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**Semipapposides A-M, triterpene saponins from the roots of *Scabiosa*
*semipapposa***

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Abstract

Phytochemical investigations of the roots of *Scabiosa semipapposa* Salzem ex D.C. have led to the isolation of twelve undescribed triterpenoid saponins named semipapposides A-L, one undescribed saponin semipapposide M obtained as an inseparable mixture, together with three known oleanolic acid glycosides. Their structures were elucidated by analysis of 1D and 2D-NMR (^1H - ^1H COSY, TOCSY, HSQC-TOCSY, ROESY, HSQC, and HMBC) spectroscopic data and mass spectrometry (HR-ESI-MS), and by comparison with those of related metabolites. These results represent a contribution to the chemotaxonomy of the genus *Scabiosa*, highlighting a partial sequence rhamnopyranosyl-(1 \rightarrow 2)-xylopyranosyl or rhamnopyranosyl-(1 \rightarrow 2)-arabinopyranosyl- at C-3 of the aglycon and a gentiobiose unit at C-28 as chemotaxonomic markers of this genus.

Keywords:

Scabiosa semipapposa Salzem ex D.C., Caprifoliaceae, Triterpenoid saponins, Semipapposides A-M

1. Introduction

The genus *Scabiosa*, belonging to the Caprifoliaceae family, is formed by around 100 species (Carlson et al., 2012) which grow as annual or perennial herbs, distributed in Europe and the Mediterranean Basin, southern Africa and eastern Asia (Reveal and Chase, 2011). It is well represented in Algeria by twelve species (Quezel and Santa, 1963).

Several *Scabiosa* species have been used in traditional medicine to treat measles and furuncles (Bonet et al., 2007), diphtheria (Rigat et al., 2007), respiratory infections including bronchitis, bronchial pneumonia, influenza and asthma, as well as high blood pressure, uterine disorders (Rigat et al., 2007; Kose et al., 2015; Moteetee et al., 2016), heel cracks (Bammi and Douira, 2002), dermatoses (herpes ringworm, scabies), ulcers (Girre, 1980) and liver diseases (Zhang et al., 2015).

Many *Scabiosa* species are characterized by an extremely rich chemical diversity (Pinto et al., 2018), in particular, pentacyclic triterpene saponins (Alimbaeva et al., 1977; Baykal et al., 1998; Zheng et al., 2004; Lehbili et al., 2018a; Kılınç et al., 2020) in addition to the flavonoids, coumarins (Garaev et al., 2008; Al-Qudah et al., 2017; Lehbili et al., 2018b), iridoid glycosides (Papalexandrou et al., 2003; Polat et al., 2010; Lehbili et al., 2018b) and lignan glycosides (Pasi et al., 2002).

In a continuation of our phytochemical investigations of *Scabiosa* species growing in Algeria (Lehbili et al., 2018a, Lehbili et al., 2018b), we are interested to *Scabiosa semipapposa* Salzem ex D.C. (*Scabiosa semipapposa* f. *albiflora* Faure & Maire is the synonyme), an herbaceous, hairy annual plant, rather canescent, with a lilac flowers and branched stems. The lower leaves are oval coarsely toothed. The petiolate superior ones are pinnatifid with oblong linear sub dentate lobes (Don, 1834; Quezel and Santa, 1963). As far as we know, no previous research work has investigated the chemical profile of *S. semipapposa* roots. In this study, the phytochemical composition of *S. semipapposa* roots has been explored and resulted in the isolation of twelve undescribed triterpene saponins, namely, semipapposides A-L (1–12), one undescribed saponin semipapposide M (13) obtained as an inseparable mixture with compound 4 (Fig.1), together with three known triterpene saponins (14–16).

2. Results and discussion

The 80% methanol extract of the roots of *S. semipapposa* was fractionated by vacuum-liquid chromatography (VLC) on RP-C₁₈ and purified by successive chromatographic techniques, including flash chromatography as well as semi-preparative and preparative high performance liquid chromatography (HPLC) yielding sixteen compounds including thirteen undescribed

compounds (**1–13**) (Fig.1) and three known ones. Their structures were mainly elucidated by the use of 1D and 2D NMR techniques (^1H , J -modulated ^{13}C , DEPT, ^1H - ^1H -COSY, TOCSY, J -modulated HSQC, HSQC-TOCSY, HMBC, ROESY, and NOESY) in combination with HR-ESI-MS and by comparison of their physical and spectral data with literature values. The known compounds were identified by comparison of their spectral data with literature values as scabiosaponine E (**14**) previously isolated from *Scabiosa tschiliensis* (Zheng et al., 2004), scabiostellatoside B (**15**) and D (**16**) previously isolated from *Scabiosa stellata* (Lehbili et al., 2018a).

Compounds **1–16** were isolated as white amorphous powders. The monosaccharides obtained by acid hydrolysis of an aliquot of the saponin containing fraction were identified as L-arabinose (Ara), L-rhamnose (Rha), D-glucose (Glc), D-xylose (Xyl), and D-galactose (Gal) by comparison on TLC with authentic samples followed by measurement of the optical rotations values of each purified sugar (see Experimental Section).

Compound **1** exhibited, in the positive ion-mode HR-ESI-MS, a quasi-molecular ion peak at m/z 1645.7848 $[\text{M}+\text{H}]^+$ (calcd for 1645.7849) compatible with the molecular formula $\text{C}_{76}\text{H}_{124}\text{O}_{38}$.

The ^1H and ^{13}C NMR spectra displayed resonances due to the triterpene part characteristic of oleanolic acid aglycone (Boutaghane et al., 2013, Mahato and Kundu 1994) (Table 1) with seven angular methyl groups at δ_{H} 1.07, 0.88, 0.97, 0.82, 1.17, 0.93 and 0.96 (s, each) showing correlations in the HSQC spectrum with their corresponding carbon at δ_{C} 27.1 (C-23), 15.9 (C-24), 14.8 (C-25), 16.4 (C-26), 24.9 (C-27), 32.1 (C-29) and 22.7 (C-30). Furthermore, other characteristic signals were observed such as one olefinic proton at δ_{H} 5.27 (1H, t, $J = 3.7$ Hz, H-12) and one oxygen-bearing methine protons at δ_{H} 3.14 (dd, $J = 11.8, 4.3$ Hz, H-3) showing HSQC correlation with δ_{C} 122.4 (C-12) and 88.8 (C-3), respectively. The ROESY correlations between H-3/H-5 (δ_{H} 0.80, d, $J = 12.3$ Hz) and H-5/H-9 (δ_{H} 1.59, m) indicated their α -axial orientation and thus the β -orientation of the oxygen at C-3. Extensive 2D NMR analysis confirmed the structure of the aglycone to be oleanolic acid. The chemical shift values at δ_{C} 88.8 (C-3) and 176.7 (C-28), suggested that the saponin was a bisdesmosidic glycoside with saccharide units attached to these positions.

The presence of eight sugar moieties in **1** was evidenced by the ^1H NMR spectrum which displayed eight anomeric protons at δ_{H} 5.38 (d, $J = 1.5$ Hz), 5.37 (d, $J = 8.3$ Hz), 5.21 (d, $J = 1.1$ Hz), 5.16 (d, $J = 1.7$ Hz), 4.62 (d, $J = 7.9$ Hz), 4.47 (d, $J = 7.7$ Hz), 4.39 (d, $J = 7.2$ Hz), and 4.36 (d, $J = 7.6$ Hz) (Table 2) giving correlations with eight anomeric carbons at δ_{C} 99.9, 94.3, 100.7, 101.3, 104.1, 105.0, 105.0, and 103.2, respectively in the HSQC spectrum.

Complete assignments of each sugar were achieved by extensive ^1D - and ^2D -NMR analyses (^1H - ^1H -COSY, TOCSY, HSQC, HSQC-TOCSY, and ROESY) and by optical rotation (see experimental), allowing the characterization of two β -D-xylopyranosyl (Xyl I, $\delta_{\text{H-1}}$ 4.39 and Xyl II, $\delta_{\text{H-1}}$ 4.47), three α -L-rhamnopyranosyl (Rha I $\delta_{\text{H-1}}$ 5.38; Rha II, $\delta_{\text{H-1}}$ 5.21; and Rha III $\delta_{\text{H-1}}$ 5.16), and three β -D-glucopyranosyl (Glc I, $\delta_{\text{H-1}}$ 5.37; Glc II, $\delta_{\text{H-1}}$ 4.62; and Glc III $\delta_{\text{H-1}}$ 4.36) (Table 2). The large coupling constant (> 7 Hz) for xylose and glucose coupled with the ROE effect between H-1/H-3/H-5 axial, indicated their β -configuration. The small J -value of the anomeric proton of rhamnose and the chemical shift of Rha-C-5 at δ_{C} 67-68 indicated their α -configuration (Kasai et al, 1979). The deshielding signals of Xyl I-C-2 (δ_{C} 76.7), Rha I-C-3 (δ_{C} 80.7), Xyl I-C-3 (δ_{C} 81.7), Rha II-C-4 (δ_{C} 82.3), Glc I-C-3 (δ_{C} 83.3), and Glc II-C-6 (δ_{C} 68.0), suggested that Xyl I, Xyl II, Rha I, Rha II, Glc I and Glc II were monosubstituted and that the two sugars chains were linear. The linkages between these sugars were established using mainly HMBC and ROESY spectra. The HMBC correlation between Xyl I-H-1 and C-3 of the aglycone and the ROESY correlation between Xyl I-H-1 and H-3 of the aglycone indicated the glycosidic linkage of the Xyl I at the C-3 position of the aglycone (Fig. 2). Moreover, the HMBC spectrum of compound **1** displayed long-range correlations between Rha I-H-1 /Xyl I-C-2, Xyl II-H-1/Rha I-C-3, Rha II-H-1/Xyl I-C-3, Glc I-H-1/ Rha II-C-4, and Rha III-H-1/ Glc I-C-3 indicating that the saccharidic chain α -L-rhamnopyranosyl-(1 \rightarrow 3)- β -D-glucopyranosyl-(1 \rightarrow 4)- α -L-rhamnopyranosyl-(1 \rightarrow 3)- β -D-xylopyranosyl-(1 \rightarrow 3)- α -L-rhamnopyranosyl-(1 \rightarrow 2)- β -D-xylopyranoside- was linked to C-3 of the aglycone. In a similar fashion the cross peak observed in the HMBC spectrum between Glc III-H-1/Glc II-C-6 and Glc II-H-1/aglycone-C-28 established that the disaccharide gentiobiose [Glc III-(1 \rightarrow 6)-Glc II] was linked to the C-28 of the aglycone. The linkages were ensured by the ROESY cross-peaks at: Rha III H-1/Glc I-H-3, Glc I-H-1/Rha II-H-4, Rha II-H-1/Xyl II-H-3, Xyl II-H-1/Rha I-H-3, Rha I-H-1/Xyl I-H-2, Xyl I-H-1/aglycone-H-3 and Glc III-H-1/Glc II-H-2-6. Compared to scabiostellatoside D (**16**), the sugar part at C-3 in **1** is composed of a supplementary rhamnopyranosyl unit (Lehbili et al., 2018a), and the signals due to gentiobiosyl at C-28 were superimposable.

The partial sequence -Rha-(1 \rightarrow 2)-Xyl- at the C-3 position of the aglycone was often encountered in the *Scabiosa* genus, (Lehbili et al., 2018a; Zheng et al., 2004) and was characterized for all saponins **1**, **3**, **4**, **6**, **11-16**.

According to the above-described results, the structure of compound **1** was elucidated as 3-*O*-[α -L-rhamnopyranosyl-(1 \rightarrow 3)- β -D-glucopyranosyl-(1 \rightarrow 4)- α -L-rhamnopyranosyl-(1 \rightarrow 3)- β -D-

xylopyranosyl-(1→3)- α -L-rhamnopyranosyl-(1→2)- β -D-xylopyranosyl]-28-*O*-[β -D-glucopyranosyl-(1→6)- β -D-glucopyranosyl]-oleanolic acid (Fig. 1), named semipapposide A. For semipapposide B (**2**), the same molecular formula as **1** (C₇₆H₁₂₄O₃₈) was obtained according to its HR-ESI-MS (positive-ion mode) spectrum which displayed a pseudo-molecular ion peak at m/z 1645.7859 [M+H]⁺, suggesting that compounds **1** and **2** were isomeric. All NMR signals observed for **2** were comparable to those of **1** (Tables 1 and 2), excepted for the sugar linked at the C-3 position of the aglycone. Its ring protons were assigned starting from anomeric protons resonance at δ_H 4.50 (d, $J = 5.9$ Hz) by means of the ¹H-¹H COSY, TOCSY, HSQC, and HMBC experiments and it was thus identified as an α -L-arabinopyranosyl moiety, characterized by its axial hydroxyl in C-4 position ($J_{H-3-H-4} = 3.7$ Hz) (Lehbili et al., 2018a). Its attachment to the aglycone was confirmed by the HMBC correlation between δ_H 4.50 (Ara-H-1) and δ_C 89.2 (aglycone-C-3), and by the ROESY correlation between Ara-H-1 and aglycone H-3 (3.14, dd, $J=11.8, 4.5$ Hz, H-3). Hence, the structure of semipapposide B (**2**) was established as 3-*O*-[α -L-rhamnopyranosyl-(1→3)- β -D-glucopyranosyl-(1→4)- α -L-rhamnopyranosyl-(1→3)- β -D-xylopyranosyl-(1→3)- α -L-rhamnopyranosyl-(1→2)- α -L-arabinopyranosyl]-28-*O*-[β -D-glucopyranosyl-(1→6)- β -D-glucopyranosyl]-oleanolic acid (Fig. 1).

Semipapposide C (**3**) exhibited in the HR-ESI-MS spectrum a quasi-molecular ion peak at m/z 1675.7977 [M+H]⁺ (calcd for 1675.7954), compatible with the molecular formula C₇₇H₁₂₆O₃₉. Extensive 2D NMR analysis (Tables 1 and 2) showed that compounds **1** and **3** differed only by the nature of the sugar linked at the C-3 of the Rha I. The analysis of mass spectroscopy and 1D- and 2D-NMR spectra allowed the identification of one β -D-glucopyranosyl in **3** instead of a β -D-xylopyranosyl in **1**. The HMBC correlations between Glc I-H-1 (δ_H 4.50, d, $J=7.9$ Hz) and Rha I-C-3 (δ_C 81.5) suggested that Glc I was linked to the Rha I-C-3, which was confirmed by the ROESY cross-peak between Glc I-H-1 and Rha I-H-3 (δ_H 3.92, dd, $J=9.6, 3.1$ Hz). These evidences led to the elucidation of semipapposide C (**3**) as 3-*O*-[α -L-rhamnopyranosyl-(1→3)- β -D-glucopyranosyl-(1→4)- α -L-rhamnopyranosyl-(1→3)- β -D-glucopyranosyl-(1→3)- α -L-rhamnopyranosyl-(1→2)- β -D-xylopyranosyl]-28-*O*-[β -D-glucopyranosyl-(1→6)- β -D-glucopyranosyl]-oleanolic acid.

The molecular formula of Semipapposide D (**4**) was determined as C₇₅H₁₂₂O₃₈ by the HR-ESI-MS showing a molecular ion peak at m/z 1631.7701 [M+H]⁺ (calcd for 1631.7692). As in compounds **1–3**, the aglycone of **4** was identified by 2D-NMR analysis as oleanolic acid. Extensive 1D- and 2D-NMR analysis (Tables 1 and 2) showed that compounds **4** and **1** differed only by the sugar part. Eight sugar units were identified in **4** as three β -D-xylopyranose (Xyl I, Xyl II, and Xyl III), two α -L-rhamnopyranose (Rha I and Rha II) and three β -D-glucopyranose

(Glc I, Glc II, and Glc III) (Table 2). All signals corresponding to the partial sequence Xyl II-(1→3)-Rha I-(1→2)-Xyl I-(1→3)-oleanolic acid were almost superimposable to those of compound **1**. The sequence of the three remaining sugar units was suggested to be Rha II-(1→3)-Xyl III-(1→4)-Glc I-(1→4)- linked to C-4 of Xyl II based on the HMBC correlations between Rha II-H-1 (δ_{H} 5.18) / Xyl III-C-3 (δ_{C} 82.1), Xyl III-H-1 (δ_{H} 4.35) / Glc I-C-4 (δ_{C} 79.0), and Glc I-H-1 (δ_{H} 4.41)/Xyl II-C-4 (δ_{C} 76.9). The linkage was confirmed by the rOe effects observed between Rha III-H-1/Xyl III-H-3, Xyl III-H-1/Glc I-H-4, and Glc I-H-1/Xyl II-H-4. All these data were consistent with the structure of semipapposide D (**4**) as 3-*O*-[α -L-rhamnopyranosyl-(1→3)- β -D-xylopyranosyl-(1→4)- β -D-glucopyranosyl-(1→4)- β -D-xylopyranosyl-(1→3)- α -L-rhamnopyranosyl-(1→2)- β -D-xylopyranosyl]-28-*O*-[β -D-glucopyranosyl-(1→6)- β -D-glucopyranosyl]-oleanolic acid (Fig. 1).

Semipapposide E (**5**) has the same molecular formula $\text{C}_{75}\text{H}_{122}\text{O}_{38}$ as compound **4**, as suggested by the HR-ESI-MS spectrum (m/z 1631.7699 [$\text{M} + \text{H}$]⁺). The ^1H and ^{13}C NMR spectra (Tables 1 and 2) indicated that **5** was an oleanolic acid bidesmoside but differed from **4** in the nature of the sugar part. The HSQC spectrum of the sugar part showed eight cross-peaks at $\delta_{\text{H}}/\delta_{\text{C}}$ 4.50 (d, $J=4.5$ Hz)/103.9, 4.51 (d, $J=7.3$ Hz)/104.9, 4.35 (d, $J=7.7$ Hz)/103.9, 5.21 (br s)/100.0, 5.18 (d, $J=1.2$ Hz)/101.2, 4.41 (d, $J=7.8$ Hz)/101.7, 5.37 (d, $J=8.2$ Hz)/94.3 and 4.36 (d, $J=7.8$ Hz)/103.2, indicating the presence of eight sugar units: Ara, Xyl I, Xyl II, Rha I, Rha II, Glc I, Glc II, and Glc III, respectively (Table 2). All the NMR signals observed for **5** were similar to those of **4**, except for the pentosyl moiety linked to the C-3 of the aglycone which was Ara in **5** instead of Xyl I in **4**. This was confirmed by the HMBC correlation at $\delta_{\text{H}}/\delta_{\text{C}}$ 4.50 (Ara-H-1)/89.2 (C-3), and by the ROESY correlation at $\delta_{\text{H}}/\delta_{\text{H}}$ 4.50 (Ara-H-1)/3.13 (dd, $J=11.7, 4.3$ Hz, aglycone-H-3). Hence, the structure of semipapposide E (**5**) was established as 3-*O*-[α -L-rhamnopyranosyl-(1→3)- β -D-xylopyranosyl-(1→4)- β -D-glucopyranosyl-(1→4)- β -D-xylopyranosyl-(1→3)- α -L-rhamnopyranosyl-(1→2)- α -L-arabinopyranosyl]-28-*O*-[β -D-glucopyranosyl-(1→6)- β -D-glucopyranosyl]-oleanolic acid (Fig. 1).

For semipapposide F (**6**), the molecular formula $\text{C}_{82}\text{H}_{134}\text{O}_{43}$, obtained according to its [$\text{M} + \text{H}$]⁺ ion at m/z 1807.8400 (in HR-ESI-MS positive-ion mode), differs from **1** only by 162 amu, corresponding to a supplementary hexosyl group. The findings from the HR-ESI-MS analysis were confirmed by the 2D-NMR data (Tables 3 and 4), which showed that compounds **6** and **1** differed only by the presence of one additional hexose unit identified as β -D-galactopyranosyl (Gal) (Lehbili et al., 2017). The observation of a HMBC correlation at $\delta_{\text{H}}/\delta_{\text{C}}$ 4.46/72.9 (Gal-H-1/Glc I-C-4) and a ROESY cross-peak at $\delta_{\text{H}}/\delta_{\text{H}}$ 4.46 (Gal-H-1)/3.83 (Glc I-H-4) proved the location of this additional Gal at Glc I-C-4. In addition, the HMBC correlation at $\delta_{\text{H}}/\delta_{\text{C}}$ 5.39

(Rha III-H-1)/ 76.1 (Glc I-C-3) confirmed the linkage of Rha III to Glc C-3 position. Thus, the structure of semipapposide F (**6**) was elucidated as 3-*O*-[β -D-galactopyranosyl-(1 \rightarrow 4)-[α -L-rhamnopyranosyl-(1 \rightarrow 3)]- β -D-glucopyranosyl-(1 \rightarrow 4)- α -L-rhamnopyranosyl-(1 \rightarrow 3)- β -D-xylopyranosyl-(1 \rightarrow 3)- α -L-rhamnopyranosyl-(1 \rightarrow 2)- β -D-xylopyranosyl]-28-*O*-[β -D-glucopyranosyl-(1 \rightarrow 6)- β -D-glucopyranosyl]-oleanolic acid (Fig. 1).

Semipapposide G (**7**) exhibited in the HR-ESI-MS experiment a quasi-molecular ion peak at m/z 1807.8390 [M+H]⁺ (C₈₂H₁₃₅O₄₃, calcd 1807.8377). Extensive 2D-NMR analysis (Tables 1-4) showed that compounds **7** and **2** differed by the presence of one additional sugar unit which was identified as β -D-galactopyranosyl (Gal) (Table 4) (δ_{H-1} 4.46, d, $J=7.7$ Hz; δ_{C-1} 102.9). The HMBC correlations at δ_H/δ_C 5.39 (Rha III-H-1)/76.1 (Glc I-C-3) and δ_H/δ_C 4.46 (Gal-H-1)/72.9 (Glc I-C-4) suggested the linkage of Rha III and Gal at the Glc I-C-3 and Glc I-C-4, respectively. The location of the supplementary Gal unit was confirmed by the ROESY cross-peak at δ_H/δ_H 4.46 (Gal-H-1)/3.83 (Glc I-H-4). Accordingly, the structure of semipapposide G (**7**) was elucidated as 3-*O*-[β -D-galactopyranosyl-(1 \rightarrow 4)-[α -L-rhamnopyranosyl-(1 \rightarrow 3)]- β -D-glucopyranosyl-(1 \rightarrow 4)- α -L-rhamnopyranosyl-(1 \rightarrow 3)- β -D-xylopyranosyl-(1 \rightarrow 3)- α -L-rhamnopyranosyl-(1 \rightarrow 2)- α -L-arabinopyranosyl]-28-*O*-[β -D-glucopyranosyl-(1 \rightarrow 6)- β -D-glucopyranosyl]-oleanolic acid (Fig. 1).

The HR-ESI-MS spectrum of semipapposide H (**8**) showed a pseudo-molecular ion peak [M+H]⁺ at m/z 1837.8517, indicating a molecular formula of C₈₃H₁₃₆O₄₄. It is higher than that of compound **7** by 30 amu, suggesting the presence of a hexose unit instead of a pentose unit. Extensive 2D-NMR analysis (Tables 3 and 4) showed that compounds **7** and **8** differed only by the nature of the sugar linked at Rha I-C-3. Analysis of 1D- and 2D-NMR spectra allowed the identification of one β -D-glucopyranose moiety in **8** instead of the β -D-xylopyranose unit in **7**. The HMBC correlations observed between Glc I-H-1/Rha I-C-3 indicated the linkage of Glc I at Rha I-C-3, and this was confirmed by the ROESY cross-peak between Glc I-H-1 and Rha I-H-3. Thus the structure of semipapposide H (**8**) was elucidated as 3-*O*-[β -D-galactopyranosyl-(1 \rightarrow 4)-[α -L-rhamnopyranosyl-(1 \rightarrow 3)]- β -D-glucopyranosyl-(1 \rightarrow 4)- α -L-rhamnopyranosyl-(1 \rightarrow 3)- β -D-glucopyranosyl-(1 \rightarrow 3)- α -L-rhamnopyranosyl-(1 \rightarrow 2)- α -L-arabinopyranosyl]-28-*O*-[β -D-glucopyranosyl-(1 \rightarrow 6)- β -D-glucopyranosyl]-oleanolic acid (Fig. 1).

The molecular formula of semipapposide I (**9**) was determined as C₈₃H₁₃₆O₄₅ by the HR-ESI-MS showing a protonated molecular ion peak at m/z 1853.8469 [M+H]⁺. According to the ¹H and ¹³C NMR data (Tables 3-6), the compounds **9** and **8** showed the same sugar constituents and sequence of sugar chains. The difference was in the aglycone part, the methyl group at C-23 of aglycone in **8** was replaced by a hydroxymethyl group. The NMR spectra of **9** showed

two proton signals at δ_{H} 3.35 (H-23a) and 3.60 (H-23b) with carbon signal at δ_{C} 63.1 (C-23) instead of the methyl signal in **8**. In addition, the HMBC correlations of H-23 with C-3 (δ_{C} 81.0), C-5 (δ_{C} 46.7), and C-24 (δ_{C} 12.4) also confirmed the presence of the hydroxymethyl group at C-23. Thus, the aglycone of **9** was identified as hederagenin (Alabdul Magid et al., 2006; Mahato and Kundu 1994). Finally, the structure of **9** was assigned as 3-*O*-[β -D-galactopyranosyl-(1 \rightarrow 4)-[α -L-rhamnopyranosyl-(1 \rightarrow 3)]- β -D-glucopyranosyl-(1 \rightarrow 4)- α -L-rhamnopyranosyl-(1 \rightarrow 3)- β -D-glucopyranosyl-(1 \rightarrow 3)- α -L-rhamnopyranosyl-(1 \rightarrow 2)- α -L-arabinopyranosyl]-28-*O*-[β -D-glucopyranosyl-(1 \rightarrow 6)- β -D-glucopyranosyl]-hederagenin (Fig. 1).

Semipapposide J (**10**) had the molecular formula $\text{C}_{82}\text{H}_{134}\text{O}_{44}$ [HR-ESI-MS (positive ion mode: m/z 1823.8344 [M+H]⁺, (calcd for 1823.8326)], suggesting that this compound possessed a supplementary hydroxyl in comparison with the previous described saponins **7**. Comparative analysis of ¹H and ¹³C NMR signals of compounds **10** and **7** indicated that **10** possessed the same glycosidic chains (Tables 5 and 6). The NMR spectra showed signals for only six methyl groups and one hydroxylated methylene (δ_{C} 63.1; δ_{H} 3.35 and 3.56) characterizing hederagenin as the aglycone of saponin **10** as in **9**. An extensive analysis of 1D- and 2D-NMR spectra of **10** allowed to conclude that semipapposide J (**10**) was 3-*O*-[β -D-galactopyranosyl-(1 \rightarrow 4)-[α -L-rhamnopyranosyl-(1 \rightarrow 3)]- β -D-glucopyranosyl-(1 \rightarrow 4)- α -L-rhamnopyranosyl-(1 \rightarrow 3)- β -D-xylopyranosyl-(1 \rightarrow 3)- α -L-rhamnopyranosyl-(1 \rightarrow 2)- α -L-arabinopyranosyl]-28-*O*-[β -D-glucopyranosyl-(1 \rightarrow 6)- β -D-glucopyranosyl]-hederagenin (Fig. 1).

Semipapposide K (**11**) has the same molecular formula $\text{C}_{82}\text{H}_{134}\text{O}_{44}$ as compound **10**, as suggested by the HR-ESI-MS spectrum (m/z 1823.8350 [M+H]⁺). As for compounds **9** and **10**, the aglycone of semipapposide K (**11**) displayed classical signals in the ¹H and ¹³C NMR spectra of hederagenin. All the NMR signals observed for **11** were similar to those of **10** (Tables 5 and 6), except for the pentose moiety linked to the C-3 of the aglycone which was Xyl I in **11** instead of Ara in **10**. The linkage was confirmed by the HMBC correlation at $\delta_{\text{H}}/\delta_{\text{C}}$ 4.48 (Xyl I-H-1)/80.8 (aglycone-C-3), and by the ROESY correlation at $\delta_{\text{H}}/\delta_{\text{H}}$ 4.48 (Xyl I-H-1)/3.62 (aglycone-H-3). Therefore, semipapposide K (**11**) was elucidated as 3-*O*-[β -D-galactopyranosyl-(1 \rightarrow 4)-[α -L-rhamnopyranosyl-(1 \rightarrow 3)]- β -D-glucopyranosyl-(1 \rightarrow 4)- α -L-rhamnopyranosyl-(1 \rightarrow 3)- β -D-xylopyranosyl-(1 \rightarrow 3)- α -L-rhamnopyranosyl-(1 \rightarrow 2)- β -D-xylopyranosyl]-28-*O*-[β -D-glucopyranosyl-(1 \rightarrow 6)- β -D-glucopyranosyl]-hederagenin (Fig. 1).

Semipapposide L (**12**) gave the same molecular formula $\text{C}_{83}\text{H}_{136}\text{O}_{45}$ as **9** deduced from the HR-ESI-MS spectrum (m/z 1853.8445 [M+H]⁺, calcd for 1853.8432). As for the pair of saponins **10** and **11**, the isomeric saponins **12** and **9** differed by the nature of pentose unit linked to the

aglycone (Tables 5 and 6). Consequently, semipapposide L (**12**) was deduced to be 3-*O*-[β -D-galactopyranosyl-(1 \rightarrow 4)-[α -L-rhamnopyranosyl-(1 \rightarrow 3)]- β -D-glucopyranosyl-(1 \rightarrow 4)- α -L-rhamnopyranosyl-(1 \rightarrow 3)- β -D-glucopyranosyl-(1 \rightarrow 3)- α -L-rhamnopyranosyl-(1 \rightarrow 2)- β -D-xylopyranosyl]-28-*O*-[β -D-glucopyranosyl-(1 \rightarrow 6)- β -D-glucopyranosyl]-hederagenin (Fig. 1).

Semipapposide M (**13**) and semipapposide D (**4**) were obtained as an inseparable mixture with the ratio 4:6, based on the integral intensity of the corresponding signals in their ^1H NMR spectra and HR-ESI-MS. Exhaustive efforts to separate this mixture employing normal and reversed-phase flash chromatography and HPLC using various stationary and mobile phases were failed. Therefore, the structures of these two compounds were elucidated as a mixture.

According to the HR-ESI-MS $[[\text{M}+\text{H}]^+]$ at m/z 1631.7709 and NMR analysis, semipapposide D (**4**) was identified as the major compound of this mixture. The second protonated molecular ion $[\text{M}+\text{H}]^+$ at m/z 1837.8508 correspond to semipapposide M (**13**) that allowed establishment of the molecular formula $\text{C}_{83}\text{H}_{136}\text{O}_{44}$. Comparing the ^1H and ^{13}C NMR data (Tables 3-6) of **13** with those of **12** showed the same sugar components and sequence of sugar chains. The difference was in the aglycone part; the hydroxymethyl group at C-23 of the aglycone in **12** was replaced by a methyl group, suggesting oleanolic acid as aglycone. Thus the structure of semipapposide M (**13**) was elucidated as 3-*O*-[β -D-galactopyranosyl-(1 \rightarrow 4)-[α -L-rhamnopyranosyl-(1 \rightarrow 3)]- β -D-glucopyranosyl-(1 \rightarrow 4)- α -L-rhamnopyranosyl-(1 \rightarrow 3)- β -D-glucopyranosyl-(1 \rightarrow 3)- α -L-rhamnopyranosyl-(1 \rightarrow 2)- β -D-xylopyranosyl]-28-*O*-[β -D-glucopyranosyl-(1 \rightarrow 6)- β -D-glucopyranosyl]-oleanolic acid (Fig. 1).

3. Conclusion

The present phytochemical study carried out for the first time on the Algerian *S. semipapposa* species, allowed the isolation and elucidation of twelve undescribed oleanolic acid (**1-8**) and hederagenin (**9-12**) bidesmosidic saponins, with one undescribed oleanolic acid bidesmosidic saponin (**13**) obtained as an inseparable mixture with compound **4**, together with three known oleanolic acid glycosides (**14-16**). All triterpene saponins (**1-16**) were characterized with a gentiobiose unit at C-28 and a common partial sequence as (-Rha-(1 \rightarrow 2)-Xyl-) or (-Rha-(1 \rightarrow 2)-Ara-) at the C-3 position of the aglycone with additional glycosylation at the C-3 of the Rha, frequently encountered in several *Scabiosa* species (Baykal et al., 1998; Zheng et al., 2004; Lehbili et al., 2018a) and in some plants of the Caprifoliaceae family such as *Cephalaria* (Sarikahya et al., 2014), and seems to represent a chemotaxonomic marker for this genus. Our investigation contributes to phytochemical database of *S. semipapposa* associated with

chemotaxonomic meaning of *Scabiosa* spp. Therefore, our results are in accordance with these findings and bring an additional contribution to the knowledge of the saponins of *Scabiosa* species. They confirmed the richness of pentacyclic triterpenoids in the *Scabiosa* species observed by [Pinto et al. \(2018\)](#) with the presence of oleanolic acid as main aglycone, and glucose, xylose, rhamnose and arabinose as sugars. It should be interesting to evaluate the biological activities of these saponins.

4. Experimental

4.1. General experimental procedures

Optical rotations values were recorded on a PerkinElmer 341 Polarimeter. The 1D and 2D NMR spectra (^1H and ^{13}C NMR, ^1H - ^1H COSY, TOCSY, ROESY, J -modulated HSQC, HSQC-TOCSY and HMBC) were performed using a Bruker Avance III 600 spectrometer (^1H at 600 MHz and ^{13}C at 150 MHz) equipped with a 5 mm TCI cryoprobe. 2D-NMR experiments were performed using standard Bruker microprograms (TopSpin 3.5 software). HR-ESI-MS experiments were performed using a Micromass Q-TOF instrument. Flash chromatography was carried out on a Grace Reveleris system equipped with dual UV and ELSD detection using Grace® cartridges (Silica gel or RP- C_{18}). Preparative HPLC was performed on Armen Instrument apparatus equipped with an AP 250 pump and a Knauer (Merck) detector UV K-2501. A manually packed C_{18} column (LiChrospher, 20 x 5 cm, 12 μ) was used for preparative HPLC. The mobile phase consisted of H_2O with TFA (0.0025%) and CH_3CN with a flow rate of 75 mL/min and the chromatograms were monitored at 205, 254, 300 and 360 nm. Semi-preparative HPLC was realized on a Dionex apparatus equipped with an ASI-100 automated sample injector, a STH 585 column oven, a P580 pump, a diode array detector UVD 340S and the Chromeleon® software version 6.8. A prepacked RP- C_{18} column (Phenomenex 250 x 10 mm, Luna 5 μ) was used for semi-preparative HPLC. The eluting mobile phase consisted of H_2O with TFA (0.0025%) and CH_3CN with a flow rate of 5 mL/min and the chromatogram was monitored at 205 and 215 nm. Analytical HPLC experiments were performed using a Thermofisher Ultimate 3000 (Thermo Fischer Scientific, Villebon sur Yvette, France), equipped with a 4 ways pump LPG 3400 SD, an automatic injector WPS 3000 SL, a UV/visible diode array detector 3000 and the Chromeleon® software version 6.8. A prepacked C_{18} column Uptisphere Strategy C_{18} (Interchim, 4.6 x 250 mm, 5 μ) was used for analytical HPLC and the mobile phase consisted of H_2O with TFA (0.0025% v/v) and CH_3CN with a flow rate of 1 mL/min and the chromatograms were monitored at 205, 215, 254, and 360 nm. TLC was

performed on pre-coated silica gel 60 F₂₅₄ Merck and compounds were visualized by spraying the dried plates with 50% H₂SO₄, followed by heating.

4.2. Plant material

The plant material (roots) of *Scabiosa semipapposa* Salzem ex D.C. was collected from Alguemas, in the region of Constantine North-Eastern Algeria (latitude 36.3479 and longitude 6.650773) in May 2017. The plant material was authenticated by Mr. Kamel Kabouche. A voucher specimen (LOST Ss.05/17) has been deposited at the herbarium of LOST Laboratory, University Frères Mentouri-Constantine, Algeria.

4.3. Extraction and isolation

Dried powdered roots of *S. semipapposa* (1 kg) were extracted with 80% MeOH (3 × 10 L, 24 h) at room temperature. The resulting extracts were combined and concentrated under vacuum to give the crude extract (100 g). A part of this (55 g) was subjected to RP-C₁₈ vacuum liquid chromatography (VLC) eluted successively with MeOH-H₂O (3:7, 4:6, 6:4, 8:2 and 10:0), to give 5 main fractions (VLC-A to VLC-E, respectively). The saponins enriched fraction E (4.6 g) was fractionated by flash chromatography over silica gel, eluted by a gradient system of CHCl₃-MeOH-H₂O (10:0:0 to 4:6:0.7), in 68 min to afford 12 sub-fractions (E1-E12). Sub-fraction E₁₀ (482 mg) was purified by preparative HPLC using a gradient (30-35% CH₃CN, in 45 min) to give 56 sub-fractions. Sub-fractions E₁₀₋₂₇₋₂₈ contained the pure compound **5** (9.4 mg). The purification by semi-prep HPLC of sub-fractions E₁₀₋₃₅₋₄₄ (98.7 mg) led to compounds **4** (3.0 mg, *t_R* 11.5 min), **14** (2.2 mg, *t_R* 12.4 min), **3** (3.2 mg, *t_R* 13.1 min), **2** (7.28 mg, *t_R* 14.4 min), **16** (3.7 mg, *t_R* 15.4 min), **1** (10.4 mg, *t_R* 15.5 min) and **15** (2.5 mg, *t_R* 17.1 min) using a gradient 32-34% CH₃CN, in 18 min. Sub-fraction E₁₁ (329 mg) was subjected to High Performance Flash Chromatography, over RP-C₁₈, using a binary gradient of MeOH-H₂O (20-80% MeOH in 34 min) as eluting solvent to obtain 39 sub-fractions. Sub-fraction E₁₁₋₂₆₋₂₇ was obtained as pure compound **7** (9.3 mg). Further separations of the remaining sub-fractions E₁₁₋₂₈₋₃₉ were performed by flash Chromatography on silica gel (CHCl₃-MeOH-H₂O 68/32/3) and then, purification by semi-prep HPLC eluted by gradient system 32-34% CH₃CN, in 18 min to give compounds **4** (2 mg, *t_R* 11.3 min), **7** (10.8 mg, *t_R* 12.4 min), **6** (21.4 mg, *t_R* 13.7 min) and **1** (2.7 mg, *t_R* 14.8 min).

Sub-fraction E₁₂ (1.4 g) was subjected to preparative HPLC (30-35% CH₃CN, in 45 min) to afford 48 sub-fractions and the pure compounds **6** (70 mg) and **10** (7.9 mg) in the sub-fraction E₁₂₋₄₁ and E₁₂₋₁₄, respectively. The combined sub-fractions E₁₂₋₁₂₋₁₃ (16.3 mg) were purified

by semi-preparative HPLC (30-32% CH₃CN, in 15 min) to furnish compounds **9** (2.8 mg, *t_R* 6.9 min) and **10** (3.3 mg, *t_R* 7.7 min). Sub-fraction E12-15 (7.9 mg) was purified by semi-prep. HPLC using a gradient of 30-32% CH₃CN, in 15 min as eluant to give compounds **12** (2.6 mg, *t_R* 8.2 min) and **11** (1.9 mg, *t_R* 8.9 min) whereas the sub-fractions E12-25-27 (29.3 mg) and E12-31-34 (77 mg) were purified by semi preparative HPLC using an elution program: 32-34% of CH₃CN, for 18 min to afford compounds **8** (17.5 mg, *t_R* 10.6 min), **7** (8.4 mg, *t_R* 11.1 min), mixture of **13** and **4** (15.3 mg, *t_R* 11.3 min) and **6** (5.5 mg, *t_R* 11.8 min). Finally compounds **6** (4.4 mg, *t_R* 11.0 min), **1** (9.7 mg, *t_R* 12.1 min) and **16** (1 mg, *t_R* 12.4 min) were obtained from E12-46-48 (60 mg) by semi-prep HPLC using a gradient (33-35% CH₃CN, in 15 min).

4.3.1. *Semipapposide A (1)*

Amorphous white powder; $[\alpha]_D^{20}$ -40.7 (*c* 0.83, MeOH); ¹H (600 MHz, CD₃OD) and ¹³C NMR (150 MHz, CD₃OD) data; see Tables 1 and 2. HR-ESI-MS *m/z*: 1645.7848 [M+H]⁺ (calcd for C₇₆H₁₂₅O₃₈, 1645.7849).

4.3.2. *Semipapposide B (2)*

Amorphous white powder; $[\alpha]_D^{20}$ -35.4 (*c* 0.65, MeOH); ¹H (600 MHz, CD₃OD) and ¹³C NMR (150 MHz, CD₃OD) data; see Tables 1 and 2. HR-ESI-MS *m/z*: 1667.7676 [M+Na]⁺, 1645.7859 [M+H]⁺ (calcd for C₇₆H₁₂₅O₃₈, 1645.7884).

4.3.3. *Semipapposide C (3)*

Amorphous white powder; $[\alpha]_D^{20}$ -24.8 (*c* 0.27, MeOH); ¹H (600 MHz, CD₃OD) and ¹³C NMR (150 MHz, CD₃OD) data; see Tables 1 and 2. HR-ESI-MS *m/z*: 1697.7797 [M+Na]⁺, 1675.7977 [M+H]⁺ (calcd for C₇₇H₁₂₇O₃₉, 1675.7954).

4.3.4. *Semipapposide D (4)*

Amorphous white powder; $[\alpha]_D^{20}$ -16.8 (*c* 0.25, MeOH); ¹H (600 MHz, CD₃OD) and ¹³C NMR (150 MHz, CD₃OD) data; see Tables 1 and 2. HR-ESI-MS *m/z*: 1653.7532 [M+Na]⁺, 1631.7701 [M+H]⁺ (calcd for C₇₅H₁₂₃O₃₈, 1631.7692).

4.3.5. *Semipapposide E (5)*

Amorphous white powder; $[\alpha]_D^{20}$ -33.3 (*c* 0.42, MeOH); ¹H (600 MHz, CD₃OD) and ¹³C NMR (150 MHz, CD₃OD) data; see Tables 1 and 2. HR-ESI-MS *m/z*: 1631.7699 [M+H]⁺ (calcd for C₇₅H₁₂₃O₃₈, 1631.7692).

4.3.6. *Semipapposide F (6)*

Amorphous white powder; $[\alpha]_D^{20}$ -37.1 (*c* 0.83, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C NMR (150 MHz, CD_3OD) data; see Tables 3 and 4. HR-ESI-MS *m/z*: 1829.8225 $[\text{M}+\text{Na}]^+$, 1807.8400 $[\text{M}+\text{H}]^+$ (calcd for $\text{C}_{82}\text{H}_{135}\text{O}_{43}$, 1807.8377).

4.3.7. *Semipapposide G (7)*

Amorphous white powder; $[\alpha]_D^{20}$ -19.7 (*c* 0.37, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C NMR (150 MHz, CD_3OD) data; see Tables 3 and 4. HR-ESI-MS *m/z*: 1807.8390 $[\text{M}+\text{H}]^+$ (calcd for $\text{C}_{82}\text{H}_{135}\text{O}_{43}$, 1807.8377).

4.3.8. *Semipapposide H (8)*

Amorphous white powder; $[\alpha]_D^{20}$ -27.2 (*c* 1.14, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C NMR (150 MHz, CD_3OD) data; see Tables 3 and 4. HR-ESI-MS *m/z*: 1859.8307 $[\text{M}+\text{Na}]^+$, 1837.8517 $[\text{M}+\text{H}]^+$ (calcd for $\text{C}_{83}\text{H}_{137}\text{O}_{44}$, 1837.8483).

4.3.9. *Semipapposide I (9)*

Amorphous white powder; $[\alpha]_D^{20}$ -17.8 (*c* 0.23, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C NMR (150 MHz, CD_3OD) data; see Tables 5 and 6. HR-ESI-MS *m/z*: 1875.8267 $[\text{M}+\text{Na}]^+$, 1853.8469 $[\text{M}+\text{H}]^+$ (calcd for $\text{C}_{83}\text{H}_{137}\text{O}_{45}$, 1853.8432).

4.3.10. *Semipapposide J (10)*

Amorphous white powder; $[\alpha]_D^{20}$ -28.2 (*c* 0.66, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C NMR (150 MHz, CD_3OD) data; see Tables 5 and 6. HR-ESI-MS *m/z*: 1845.8151 $[\text{M}+\text{Na}]^+$, 1823.8344 $[\text{M}+\text{H}]^+$ (calcd for $\text{C}_{82}\text{H}_{135}\text{O}_{44}$, 1823.8326).

4.3.11. *Semipapposide K (11)*

Amorphous white powder; $[\alpha]_D^{20}$ -28.6 (*c* 0.79, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C NMR (150 MHz, CD_3OD) data; see Tables 5 and 6. HR-ESI-MS *m/z*: 1845.8151 $[\text{M}+\text{Na}]^+$, 1823.8350 $[\text{M}+\text{H}]^+$ (calcd for $\text{C}_{82}\text{H}_{135}\text{O}_{44}$, 1823.8326).

4.3.12. *Semipapposide L (12)*

Amorphous white powder; $[\alpha]_D^{20}$ -22.8 (*c* 0.21, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C NMR (150 MHz, CD_3OD) data; see Tables 5 and 6. HR-ESI-MS *m/z*: 1875.8276 $[\text{M}+\text{Na}]^+$, 1853.8445 $[\text{M}+\text{H}]^+$ (calcd for $\text{C}_{83}\text{H}_{137}\text{O}_{45}$, 1853.8432).

4.3.13. *Semipapposide M (13)*

^1H (600 MHz, CD_3OD) and ^{13}C NMR (150 MHz, CD_3OD) data; see Tables 3 and 4. HR-ESI-MS *m/z*: 1837.8508 $[\text{M}+\text{H}]^+$ (calcd for $\text{C}_{83}\text{H}_{137}\text{O}_{44}$, 1837.8483).

4.4. Acid hydrolysis.

A part of the saponins rich fraction E (100 mg) was hydrolyzed with 15 mL of 2 N TFA (trifluoroacetic acid, aqueous solution) at 90 °C for 4 h. After extraction with CH₂Cl₂ (3×7 mL), the aqueous layer was evaporated to furnish the monosaccharide residue (56.7 mg). Five sugars were identified and compared with authentic samples by TLC using BuOH-iso-PrOH-Me₂CO-H₂O (20:10:7:6) as glucose, galactose, xylose, arabinose and rhamnose. After purification of these sugars by preparative TLC in the same solvent, the optical rotation of each purified sugar was measured and the obtained values were as follow: D-glucose [10.7 mg, $R_f = 0.42$, $[\alpha]_D^{20} +33$ (c 0.89, H₂O)], D-galactose [2.7 mg, $R_f = 0.45$, $[\alpha]_D^{20} +25$ (c 0.22, H₂O)], D-xylose [3.3 mg, $R_f = 0.61$, $[\alpha]_D^{20} +18.8$ (c 0.27, H₂O)], L-arabinose [3.6 mg, $R_f = 0.36$, $[\alpha]_D^{20} +43$ (c 0.30, H₂O)], and L-rhamnose [10.4 mg, $R_f = 0.53$, $[\alpha]_D^{20} +5.6$ (c 0.86, H₂O)].

Declaration of competing interest

All authors state no conflict of interest

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Supplementary data

¹H, ¹³C NMR, and HSQC spectra of new compounds **1-13** are available online.

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Table 1 ^{13}C NMR and ^1H NMR spectroscopic data of the aglycone moieties of compounds **1–5** in

| Position | 1 | | 2 | | 3 | | 4 | | 5 | |
|----------|---------------------|------------------------------------|---------------------|--|---------------------|------------------------------------|---------------------|------------------------------------|---------------------|------------------------------------|
| | δ_{C} | δ_{H} | δ_{C} | δ_{H} | δ_{C} | δ_{H} | δ_{C} | δ_{H} | δ_{C} | δ_{H} |
| 1 | 38.7 | 1.00, td (13.5, 3.1) 1.63, m | 38.6 | 1.00, td (13.6, 3.3) 1.64, m | 38.6 | 1.00, td (13.5, 4.4) 1.62, m | 38.6 | 1.00, td (13.7, 3.9) 1.63, m | 38.5 | 1.00, m 1.64, m |
| 2 | 25.9 | 1.70, m 1.82, m | 25.7 | 1.73, m 1.86, m | 25.9 | 1.70, m 1.82, m | 25.9 | 1.70, m 1.82, m | 25.7 | 1.73, m 1.86, td (13.3, 3.4) |
| 3 | 88.8 | 3.14, dd (11.8, 4.3) | 89.2 | 3.14, dd (11.8, 4.5) | 88.9 | 3.14, dd (11.5, 4.2) | 88.9 | 3.14, dd (11.7, 4.3) | 89.2 | 3.13, dd (11.7, 4.3) |
| 4 | 38.9 | - | 38.9 | - | 38.9 | - | 38.9 | - | 38.9 | - |
| 5 | 55.9 | 0.80, d (12.3) | 55.7 | 0.80, d (12.3) | 55.8 | 0.80, d (11.9) | 55.9 | 0.80, d (12.0) | 55.7 | 0.80, m |
| 6 | 18.0 | 1.42, m 1.55, m | 18 | 1.43, m 1.56, m | 18.0 | 1.42, td (13.2,3.2) 1.56, m | 18.0 | 1.43, m 1.56, m | 18.0 | 1.43, m 1.55, m |
| 7 | 32.5 | 1.33, m 1.51, td (13.7, 4.3) | 32.5 | 1.34, m 1.51, td (12.2, 3.3) | 32.5 | 1.33, m 1.50, td (13.0, 3.5) | 32.5 | 1.34, m 1.50, td (12.4, 3.5) | 32.5 | 1.34, m 1.50, td (12.2, 3.5) |
| 8 | 39.3 | - | 39.3 | - | 39.3 | - | 39.3 | - | 39.3 | - |
| 9 | 47.8 | 1.59, m | 47.6 | 1.60, m | 47.9 | 1.60, m | 47.6 | 1.60, m | 47.7 | 1.60, m |
| 10 | 36.5 | - | 36.5 | - | 36.5 | - | 36.5 | - | 36.5 | - |
| 11 | 23.2 | 1.91, m | 23.1 | 1.91, m | 23.1 | 1.90, m | 23.1 | 1.90, m | 23.1 | 1.91, m |
| 12 | 122.4 | 5.27, t (3.7) | 122.4 | 5.27, t (3.7) | 122.4 | 5.27, t (3.6) | 122.4 | 5.27, t (3.6) | 122.4 | 5.27, t (3.4) |
| 13 | 143.5 | - | 143.5 | - | 143.5 | - | 143.5 | - | 143.5 | - |
| 14 | 41.5 | - | 41.5 | - | 41.5 | - | 41.5 | - | 41.5 | - |
| 15 | 27.5 | 1.10, dm (13.7) 1.80, m | 27.5 | 1.10, dm (13.7) 1.80, td (13.7,3.0) | 27.5 | 1.10, dm (13.9) 1.80, m | 27.5 | 1.10, dm (13.6) 1.80, m | 27.5 | 1.10, dm (13.9) 1.80, m |
| 16 | 22.6 | 1.73, m 2.07, td (13.2, 3.6) | 22.6 | 1.73, m 2.07, td (13.3, 3.7) | 22.6 | 1.73, m 2.07, td (13.6, 3.6) | 22.4 | 1.73, m 2.07, td (13.2, 3.4) | 22.6 | 1.73, m 2.07, td (13.2, 3.3) |
| 17 | 46.6 | - | 46.6 | - | 46.6 | - | 46.6 | - | 45.8 | - |
| 18 | 41.1 | 2.88, dd (13.7, 4.2) | 41.1 | 2.88, dd (13.7, 4.0) | 41.1 | 2.88, dd (13.6, 4.1) | 41.1 | 2.88, dd (13.5, 4.0) | 41.1 | 2.88, dd (13.4, 4.1) |
| 19 | 45.8 | 1.17, m 1.73, t (13.7) | 45.9 | 1.16, m 1.73, t (13.7) | 45.3 | 1.16, m 1.73, t (13.6) | 45.8 | 1.16, m 1.73, t (13.5) | 46.6 | 1.16, m 1.73, t (13.4) |
| 20 | 30.2 | - | 30.2 | - | 30.1 | - | 30.1 | - | 30.1 | - |
| 21 | 33.5 | 1.24, m 1.42, td (13.2, 2.8) | 33.5 | 1.24, m 1.42, td (13.0, 2.6) | 33.5 | 1.24, m 1.42, td (13.6, 4.1) | 33.5 | 1.24, m 1.42, m | 33.5 | 1.24, m 1.42, td (13.2, 3.5) |
| 22 | 31.8 | 1.62, m 1.73, m | 31.8 | 1.62, m 1.74, m | 31.8 | 1.62, m 1.74, m | 31.7 | 1.62, m 1.74, m | 31.8 | 1.62, m 1.74, m |
| 23 | 27.1 | 1.07, s | 27.3 | 1.05, s | 27.1 | 1.07, s | 27.1 | 1.07, s | 27.2 | 1.05, s |
| 24 | 15.9 | 0.88, s | 15.8 | 0.88, s | 15.8 | 0.87, s | 15.85 | 0.88, s | 15.8 | 0.87, s |
| 25 | 14.8 | 0.97, s | 14.7 | 0.98, s | 14.8 | 0.96, s | 14.8 | 0.97, s | 14.8 | 0.98, s |
| 26 | 16.4 | 0.82, s | 16.4 | 0.82, s | 16.4 | 0.82, s | 16.4 | 0.82, s | 16.4 | 0.82, s |
| 27 | 24.9 | 1.17, s | 24.9 | 1.18, s | 24.9 | 1.17, s | 24.9 | 1.17, s | 24.9 | 1.17, s |
| 28 | 176.7 | - | 176.7 | - | 176.7 | - | 176.7 | - | 176.7 | - |
| 29 | 32.1 | 0.93, s | 32.1 | 0.93, s | 32.1 | 0.93, s | 32.1 | 0.93, s | 32.1 | 0.93, s |
| 30 | 22.7 | 0.96, s | 22.6 | 0.96, s | 22.6 | 0.96, s | 22.6 | 0.96, s | 22.6 | 0.96, s |

 CD_3OD .^a^a in ppm, *J* in parentheses in Hz.

Table 2 ^{13}C NMR and ^1H NMR spectroscopic data in CD_3OD of the sugar moieties of compounds **1-5**^a

3.86, m

3.87, dm (12.0)

3.86, m

3.85, dd (12.0, 2.4)

^a in ppm, *J* in parentheses in Hz

Table 3 ¹³C NMR and ¹H NMR spectroscopic data of the aglycone moieties of compounds **6–8** and **13** in CD₃OD.^a

| position | 6 | | 7 | | 8 | | 13 | |
|----------|------------|---------------------------------|------------|---|------------|---|------------|---------------------------------|
| | δ_C | δ_H | δ_C | δ_H | δ_C | δ_H | δ_C | δ_H |
| 1 | 38.7 | 1.00, td (13.9, 3.3) 1.63, m | 38.6 | 1.00, m 1.63, m | 38.5 | 1.00, m 1.64, m | 38.6 | 1.00, td (13.9, 3.3) 1.63, m |
| 2 | 25.9 | 1.70, m 1.83, m | 25.7 | 1.86, m 1.76, m | 25.7 | 1.73, m 1.86, m | 25.9 | 1.70, m 1.83, m |
| 3 | 88.8 | 3.14, dd (11.5, 4.3) | 89.2 | 3.14, dd (11.5, 4.2) | 89.2 | 3.14, dd (11.6, 4.2) | 88.9 | 3.14, dd (11.5, 4.1) |
| 4 | 38.9 | - | 38.9 | - | 38.9 | - | 38.9 | - |
| 5 | 55.9 | 0.80, d (12.1) | 55.7 | 0.80, m | 55.7 | 0.80, m | 55.8 | 0.80, m |
| 6 | 18.0 | 1.43, m 1.56, m | 18.0 | 1.42, m 1.56, m | 18.0 | 1.42, td (13.8, 3.0) 1.55, m | 18.0 | 1.43, m 1.56, m |
| 7 | 32.5 | 1.34, m 1.50, td (12.6, 3.3) | 32.5 | 1.32, m 1.50, td (11.6, 4.5) | 32.5 | 1.34, m 1.50, td (12.0, 3.1) | 32.5 | 1.34, m 1.50, m |
| 8 | 39.3 | - | 39.3 | - | 39.3 | - | 39.3 | - |
| 9 | 47.8 | 1.60, m | 47.8 | 1.60, m | 47.9 | 1.60, m | 47.8 | 1.60, m |
| 10 | 36.5 | - | 36.5 | - | 36.5 | - | 36.5 | - |
| 11 | 23.1 | 1.90, m | 23.2 | 1.92, m | 23.2 | 1.92, m | 23.2 | 1.90, m |
| 12 | 122.4 | 5.27, t (3.6) | 122.4 | 5.27, t (3.5) | 122.4 | 5.27, t (3.6) | 122.4 | 5.27, t (3.5) |
| 13 | 143.5 | - | 143.5 | - | 143.5 | - | 143.5 | - |
| 14 | 41.5 | - | 41.5 | - | 41.5 | - | 41.5 | - |
| 15 | 27.3 | 1.10, dm (14.2) 1.80, m | 27.5 | 1.11, dm (13.9) 1.80, td (13.9, 3.2) | 27.5 | 1.10, dm (14.1) 1.80, td (14.1, 3.3) | 27.5 | 1.10, dm (14.0) 1.80, m |
| 16 | 22.6 | 1.73, m 2.07, td (13.4, 3.7) | 22.6 | 1.73, m 2.07, td (13.2, 3.4) | 22.6 | 1.73, m 2.07, td (13.2, 3.3) | 22.6 | 1.73, m 2.07, td (13.4, 3.7) |
| 17 | 46.6 | - | 46.6 | - | 46.6 | - | 46.6 | - |
| 18 | 41.1 | 2.88, dd (13.6, 4.1) | 41.2 | 2.88, dd (13.5, 3.7) | 41.1 | 2.88, dd (13.6, 4.3) | 41.1 | 2.88, dd (13.7, 4.1) |
| 19 | 45.9 | 1.17, m 1.73, t (13.6) | 45.8 | 1.17, m 1.73, t (13.5) | 46.6 | 1.16, m 1.73, t (13.6) | 45.8 | 1.17, m 1.73, t (13.7) |
| 20 | 30.2 | - | 30.2 | - | 30.1 | - | 30.2 | - |
| 21 | 33.5 | 1.24, m 1.42, td (12.9, 3.3) | 33.5 | 1.24, m 1.42, td (13.4, 3.4) | 33.5 | 1.24, m 1.42, td (13.4, 3.0) | 33.5 | 1.24, m 1.42, td (13.2, 4.2) |
| 22 | 31.8 | 1.62, m 1.74, td (13.6, 3.5) | 31.8 | 1.62, m 1.74, m | 31.8 | 1.62, m 1.74, td (13.7, 4.6) | 31.8 | 1.62, m 1.74, td (13.6, 3.5) |
| 23 | 27.2 | 1.07, s | 27.2 | 1.05, s | 27.2 | 1.06, s | 27.1 | 1.07, s |
| 24 | 15.9 | 0.88, s | 15.8 | 0.88, s | 15.7 | 0.87, s | 15.8 | 0.87, s |
| 25 | 14.8 | 0.97, s | 14.8 | 0.98, s | 14.8 | 0.98, s | 14.8 | 0.97, s |
| 26 | 16.4 | 0.82, s | 16.4 | 0.82, s | 16.4 | 0.82, s | 16.4 | 0.82, s |
| 27 | 25.0 | 1.17, s | 24.9 | 1.19, s | 24.9 | 1.17, s | 24.9 | 1.17, s |
| 28 | 176.7 | - | 176.7 | - | 176.7 | - | 176.7 | - |
| 29 | 32.1 | 0.93, s | 32.1 | 0.93, s | 32.1 | 0.93, s | 32.1 | 0.93, s |
| 30 | 22.7 | 0.97, s | 22.6 | 0.96, s | 22.6 | 0.96, s | 22.6 | 0.96, s |

^a in ppm, *J* in parentheses in Hz

Table 4 ¹³C NMR and ¹H NMR spectroscopic data in CD₃OD of the sugar moieties of compounds **6-8** and **13**.^a

| Position | 6 | | 7 | | 8 | | 13 | |
|-------------|----------------|----------------------|----------------|----------------------|----------------|----------------------|--------------------|----------------------|
| | δ_C | δ_H | δ_C | δ_H | δ_C | δ_H | $\delta_C\delta_H$ | |
| C-3 | Xyl I | | Ara | | Ara | | Xyl I | |
| 1 | 105.1 | 4.39, d (7.1) | 103.9 | 4.50, d (6.2) | 104.2 | 4.47, d (6.0) | 105.2 | 4.39, d (7.1) |
| 2 | 76.7 | 3.41, t (7.7) | 74.9 | 3.78, m | 75.5 | 3.71, m | 77.0 | 3.41, m |
| 3 | 77.5 | 3.45, t (8.7) | 72.4 | 3.73, dd (7.7, 3.6) | 72.2 | 3.72, dd (6.3, 4.6) | 77.5 | 3.45, m |
| 4 | 70.2 | 3.48, m | 67.8 | 3.79, m | 67.9 | 3.79, m | 70.3 | 3.48, m |
| 5 | 65.2 | 3.18, dd (11.4, 9.9) | 63.4 | 3.52, dd (10.8, 4.7) | 63.7 | 3.52, dd (12.0, 1.3) | 65.2 | 3.19, t (10.7) |
| | | 3.85, m | | 3.85, d (10.8) | | 3.85, m | | 3.84, m |
| | Rha I | | Rha I | | Rha I | | Rha I | |
| 1 | 99.9 | 5.38, d (1.7) | 100.1 | 5.22, d (1.6) | 100.4 | 5.17, d (1.3) | 100.3 | 5.30, d (1.3) |
| 2 | 70.2 | 4.13, dd (3.2, 1.7) | 70.4 | 4.08, dd (2.9, 1.6) | 69.8 | 4.23, dd (3.2, 1.3) | 69.5 | 4.27, dd (2.4, 1.3) |
| 3 | 80.7 | 3.90, dd (9.4-3.2) | 80.6 | 3.85, dd (9.6, 2.9) | 81.4 | 3.88, dd (9.5, 3.2) | 81.5 | 3.93, dd (9.6, 2.4) |
| 4 | 71.4 | 3.58, t (9.6) | 71.4 | 3.57, t (9.6) | 71.2 | 3.58, t (9.5) | 71.2 | 3.58, t (9.6) |
| 5 | 68.6 | 3.99, m | 68.6 | 3.91, m | 68.7 | 3.91, m | 68.5 | 4.01, m |
| 6 | 16.7 | 1.25, d (6.2) | 16.7 | 1.25, d (6.2) | 16.5 | 1.25, d (6.2) | 16.7 | 1.25, d (6.2) |
| | Xyl II | | Xyl I | | Glc I | | Glc I | |
| 1 | 105.1 | 4.47, d (7.7) | 105.1 | 4.48, d (7.9) | 104.3 | 4.51, d (7.7) | 104.2 | 4.51, d (7.7) |
| 2 | 74.5 | 3.40, dd (8.7, 7.7) | 74.6 | 3.40, m | 74.7 | 3.42, m | 74.7 | 3.40, dd (9.0, 7.7) |
| 3 | 81.6 | 3.49, t (8.7) | 81.6 | 3.48, t (8.9) | 82.0 | 3.55, t (9.0) | 82.0 | 3.53, t (9.0) |
| 4 | 68.3 | 3.53, m | 68.3 | 3.53, m | 68.3 | 3.39, m | 68.3 | 3.39, t (8.8) |
| 5 | 65.7 | 3.22, dd (11.1, 9.2) | 65.7 | 3.23, t (10.6) | 76.3 | 3.33, m | 76.3 | 3.33, m |
| | | 3.87, m | | 3.89, dd (10.6, 2.9) | | | | |
| 6 | | | | | 60.9 | 3.72, dd (11.6, 4.4) | 60.9 | 3.72, dd (11.6, 3.3) |
| | | | | | | 3.86, m | | 3.85, dd (11.6, 2.0) |
| | Rha II | | Rha II | | Rha II | | Rha II | |
| 1 | 100.7 | 5.21, brs | 100.7 | 5.21, brs | 100.9 | 5.22, d (1.6) | 100.9 | 5.22, d (1.2) |
| 2 | 70.8 | 3.97, m | 70.8 | 3.97, dd (2.8, 1.2) | 70.8 | 3.98, dd (3.1, 1.6) | 70.8 | 3.98, m |
| 3 | 70.8 | 3.95, dd (9.4, 3.3) | 70.9 | 3.95, dd (9.3, 2.8) | 70.8 | 3.96, m | 70.9 | 3.96, dd (9.5, 3.0) |
| 4 | 82.6 | 3.61, t (9.4) | 82.6 | 3.61, t (9.3) | 82.6 | 3.61, t (9.5) | 82.6 | 3.61, t (9.5) |
| 5 | 67.1 | 4.13, m | 67.1 | 4.13, m | 67.2 | 4.12, m | 67.2 | 4.12, m |
| 6 | 16.7 | 1.34, d (6.1) | 16.6 | 1.34, d (6.2) | 16.7 | 1.35, d (6.1) | 16.7 | 1.35, d (6.1) |
| | Glc I | | Glc I | | Glc II | | Glc II | |
| 1 | 104.4 | 4.62, d (7.8) | 104.4 | 4.62, d (7.9) | 104.4 | 4.62, d (7.8) | 104.4 | 4.62, d (7.8) |
| 2 | 76.3 | 3.41, m | 76.3 | 3.40, m | 75.8 | 3.41, m | 76.2 | 3.41, m |
| 3 | 76.1 | 3.80, t (9.2) | 76.1 | 3.80, t (9.2) | 76.1 | 3.80, t (9.1) | 76.1 | 3.80, t (9.2) |
| 4 | 72.9 | 3.83, m | 72.9 | 3.83, t (9.3) | 72.9 | 3.81, t (9.1) | 73.0 | 3.83, t (9.2) |
| 5 | 75.8 | 3.41, m | 75.8 | 3.40, m | 76.2 | 3.41, m | 75.8 | 3.41, m |
| 6 | 59.7 | 3.87, m | 59.6 | 3.87, dd (12.2, 2.9) | 59.7 | 3.88, m | 59.6 | 3.88, dd (12.9, 4.1) |
| | | 3.95, dd (12.9, 2.2) | | 3.95, m | | 3.96, dd (12.8, 2.9) | | 3.95, m |
| | Rha III | | Rha III | | Rha III | | Rha III | |
| 1 | 99.5 | 5.39, d (2.1) | 99.5 | 5.39, d (1.7) | 99.5 | 5.39, d (1.5) | 99.5 | 5.40, brs |
| 2 | 71.0 | 3.91, dd (3.4, 2.1) | 71.0 | 3.90, dd (3.1, 1.7) | 71.0 | 3.91, dd (3.2, 1.5) | 71.1 | 3.91, dd (3.2, 1.3) |
| 3 | 70.3 | 3.95, dd (9.3, 3.4) | 70.3 | 3.94, dd (9.2, 3.1) | 70.3 | 3.95, dd (9.1, 3.2) | 70.3 | 3.95, dd (9.3, 3.2) |
| 4 | 73.3 | 3.32, m | 73.4 | 3.33, m | 73.4 | 3.32, m | 73.9 | 3.33, m |
| 5 | 67.7 | 4.50, m | 67.7 | 4.46, m | 67.7 | 4.51, m | 67.6 | 4.50, m |
| 6 | 16.6 | 1.26, d (6.3) | 16.5 | 1.26, d (6.2) | 16.5 | 1.27, d (6.0) | 16.5 | 1.27, d (6.2) |
| | Gal | | Gal | | Gal | | Gal | |
| 1 | 102.9 | 4.46, d (7.6) | 102.9 | 4.46, d (7.7) | 102.9 | 4.46, d (8.2) | 102.9 | 4.46, d (7.6) |
| 2 | 71.8 | 3.45, m | 71.7 | 3.45, m | 71.7 | 3.46, m | 71.7 | 3.46, m |
| 3 | 73.6 | 3.45, m | 73.6 | 3.46, m | 73.6 | 3.46, m | 73.6 | 3.45, m |
| 4 | 68.8 | 3.85, m | 68.8 | 3.84, m | 68.9 | 3.85, d (2.3) | 68.8 | 3.84, m |
| 5 | 75.3 | 3.51, m | 75.3 | 3.51, m | 75.3 | 3.52, m | 75.3 | 3.51, m |
| 6 | 60.7 | 3.79, m | 60.7 | 3.80, m | 60.7 | 3.80, m | 60.7 | 3.80, m |
| | | 3.81, m | | | | | | |
| C-28 | Glc II | | Glc II | | Glc III | | Glc III | |
| 1 | 94.3 | 5.37, d (8.2) | 94.3 | 5.37, d (8.2) | 94.3 | 5.36, d (8.2) | 94.3 | 5.36, d (8.2) |
| 2 | 72.4 | 3.35, m | 72.4 | 3.35, m | 72.4 | 3.35, m | 72.4 | 3.35, m |
| 3 | 76.7 | 3.43, t (8.6) | 76.7 | 3.43, t (9.0) | 76.7 | 3.43, t (9.1) | 76.7 | 3.41, t (8.7) |
| 4 | 69.5 | 3.45, t (8.6) | 69.5 | 3.46, t (9.0) | 69.5 | 3.46, t (9.0) | 69.5 | 3.43, t (8.7) |
| 5 | 76.4 | 3.52, m | 76.4 | 3.53, m | 76.4 | 3.52, m | 76.4 | 3.52, m |
| 6 | 68.0 | 3.77, dd (11.2, 4.5) | 68.0 | 3.78, m | 68.0 | 3.78, dd (11.6, 4.4) | 68.0 | 3.78, dd (11.7, 4.7) |
| | | 4.13, dd (11.2, 1.8) | | 4.13, dd (11.7, 1.8) | | 4.14, dd (11.6, 1.7) | | 4.14, dd (11.7, 1.9) |

| | Glc III | | GlcIII | | GlcIV | | Glc IV | |
|---|----------------|---|---------------|---------------------------------|--------------|---------------------------------|---------------|--|
| 1 | 103.2 | 4.36, d (7.8) | 103.2 | 4.36, d (7.8) | 103.2 | 4.36, d (7.8) | 103.2 | 4.36, d (7.8) |
| 2 | 73.7 | 3.23, t (7.8) | 73.7 | 3.23, dd (9.2, 7.8) | 73.7 | 3.23, dd (9.1, 7.8) | 73.7 | 3.23, dd (9.0, 7.8) |
| 3 | 76.6 | 3.35, m | 76.6 | 3.37, m | 76.6 | 3.37, m | 76.5 | 3.37, m |
| 4 | 70.1 | 3.31, t (8.7) | 70.1 | 3.31, t (8.7) | 70.1 | 3.31, t (8.6) | 70.1 | 3.31, t (8.7) |
| 5 | 76.5 | 3.25, m | 76.6 | 3.26, m | 76.6 | 3.27, m | 76.6 | 3.25, m |
| 6 | 61.3 | 3.68, dd (12.0, 5.6) 3.86, dm (12.0) | 61.3 | 3.68, dd (11.8, 5.5) 3.87, m | 61.3 | 3.68, dd (11.8, 5.5) 3.87, m | 61.3 | 3.67, dd (11.9, 5.5) 3.86, dd (11.9, 2.0) |

^a in ppm, *J* in parentheses in Hz

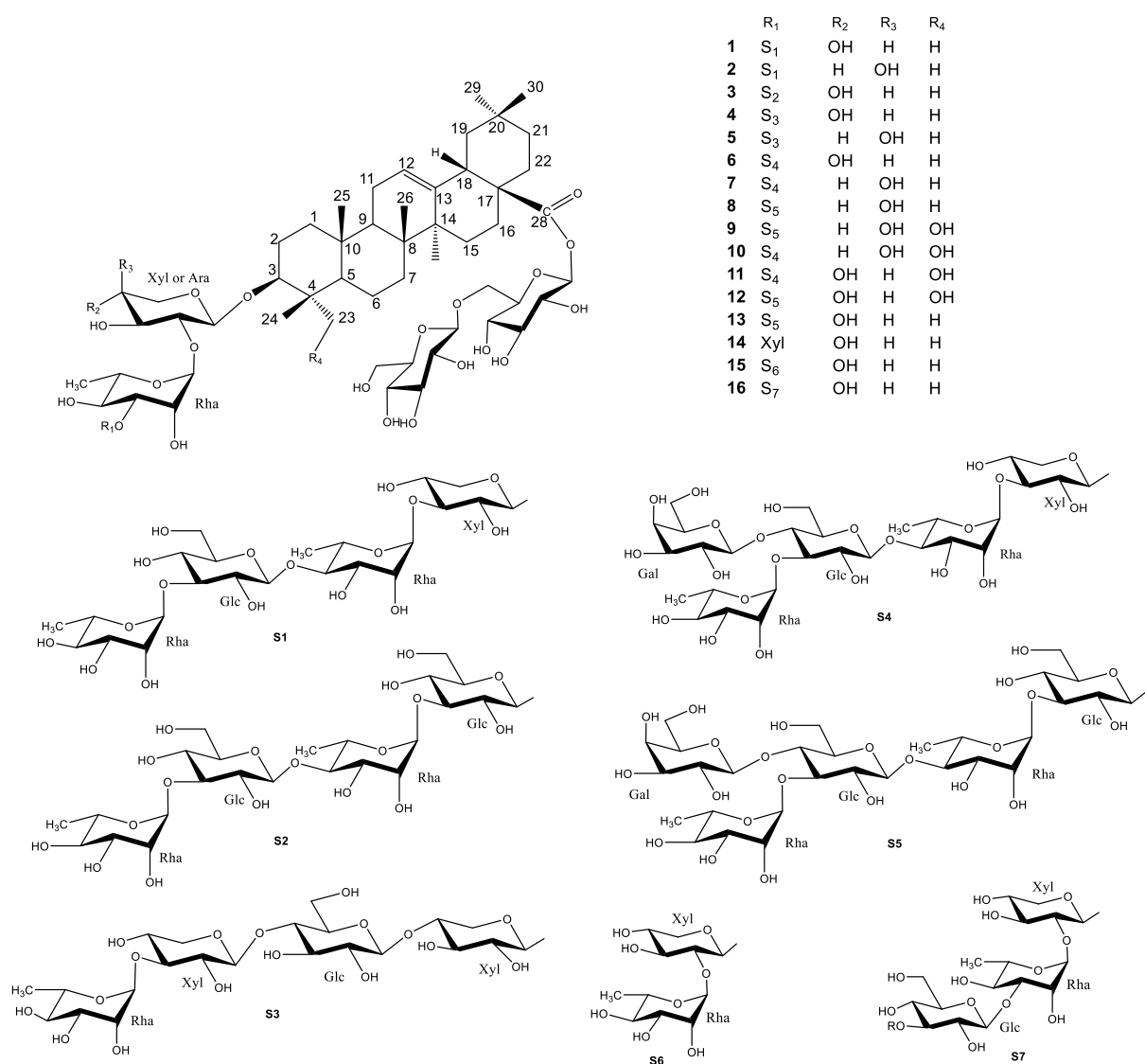


Fig. 1. The structures of compounds **1-16** isolated from *Scabiosa semipapposa*.

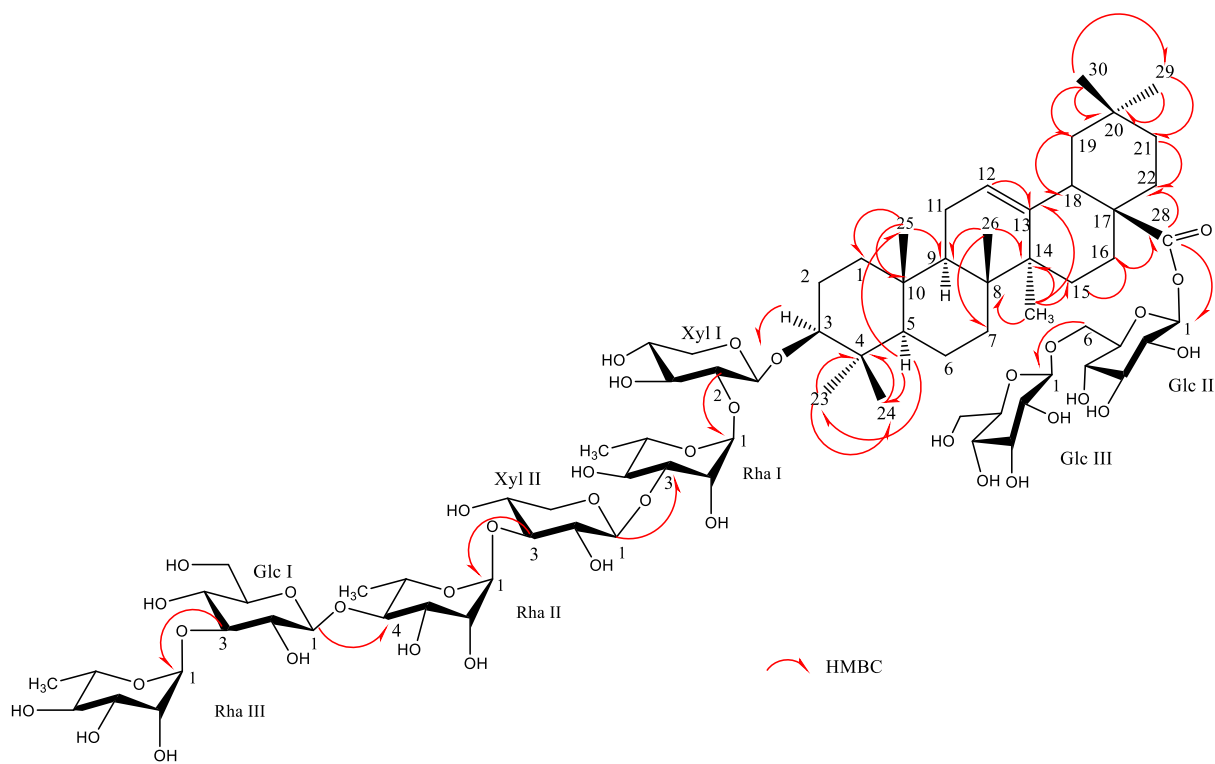


Fig. 2. Key HMBC correlations for compound 1.

Figure captions

Fig. 1. The structures of compounds **1-16** isolated from *Scabiosa semipapposa*.

Fig. 2. Key HMBC correlations for compound 1.