]_D^{25} -36.6^\circ$ ($c=0.8$, CHCl₃). Anal. Calcd for C₅₄H₅₆O₂₈·H₂O: C, 55.38; H, 4.96. Found: C, 55.52; H, 5.00. FD-MS m/z : 1152 (M⁺). ¹H-NMR (CDCl₃) ppm: 3.22 (1H, d, $J=18$ Hz, H-5'), 3.38 (1H, d, $J=18$ Hz, H-5'), 3.54—4.04 (39H in total, OMe), 4.26 (1H, dd, $J=8$, 11 Hz, H-6), 4.58 (1H, brs, H-4), 4.69 (1H, dd, $J=8$, 11 Hz, H-5), 5.03 (1H, brs, H-3), 5.07 (1H, d, $J=2$ Hz, H-3'), 5.09 (1H, d, $J=2$ Hz, H-2'), 5.16 (1H, t, $J=11$ Hz, H-6), 5.46 (1H, s, H-2), 6.62 (1H, s, H-1), 6.78, 6.81 (each 1H, s, HHDP-H), 7.26 (2H, s, trimethoxy benzoyl H), 7.27 (1H, s, H-3'').

Acetylation of 15a 15a (11 mg) was kept overnight in a mixture of pyridine and acetic anhydride (1:1, 2 ml) at room temperature. Usual work-up yielded 15b (8 mg) as a white amorphous powder, $[\alpha]_D^{29} -39.0^\circ$ ($c=0.4$, CHCl₃). FD-MS m/z : 1194 (M⁺). ¹H-NMR (CDCl₃) ppm: 2.01 (3H, s, OCOMe), 3.22 (1H, d, $J=17$ Hz, H-5'), 3.37 (1H, d, $J=17$ Hz, H-5'), 3.47—4.05 (39H in total, OMe), 4.33 (1H, dd, $J=8$, 11 Hz, H-6), 4.71 (1H, dd, $J=8$, 11 Hz, H-5), 5.02 (1H, d, $J=2$ Hz, H-3'), 5.03 (1H, d, $J=2$ Hz, H-2'), 5.13 (1H, t, $J=11$ Hz, H-6), 5.13 (1H, brs, H-3), 5.36 (1H, s, H-2), 5.58 (1H, brs, H-4), 6.61 (1H, s, H-1), 6.76, 6.93 (each 1H, s, HHDP-H), 7.25 (2H, s, trimethoxybenzoyl H), 7.33 (1H, s, H-3'').

2 Hz, H-2'), 5.13 (1H, t, $J=11$ Hz, H-6), 5.13 (1H, brs, H-3), 5.36 (1H, s, H-2), 5.58 (1H, brs, H-4), 6.61 (1H, s, H-1), 6.76, 6.93 (each 1H, s, HHDP-H), 7.25 (2H, s, trimethoxybenzoyl H), 7.33 (1H, s, H-3'').

Treatment of 15 with Diazomethane A solution of 15 (45 mg) in MeOH (2 ml) was treated with ethereal diazomethane for 1 h. The solution was concentrated, and the residue was similarly treated three times. The reaction products were separated by chromatography on silica gel. Elution with benzene-acetone (10:1—5:1) afforded 15c (13 mg) and 15d (7 mg). 15c: Colorless needles (MeOH), mp 229—231 °C, $[\alpha]_D^{22} -166.9^\circ$ ($c=0.8$, CHCl₃). ¹H-NMR (CDCl₃) ppm: 3.22 (3H, s, OMe), 3.69—3.97 (24H in total, OMe), 6.54 (1H, brs, H-1), 6.57, 6.76 (each 1H, s, HHDP-H), 7.22 (2H, s, trimethoxybenzoyl H). 15d: A white amorphous powder, $[\alpha]_D^{25} +110.0^\circ$ ($c=0.5$, CHCl₃). EI-MS m/z (%): 424 (M⁺, 100), 393 [(M-OMe)⁺, 33], 351 [(M-CH₂COOMe)⁺, 23], 348 (53), 320 (89), 291 (45), 277 (45), 249 (58). High-resolution MS: Calcd for C₁₉H₂₀O₁₁ (M⁺), m/z : 424.1004. Found m/z : 424.1007. Calcd for C₁₆H₁₅O₉ (M-CH₂COOMe)⁺, m/z : 351.0715. Found m/z : 351.0723. ¹H-NMR (CDCl₃) ppm: 3.14 (1H, d, $J=17$ Hz, H-5), 3.40 (1H, d, $J=17$ Hz, H-5), 3.66, 3.90, 3.90, 3.92, 4.01 (each 3H, s, OMe), 4.96 (1H, d, $J=2$ Hz, H-3), 5.07 (1H, d, $J=2$ Hz, H-2), 7.27 (1H, s, H-3').

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