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Iridoid and megastigmane glycosides from *Phlomis aurea*

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Abstract

From the leaves of *Phlomis aurea*, two new iridoids of unique structures named 3-epiphlomurin (**1**) and phlomurin (**2**), a new megastigmane glucoside phlomuroside (**3**) and a new benzyl alcohol glycoside having the structure benzyl alcohol-*O*-β-xylopyranosyl-(1→2)-β-glucopyranoside (**4**) have been isolated together with four known iridoids auroside, lamiide, 8-epiloganin and ipolamiide, two known phenolic glycosides acteoside (verbascoside) and syringin, one known phenylethanoid glycoside 2-phenylethyl-*O*-β-xylopyranosyl-(1→2)-β-glucopyranoside, one known lignan liriodendrin and three known flavonoids chrysoeriol-7-*O*-β-glucopyranoside, acacetin-7-*O*-β-glucopyranoside and luteolin-7-*O*-β-glucopyranoside. The structures of the isolated compounds were verified by means of mass spectrometry (MS) and nuclear magnetic resonance (NMR) spectral analyses.

Keywords: *Phlomis aurea*; Lamiaceae; Iridoids; Megastigmane; Benzyl alcohol glycosides

1. Introduction

Phlomis aurea Decne (Lamiaceae) is a wild plant growing in Sinai region especially in Gebel Mousa and Saint Katharine mountains (Tackholm, 1974). In Egyptian folk medicine, the plant is used as antidiabetic (Watt and Breyer, 1962). Different classes of glycosides comprising diterpenoids (Tanaka et al., 1983, 1985; Katagiri et al., 1994), iridoids (El-Naggar and Beal, 1980; Çalis et al., 1991), phenylpropanoids (Çalis et al., 1991; Saracoglu et al., 1995), phenylethanoids (Saracoglu et al., 1998) and flavonoids (El-Negoumy et al., 1986; Tomas et al., 1986) had been identified from genus *Phlomis*. Many of the phenylpropanoids isolated from genus *Phlomis* showed significant biological activities, e.g. cytotoxic, cytostatic, anti-inflammatory, immunosuppressant and antimicrobial effects (Saracoglu et al., 1995). Reviewing current literature, only flavonoids had been described from *P. aurea* (El-Negoumy et al., 1986). The present study deals with the isolation and structure elucidation of four new compounds including two iridoids, a megastigmane glucoside and a benzyl alcohol glycoside together with 11 known glycosides from the leaves of *P. aurea*.

2. Results and discussion

The ethanolic extract of the leaves of *P. aurea* was deffated with *n*-hexane and the aqueous layer was subjected to a column chromatography of Diaion HP-20. The 50% methanol and methanol eluates were repeatedly chromatographed on columns of silica gel and then by MPLC and HPLC to afford 15 glycosides.

The molecular formula of compound **1** was deduced as $C_{18}H_{28}O_{11}$ from HR FAB-MS spectrometry (see Experimental). The ^{13}C NMR spectrum (Table 1) of **1** displayed the presence of one β-glucopyranosyl unit in addition to 12 carbon signals for the aglycone. DEPT experiments indicated the presence of one methyl group (δ 12.7), two methoxyl groups (δ 51.4 and 56.1), one methylene group (δ 41.4), five methines (δ 42.7, 48.3, 76.2, 92.3 and 98.2) as well as three quaternary carbons (δ 123.2, 160.4 and 165.6). The chemical shifts of the aglycone carbons were similar to those reported for iridoids (El-Naggar and Beal, 1980). However, the two

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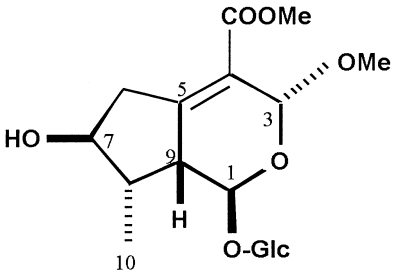

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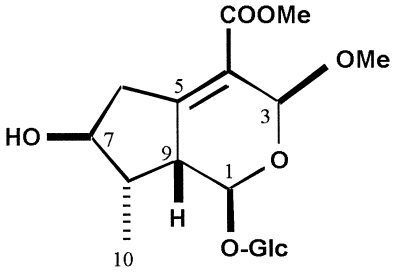

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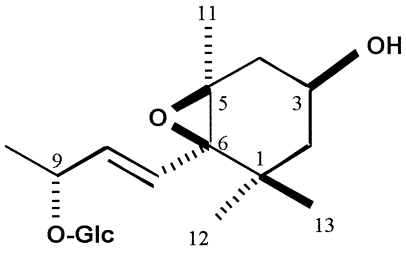

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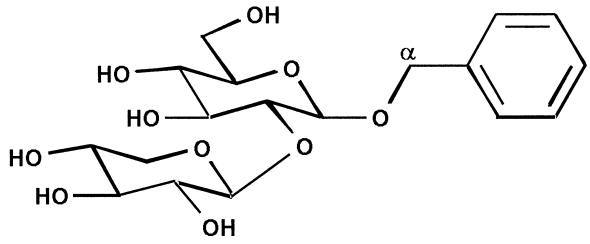

(4)

Table 1
^{13}C NMR spectral data of compounds **1**–**4** (100 MHz, C_5D_5N): (δ in ppm)

C	1	2	C	3	C	4
1	92.3	96.1	1	35.0	1	138.8
3	98.2	97.5	2	47.9	2,6	128.5
4	123.2	125.4	3	63.1	3,5	127.9
5	160.4	160.7	4	41.7	4	127.7
6	41.4	40.7	5	66.5	α	70.9
7	76.2	76.8	6	69.6	β-Glc	
8	42.7	42.9	7	126.8	1	102.2
9	48.3	47.3	8	136.4	2	84.1
10	12.7	13.4	9	75.3	3	78.2[b]
11	165.6	165.1	10	20.8[a]	4	71.2
OMe	51.4	51.2	11	20.2[a]	5	78.5
	56.1	55.8	12	25.2	6	62.4
β-Glc			13	29.7	β-Xyl	
1	100.6	100.2	β-Glc		1	107.6
2	74.9	74.8	1	102.6	2	76.3
3	78.6	78.5	2	75.2	3	78.0[b]
4	71.7	71.8	3	78.4	4	71.1
5	78.9	78.5	4	71.4	5	67.4
6	62.7	62.9	5	78.3		
			6	62.6		

[a,b] Values may be interchangeable.

quaternary signals at δ 123.2 and 160.2 revealed that the double bond is located between C-4 and C-5 instead of its normal position between C-3 and C-4 as confirmed from 2D NMR experiments and by comparison with pinifolin, an iridoid isolated from *Penstemon pinifolius* (Junior, 1989). Moreover, the methine signal at δ 98.2 together with the methoxyl signal at δ 56.1 indicated the attachment of this methoxyl group to C-3 of the aglycone (Junior, 1989). The methine signal at δ 76.2 was clear for the substitution of C-7 with a hydroxyl group (El-Naggar and Beal, 1980). The β-glucopyranosyl unit is linked to C-1 of the aglycone from the chemical shift value of this carbon at δ 92.3 (Endo et al., 1979). The ^{13}C NMR data showed a signal at δ 100.6 corresponding to the anomeric carbon of the β-glucopyranosyl moiety (Bradbury and Jenkins, 1984). The ^{1}H NMR spectrum exhibited the presence of signals at δ 5.80 (1H, *d*, $J=9$ Hz), 5.60 (1H, *s*), 4.40 (1H, *m*), 3.30 (1H, *dd*,

$J = 9.0$ and 5.3 Hz) and 2.65 (1H, *m*) assignable for the methine protons H-1, H-3, H-7, H-9 and H-8 respectively. It showed also an AB methylene signals at δ 3.60 (1H, *bd*, $J = 20.2$ Hz) and 3.40 (1H, *dd*, $J = 20.2$ and 8.2 Hz) attributable to H-6β and H-6α respectively. The proton signals at δ 3.61 and 3.50 (each 3H, *s*) as well as at δ 0.80 (3H, *d*, $J = 7.3$ Hz) corresponding to the methoxyl group located at C-3, the methyl group of the ester functionality at C-4 and the methyl group C-10 respectively. The doublet signal at δ 5.40 (1H) with *J* constant 8.1 Hz of the anomeric proton of the glucose moiety indicated the β configuration. The HMQC spectral analysis of **1** assigned significantly the correlations between each carbon and its directly attached protons while the interpretation of the proton–proton couplings were established by measurements of H–H COSY. The HMBC spectral analysis (Fig. 1) displayed correlation peaks between H-3 with both C-1 and C-5, H-7 with both C-8 and C-10, H-9 with C-1 and the anomeric proton of the glucose moiety with C-1. In the ROE spectra (Fig. 1), on irradiation of H-1 a ROE was observed with H-10 and the same experiment with H-10 a ROE was shown with H-7. In addition, on irradiation of H-3 a ROE was resulted with H-9. Consequently, the methoxyl group attached to C-3 and the methyl group at C-8 were assigned to be α while the hydroxyl group at C-7 and H-9 were β. Therefore, the structure of compound **1** was elucidated as shown and named 3-epiphlomurin.

HR FAB-MS of compound **2** (see Experimental) showed the same molecular formula as **1** ($C_{18}H_{28}O_{11}$). At the same time, ^{1}H NMR and positive FAB-MS spectra of **2** were very similar to those of **1**. Comparison of the ^{13}C NMR spectrum of **2** (Table 1) with that of **1** revealed the downfield shift of C-1 of **2** to δ 96.1 (+3.8 ppm) which indicated that the orientation of the methoxyl group located at C-3 is β in case of **2** (Breitmaier and Voelter, 1987). Consequently, the structure of compound **2** was assigned as given and named phlomurin.

In general, the structures of compounds **1** and **2** are unusual due to location of the double bond between C-4 and C-5, methyl ether at C-3 and methyl ester at C-4 of the iridoidic skeleton. It was previously reported the isolation of pinifolin, an iridoid with a double bond between C-4 and C-5 (Junior, 1989). The methoxyl group at C-3 of pinifolin was determined as β. However, the published ^{13}C NMR data when compared with those of compounds **1** and **2** indicated that the orientation of the methoxyl group at C-3 of pinifolin could be revised to α orientation not β.

The molecular formula of compound **3** was determined as $C_{19}H_{32}O_8$ from HR FAB-MS spectral analysis (see Experimental section). The ^{13}C NMR (Table 1) and ^{1}H NMR spectra of **3** showed the presence of a β-glucopyranosyl moiety from the signals at δ_C 102.6 and δ_H 4.9 (1H, *d*, $J = 6.0$ Hz). The ^{13}C NMR together with DEPT mode measurement and H–H COSY revealed that the aglycone of compound **3** is (3*S*, 5*S*, 6*R*, 9*R*)-3-hydroxy-5,6-epoxy-β-ionol (Grayson, 1997). The attachment of the glucose moiety at C-9 of the aglycone was proved from the downfield shift of this carbon to δ 75.3 when compared with closely similar megastigmanes (Otsuka et al., 1995). In order to establish the relative configuration of the epoxy group, H–H NOESY experiment was carried out (Fig. 2) and it showed correlation peaks between H-11 with both H-3 and H-7 indicating the β configuration of the epoxy group at C-5 and C-6. Therefore, compound **3** can be identified as (3*S*, 5*S*, 6*R*, 9*R*)-3-hydroxy-5,6-epoxy-β-ionol-9-*O*-β-glucopyranoside.

The structure of compound **4** was assigned as benzyl alcohol-*O*-β-xylopyranosyl-(1→2)-β-glucopyranoside from the data of ^{13}C NMR (Table 1), ^{1}H NMR and HR FAB-MS (see Experimental). It is noteworthy that this compound was isolated and identified by our group from the titled plant as well as by Sudo et al. at the same time from *Premna subscandens* as a new natural product (Sudo et al., 2000).

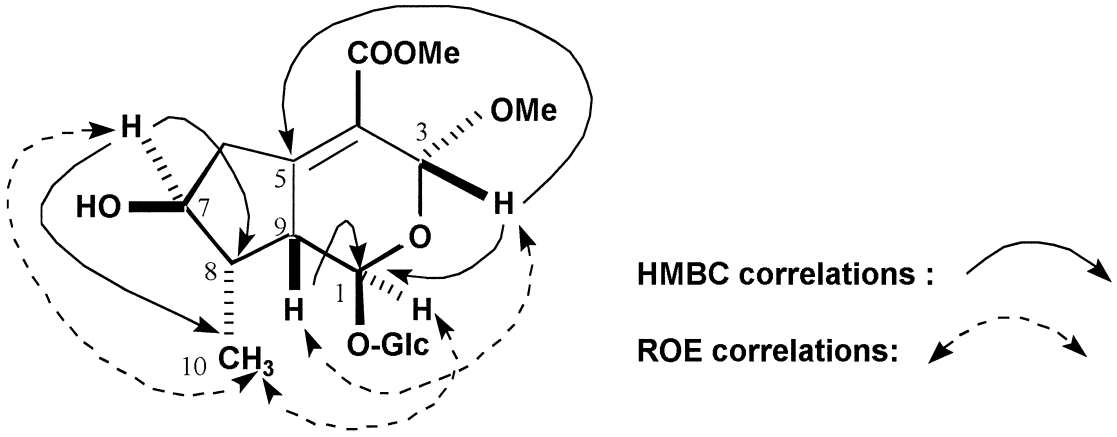

Fig. 1. Significant HMBC and ROE correlations of (**1**).

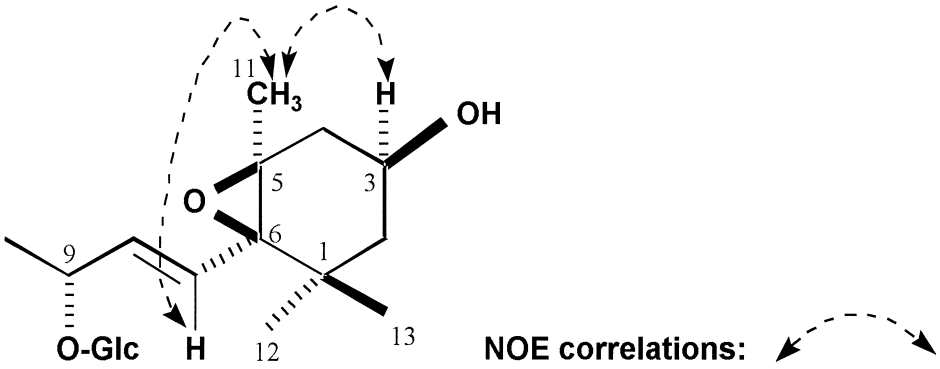

Fig. 2. Significant NOE correlations of (**3**).

Compounds **5**–**15** were identified as follows: compound (**5**) auroside (Çalis et al., 1991), compound (**6**) lamiide (El-Naggar and Beal, 1980), compound (**7**) 8-epiloganin (Bianco and Passacantilli, 1981), compound (**8**) ipolamiide (Saracoglu et al., 1995), compound (**9**) syringin (Sugiyama et al., 1993), compound (**10**) 2-phenylethyl-*O*-β-xylopyranosyl-(1→2)-β-glucopyranoside (Nishimura et al., 1990), compound (**11**) acteoside (Saracoglu et al., 1995), compound (**12**) chrysoeriol-7-*O*-β-glucopyranoside (Tomas et al., 1986), compound (**13**) acacetin-7-*O*-β-glucopyranoside (Harborne and Mabry, 1982), compound (**14**) luteolin-7-*O*-β-glucopyranoside (El-Negoumy et al., 1986) and compound (**15**) liriodendrin (Kamel et al., 1992).

3. Experimental

^{1}H and ^{13}C NMR (TMS as internal standard): 400 and 100 MHz respectively were recorded on a JEOL JNM α-400 spectrometer. FAB MS were taken on a JEOL JMS-SX 102 spectrometer by direct inlet method at an ionizing voltage of 70 eV. Optical rotations were measured with a Union PM-1 digital polarimeter. MPLC: RP-18 column (20 mm i.d.×40 cm); flow rate of mobile phase 3 ml/min. HPLC: D-ODS-5 and polyamine columns (each 20 mm i.d.×25 cm, YMC) with a Toyo Soda high speed chromatograph HLC-803 D pump and a Tosoh refraction index (RI-8) detector; flow rate of mobile phase 6 ml/min, injection vol. 0.8–1.0 ml. On the ODS column, 28% MeOH (**I**) and 48% MeOH (**II**) were used while 85% MeCN (**III**) and 90% MeCN (**IV**) were used on the polyamine column. CC: Kieselgel 60 (70–230 mesh, Merck) and Diaion HP 20 (Mitsubishi). TLC: silica gel 60 precoated plates, F-254 and HPTLC using RP-18 precoated plates, F-254 s (Merck).

3.1. Plant material

Leaves of *P. aurea* Decne (Syn.: *P. angustifolia* Miller and *P. flavescens* Miller) were collected from Saint Katharine mountain, Sinai, Egypt, in April 1997. The plant was identified by Professor A. Fayed, Department of Botany, Faculty of Science, Assiut University, Assiut, Egypt. A voucher specimen is deposited at the Herbarium of Department of Pharmacognosy, Faculty of Pharmacy, Assiut University, Assiut, Egypt.

3.2. Extraction and isolation of compounds (*1*–*15*)

The air dried powdered leaves of *P. aurea* (5 kg) were extracted with 70% EtOH. The dried ethanolic extract (450 g) was suspended in H_2O and deffated with *n*-hexane. The aqueous fraction (190 g) was applied to a column of Diaion HP-20 and eluted with H_2O, 50% MeOH, MeOH and acetone successively. The 50% MeOH eluate named fraction A (30 g) was chromatographed by silica gel CC using CH_2Cl_2–MeOH–H_2O (70:30:3) to give four fractions. Fraction A-1 was separated by HPLC using ODS column and 28% MeOH as a solvent system to afford compounds **5** (white powder, 1.2 g), **6** (white powder, 40 mg) and **11** (white powder, 215 mg). Fraction A-2 was subjected to HPLC using polyamine column and 85% MeCN as a solvent system to give compounds **4** (white powder, 6 mg), **8** (white powder, 9 mg), **10** (white powder, 25 mg) and **12** (yellow powder, 6 mg). Fraction A-3 was separated by HPLC using polyamine column and 90% MeCN as a solvent system to afford compounds **1** (white powder, 80 mg), **2** (white powder, 20 mg), **3** (white powder, 40 mg), **7** (white powder, 50 mg) and **9** (white powder, 40 mg). The methanolic eluate named fraction B (10 g) was chromatographed by silica gel CC using CH_2Cl_2–MeOH–H_2O (80:20:2) to give three fractions. Fraction B-2 was separated by MPLC using RP-18 column and 40% MeOH as a solvent system to give three sub-fractions. Fraction B-2-1 was subjected to HPLC using polyamine column and 90% MeCN as a solvent system to give compound **15** (white powder, 35 mg). Fraction B-2-3 was separated by HPLC using ODS column and 48% MeOH as a solvent system to obtain compounds **13** (yellow powder, 10 mg) and **14** (yellow powder, 15 mg).

*3.2.1. Compound (**1**)*

3-Epiphlomurin, $[\alpha]_D^{21}$ −22.2°C (MeOH; *c* 0.7), R_t 18 min (system **IV**). HR FAB-MS (positive) *m/z*: 443.1592 $[M+Na]^+$ $C_{18}H_{28}O_{11}Na$ (req. 443.1529). ^{13}C NMR (C_5D_5N Table 1). ^1H NMR (C_5D_5N): δ 5.80 (1H, *d, J*=9 Hz, H-1), 5.60 (1H, *s*, H-3), 5.40 (1H, *d, J*=8.1 Hz, H-1 Glc), 4.40 (1H, *m*, H-7), 3.61 (3H, *s*, -OMe), 3.60 (1H, *bd, J*=20.2 Hz, H-6β), 3.50 (3H, *s*, -OMe), 3.40 (1H, *dd, J*=20.2 and 8.2 Hz, H-6α), 3.30 (1H, *dd, J*=9.0 and 5.3 Hz, H-9), 2.65 (1H, *m*, H-8) and 0.8 (3H, *d, J*=7.3 Hz, CH_3-10).

*3.2.2. Compound (**2**)*

Phlomurin, $[\alpha]_D^{21}$ +12.4°C (MeOH; *c* 0.5), R_t 17 min (system **IV**). HR FAB-MS (positive) *m/z*: 443.1539 $[M+Na]^+$ $C_{18}H_{28}O_{11}Na$ (req. 443.1538). ^{13}C NMR (C_5D_5N Table 1). ^1H NMR (C_5D_5N): δ 5.90 (1H, *s*, H-3), 5.80 (1H, *d, J*=7.3 Hz, H-1), 5.50 (1H, *d, J*=7.8 Hz, H-1 Glc), 4.60 (1H, *m*, H-7), 3.72 (3H, *s*,-OMe), 3.61 (3H, *s*,-OMe), 3.65 (1H, *dd, J*=20.0 and 8.0 Hz, H-6α), 3.20 (1H, *bd, J*=20.0, H-6β), 3.30 (1H, *dd, J*=9.0 and 5.3 Hz, H-9), 2.80 (1H, *m*, H-8) and 0.9 (3H, *d, J*=7.3 Hz, CH_3-10).

*3.2.3. Compound (**3**)*

(3 *S*, 5 *S*, 6*R*, 9*R*)-3-hydroxy-5,6-epoxy-β-ionol-9-*O*-β-glucopyranoside, $[\alpha]_D^{21}$ −52.5°C (MeOH; *c* 0.8), R_t 35 min (system **IV**). HR FAB-MS (negative) *m/z*: 387.2022 $[M-H]^-$ $C_{19}H_{31}O_8$ (req. 387.2019). ^{13}C NMR (C_5D_5N Table 1). ^1H NMR (C_5D_5N): δ 6.20 (1H, *d, J*=11.7 Hz, H-7), 4.90 (1H, *d, J*=6.0 Hz, H-1 Glc), 4.40 (1H, *dq, J*=6.7 and 5.1 Hz, H-9), 3.90 (1H, *m*, H-3), 2.60 (1H, *dd, J*=14.2 and 4.2 Hz, H-4), 1.90 (1H, *ddd, J*=14.2, 8.8 and 1.9 Hz, H-2a), 1.80 (1H, *m*, H-2b), 1.50 (1H, *bt, J*=12.9 Hz, H-4), 1.40 (3H, *d, J*=6.1 Hz, CH_3-10), 1.20, 1.10, 1.00 (9H, each *s*, CH_3-11, 12, 13) and H-8 obscured with H_2O signal.

*3.2.4. Compound (**4**)*

Benzyl alcohol-*O*-β-xylopyranosyl-(1→2)-β-glucopyranoside, R_t 20 min (system **III**). HR FAB-MS (negative) *m/z*: 401.1463 $[M-H]^-$ $C_{18}H_{25}O_{10}$ (req. 401.1448), 269 $[M-H-Xyl]^-$. ^{13}C NMR (C_5D_5N Table 1). ^1H NMR (C_5D_5N): δ 7.20–7.50 (5H, *m*, H-2,3,4,5,6), 5.20 (1H, *d, J*=7.1 Hz, H-1 Xyl), 5.15 (1H, *d, J*=12.7 Hz, H-α), 4.95 (1H, *d, J*=7.6 Hz, H-1 Glc) and 4.90 (1H, *d, J*=12.7 Hz, H-α′).

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