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ANTIALGAL COMPOUNDS FROM *ZANTEDESCHIA AETHIOPICA*

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Key Word Index—*Zantedeschia aethiopica*; Araceae; antialgal compounds; allelopathy; fatty acids; sterols; phenylpropanoids; lignans.

Abstract—Two cycloartane triterpenes and 10 sterols present in *Zantedeschia aethiopica* along with three lignans and 10 phenylpropanoids were identified by spectroscopic means. 3-(4-hydroxy-3-methoxy)-phenyl-1,2-propandiol and 1-(4-hydroxy-3-methoxy)-phenyl-2-[4-(2,3-dihydroxypropyl)-2-methoxy]-phenoxy-1,3-propandiol have been isolated for the first time. Antialgal assays show good activity for some aromatic compounds.

INTRODUCTION

In our studies of the allelochemical efforts of macrophytes against freshwater microalgae, we have extensively examined many aquatic and wetland plants [1].

In vitro assays showed that some aliphatic compounds such as hydroxy fatty acids and sterols inhibit algal growth but higher inhibitory activities were found with aromatic compounds such as phenylpropanoids and lignans. These compounds are present in significant amounts in *Pistia stratiotes* [2] and *Arum italicum* [3], two Araceae widely distributed in the mediterranean area, and a study of the growing waters of the first plant has shown that these compounds are released into the environment [4].

In the light of these data, we have investigated a further wetland Araceae *Zantedeschia aethiopica* (*Arum aethiopicum*) and in this paper we can report on the chemical and biological results of such a study. The plant has already been shown to have a high content of α-linolenic acid along with an unusual Δ^3-*trans*-hexadecenoic acid, galactolipids and galactosyldiacylglycerols in the thylakoid membranes from the leaves and regreened sphates [5].

RESULTS AND DISCUSSION

Plants of *Z. aethiopica* were cultured in the Botanical Garden of the University Federico II, air dried and sequentially extracted with EtOAc and MeOH. Both the extracts showed inhibitory effects on the green alga *Selenastrum capricornutum* [6] in a paper disk assay [7]. The less polar extract was separated by conventional procedures into an acid and a neutral fraction, both of them having bioactivity.

Table 1. Steroid Composition (% of total steroids)

(24R)-24-Ethyl-cholest-5-en-3β-ol (**3**)	93.11
(24R)-24-Methyl-cholest-5-en-3β-ol (**4**)	0.73
(24S)-24-Ethyl-cholesta-5,22-dien-3β-ol (**5**)	1.06
24-Methylene-cholest-7-en-3β-ol (**6**)	0.16
4α-Methyl-24-methylene-cholest-7-en-3β-ol (**7**)	0.33
(24R)-24-Ethyl-cholest-4-en-6β-ol-3-one (**8**)	0.69
(24R)-24-Methyl-5α,8-epidioxy-cholesta-6,22-dien-3β-ol (**9**)	1.44
(24R)-24-Ethyl-cholest-5-en-3β,7β-diol (**10**)	0.69
(24R)-24-Ethyl-cholest-5-en-3β,7α-diol (**11**)	0.19
(24R)-24-Ethyl-cholest-5-en-3β-ol-7-one (**12**)	1.60

Part of the acid fraction, after derivatization with diazomethane and chlorotrimethylsilane, was checked by GC-MS. Analysis showed the presence of α-linolenic acid, linoleic acid, the 13-hydroxyderivative of the former and the 9- and 12-hydroxyderivatives of the latter. The hydroxy acids were not identified in the previous study [5]. They might be formed by autoxidation of the corresponding unsaturated acid [8] and might be responsible for the antialgal activity of the fraction [2].

Repeated chromatography of the neutral fraction led to the isolation of the cycloartane triterpenes, cycloartenol (**1**) and 24-methylene-cycloartanol (**2**), and 10 sterols (**3**–**12**) (Table 1). The structures **1**–**12** have been attributed to the already known compounds by comparisons of their ^{1}H- and ^{13}C-NMR data with

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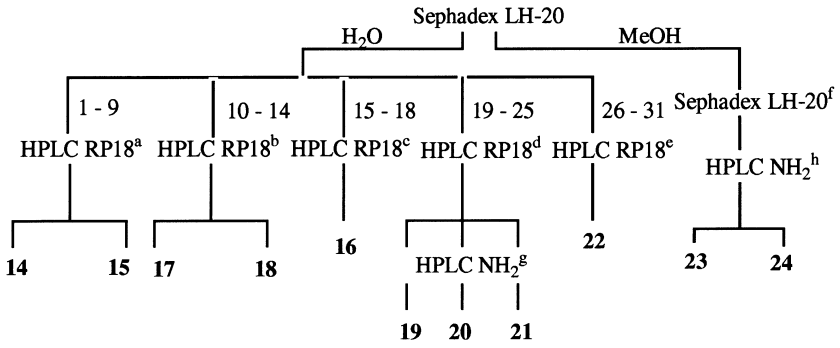


[a] H_2O - MeOH - AcOH (100 : 10 : 1); [b] H_2O - MeOH (3 : 1); [c] H_2O - MeOH (4 : 1); [d] H_2O - MeCN (4 : 1); [e] H_2O - MeCN (3 : 1); [f] $CHCl_3$ - MeOH (10 : 1); [g] MeCN - MeOH - H_2O (39 : 10 : 1); [h] MeCN - MeOH - H_2O (39 : 10 : 3).

Scheme 1.

those reported [9–12]. No pure sterol or triterpene inhibited algal growth so that the activity of the neutral fraction may be due to some minor unidentified component or to a synergistic action [13] of the isoprenoids.

The methanolic extract was partitioned between ethyl acetate and water. The organic layer on chromatograph gave, besides the already isolated sterols **11** and **12**, the lignan (+) pinoresinol (**13**) [14].

The bioactive aqueous layer was chromatographed on Amberlite XAD-2 eluting with methanol. The eluate was partitioned between *n*-butanol and water and the organic phase was chromatographed on Sephadex LH-20 (Scheme 1) to give 12 free and glucosylated aromatic compounds (**14**–**24**) which were identified on the basis of their spectroscopic features.

Racemic phenylpropanoid **14** has been previously synthesized as a standard in a study of the metabolites of eugenol in man [15], but its physical data were not reported. Compounds **15**–**23** are already known as natural products and have been isolated from several sources while the 8-*O*-4′ neolignan **24** has been isolated for the first time.

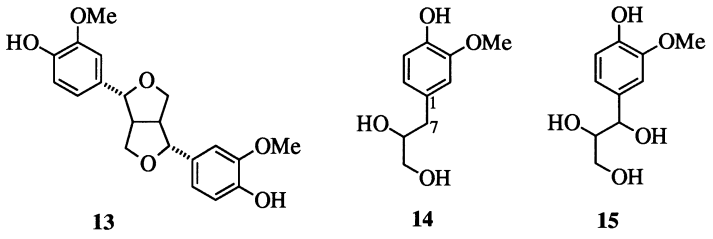
3-(4-hydroxy-3-methoxy)-phenyl-1,2-propandiol (**14**), $[\alpha]_D - 6^\circ$, on ^1H NMR in C_5D_5N showed the aromatic H-2, H-5 and H-6 protons at δ 7.13, 7.18 and 7.04, respectively, the H-7 methylene protons as a multiplet at δ 4.03, the H-8 methine proton as a multiplet at δ 4.37, the H-9 methylene protons as two double doublets at δ 3.07 and 3.18 and the methoxyl methyl as a singlet at δ 3.69. Numbering of carbon and hydrogen atoms shown on formulae **14**–**24**. In agreement with the pattern of substitution in the aromatic ring, the proton at δ 7.13 gave an nOe with the methoxyl methyl. The configurations at C-2 was attributed by a comparison of its rotation with that of a sample obtained by osmium-catalyzed asymmetric dihydroxylation of eugenol by Ad-mix α [16].

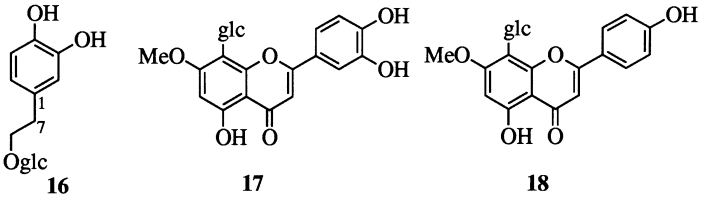
1-(4-hydroxy-3-methoxy)-phenyl-1,2,3-propantriol (**15**) has been isolated previously as a *threo* enantiomeric mixture, $[\alpha]_D + 12.8^\circ$, from *Pinus silvestris* [17]. The sample from *Z. aethiopica* had $[\alpha]_D - 25^\circ$. Its ^1H NMR spectrum in C_5D_5N showed the aromatic H-2, H-5 and H-6 protons at δ 7.43, 7.18 and 7.28, H-7 as a doublet at δ 5.24, H-8 as a multiplet at δ 4.33, the H-9 protons as two double doublets at δ 4.04 and 4.17, and the methoxyl methyl at δ 3.62.

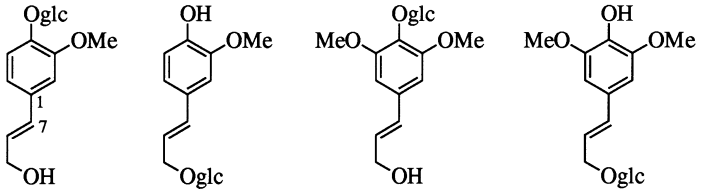
The ^1H NMR spectrum of the tetraacetate of **15** in $CDCl_3$ aromatic protons H-2, H-5 and H-6 gave rise to signals at δ 6.96, 7.03 and 6.96, H-7 a doublet at δ 5.97, H-8 a multiplet at δ 5.44 and the H-9 protons two double doublets at δ 3.82 and 4.29. The rotation of **15** and the chemical shifts of its tetraacetate were identical to those reported for the D *threo* isomer synthesized by Lundgren *et al.* [17] thus confirming the 1R,2R configurations.

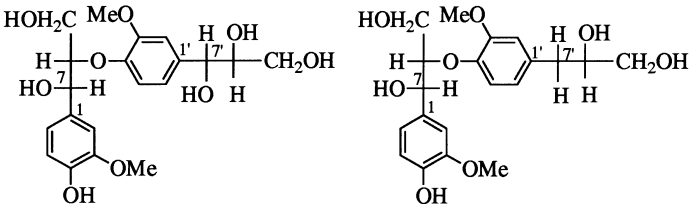
The phenylethanoid 2-(3,4-dihydroxy)-phenylethyl-*O*-*β*-D-glucopyranoside (**16**) has been reported as a component of the bark of *Prunus grayana* [18] and the C-glycosylflavonoids isoswertisin (**17**) and isoswertiajaponin (**18**) have been isolated from the leaves of *Passiflora sexflora* [19]. Finally, the phenylpropanoid glucosides coniferyl 4-*O*-*β*-D-glucopyranoside (**19**), coniferyl 9-*O*-*β*-D-glucopyranoside (**20**), sinapyl 4-*O*-*β*-D-glucopyranoside (**21**) and sinapyl 9-*O*-*β*-D-glucopyranoside (**22**) are components of *Pistia stratiotes* [4].

The first neolignan was assigned structure 1-(4-hydroxy-3-methoxy)-phenyl-2-[4-(1,2,3-trihydroxypropyl)-2-methoxy]-phenoxy-1,3-propandiol (**23**). It had been reported previously as a component of *Picea excelsa* but few significant data were described [20]. The sample from *Z. aethiopica* had $[\alpha]_D + 4.2^\circ$ and showed a pseudomolecular ion at m/z 433 $[M+Na]^+$ in the FAB-MS spectrum in agreement with the molecular formula $C_{20}H_{26}O_9$. The IR spectrum showed absorptions at 3645 and 3560 cm^{-1} due to hydroxyl groups and aromatic absorptions at 1605 cm^{-1}. The well resolved ^1H NMR spectrum in CD_3OD displayed H-2 and H-2′ as narrow doublets at δ 7.01









and 7.21, H-5 and H-5′ as doublets at δ 6.74 and 7.04 and the partly overlapped H-6 and H-6′ as double doublets at δ 6.86 and 6.82. In addition to the two methoxyl methyl singlets at δ 3.85 and 3.87, the spectrum displayed H-7 and H-7′ as two doublets at δ 4.91 and 4.61, the H-8 and H-8′ protons as multiplets at δ 4.36 and 3.64, the H-9 protons as two double doublets at δ 3.50 and 3.75 and the H-9′ protons as partly overlapped double doublets at δ 3.43 and 3.47. In the ^{1}H-^{13}C long-range COSY spectrum the aromatic protons at δ 6.86 and 7.01 gave cross peaks with the carbon at δ 146.7 and the proton at δ 6.74 was correlated to the carbons at δ 133.8 and 148.0, the first carbon being also correlated to the methine proton at δ 4.91. Likewise, the protons at δ 6.82 and 7.21 were correlated to the carbon at δ 146.7 while the proton at δ 7.04 was correlated to the carbons at δ 134.9 and 148.0. Furthermore, the proton at δ 4.61 was correlated to the carbon at δ 134.9 and the methyl at δ 3.85 and 3.87 was correlated to the carbons at δ 148.0. Finally, the methoxyl methyl at δ 3.85 gave a nOe with the proton at δ 7.01 and the methyl at δ 3.87 with the proton at δ 7.21. The relatively high couplings of the protons at δ 4.61 and 4.91 indicated the *threo* forms of both the glyceryl chains [21].

1-(4-hydroxy-3-methoxy)-phenyl-2-[4-(2,3-dihydroxy-propyl)-2-methoxy]-phenoxy-1,3-propandiol (**24**) had $[\alpha]_D$ +24.4° and a pseudomolecular peak at *m.z* 417 in the FAB-MS spectrum for the molecular formula $C_{20}H_{26}O_9$. The ^{1}H NMR spectrum was rather similar to that of **23**. The main differences were two double doublets in the highfield region at δ 2.60 and 2.73 and the lack of the methine multiplet at δ 4.61 thus suggesting the absence of the hydroxyl group at C-7′. The coupling of the H-7 proton suggested the *threo* form.

Compounds **13**–**22** were assayed in broth against the green alga *S. capricornutum* at concentrations

ranging from 10^{-3} M to 10^{-5} M while neolignans **23** and **24** were only tested by paper disk assays owing to the small amounts which were available.

Phenylpropanoid glucosides **19**–**22** were inactive, as has already been observed in *Pistia stratiotes*, as were the remaining glucosylated compounds **16**–**18**.

Neolignans **23** and **24** (0.1 μmol) gave 15–23 mm diameters of inhibition in the tests thus showing activities similar to that of the algicide $CuSO_4$. Pinoresinol (**13**), (−) 3-(4′-hydroxy-3′-methoxy)-phenyl-1,2-propandiol (**14**) and (−) 1-(4′-hydroxy-3′-methoxy)-phenyl-1,2,3-propantriol (**15**) showed weak activity causing 40% inhibition at 10^{-4} M.

EXPERIMENTAL

NMR: 400 MHz for ^{1}H and 100 MHz for ^{13}C. One-bond and long-range ^{1}H-^{13}C COSY experiments were performed with the XHCORR microprogram using delays corresponding to $J_{C,H}$ 160 and 8 Hz, respectively. The antialgal assays in broth and on plate were carried out by methods reported elsewhere [7, 22].

Plants of *Z. aethiopica* were cultured in the Botanical Garden of the University Federico II of Naples and a voucher specimen is deposited in the herbarium of the Dipartimento di Biologia Vegetale of the same University. The whole plants, collected in the Summer and air dried (4.5 kg) were extracted sequentially with EtOAc and MeOH. An aliquot (10 g) of the EtOAc extract (110 g) was separated by conventional procedures into an acid (4 g) and a neutral fraction (5.3 g).

GC-MS analysis of the acid fraction from the EtOAc extract

An aliquot (5 mg) of the acid fr. was treated with an excess of ethereal CH_2N_2. After evapn the residue was treated with Sil-A (Me_3SiCl in pyridine, 0.5 ml) at 80° for 20 min. MeOH and toluene were added and the reaction mixt., after evapn *in vacuo*, was analysed by GC-MS using as standards methyl linolenate, methyl linoleate and the sylilated methyl esters of 9- and 12-hydroxylinoleic acids.

Neutral fraction from EtOAc extract

The neutral fraction subjected to CC on silica gel (160 g): hexane eluted waxes and fats while mixts of hexane–Et_2O gave three frs A–C. Fraction A (hexane–Et_2O 9:1; 800 mg) consisted of cycloartenol (**1**) and 24-methylene-cycloartanol (**2**) which were sepd by prep. Ag^+–TLC (hexane–Et_2O 19:1); Fraction B (hexane–Et_2O 4:1; 2.2 g) consisted of (24R)-24-ethyl-cholest-5-en-3β-ol (**3**), (24R)-24-methyl-cholest-5-en-3β-ol (**4**), (24S)-24-ethyl-cholesta-5,22-dien-3β-ol (**5**), 24-methylene-cholest-7-en-3β-ol (**6**) and 4α-methyl-24-methylene-cholest-7-en-3β-ol (**7**). Crystallization from hexane gave **3** (1.6 g) and CC of the mother liquors on silica gel (21 g) gave a mixt. of **4** and **5** (hexane–Et_2O 9:1) and a mixt. of **6** and **7** (hexane–Et_2O 4:1). Prep. Ag^+–TLC (hexane–EtOAc 4:1) gave **4** (12 mg) and **5** (18 mg), while HPLC (hexane–EtOAc 97:3) gave **6** (3 mg) and **7** (6 mg). Fraction C (Et_2O; 1.3 g), consisting of (24R)-24-ethyl-cholest-4-en-6β-ol-3-one (**8**), (24R)-24-methyl-5α,8-epidioxy-cholesta-6,22-dien-3β-ol (**9**), (24R)-24-ethyl-cholest-5-en-3β,7β-diol (**10**), (24R)-24-ethyl-cholest-5-en-3β,7α-diol (**11**) and (24R)-24-ethyl-cholest-5-en-3β-ol-7-one (**12**), was rechromatographed on silica gel. The benzene–Et_2O (17:3) eluate was chromatographed on Sephadex LH-20 and elution with $CHCl_3$–MeOH–hexane (1:1:3) gave two mixts. The first mixt. was resolved by prep. TLC (hexane–Et_2O 7:3) into **8** (12 mg) and **9** (25 mg). Pre. Ag^+–TLC (hexane–EtOAc 7:3) of the latter mixt. gave crude **10** (12 mg), purified by TLC (benzene–Et_2O 19:1), and **11** (3 mg) and **12** (26 mg), purified by HPLC (hexane–Me_2CO 4:1).

MeOH extract

An aliquot (20 g) of the MeOH extract (300 g) was partitioned between EtOAc and water. The organic fr. (600 mg) was chromatographed on silica gel; hexane–Et_2O (7:3) gave a mixt. of **11** and **12** (37 mg), and hexane–Et_2O (2:3) gave crude (+) pinoresinol (**13**) (190 mg), which was purified by CC ($CHCl_3$–MeOH, 50:1): ^{1}H NMR ($CDCl_3$): δ 6.82 (6H, *m*, H-2′, H-5′ and H-6′), 4.75 (2H, *d*, J = 5.1 Hz, H-2 and H-6), 4.31 (2H, *dd*, J = 9.1 and 6.9 Hz, H-4$_{eq}$ and H-8$_{eq}$), 3.92 (6H, *s*, OMe), 3.87 (2H, *dd*, J = 9.1 and 4.3 Hz, H-4$_{ax}$ and H-8$_{ax}$), 3.10 (2H, *m*, H-1 and H-5); ^{13}C NMR ($CDCl_3$): δ 54.3 (C-1 and C-5), 86.1 (C-2 and C-6), 71.9 (C-4 and C-8), 133.0 (C-1′), 108.9 (C-2′), 146.8 (C-3′), 145.4 (C-4′), 114.3 (C-5′), 118.6 (C-6′), 55.9 (OMe).

The aq. fr. was chromatographed on Amberlite XAD-2 and the eluate with MeOH was separated by *n*-butanol and water. An aliquot (300 mg) of the material (1.8 g) from the organic layer was chromatographed on Sephadex LH-20 (Scheme 1) to give compounds **14**–**24**.

3-(4-*hydroxy*-3-*methoxy*)-*phenyl*-1,2-*propandiol* (**14**) (19 *mg*). $[\alpha]_D$ −6°; ^{1}H NMR (C_5D_5N): δ 7.13 (1H, *d*, J = 1.5 Hz, H-2), 7.18 (1H, *d*, J = 8.0 Hz, H-5), 7.04 (1H, *dd*, J = 1.5 and 8.0 Hz, H-6), 4.03 (2H, *m*, H-7), 4.37 (1H, *m*, H-8), 3.07 (1H, *dd*, J = 7.5 and 13.6 Hz, H-9), 3.18 (1H, *dd*, J = 5.3 and 13.6 Hz, H-9), 3.69 (3H, *s*, OMe); ^{1}H NMR (CD_3OD): δ 6.82 (1H, *d*, J = 1.8 Hz, H-2), 6.71 (1H, *d*, J = 8.0 Hz, H-5), 6.60 (1H, *dd*, J = 1.8 and 8.0 Hz, H-6), 3.50 (1H, *dd*, J = 4.4 and 11.1 Hz, H-1), 3.43 (1H, *dd*, J = 6.2 and 11.1 Hz, H-7), 3.78 (1H, *m*, H-8), 2.73 (1H, *dd*, J = 5.7 and 13.8 Hz, H-9), 2.60 (1H, *dd*, J = 7.4 and 13.8 Hz, H-3), 3.83 (3H, *s*, OMe); ^{13}C NMR (C_5D_5N): δ 131.4 (C-1), 114.3 (C-2), 148.5 (C-3), 146.6 (C-4), 116.4 (C-5), 122.9 (C-6), 66.9 (C-7), 74.3 (C-8), 40.9 (C-9), 55.9 (OMe); ^{13}C NMR (CD_3OD): δ 130.6 (C-1), 113.1 (C-2), 147.9 (C-3), 144.8 (C-4), 115.0 (C-5), 121.8 (C-6), 65.5 (C-7), 73.6 (C-8), 39.4 (C-9), 55.3 (OMe).

3-(4-*hydroxy*-3-*methoxy*-*phenyl*)-1,2,3-*propantriol* (**15**) (16 *mg*). $[\alpha]_D$ −25° (*c* 0.7); ^{1}H NMR (C_5D_5N): δ 7.43 (1H, *d*, *J* = 1.8 Hz, H-2), 7.18 (1H, *d*, *J* = 7.9 Hz, H-5), 7.28 (1H, *dd*, *J* = 1.8 and 7.9 Hz, H-6), 5.24 (1H, *d*, *J* = 5.8 Hz, H-7), 4.33 (1H, *m*, H-8), 4.17 (1H, *dd*, *J* = 3.2 and 11.2 Hz, H-9), 4.04 (1H, *dd*, *J* = 6.2 and 11.2 Hz, H-9), 3.62 (3H, *s*, OMe); ^{13}C NMR (C_5D_5N): δ 114.9 (C-1), 111.8 (C-2), 148.5 (C-3), 147.4 (C-4), 116.1 (C-5), 120.6 (C-6), 55.9 (OMe), 75.0 (C-7), 77.9 (C-8), 64.4 (C-9). Tetraacetate of **15**: ^{1}H NMR ($CDCl_3$): δ 6.96 (1H, *d*, *J* = 1.9 Hz, H-2), 7.03 (1H, *d*, *J* = 8.4 Hz, H-5), 6.97 (1H, *dd*, *J* = 1.9 and 8.4 Hz, H-6), 5.97 (1H, *d*, *J* = 7.6 Hz, H-7), 5.44 (1H, *m*, H-8), 4.29 (1H, *dd*, *J* = 3.6 and 12.0 Hz, H-9), 3.82 (1H, *dd*, *J* = 5.8 and 12.0 Hz, H-9), 3.86 (3H, *s*, OMe); ^{13}C NMR ($CDCl_3$): δ 134.6 (C-1), 111.3 (C-2), 151.8 (C-3), 140.7 (C-4), 119.7 (C-5), 123.1 (C-6), 72.2 (C-7), 77.4 (C-8), 62.1 (C-9), 56.0 (OMe).

2-(3,4-*dihydroxy*)-*phenyl*-*ethyl*-β-D-*glucopyranoside* (**16**) (18 *mg*). ^{1}H NMR (CD_3OD): δ 6.70 (1H, *d*, *J* = 2.1 Hz, H-2), 6.66 (1H, *d*, *J* = 8.1 Hz, H-5), 6.55 (1H, *dd*, *J* = 2.1 and 8.1 Hz, H-6), 4.02 (1H, *m*, H-8), 3.69 (1H, *m*, H-8), 2.78 (2H, *t*, *J* = ●, H-7), 4.28 (1H, *d*, *J* = 7.9 Hz, H-1glc), 3.29–3.33 (2H, overlapped, H-2glc and H-3glc), 3.20 (1H, *dd*, 7.8 and 8.8 Hz, H-4glc), 3.65–3.70 (2H, overlapped, H-5glc and H-6glc), 3.86 (1H, *dd*, *J* = 2.1 and 11.9 Hz, H-6glc); ^{13}C NMR (CD_3OD): δ 131.4 (C-1), 115.8 (C-2), 145.9 (C-3), 144.4 (C-4), 117.1 (C-5), 120.9 (C-6), 72.0 (C-8), 36.5 (C-7), 104.3 (C-1glc), 75.1 (C-2glc), 77.9 (C-3glc), 71.6 (C-4glc), 78.3 (C-5glc), 62.9 (C-6glc).

Isoswertiajaponin (**17**) (50 *mg*). ^{1}H NMR (DMSO-d_6): δ 7.62 (1H, *dd*, *J* = 2.0 and 8.5 Hz, H-6′), 7.56 (1H, *brs*, H-2′), 6.93 (1H, *d*, *J* = 8.3 Hz, H-5′), 6.75 (1H, *s*, H-3), 6.58 (1H, *s*, H-6), 3.93 (3H, *s*, OMe), 4.78 (1H, *d*, *J* = 11.1 Hz, H-1glc); ^{13}C NMR (DMSO-d_6): δ 164.2 (C-2), 102.0 (C-3), 182.0 (C-4), 161.3 (C-5), 94.6 (C-6), 163.2 (C-7), 105.4 (C-8), 154.8 (C-9), 104.1 (C-10), 121.8 (C-1′), 113.7 (C-2′), 145.6 (C-3′), 149.6 (C-4′), 115.6 (C-5′), 119.4 (C-6′), 56.5 (OMe), 73.2 (C-1glc), 70.8 (C-2glc), 78.5 (C-3glc), 70.3 (C-4glc), 81.6 (C-5glc), 61.3 (C-6glc).

Isoswertisin (**18**) (13 *mg*). ^{1}H NMR (DMSO-d_6): δ 8.07 (2H, *d*, *J* = 8.6 Hz, H-2′ and H-6′), 6.91 (2H, *d*, *J* = 8.6 Hz, H-3′ and H-5′), 6.72 (1H, *s*, H-3), 6.56 (1H, *s*, H-6), 3.90 (3H, *s*, OMe), 4.77 (1H, *d*, *J* = 11.1 Hz, H-1glc); ^{13}C NMR (DMSO-d_6): δ 164.2 (C-2), 102.0 (C-3), 182.0 (C-4), 161.3 (C-5), 94.6 (C-6), 163.2 (C-7), 105.4 (C-8), 154.8 (C-9), 104.1 (C-10), 121.4 (C-1′), 129.3 (C-2′ and C-6′), 115.8 (C-3′ and C-5′), 161.5 (C-4′), 56.5 (OMe), 73.2 (C-1glc), 70.8 (C-2glc), 78.5 (C-3glc), 70.3 (C-4glc), 81.6 (C-5glc), 61.3 (C-6glc).

3-(4β-D-*glucopyranosyloxy*-3-*methoxy*)-*phenyl*-2E-*propenol* (**19**) (19 *mg*). ^{1}H NMR (CD_3OD): δ 7.11 (1H, *d*, *J* = 8.4 Hz, H-5), 7.07 (1H, *d*, *J* = 1.9 Hz, H-2), 6.95 (1H, *dd*, *J* = 1.9 and 8.4 Hz, H-6), 6.56 (1H, *dt*, *J* = 1.5 and 15.8 Hz, H-7), 6.28 (1H, *dt*, *J* = 5.8 and 15.8 Hz, H-8), 4.23 (2H, *dd*, *J* = 1.5 and 5.8 Hz, H-9), 3.88 (3H, *s*, OMe), 4.97 (1H, *d*, *J* = 7.7 Hz, H-1glc), 3.38 (1H, *m*, H-2glc), 3.49 (1H, *m*, H-3glc), 3.40 (1H, *m*, H-4glc), 3.20 (1H, *m*, H-5glc), 3.72 (1H, *m*, H-6glc), 3.90 (1H, *m*, H-6glc; ^{13}C NMR (CD_3OD): δ 133.9 (C-1), 111.6 (C-2), 153.7 (C-3), 142.3 (C-4), 118.1 (C-5), 120.9 (C-6), 129.1 (C-7), 131.5 (C-8), 64.0 (C-9), 56.8 (OMe), 103.0 (C-1glc), 75.1 (C-2glc), 78.4 (C-3glc), 71.5 (C-4glc), 78.1 (C-5glc), 62.7 (C-6glc).

3-(4-*hydroxy*-3-*methoxy*)-*phenyl*-2E-*propenyl*-1β-D-*glucopyranoside* (**20**) (12 *mg*). ^{1}H NMR (CD_3OD): δ 7.03 (1H, *d*, *J* = 1.8 Hz, H-2), 6.97 (1H, *dd*, *J* = 1.8 and 8.2 Hz, H-6), 6.75 (1H, *d*, *J* = 8.2 Hz, H-5), 6.40 (1H, *dd*, *J* = 1.5 and 16.0 Hz, H-7), 6.18 (1H, *dt*, *J* = 5.8 and 16.0 Hz, H-8), 4.30 (2H, *dd*, *J* = 1.5 and 5.8 Hz, H-9), 3.88 (3H, *s*, OMe), 4.97 (1H, *d*, *J* = 7.7 Hz, H-1glc), 3.35 (1H, *t*, *J* = 7.5 Hz, H-2glc), 3.49 (1H, *m*, H-3glc), 3.48 (1H, *m*, H-4glc), 3.17 (1H, *m*, H-5glc), 3.68 (1H, *m*, H-6glc), 3.79 (1H, *m*, H-6glc); ^{13}C NMR (CD_3OD): δ130.4 (C-1), 109.2 (C-2), 154.2 (C-3), 142.3 (C-4), 116.4 (C-5), 121.9 (C-6), 129.4 (C-7), 127.0 (C-8), 71.2 (C-9), 56.4 (OMe), 102.0 (C-1glc), 75.3 (C-2glc), 78.4 (C-3glc), 71.7 (C-4glc), 78.0 (C-5glc), 62.8 (C-6glc).

3-(4β-D-*glucopyranosyloxy*-3,5-*dimethoxy*)-*phenyl*-2E-*propenol* (**21**) (9 *mg*). ^{1}H NMR (CD_3OD): δ 6.77 (2H, *s*, H-2 and H-6), 6.56 (1H, *dt*, *J* = 1.5 and 16.1 Hz, H-7), 6.32 (1H, *dt*, *J* = 5.2 and 16.1 Hz, H-8), 4.24 (2H, *dd*, *J* = 1.5 and 5.2 Hz, H-9), 3.86 (6H, *s*, OMe), 4.87 (1H, *d*, *J* = 7.8 Hz, H-1glc), 3.46 (1H, *m*, H-2glc), 3.45 (1H, *m*, H-3glc), 3.46 (1H, *m*, H-4glc), 3.21 (1H, *m*, H-5glc), 3.67 (1H, *dd*, *J* = 6.7 and 10.5 Hz, H-6glc), 3.79 (1H, *dd*, *J* = 2.1 and 10.5 Hz, H-6glc); ^{13}C NMR (CD_3OD): δ 130.5 (C-1), 105.7 (C-2 and C-6), 154.6 (C-3 and C-5), 135.8 (C-4), 131.5 (C-7), 130.2 (C-8), 63.8 (C-9), 57.4 (OMe), 105.6 (C-1glc), 76.0 (C-2glc), 78.5 (C-3glc), 71.6 (C-4glc), 78.0 (C-5glc), 62.7 (C-6glc).

3-(4-*hydroxy*-3,5-*dimethoxy*)-*phenyl*-2E-*propenyl*-1β-D-*glucopyranoside* (**22**) (7 *mg*). ^{1}H NMR (CD_3OD): δ 6.56 (2H, *s*, H-2 and H-6), 6.38 (1H, *dt*, *J* = 1.5 and 16.0 Hz, H-7), 5.81 (1H, *dt*, *J* = 5.2 and 16.0 Hz, H-8), 4.31 (2H, *dd*, *J* = 1.5 and 5.2 Hz, H-9), 3.84 (6H, *s*, OMe), 4.87 (1H, *d*, *J* = 7.8 Hz, H-1glc), 3.46 (1H, *m*, H-2glc), 3.45 (1H, *m*, H-3glc), 3.46 (1H, *m*, H-4glc), 3.21 (1H, *m*, H-5glc), 3.67 (1H, *dd*, *J* = 6.7 and 10.5 Hz, H-6glc), 3.79 (1H, *dd*, *J* = 2.1 and 10.5 Hz, H-6glc); ^{13}C NMR (CD_3OD): δ 128.2 (C-1), 105.3 (C-2 and C-6), 149.7 (C-3 and C-5), 133.3 (C-4), 132.1 (C-7), 126.5 (C-8), 70.7 (C-9), 56.8 (OMe), 104.6 (C-1glc), 75.0 (C-2glc), 78.3 (C-3glc), 72.1 (C-4glc), 78.1 (C-5glc), 70.2 (C-6glc).

1-(4-*hydroxy*-3-*methoxy*)-*phenyl*-2-[4-(1,2,3-*trihydroxypropyl*)-2-*methoxy*]-*phenoxy*-1,3-*propandiol* (**23**) (3 *mg*). $[\alpha]_D$ +4.2° (*c* 0.3 in EtOH); FAB-MS *m*/*z* 433; ^{1}H NMR (CD_3OD): δ 7.01 (1H, *d*, *J* = 1.8 Hz, H-2), 6.74 (1H, *d*, *J* = 8.0 Hz, H-5), 6.86 (1H, *dd*, *J* = 1.8 and 8.0 Hz, H-6), 4.91 (1H, *d*, *J* = 6.5 Hz, H-7), 4.36 (1H, *m*, H-8), 3.47 (1H, *dd*, *J* = 5.0 and 11.5 Hz, H-9), 3.75 (1H, *dd*, *J* = 4.0 and 11.5 Hz, H-9), 3.85 (3H, *s*, OMe), 7.21 (1H, *d*, *J* = 2.1 Hz, H-2′), 7.04 (1H, *d*, *J* = 8.3 Hz, H-5′), 6.82 (1H, *dd*, *J* = 2.1 and 8.3 Hz, H-6′), 4.61 (1H, *d*, *J* = 6.1 Hz, H-7′), 3.64 (1H,

m, H-8′), 3.43 (1H, *dd*, $J = 5.9$ and 11.1 Hz, H-9′), 3.50 (1H, *dd*, $J = 4.0$ and 11.1 Hz, H-9′), 3.87 (3H, *s*, OMe′); ^{13}C NMR (acetone-d_6): δ 133.8 (C-1), 111.6 (C-2), 148.0 (C-3), 146.7 (C-4), 115.2 (C-5), 120.4 (C-6), 73.6 (C-7), 88.0 (C-8), 61.5 (C-9), 55.5 (OMe), 134.9 (C-1′), 113.7 (C-2′), 148.0 (C-3′), 146.7 (C-4′), 115.2 (C-5′), 120.3 (C-6′), 74.8 (C-7′), 77.3 (C-8′), 64.0 (C-9′), 56.2 (OMe′).

1-(4-*hydroxy*-3-*methoxy*)-*phenyl*-2-[4-(2,3-*dihydroxypropyl*)-2-*methoxy*]-*phenoxy*-1,3-*propandiol* (**24**) (4 *mg*). $[\alpha]_D$ +24.4° (*c* 0.4 in EtOH); FAB-MS *m*/*z* 417; ^{1}H NMR (CD_3OD): δ 7.04 (1H, *d*, $J = 1.9$ Hz, H-2), 6.74 (1H, *d*, $J = 8.1$ Hz, H-5), 6.85 (1H, *dd*, $J = 1.9$ and 8.1 Hz, H-6), 4.86 (1H, *d*, $J = 6.4$ Hz, H-7), 4.36 (1H, *m*, H-8), 3.48 (1H, *dd*, $J = 5.0$ and 11.5 Hz, H-9), 3.72 (1H, *dd*, $J = 4.0$ and 11.5 Hz, H-9), 3.84 (3H, *s*, OMe), 7.04 (1H, *d*, $J = 2.1$ Hz, H-2′), 6.98 (1H, *d*, $J = 8.2$ Hz, H-5′), 6.70 (1H, *dd*, $J = 2.1$ and 8.2 Hz, H-6′), 2.60 (1H, *dd*, $J = 7.5$ and 13.8 Hz, H-7′), 2.73 (1H, *dd*, $J = 5.7$ and 13.8 Hz, H-7′), 3.78 (1H, *m*, H-8′), 3.43 (1H, *dd*, $J = 5.9$ and 11.0 Hz, H-9′), 3.50 (1H, *dd*, $J = 4.0$ and 11.0 Hz, H-9′), 3.87 (3H, *s*, OMe′); ^{13}C NMR (acetone-d_6): δ 133.6 (C-1), 112.1 (C-2), 148.3 (C-3), 146.2 (C-4), 116.0 (C-5), 120.8 (C-6), 73.7 (C-7), 87.8 (C-8), 61.2 (C-9), 55.5 (OMe), 131.4 (C-1′), 116.4 (C-2′), 148.1 (C-3′), 145.9 (C-4′), 115.5 (C-5′), 122.7 (C-6′), 39.2 (C-7′), 75.2 (C-8′), 66.5 (C-9′), 56.2 OMe′).

Enantioselective synthesis of 3-(4-*hydroxy*-3-*methoxy*)-*phenyl*-1,2-*propandiol* (**14**). To a stirred mixt. of anhydrous K_2CO_3 (8.8 g) and eugenol (1 g) in dry Me_2CO (6 ml) under N_2 at room temp. a soln of benzyl bromide (732 μl) in Me_2CO (10 ml) was added during 30 min. After 14 h the mixt. was filtered and the residue was dissolved in water and extracted with Et_2O to give benzyleugenol (1.4 g). *t*-Butyl alcohol (2.1 ml), water (2.1 ml) and AD-mix α (590 mg) were stirred at room temp. giving up to two phases. The mixt. was cooled to 0° and benzyleugenol (110 mg; 0.41 mmol) was added at once. After 24 h with magnetic stirring solid sodium sulphite was added and the mixt. was allowed to warm to room temp. and stirred for 30 min. Extraction with EtOAc gave a crude product (98 mg) which on flash chromatography (silica gel, EtOAc–hexane 3:1). To a soln of the purified product (80 mg) in MeOH–HCOOH (4.6 ml, 1:1) Pd/C (70 mg) was added and the mixt. was sonicated for 5 h. The crude product was filtered on celite and chromatographed by flash chromatography (silica gel, $CHCl_3$–MeOH 19:1) to give 3-(4-hydroxy-3-methoxy)-phenyl-1,2-propandiol (**14**), had $[\alpha]_D$ −4.7°.

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