Triterpenoid saponins from Anagallis monelli ssp. linifolia (L.) Maire and their chemotaxonomic significance

Chouaib Aouane, Ahmed Kabouche, Laurence Voutquenne-Nazabadioko, Charlotte Sayagh, Agathe Martinez, Abdulmagid Alabdul Magid, Zahia Kabouche

Triterpenoid saponins from *Anagallis monelli* ssp. *linifolia* (L.) Maire and their chemotaxonomic significance

Chouaib Aouane[a,b], Ahmed Kabouche[a], Laurence Voutquenne-Nazabadioko[b*], Charlotte Sayagh[b], Agathe Martinez[b], Abdulmagid Alabdul Magid[b], Zahia Kabouche[a]

[a]*Université des frères Mentouri-Constantine 1, Département de chimie, Laboratoire d'Obtention des Substances Thérapeutiques (LOST), Campus Chaabet-Ersas, 25000 Constantine, Algeria*

[b]*Université de Reims Champagne Ardenne, CNRS, ICMR UMR 7312, 51097 Reims, France*

Abstract

Thirteen undescribed triterpenoid saponins named monellosides A-M, were isolated from the aerial parts of *Anagallis monelli* ssp. *linifolia* (L.) Maire, together with ten known oleanane-type glycosides. Their structures were elucidated by 1D and 2D-NMR spectroscopy (COSY, TOCSY, HSQC, HMBC and ROESY) as well as high resolution mass spectrometry (HR-ESI-MS) and acid hydrolysis. Monellosides A-M have a carbohydrate chain linked on the C-3 of the aglycone with a common *β*-D-glucopyranosyl-(1→4)-*α*-L-arabinopyranosyl sequence which was further glycosylated by a glucose and/or a xylose. The sequence *β*-D-xylopyranosyl-(1→2)-*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl-(1→2)-]*α*-L-arabinopyranosyl was common to all the 13,28-epoxy-oleanane core skeleton except one compound. In order to discuss the reclassification of *Anagallis* in Primulaceae, we compared saponins from species of Myrsinaceae and Primulaceae families and showed that these species were characterized by a pentacyclic triterpenoid saponin with a 13,28-epoxy bridge skeleton. Our phytochemical results increase the knowledge of saponins of the genus *Anagallis*, their chemotaxonomy and stimulate the evaluation of the biological activities of these saponins.

Keywords: *Anagallis monelli*, Primulaceae, Triterpenoid saponins, Chemotaxonomy

1. Introduction

The genus *Anagallis* currently belongs to the Primulaceae family, although recent studies based on DNA sequences of three chloroplast genes and morphology have suggested its placement in the Myrsinaceae as *Lysimachia* (Källersjö et al., 2000; Manns and Anderberg, 2009 and 2011). *Anagallis* contained about 28 species growing as mainly annual herbs, distributed in Africa, Madagascar, Europe and South America. This genus is represented in Algeria by four species *A. arvensis* L., *A. monelli* L., *A. repens* Pomel. and *A. enella* L. (Quezel and Santa, 1963). The plant *Anagallis monelli* is an endemic herb from North Africa and is represented in Algeria by two different subspecies, *Anagallis monelli* ssp. *collina* (Schousb.) Maire and *Anagallis monelli* ssp. *linifolia* (L.) Maire (Quezel and Santa, 1963). Among the

studied species of the genus *Anagallis*, *A. arvensis* and *A. foemina* have been used in traditional medicine in Navarre (Spain) against skin injuries like burns and wounds (López et al., 2011). The whole plant of *A. arvensis* has been used for liver complications in Taiwan, for skin diseases in Italy and for fish poisoning in rural areas of Nepal (Yasmeen et al., 2020). Chemical investigations on *Anagallis* spp. have been mainly characterized by the presence of saponins (Aliotta et al., 1992 ; Amoros and Girre, 1987; Glombitza and Kurth, 1987a and b; Shoji et al., 1994a and b; Soberón et al., 2017), pentacyclic triterpenes (Aliotta et al., 1992; De Napoli et al., 1992; Heitz et al.,1971), flavonoids and polyphenols (Ammar et al., 2008; Ishikura, 1981; Kawashty et al., 1998; Rastogi and Norula, 1980), sterols (Rastogi and Norula, 1980), in addition to alkaloids and quinones (Saxena and Rao, 2021). Triterpenoid saponins were found in a wide variety of higher plants and display a wide range of pharmacological activities, including haemolytic, expectorant, anti-inflammatory, hypolipidemic, gastroprotective, immunomodulatory and antimicrobial properties (Netala et al., 2015; Podolak et al., 2010). The potential anticancer activity of saponins has been suggested by their cytotoxic, cytostatic, pro-apoptotic and anti-invasive effects (Koczurkiewicz et al., 2015). The 13,28-epoxy-oleanane type saponins from the plant families Myrsinaceae and Primulaceae show also a wide range of biological activities such as cytotoxic activities (Foubert al., 2008; Podolak et al., 2013a).

Anagallis monelli ssp. *linifolia* (L.) Maire [Synonym of *Anagallis monelli* L.], also known under the synonym *Lysimachia monelli* (L.) U. Mann and Anderb, is an herbaceous, perennial herb. The 8 to 60 cm long stems are woody at the base. The leaves are opposite. The flowers in the axils of the upper leaves are carried by pedicels of 12 to 40 mm, opposite or in 3 veinlets, longer than the leaves. The lobes of the calyx of 3.6 to 7 mm, are lanceolate, with a scarious margin, sometimes finely serrated (Valdes et al., 1987). In this work, we have studied the chemical profile of *Anagallis monelli* ssp. *linifolia* and isolated 13 undescribed triterpenoid saponins, namely monellosides A-M (**1**-**13**) and ten known triterpenoid saponins (**14**-**23**). The chemophenetic significance of the isolated saponins was discussed by comparing saponins from other Primulaceae species.

2. Results and discussion

2.1 Isolation and structural elucidation

The 70% EtOH extract from the aerial parts of *A. monelli* ssp. *linifolia* was sequentially partitioned with EtOAc and *n*-BuOH, respectively. The *n*-BuOH soluble fraction was subjected to a Diaion HP-20 resin chromatography to give three fractions (A-C). The saponin-containing fraction (C), was subjected to further column chromatography to give ten known compounds and thirteen undescribed saponins named monellosides A-M (**1**-**13**) (Fig. 1). Their structures were elucidated by NMR techniques (^{1}H, ^{13}C, COSY, TOCSY, ROESY, HSQC, and HMBC) and mass spectrometry (HR-ESI-MS) and by comparison with literature data. The

monosaccharides of monellosides A-M (**1**-**13**) obtained by acid hydrolysis of an aliquot of the saponin-containing fraction (C) were identified as L-arabinose, D-glucose and D-xylose by comparison on TLC with authentic samples followed by measurement of their optical rotation values after purification on TLC.

Compound 1 was obtained as an amorphous white powder. Its molecular formula was determined as $C_{52}H_{86}O_{22}$ based on the negative-ion HR-ESI-MS (1061.5537 $[M-H]^-$, calcd 1061.5532). The ^{1}H NMR data (Table 1) showed the presence of seven signals corresponding to the tertiary methyls at δ_H 1.28, 1.17, 1.08, 1.00, 0.98, 0.92 and 0.87 giving correlations with seven carbons signals in the HSQC spectrum at δ_C 18.7 (C-27), 17.4 (C-26), 27.0 (C-23), 32.3 (C-29), 24.6 (C-30), 15.3 (C-25) and 15.3 (C-24), respectively. In addition, the HSQC spectrum showed correlations at δ_H 4.33 (1H, d, J = 5.0 Hz, H-16) / δ_C 69.8 (C-16), δ_H 3.16 (1H, dd, J = 11.7, 4.3 Hz, H-3) / 90.0 (C-3) and δ_H 3.74 (1H, dd, J = 11.6, 4.9 Hz, H-22) / δ_C 74.2 (C-22). Furthermore, a quaternary carbon signal at δ_C 86.9 due to C-13 was linked to an oxygenated methylene at δ_H 3.67 (m, H_2-28) in the HMBC spectrum (Aliotta et al., 1992). HMBC spectrum showed also correlations from H_2-28 and H-18 [δ_H 1.47 (1H, dd, J = 14.0, 2.5 Hz)] to two oxygenated methines at δ_C 69.8 (C-16) and δ_C 74.2 (C-22) and from H-3 (δ_H 3.16) to carbons at δ_C 27.0 (C-23), 15.3 (C-24) and a quaternary carbon at δ_C 39.2 (C-4) (Fig. 2). Taken together, these data were indicative of a 13,28-epoxy-16,22-dihydroxyoleanan skeleton (priverogenin B) (Kitagawa et al., 1972 ; Yosioka et al., 1967). This assumption was confirmed by detailed analysis of the COSY, ROESY, HSQC and HMBC spectra which allowed the full assignment of the proton and carbon resonances of the aglycone (Table 1). Correlations observed between H-3/H-5 and H-5/H-9 in the ROESY spectrum indicated their α-axial orientation and thus the β-orientation of the oxygen at C-3 (Aliotta et al., 1992). The 16α-configuration of hydroxyl group was evident from the small coupling constant $^3J_{H\text{-}16/H\text{-}15}$ value (J = 5 Hz), characteristic of an equatorial H-16 proton (Lehbili et al., 2018), which was confirmed by the correlations from H-16/ H-15$_{ax}$ and H-16/ H_3-26 β-oriented in the ROESY spectrum. In the same fashion, the coupling constants of H-22 at δ_H 3.74 (1H, dd, J = 11.6, 4.9 Hz) indicated its axial orientation which was confirmed by the correlations H-22/ H-30 and H-22/ H-28 in the ROESY spectrum; leading to the α-orientation of the oxygen at C-22 (Aliotta et al., 1992).

In addition, the HMBC correlation between the H-3 proton (δ_H 3.16) and an anomeric carbon at δ_C 104.2 (C-1') indicated that a glycosidic moiety was linked to C-3. After acid hydrolysis, the sugar units were identified as L-arabinose, D-glucose and D-xylose by co-TLC with authentic sugar followed by measurement of the optical rotation values of each purified monosaccharide. The 1D and 2D NMR spectra of compound **1** confirmed the presence of one α-L-arabinopyranosyl unit [δ_H 4.41 (1H, d, J = 6.6 Hz, H-1'), δ_C 104.2, C-1'], two β-D-glucopyranosyl units [δ_H 4.71 (1H, d, J = 7.7 Hz, H-1''), δ_C 103.0, C-1''; δ_H 4.54 (1H, d, J = 7.8 Hz, H-1'''), δ_C 103.4, C-1'''] and one β-D-xylopyranosyl unit [δ_H 4.53 (1H, d, J = 7.6 Hz, H-1''''), δ_C 105.9, C-1''''] (Table 2). The coupling constant of H-1' ($^3J_{H\text{-}1'/H\text{-}2'}$ = 6.6 Hz) and the axial

correlations observed between H-1'/H-3' and H-1'/H-5' in the ROESY spectrum of **1**, indicated the *α*-anomer configuration of the arabinose unit. The large coupling constants from anomeric protons (>7 Hz) of the xylose and glucoses units, indicated their *β*-configurations (Liang et al., 2011). Extensive 2D-NMR analysis (COSY, TOCSY, ROESY, HSQC and HMBC) enabled the full assignments of all proton and carbon resonances of each monosaccharide (Table 2). HMBC correlation between H-1' and C-3 indicated that the arabinose unit was linked to C-3 of the aglycone. The glycoside sequence of compound **1** was determined by analysis of the HMBC and ROESY spectra. Thus, HMBC correlations were observed between H-1'' / C-2' (δ_C 78.0), H-1''' / C-4' (δ_C 78.8) and H-1'''' / C-2''' (δ_C 83.7) (Fig. 2). In addition, ROESY correlations confirming the interglycosidic linkage and the point of attachment of the tetra-saccharide at the C-3 of the aglycone were observed between H-1'/ H-3, H-1'' / H-2', H-1''' / H-4' and H-1'''' / H-2''' (Fig. 2). According to the above results, the structure of compound **1** was elucidated as 3-*O*-*β*-D-xylopyranosyl-(1→2)-*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl-(1→2)-]*α*-L-arabinopyranosyl-priverogenin B, named monelloside A.

Compound 2, isolated as white amorphous powder, had a molecular formula of $C_{58}H_{96}O_{27}$ determined by the negative-ion HR-ESI-MS (1223.6061 $[M-H]^-$, calcd 1223.6071), and differed from **1** by 162 amu corresponding to a supplementary hexosyl group. Comparison of the NMR data of **2** with those of **1** (Tables 1 and 2) showed that they shared the same aglycone but differed by the presence in **2** of an additional hexose unit identified as *β*-D-glucopyranose (GlcIII, $\delta_{H\text{-}1''''}$ 4.71). The HMBC correlation between H-1'''' and C-4''' (δ_C 78.5) indicated the linkage of GlcIII to GlcII on C-4''' (Shoji et al., 1994a). Therefore, the structure of compound **2** was established as 3-*O*-*β*-D-glucopyranosyl-(1→4)-[*β*-D-xylopyranosyl-(1→2)-]*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl-(1→2)-]*α*-L-arabinopyranosyl-priverogenin B, named monelloside B.

Compound 3 was obtained as a white amorphous powder. Its molecular formula was determined as $C_{54}H_{88}O_{23}$ on the basis of its negative-ion HR-ES-IMS (1103.5629 $[M-H]^-$, calcd 1103.5638) and it differed from **1** by 42 amu corresponding to an additional acetyl group. Extensive 1D and 2D-NMR analysis (Tables 1 and 2) showed that compound **3** differ from **2** by the absence of a hydroxyl group at C-22 and the presence of a hydroxyl group at C-23 of the aglycone, as in anagalligenin B (Mahato et al., 1991, Shoji et al., 1994b). Additional signals assigned to an acetyl group linked to C-6'' of GlcI, was evidenced by the HMBC correlations between a carbonyl carbon signal at δ_C 171.5 with methyl protons at δ_H 2.08 and the same carbonyl carbon signal with H_2-6'' of GlcI ($\delta_{H\text{-}6''}$ 4.20 (1H, dd, J = 11.5, 2.5 Hz); indicating that **3** was an acetylated derivative of desglucoanagalosine B (**20**) (Shoji et al., 1994b). According to the above results, the structure of compound **3** was elucidated as 3-*O*-*β*-D-xylopyranosyl-(1→2)-*β*-D-glucopyranosyl-(1→4)-[6-*O*-acetyl-*β*-D-glucopyranosyl-(1→2)-]*α*-L-arabinopyranosyl-anagalligenin B, named monelloside C

Compound 4 had a molecular formula of $C_{59}H_{98}O_{28}$, determined on the basis of its negative-ion HR-ESI-MS (1253.6169 $[M-H]^-$, calcd 1253.6166). Extensive 1D and 2D NMR analysis showed that compounds **4** and **2** differed only by the aglycone part (Tables 1 and 2). Compound **4** revealed six signals corresponding to tertiary methyls at δ_H 1.25 (H_3-27), 1.20 (H_3-26), 0.96 (H_3-25), 0.94 (H_3-29), 0.90 (H_3-30) and 0.73 (H_3-24) and two oxygenated methine protons at δ_H 3.62 (H-3) and 3.83 (1H, d, J =5.2 Hz, H-16) correlating with six methyl carbons signals at δ_C 18.4, 17.5, 15.8, 32.5, 23.5, 11.7 and two oxygenated methine carbons signals at δ_C 82.5, 75.8, respectively in the HSQC spectrum. The disappearance of the hydroxyl group at C-22 led to the deshielding of C-16. In addition, two oxygenated methylene protons signal at δ_H 3.30 (1H, d, J = 11.5 Hz, H-23a) and δ_H 3.73 (1H, d, J = 11.5 Hz, H-23b) correlated with the carbon signal at δ_C 63.2 (C-23), in the HSQC spectrum. HMBC cross-peaks from $\delta_{H\text{-}24}$ 0.72 to $\delta_{C\text{-}23}$ 63.3 suggested the location of a hydroxyl function at C-23 (Bechkri et al., 2020). In addition, a quaternary carbon signal at δ_C 87.6 (C-13) and a singlet resonance at δ_H 4.19 (1H) corresponding to H-28 indicated the presence of 13,28-epoxy-oleanane skeleton. The H-28 proton correlated in the HSQC spectrum with C-28 (δ_C 105.5) indicating the presence of another alkoxy unit. The resulting acetal was confirmed by the HMBC correlation between the C-28 and the methyl of a methoxy group at δ_H 3.33 (s, CH_3). Assignments of other proton and carbon signals of the aglycone were accomplished by extensive 2D-NMR analyses which led to the elucidation of the aglycone part of **4** as 13,28-epoxy-(3*β*,16*α*,23)-trihydroxy-28-methoxy-oleanane, which differ from anagalligenin B (Mahato et al., 1991) by the presence of a methoxy group at C-28. Thus, compound **4** was identified as 3-*O*-*β*-D-glucopyranosyl-(1→4)-[*β*-D-xylopyranosyl-(1→2)-]*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl(1→2)-]*α*-L-arabinopyranosyl-13,28-epoxy-3*β*,16*α*,23-trihydroxy-28-methoxy-oleanane or 3-*O*-*β*-D-glucopyranosyl-(1→4)-[*β*-D-xylopyranosyl-(1→2)-]*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl(1→2)-]*α*-L-arabinopyranosyl-28-methoxy-anagalligenin B, named monelloside D.

Compound 5 was obtained as a white amorphous powder. Its molecular formula was determined as $C_{53}H_{88}O_{23}$ based on its negative-ion mode HR-ESI-MS (1091.5646 $[M-H]^-$, calcd 1091. 5638). Comparison of the NMR data of **5** with those of **4** (Tables 1 and 2) and analysis of the NMR spectra showed that compounds **4** and **5** had the same aglycone moiety (28-methoxy-anagalligenin B), while comparison of the ^1H and ^{13}C NMR values of the oligosaccharide part of **5** with those of **1** indicated that **5** had the same tetrasaccharide moiety as in **1**, linked to C-3. Location of all proton and carbon signals was achieved by extensive 2D-NMR analyses, which elucidated compound **5** as 3-*O*-*β*-D-xylopyranosyl-(1→2)-*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl-(1→2)-]*α*-L-arabinopyranosyl-13,28-epoxy-3*β*,16*α*,23-trihydroxy-28-methoxy-oleanane, or 3-*O*-*β*-D-xylopyranosyl-(1→2)-*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl-(1→2)-]*α*-L-arabinopyranosyl-28-methoxy-anagalligenin B, named monelloside E.

Compound 6, isolated as a white amorphous powder, had a molecular formula of $C_{62}H_{104}O_{28}$, determined on the basis of its HR-ESI-MS negative-ion (1295.6633 $[M-H]^-$, calcd 1295.6636). Comparison of the ^1H and ^{13}C NMR data of **6** to those of **4** and analysis of the 2D NMR spectra of **6** showed that both possessed the same penta-saccharide chain (Tables 2 and 4), while slight differences were observed in the aglycone part, notably those due to the D and E rings (Tables 1 and 3). Compound **6** did not show the signals of a methoxy group bound to C-28 in its NMR spectra, but proton and carbon signals for an *n*-butyloxy group [δ_C 12.8, 19.1, 31.7 and 66.5; δ_H 0.95, 1.42, 1.56, 3.33 and 3.70]. The COSY spectrum supported the presence of the *n*-butyloxy group by correlations observed between CH_2-a (δ_H 3.33 and 3.70)/CH_2-b (δ_H 1.56), CH_2-b/CH_2-c (δ_H 1.42), and CH_2-c/CH_3-d (δ_H 0.95). The linkage of *n*-butyloxy group at the C-28 position of the aglycone was evidenced by the HMBC correlation between δ_H 4.28 (1H, brs, H-28)/δ_C 66.5 (C-a) and δ_H 1.56 (2H, t, J = 6.5Hz, CH_2-b)/δ_C 12.8 (C-d). These evidences led to the assignment of **6** as 3-*O*-*β*-D-glucopyranosyl-(1→4)-[*β*-D-xylopyranosyl-(1→2)-]-*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl-(1→2)-]*α*-L-arabinopyranosyl-13,28-epoxy-3*β*,16*α*,23-trihydroxy-28-*n*-butyloxy-oleanane, or 3-*O*-*β*-D-glucopyranosyl-(1→4)-[*β*-D-xylopyranosyl-(1→2)-]-*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl-(1→2)-]*α*-L-arabinopyranosyl-28-*n*-butyloxy-anagalligenin B, named monelloside F.

Compound 7 was obtained as an amorphous white powder. Its molecular formula was determined as $C_{56}H_{94}O_{23}$ on the basis of its negative-ion in HR-ESI-MS (1133.6107 $[M-H]^-$, calcd 1133.6108), and corresponds to the loss of 162 amu compared to **6**. Comparison of the ^1H- and ^{13}C-NMR data of **7** with those of **6** and **5** showed that the NMR data of **7** exhibited many similarities with those of **6**, particularly for resonances assigned to *n*-butyloxy-anagalligenin B (Table 3), whereas the ^1H and ^{13}C NMR signals due to the saccharide moieties showed that **7** and **5** shared the same tetra-saccharide chain (Tables 2 and 4). These data were confirmed by extensive 2D-NMR analyses and the assignments of all proton and carbon signals of **7**, leading to the elucidation of its structure as 3-*O*-*β*-D-xylopyranosyl-(1→2)-*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl-(1→2)-]*α*-L-arabinopyranosyl-13,28-epoxy-3*β*,16*α*,23-trihydroxy-28-*n*-butyoxy-oleanane, named monelloside G.

Compound 8, isolated as an amorphous white powder, had a molecular formula of $C_{58}H_{94}O_{27}$ (negative-ion HR-ESI-MS (1221.5913 $[M-H]^-$, calcd 1221.5904)). Comparison of the NMR data of **8** with those of **4** (Tables 2 and 4) and analysis of the NMR spectra showed that **8** had the same penta-saccharide moiety as **4**. Most of the aglycone NMR signals were directly attributed by comparison with the corresponding signals of **4** (Tables 1 and 3), but detailed analysis of the NMR spectra showed dissimilarities in the ring D and different chemical shifts for C-14, C-15, C-16, C-27, and C-28, due to the replacement of the hydroxyl at C-16 by a carbonyl group and the absence of signals due to the methoxy group at C-28 in **8** (Tables 1 and 3). The position of the carbonyl group was indicated by HMBC correlations of H-28 [δ_H 3.93 and 3.48; 1H each, d, J = 8.4 Hz] and H-15 [δ_H 2.80 and 1.81; 1H each, d, J = 15.8 Hz, H-15] with the

ketocarbonyl at δ_C 214.3 (C-16) (Liang et al., 2006 ; Liang et al., 2011). The aglycone part was identified as anagalligenone B (Mahato et al., 1991). According to the above results, the structure of compound **8** was elucidated 3-*O*-*β*-D-glucopyranosyl-(1→4)-[*β*-D-xylopyranosyl-(1→2)-]*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl-(1→2)]-*α*-L-arabinopyranosyl-anagalligenone B, named monelloside H.

Compound 9, isolated as an amorphous white powder, had a molecular formula of $C_{52}H_{84}O_{22}$, determined on the basis of its HR-ESI-MS negative-ion (1059.5370 $[M-H]^-$, calcd 1059.5376), indicating the loss of 162 amu compared to **8**. The complete assignments of each ^1H- and ^{13}C-NMR signals were achieved by analysis of the 2D-NMR experiments. The ^1H and ^{13}C NMR data (Tables 3 and 4), were identical to those of compound **8**, except for signals due to the *β*-D-glucopyranosyl (Glc*I*) unit linked in C-2' position of the arabinosyl unit which disappeared in compound **9**. Accordingly, the structure of **9** was elucidated as 3-*O*-*β*-D-glucopyranosyl-(1→4)-[*β*-D-xylopyranosyl-(1→2)-]*β*-D-glucopyranosyl-(1→4)-*α*-L-arabinopyranosyl- anagalligenone B, named monelloside I.

Compound 10 was obtained as an amorphous white powder. Its molecular formula was determined as $C_{58}H_{94}O_{27}$ on the basis of its HR-ESI-MS negative-ion (1221.5911 $[M-H]^-$, calcd 1221.5904). The ^1H NMR and ^{13}CNMR spectra of **10** (Tables 5 and 6) showed signals assignable to six angular methyl groups at δ_H 0.75/δ_{C-24} 11.9, 1.00/δ_{C-25} 15.1, 0.76/δ_{C-26} 16.5, 1.41/δ_{C-27} 25.9, 0.93/δ_{C-29} 32.0 and 0.98/δ_{C-30} 23.1, one olefinic proton at δ_{H-12} 5.42 (1H, t, J = 3.6 Hz; δ_{C-12} 123.0), two oxygenated methine protons at δ_{H-3} 3.63 (1H, m; δ_{C-3} 82.5), and δ_{H-16} 4.29 (1H, t, J = 3.6 Hz; δ_{C-16} 72.5) and one oxygenated methylene (δ_{H-23} 3.30 and 3.73; δ_{C23} 63.3), corresponding to a 3*β*,16*α*,23-trihydroxyolean-12-en skeleton (Bechkri et al., 2020). Moreover, an HSQC correlation between a proton singlet at δ_H 9.23 (1H, s, H_1-28) and its carbon at δ_C 205.6 (C-28) indicated the presence of an aldehyde group. This was confirmed by the HMBC correlations observed between H-18, H-16 with C-28 (Fig. 3) (Lakhal et al., 2014, Zhang et al., 2002). The aglycone of compound **10** was identified as 3*β*,16*α*,23-trihydroxyolean-12-en-28-al. Detailed analysis of the 2D-NMR spectra of **10** and comparison of its NMR data with those of **2** (Tables 2 and 6) identified the same penta-saccharide as in **2**. The HMBC correlations observed between the signal at δ_H 3.63 (H-3) and the anomeric carbon of L-arabinose at $\delta_{C-1'}$ 103.3 1 in the HMBC spectrum (Fig. 3) confirmed that the glycosidic moiety was linked to C-3 of the aglycone (Zhang et al., 2002). According to the above results, the structure of compound **10** was elucidated as 3-*O*-*β*-D-glucopyranosyl-(1→4)-[*β*-D-xylopyranosyl-(1→2)-]*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl-(1→2)-]*α*-L-arabinopyranosyl-3*β*,16*α*,23-trihydroxyolean-12-en-28-al, named monelloside J.

Compound 11 was obtained almost as an amorphous white powder. Its molecular formula was determined as $C_{52}H_{84}O_{22}$ on the basis of its HR-ESI-MS negative-ion (1059.5367 $[M-H]^-$, calcd 1059.5376). Comparison of the NMR data of **11** with those of **10** (Tables 5 and 6) showed that it had the same aglycone as **10** but differed in its saccharide units. The NMR spectroscopic

data of the saccharide part of **11** were identical to those of **1** (Tables 2 and 6). Extensive 2D-NMR analysis enabled the full assignments of the same tetra-saccharide as in **1**. The correlation between H-3 of aglycone (δ_H 3.64, 1H, dd, *J* =11.7, 4.3 Hz,) and the anomeric carbon of the arabinose unit ($\delta_{C\text{-}1'}$ 103.3) on the HMBC spectrum confirmed that the glycosidic moiety was linked to C-3. According to the above evidences, the structure of **11** was elucidated as 3-*O*-*β*-D-xylopyranosyl-(1→2)-*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl-(1→2)-]*α*-L-arabinopyranosyl-3*β*,16*α*,23-trihydroxyolean-12-en-28-al, named monelloside K.

Compound 12 was obtained as an amorphous white powder. Its molecular formula was determined as $C_{53}H_{86}O_{23}$ on the basis of its HR-ESI-MS negative-ion (1089.5490 $[M\text{-}H]^-$, calcd 1089.5482). Comparison of the ^{1}H- and ^{13}C-NMR data of **12** with those of **10** (Tables 5 and 6) showed that it had the same aglycone but differed in its saccharide units. The NMR spectroscopic data of **12** were almost identical to those of **10,** except for the absence of the signals of *β*-D-xylopyranosyl. Detailed analysis of the 2D-NMR spectra of **12** led to the identification of its structure as 3-*O*-*β*-D-glucopyranosyl-(1→4)-*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl-(1→2)-]*α*-L-arabinopyranosyl-3*β*,16*α*,23-trihydroxyolean-12-en-28-al, named monelloside L.

Compound 13 was obtained as an amorphous white powder. Its molecular formula was determined as $C_{47}H_{76}O_{18}$ on the basis of its HR-ESI-MS negative-ion (927.4966 $[M\text{-}H]^-$, calcd 927.4953). Comparison of ^{1}H- and ^{13}C-NMR spectra of **13** (Tables 5 and 6) and **10** indicated a similarity of these two compounds, with the exception of the disappearance of the glucose (GlcIII) and xylose units in the glycosidic part of **13**. Extensive analysis of the 1D- and 2D-NMR spectra of **13** established that the glycosidic sequence was 3-*O*-glc-(1→4)-[glc-(1→2)-]ara. Thus, the structure of compound **13** was elucidated as 3-*O*-*β*-D-glucopyranosyl-(1→4)-*β*-D-glucopyranosyl-(1→4)-[*β*-D-glucopyranosyl-(1→2)]*α*-L-arabinopyranosyl-3*β*,16*α*,23-trihydroxyolean-12-en-28-al, named monelloside M.

The known compounds were identified as repandoside (**14**), lysikoianoside (**15**) (Dall'acqua et al., 2010), capilliposide A (**16**) (Tian et al., 2006), anagallosaponin I (**17**), anagalloside C (**18**), anagalloside B (**19**), desgluconagalloside B (**20**), (Shoji et al., 1994a), anagallosaponin IX (**21**) (Hifnawy et al., 2020), anagallisin D (**22**) (Mahato et al., 1991), heterogenoside D (**23**) (Huang et al., 2009) (Fig. S103 in supporting material). Their spectroscopic data were in perfect agreement with those reported in the literature.

2.1 Chemophenetic significance

Phytochemical studies of the genus *Anagallis* revealed its richness of triterpenoids saponins with an oleanane skeleton. Until now, 38 compounds were isolated from only one species *Anagallis arvensis* (Aliotta et al., 1992; Amoros et al., 1987; De Napoli et al., 1992; Glombitza and Kurth, 1987a; Kitagawa et al., 1976; Mahato et al., 1991; Shoji et al., 1994). The present study, which was carried out on the Algerian subspecies *Anagallis monelli* ssp.

linifolia (L). Maire, allowed the isolation and identification of 13 undescribed monodesmoside saponins (Fig. 1), as well as 10 known monodesmoside saponins (Fig. S103 in supporting material). The aglycones of theses triterpenoid glycosides were found to be priverogenin B (**1**-**2**), anagalligenin B (**3**, **19**, **20**), 28-alkoxy-anagalligenin B (**4**-**7**), anagalligenone B (**8**, **9**, **22**), 16,23-dihydroxy-oleanolicaldehyde (**10**-**13**), protoprimulagenin A (**14**-**15**), 28-hydroxy-protoprimulagenin A (**16**-**17**), 22-acetyl-priverogenin B (**18**), 22-acetoxy-anagalligenin B (**21**), and longispinogenin (**23**). All the 23 saponins isolated from *A. monelli* ssp*. linifolia* in the present study shared a carbohydrate chain linked to C-3 of the aglycone with a common sequence glc-(1→4)-ara- which was further glycosylated by glc and/or ara. In 22 of the 23 isolated saponins, arabinose unit was substituted at its C-2' by another glucose unit (glcII) to give the motif **S6**: glc-(1→4)-[glc-(1→2)-]ara-. In all the bridged oleanane skeleton, except for compound **9** (Fig. 1, **S1**, **S2** and **S3**), a xylose unit was linked to C-2 of glcI making the sequence **S2**: xyl-(1→2)-glc-(1→4)-[glc-(1→2)-]ara-, and this sequence was also found in three (**10**, **11**, **23**) of the five compounds exhibiting ring-opening of the 13,28-epoxy-oleanane skeleton (Fig. 1, F.S103). About half of the compounds isolated from *A. monelli* ssp*. linifolia* were substituted at C-4 of glcII by a third glucose unit (Fig. 1) to give the sequence **S1**: glc-(1→4)-[xyl-(1→2)-]glc-(1→4)-[glc-(1→2)-]ara- which has been encountered in saponins isolated from *A. arvensis* (Glombitza and Kurth 1987b). Similarly, the sequences **S4**: glc-(1→4)-[xyl-(1→2)-]glc-(1→4)-ara-, **S5**: glc-(1→4)-glc-(1→4)-[glc-(1→2)-]ara- and **S6**: glc-(1→4)-[glc-(1→2)-]ara- at C-3 of compounds **9**, **12** and **13**, respectively, were previously encountered in saponins isolated from of *A. arvensis* (Shoji et al., 1994a; Mahato et al., 1991). In addition, all aglycone parts of *A. monelli* ssp*. linifolia* with 13*β*,28-epoxy bridge were previously identified in saponins isolated from *A. arvensis* (Shoji et al., 1994b), except for compounds **4**-**7**, which showed novel features including the C-28 alkoxy group. The known anagallosaponin I (**17**), anagalloside C (**18**), anagalloside B (**19**), desgluconagalloside B (**20**), anagallosaponin IX (**21**) anagallisin D (**22**) were previously isolated from *A. arvensis* (Shoji et al., 1994a; Mahato et al., 1991). It worth to note that the aglycones of compounds **10**-**13** were formerly identified in saponins from *Lysimachia candida* (Zhang et al., 2002), while repandoside (**14**), lysikoianoside (**15**), capilliposide A (**16**) and heterogenoside D (**23**) were previously isolated from *Cyclamen repandum* (Dall'acqua et al., 2010), *Lysimachia sikokiana* (Dall'acqua et al., 2010; Kohda et al., 1989) (**14**, **15**), *Lysimachia capillipes* (**16**) (Tian et al., 2006) and *Lysimachia heterogenea* (**23**) (Huang et al., 2009).

This genus *Anagallis* has traditionally been assigned to the family Primulaceae (Quezel and Santa, 1963). However, data from phylogenetic analyses suggest that *Anagallis*, along with eight other genera, *Lysimachia*, *Trientalis*, *Glaux*, *Asterolinon*, *Pelletiera*, *Coris*, *Ardisiandra*, and *Cyclamen*, be re-located to the family Myrsinaceae (Källersjö et al., 2000; Hao et al., 2004). Moreover, Manns and Anderberg (2009 and 2011) have suggested to re-located

Anagallis species in *Lysimachia* genus. In order to discuss the reclassification of *Anagallis* species in the *Lysimachia* genus, both transferred from the Primulaceae to the Myrsinaceae, we analysed some saponin characteristics of species from the Myrsinaceae and Primulaceae families which showed that these species were characterized by a pentacyclic triterpenoid saponin with 16-*α*-hydroxy and 13*β*,28-epoxy bridge skeleton (Foubert al., 2008). Actually, the Primulaceae family is divided into four subfamilies: Maesoideae, Theophrastoideae, Primuloideae and Myrsinoideae. *Anagallis* was in the Myrsinoideae subfamily, which is consistent of 41 genera and 1435 species including the genus *Ardisia*, *Cyclamen*, *Lysimachia*, and *Myrsine* (Stevens, 2017). So the species previously included in Myrsinaceae family are in the subfamily Myrsinoideae in the Primulaceae family.

In the present species, we have identified a four-unit branched sugar chain linked at C-3 of the aglycone **S2** { xyl-(1→2)-glc-(1→4)-[glc-(1→2)-]ara-} (Fig. 4). This chain was found in saponins of *Anagallis* (Glombitza et al., 1987b, Shoji et al., 1994a and b), *Lysimachia* (Kohda et al., 1989, Podolack et al., 2013), *Cyclamen* (Altunkeyik et al., 2012; Bencharif-Betina et al., 2012, Dall'acqua et al., 2010, El Hosry et al., 2014), *Ardisia* (Jia et al., 1994), *Myrsine* (Bloor and QI, 1994), and *Androsace* genera (Waltho et al., 1986) (Table 7). This tetrasaccharide sequence **S2** can be substituted with glucose at C-4 of glcII or glcI in the case of *Anagallis* saponins (Shoji et al., 1994a and b; Soberón et al., 2017), at C-3 or C-6 of glcII in the case of *Cyclamen* saponins (Çalis et al., 1997), or at C-4 of the terminal glucose (glcI) in the case of *Androsace saxifragaefolia* saponins (Waltho et al., 1986); however, it was the only study found for the genus *Androsace*. In addition, this common chain was substituted with xylose at C-4 of glcII in the case of *Lysimachia* saponins (Podolak et al., 2013b), or with rhamnose at C-3 of glcII in saponins of *Ardisia gigantifolia* (Mu et al., 2010). Many saponins contain rhamnose in the sequence of the sugar moiety in the genera *Ardisia* and *Myrsine* (Foubert al., 2008). For *Primula denticulata*, it was the only species that had similarity in saponin content with the genus *Anagallis*, the other species had completely different osidic chains (Foubert al., 2008). We can conclude that the genera *Anagallis*, *Lysimachia,* and *Cyclamen* are very similar with respect to chemotaxonomic markers and thus can confirm their place in the Myrsinoideae subfamily.

Triterpene saponins identified so far from the genus *Lysimachia*, generally have oleanane-derived sapogenols of two structural types: I. 13*β*,28-epoxy and II. Δ^{12}-17-CH_2OH. Compounds of type I are considered very rare and are found almost exclusively in the Myrsinaceae and Primulaceae families (Foubert et al., 2008; Podolack et al., 2013). In the present study, eighteen type I and one type II triterpene saponins were obtained from *Anagallis monelli* ssp. *linifolia*. It is interesting to observe that the known compounds **14**-**23** were reported previously in various species belonging exclusively to genera traditionally assigned to the family Myrsinaceae or genera which were re-located to this family from the Primulaceae, i.e., *Anagallis, Lysimachia* and *Cyclamen*. Four of the ten known compounds isolated form *A. monelli* ssp. *linifolia* (**14**-**16**, and **23**), having the sequence **S2** at C-3 of the aglycone were

previously isolated from *Lysimachia* species. They may therefore be considered as chemotaxonomic markers for this family, and provide chemical support for phylogenetic analyses, which suggest the transfer of the genus *Lysimachia* to the family Myrsinaceae. It worth to note that *Lysimachia* saponins possess a second tetrasacharide C-3 linked chain, in which a rhamnose can replace the xylose at C-2 of glcII (Dai et al., 2017, Podolak et al., 2013b). The present study reinforces previous reports which indicated that sapogenols with 13*β*,28-epoxy-bridge are the predominant triterpenoid skeleton in species of the Myrsinaceae, including the genus *Anagallis* and can be considered as a chemotaxonomic marker for this plant family (Foubert et al., 2008). A branched four-unit sugar chain **S2**, with arabinose substituted at C-2 with glucose and at C-4 with glucose and terminal xylose, seems to be typical for these Primulaceae saponins.

In conclusion, in our phytochemical research on *A. monelli* ssp. *inifolia,* the chemotaxonomic significance associated with *Anagallis* was discussed. Our results confirmed the richness of *Anagallis* species in oleanan-type glycosides and showed that the sequence **S1** (glc-(1→4)-[xyl-(1→2)-]glc-(1→4)-[glc-(1→2)-]ara-) can be suggested as a chemotaxonomic marker for the genus *Anagallis,* but that proposal needs to be confirmed since only the species *Anagallis arvensis* had been studied before this work. Finally, our phytochemical results increase the knowledge on saponins of the genus *Anagallis* and its family Primulaceae and stimulate to evaluate the biological activities of these saponins.

3. Experimental

3.1 General experimental procedures

The values of the optical rotations were measured by an Anton Paar MCP 5100 polarimeter (Graz, Austria). 1D- and 2D-NMR spectra (^{1}H- and ^{13}C-NMR, ^{1}H-^{1}H COSY, ROESY, HSQC and HMBC) were recorded on a Bruker Avance III-600 spectrometer (Karlsruhe, Germany) equipped with a 5 mm TCI cryoprobe. 2D-NMR experiments were performed using a standard Bruker microprograms (TopSpin 4.0.6 software). HR-ESI-MS experiments were performed on a Waters SYNAPT G2-Si High Resolution Q-TOF Mass Spectrometer equipped with electrospray ionization (ESI) source (Waters Corp., Manchester, UK). Flash chromatography was performed on a GRACE Reveleris X1 system (Flawil, Switzerland) equipped with a Reveleris Navigator and dual UV and ELSD detection using Grace® cartridges (silica gel or RP-C_{18}). Preparative high-performance liquid chromatography (HPLC) was performed on a Gilson PLC 2050 (Saint-Avé, France) equipped with Gilson Glider software, Armen pump and Ecom UV detector, using a RP-C_{18} column (Interchim uptisphere strategy C18-HQ, 5µm, 250x21.2 mm). The mobile phase was composed of H_2O with TFA (0.0025%)/CH_3CN with a flow rate 250 mL/min. The chromatograms were monitored at 205, 215 and 360 nm. Semi-preparative HPLC was performed on an Agilent LC Series instrument (1200 Infinity Series – 1220, Les Ulis, France) equipped with an agilent G1329A sample injector, Jasco CO-4060

column oven (Lisses, France), agilent G1311A pump, Ultimate DAD3000 thermofisher detector (Villebon sur Yvette, France) and chromeleon® 7.2 software. An RP-C_{18} prep column (Interchim uptisphere strategy C18(2), 5µm, 250x10 mm, Montlucon, France). The mobile phase for semi-preparative HPLC was a mixture of H_2O with TFA (0.0025%) and CH_3CN with a flow rate of 5 mL/min. The chromatograms were monitored at 205, 215 and 360 nm. Analytical HPLC experiments were performed using a Thermofisher Ultimate 3000 (Thermo Fischer Scientific, Villebon sur Yvette, France), equipped with an LPG 3400 SD pump, a WPS 3000 SL injector and a UV-DAD-3000 detector with Chromeleon® software version 6.8 and an Interchim uptisphere strategy C18(2) column, 5µm, 250x10 mm, using the same eluent as semi-preparative HPLC with a flow rate of 1 mL/min. The chromatograms were monitored at 205, 215 and 360 nm. Thin layer chromatography (TLC) was carried out on silica gel plates (Merck 60 $F_{254,}$ Darmstadt, Germany) and visualized under UV lamps at 254 and 366 nm, then by spraying with 50% H_2SO_4, followed by heating. All solvents used for Flash chromatography were of analytical grade (Carlo Erba Reactifs SDS, Val de Reuil, France), and solvents used for analytical, semi-preparative and preparative HPLC were of HPLC grade (Carlo Erba Reactifs SDS, Val de Reuil, France). Trifluoroacetic acid (TFA) was purchased from Carlo Erba Reactifs SDS (Val de Reuil, France).

3.2 Plant material

The aerial parts of *Anagalis monelli* ssp. *linifolia* (L.) Maire were collected at Boulilhet, in the province of Oum el Bouaghi, northeast Algeria (latitude 35°43'53.1"N, longitude 6°41'34.0"E and altitude of 970 m) in May 2019. The plant was authenticated by Mr. Kamel Kabouche. A voucher specimen (LOST.Am.05.9.19) was preserved in the LOST laboratory of Université des Freres Mentouri-Constantine 1, Algeria.

3.3. Extraction and isolation

The dried powder of the aerial parts of *Aanagallis monelli* ssp. *linifolia* (L.) Maire (1 kg) was macerated in 70% EtOH (4 × 5 L, 24 h) at room temperature. After filtration and removal of the solvent by evaporation under reduced pressure, the dried 70% EtOH extract (300g, 30% yield) was dissolved in H_2O and then partitioned successively with EtOAc and *n*-BuOH. The *n*-BuOH extract (70 g) was fractionated by Diaion HP-20 resin column (4.3 40 cm), which was eluted with H_2O-MeOH (25, 50 and 100%, each 2 L), to obtain fractions A (10g), B (6g) and C (40g), respectively. Fraction C (40 g) (the saponin-containing fraction) was applied to vacuum liquid chromatography (VLC) over silica gel, using as eluent a mixture of $CHCl_3$-MeOH-H_2O (9:1:0, 8:2:0, 7:3:0, 7:3:0.1, 7:3:0.2, 7:3:0.5 and 100% MeOH) to give 7 fractions (C1-C7). The C4, C6 and C7 fractions (5.4 g), (3.9 g) and (5.1 g) were subjected to flash chromatography on RP-C_{18}, eluted by a gradient of (20→60% CH_3CN, in 35 min), to afford the fractions $C4_1$-$C4_{32}$, $C6_1$-$C6_{32}$ and $C7_1$-$C7_{31}$, respectively. Fractions $C4_{21}$ (1.1 g), $C4_{22\text{-}24}$ (600 mg) and $C4_{26\text{-}27}$ (500 mg) were purified by silica gel flash chromatography, using a gradient system of $CHCl_3$-MeOH-H_2O (8:2:0 → 7:3:2, in 45 min) to give 15 fractions $C4_{21F1}$-$C4_{21F8}$, $C4_{22\text{-}24F1}$-$C4_{22\text{-}24F14}$ and $C4_{26\text{-}27F1}$-

$C4_{26\text{-}27F10}$, respectively. Fraction $C4_{21F7\text{-}8}$ (130 mg) was purified by flash chromatography over RP-C_{18}, eluted by a gradient of (25→60% CH_3CN, in 35 min), to obtain 4 fractions $C4_{21F7\text{-}8f1\text{-}4}$, including compound **1** (32.4mg) as a pure compound in fraction $C4_{21F7\text{-}8f3}$. The purification of fraction $C4_{21F7\text{-}8f4}$ (78.5 mg) was realised by semi-prep. HPLC with a gradient of (30→70% CH_3CN, in 30 min) to give compounds **11** (2.5mg, t_R 15.8 min), **5** (5.3mg, t_R 17.1 min) and **7** (1.1mg, t_R 26.1 min). Fractions $C4_{21F10\text{-}11}$ and $C4_{22\text{-}24F14f5\text{-}6}$ were purified separately by preparative HPLC using the same gradient (30→50% CH_3CN, in 60 min) to afford compounds **6** (1.5mg), **2** (2.7mg) and **18** (1.3mg) and compounds **17** (1.5mg), **19** (2.4mg), **14** (10.2mg), **20** (1.4mg) and **8** (2.8mg), respectively. Fractions $C4_{26\text{-}27F4}$ and $C6_{16}$ were purified separately by semi-prep HPLC with a gradient of (20→80% CH_3CN, in 45 min) to yield compounds **15** (2.8mg, t_R 8.1 min), **9 (**1.5mg, t_R 11.8 min), and **3** (2.2mg, t_R 12.8 min) from $C4_{26\text{-}27F4}$ and compounds **12** (1.0mg, t_R 18.1 min), **10** (1.4mg, t_R 17.6 min), and **13** (1.5mg, t_R 19.4 min) from $C6_{16}$. The fractions $C6_{14}$ and $C7_{22}$ were purified by preparative HPLC, eluted by the gradient (20→30% CH_3CN, in 45 min) to give compounds **23** (1.4mg), **22** (1.2mg)**,** and **4** (3.0mg) from $C6_{14}$, whereas the gradient (30→60% CH_3CN, in 45 min) was used for $C7_{22}$ to give compounds **16** (1.4mg) and **21** (1.8mg).

*3.4. Monelloside A (**1**)*

Amorphous white powder, $[\alpha]^{20}_D$ -9.5 (*c* 0.10, MeOH) ; ^1H (600 MHz, CD_3OD) and ^{13}C (150 MHz, CD_3OD) data: see Tables 1 and 2 ; HR-ESI-MS *m/z*: 1061.5537 $[M\text{-}H]^-$ (calcd for $C_{52}H_{85}O_{22}$, 1061.5532).

*3.5. Monelloside B (**2**)*

Amorphous white powder, $[\alpha]^{20}_D$ -3.0 (*c* 0.10, MeOH) ; ^1H (600 MHz, CD_3OD) and ^{13}C (150 MHz, CD_3OD) data: see Tables 1 and 2 ; HR-ESI-MS *m/z*: 1223.6071 $[M\text{-}H]^-$ (calcd for $C_{58}H_{95}O_{27}$, 1223.6061).

*3.6. Monelloside C (**3**)*

Amorphous white powder, $[\alpha]^{20}_D$ -0.9 (*c* 0.20, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C (150 MHz, CD_3OD) data: see Tables 1 and 2 ; HR-ESI-MS *m/z* : 1103.5629 $[M\text{-}H]^-$ (calcd for $C_{54}H_{87}O_{23}$, 1103.5638).

*3.7. Monelloside D (**4**)*

Amorphous white powder; $[\alpha]^{20}_D$ + 3.2 (*c* 0.28, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C (150 MHz, CD_3OD) data: see Tables 1 and 2 ; HR-ESI-MS *m/z* : (1253.6169 $[M\text{-}H]^-$ (calcd for $C_{59}H_{97}O_{28}$, 1253.6166).

*3.8. Monelloside E (**5**)*

Amorphous white powder; $[\alpha]^{20}_D$ + 12.8 (*c* 0.25, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C (150 MHz, CD_3OD) data: see Tables 1 and 2 ; HR-ESI-MS *m/z* :1091.5646 $[M\text{-}H]^-$ (calcd for $C_{53}H_{87}O_{23}$, 1091. 5638).

*3.9. Monelloside F (**6**)*

Amorphous white powder; $[\alpha]^{20}_D$ + 1.3 (*c* 0.15, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C (150 MHz, CD_3OD) data: see Tables 3 and 4 ; HR-ESI-MS *m/z* : 1295.6633 $[M-H]^-$ (calcd for $C_{62}H_{103}O_{28}$, 1295.6636).

*3.10. Monelloside G (**7**)*

Amorphous white powder; $[\alpha]^{20}_D$ + 10.0 (*c* 0.11, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C (150 MHz, CD_3OD) data: see Tables 3 and 4 ; HR-ESI-MS *m/z* : 1133.6107 $[M-H]^-$ (calcd for $C_{56}H_{93}O_{23}$, 1133.6108).

*3.11. Monelloside H (**8**)*

Amorphous white powder, $[\alpha]^{20}_D$ -9.3 (*c* 0.14, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C (150 MHz, CD_3OD) data: see Tables 3 and 4; HR-ESI-MS *m/z* : 1221.5913 $[M-H]^-$ (calcd for $C_{58}H_{93}O_{27}$, 1221.5904).

*3.12. Monelloside I (**9**)*

Amorphous white powder; $[\alpha]^{20}_D$ -5.5 (*c* 0.11, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C (150 MHz, CD_3OD) data: see Tables 3 and 4; HR-ESI-MS *m/z* : 1059.5370 $[M-H]^-$ (calcd for $C_{52}H_{83}O_{22}$, 1059.5376).

*3.13. Monelloside J (**10**)*

Amorphous white powder; $[\alpha]^{20}_D$ + 15.7 (*c* 0.14, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C (150 MHz, CD_3OD) data: see Tables 5 and 6 ; HR-ESI-MS *m/z* : 1221.5911 $[M-H]^-$ (calcd $C_{58}H_{93}O_{27}$, 1221.5904).

*3.14. Monelloside K (**11**)*

Amorphous white powder; $[\alpha]^{20}_D$ -1.2 (*c* 0.25, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C (150 MHz, CD_3OD) data: see Tables 5 and 6 ; HR-ESI-MS *m/z* : 1059.5367 $[M-H]^-$ (calcd for $C_{52}H_{83}O_{22}$, 1059.5376).

*3.15. Monelloside L (**12**)*

Amorphous white powder; $[\alpha]^{20}_D$ -1.7 (*c* 0.12, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C (150 MHz, CD_3OD) data: see Tables 5 and 6 ; HR-ESI-MS *m/z* : 1089.5490 $[M-H]^-$ (calcd for $C_{53}H_{85}O_{23}$, 1089.5482).

*3.16. Monelloside M (**13**)*

Amorphous white powder; $[\alpha]^{20}_D$ + 2.5 (*c* 0.12, MeOH); ^1H (600 MHz, CD_3OD) and ^{13}C (150 MHz, CD_3OD) data: see Tables 5 and 6 ; HR-ESI-MS *m/z* : 927.4966 $[M-H]^-$ (calcd for $C_{47}H_{75}O_{18}$, 927.4953).

3.17. Acid hydrolysis :

The acid hydrolysis of fraction C (200 mg) rich in saponins was realized with 35 mL of 2 N TFA (trifluoroacetic acid, aqueous solution) at 90 °C for 4h. After extraction with CH_2Cl_2 (10 mL × 3), the aqueous phase was concentrated under vacuum to obtain the sugar residues (100 mg). Three sugars was confirmed by comparison on TLC with pure samples of glucose, xylose and arabinose, using (MeCOEt:iso-PrOH:Me_2CO:H_2O, 20:10:7 :2). The purification of sugars by preparative TLC using the same solvent system afford L-arabinose [5.9 mg, R_f = 0.52, $[\alpha]^{20}_D$

+31.7 (*c* 0.5, H_2O)]; D-glucose [10 mg, R_f = 0.46, $[\alpha]^{20}_D$ +56 (*c* 0.9, H_2O)] and D-xylose [3.2 mg, R_f = 0.63, $[\alpha]^{20}_D$ +15.3 (*c* 0.3, H_2O)].

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors are gratefully acknowledging MESRS Algeria for the PNE grant to M. Chouaib Aouane, ICMR-UMR-7312 as well as URCA PlAneT platform (University Reims Champagne-Ardenne) for giving the possibility to perform all the necessary manipulations for the realization of this publication. Anthony Robert et Carine Machado-Rodrigues were also acknowledge for NMR and MS spectra recording, respectively.

Appendix A. Supplementary data

The original spectra of monellosides A-M, including ^{1}H and ^{13}C NMR, 2D NMR, and HR-ESI-MS are given as supplementary data

References

Ahmad, V. U., Sultana, V., Arif, S., Saqib, Q. N., 1988. Saponins from *Primula denticulate*. Phytochemistry 27(1), 304-306. https://doi.org/10.1016/0031-9422(88)80644-7

Aliotta, G., De Napoli, L., Giordano, F., Picciali, G., Piccialli, V., Santacroce, C., 1992. An oleanane triterpene from *Anagallis arvensis*. Phytochemistry 31(3), 929-933. https://doi.org/10.1016/0031-9422(92)80041-C

Altunkeyik, H.,Gülcemal, D., Masullo, M., Alankus-Caliskan, O., Piacente, S., Karayildirim, T.,2012. Triterpene saponins from *Cyclamen hederifolium*. Phytochemistry 73, 127-133. https://doi.org/10.1016/j.phytochem.2011.09.003

Ammar, S., Mahjoub, M.A., Abdelkader, Ben-Abdlkader, H., Liouane, K., Skandrani, I., Chekir-ghedira, L., Mighri, Z., 2008. Mutagenic, antimutagenic and antioxidant activities of a new polyphenolic and a flavonoid substances isolated from *Anagallis monelli*. Nat. Prod. Res. 22(8), 658-665. https://doi: 10.1080/14786410701669287

Amoros, M., Girre, R., 1987. Structure of two antiviral triterpene saponins from *Anagallis arvensis*. Phytochemistry 26(3), 787-791. https://doi: 10.1016/s0031-9422(00)84787-1

Bechkri, S., Alabdul Magid, A., Sayagh, C., Berrehal, D., Harakat, D., Voutquenne-Nazabadioko, L., Kabouche, Z., Kabouche, A., 2020. Triterpene saponins from *Silene gallica* collected in North-Eastern Algeria. Phytochemistry 172, 112274. https://doi:10.1016/j.phytochem.2020.112274

568 Bencharif-Betina, S., Miyamoto, T., Tanaka, C., Kabouche, Z., Mitaine-Offer, A-C., Lacaille-
569 Dubois, M.A., 2012. Two new triterpene saponins from *Cyclamen africanum* Boiss. &
570 Reuter. Helv. Chim. Acta 95, 1573-1580. https://doi.10.1002/hlca.201200041
571 Bloor, S.J., Qi, L., 1994. Cytotoxic saponins from New Zealand *Myrsine* species. J. Nat. Prod.
572 57, 1354-1360. https://doi.10.1021/np50112a004
573 Çalis, I.,Satana, M. E., Yürüker, A., Kelican, P., Demirdamar, R., Alaçam, R., Tanker, N.,
574 Rüegger, H., Sticher, O., 1997a. Triterpene saponins from *Cyclamen mirabile* and their
575 biological activities J. Nat. Prod. 60(3), 315-318. https://doi/10.1021/np960658j
576 Çalis, I., Yürüker, A., Tanker, N., Wright, A.D., Sticher, O., 1997b. Triterpene saponins from
577 Cyclamen coum var. coum. Planta Med. 63(2), 166-170. https://doi:10.1055/s-2006-
578 957637
579 Dai L.-M., Huang R.-Z., Zhang B., Hua J., Wang H.-S., Liang D., Cytotoxic triterpenoid
580 saponins from *Lysimachia foenum-graecum* Phytochemistry 2017 165-174.
581 https://doi.org/10.1016/j.phytochem.2017.01.021
582 Dall'Acqua, S., Castagliuolo, I., Brun, P., Ditadi, F., Palù, G., Innocenti, G., 2010. Triterpene
583 glycosides with in vitro anti-inflammatory activity from *Cyclamen repandum* tubers.
584 Carbohydr. Res. 345(5), 709-714. https://doi: 10.1016/j.carres.2009.12.028
585 De Napoli, L., Piccialli, G., Piccialli, V., Santacroce, C., Carolla, R., 1992. Two oleanane
586 triterpenes from *Anagallis arvensis*. Phytochemistry 31(11), 3965-3968. https://doi:
587 10.1016/S0031-9422(00)97564-2
588 El Hosry, L., Di Giorgio, C., Birer, C., Habib, J., Tueni, M., Bun, S-S., Herbette, G-T., De Meo,
589 M., Ollivier, E., Elias, R., 2014. In vitro cytotoxic and anticlastogenic activities of
590 saxifragifolin B and cyclamin isolated from *Cyclamen persicum* and *Cyclamen*
591 *libanoticum*. Pharm Biol, 52(9), 1134–1140. https://doi:10.3109/13880209.2013.879600
592 Foubert, K., Theunis, M., Apers, S., Vlietinck, A. J., Pieters, L. 2008. Chemistry, distribution
593 and biological activities of 13, 28-epoxy-oleanane saponins from the plant families
594 Myrsinaceae and Primulaceae. Curr. Org. Chem. 12(8), 629-642.
595 https://doi.org/10.2174/138527208784577376
596 Glombitza, K.W., Kurth, H., 1987a. Die Struktur einiger Triterpensaponine aus *Anagallis*
597 *arvensis*. Planta Med. 53(6), 548-555. https://doi:10.1055/s-2006-962809
598 Glombitza, K.W., Kurth, H., 1987b. Saponine aus *Anagallis arvensis* L.(Primulaceae). Arch.
599 Pharm. 320(10), 1083-1087. https://doi:10.1002/ardp.198700012
600 Hao, G., Yuan, Y.M., Hu, C.M., Ge, X.J., Zhao, N.X., 2004. Molecular phylogeny of *Lysimachia*
601 (Myrsinaceae) based on chloroplast trnL-F and nuclear ribosomal ITS sequences. Mol.
602 Phylogen. Evol. 31, 323-339. https://doi.org/10.1016/S1055-7903(03)00286-0
603 Heitz, S., Billet, D., Raulais, D., 1971. Triterpenes d'*Anagallis arvensis* L.(Primulaceae). I.
604 Structure de l'anagalligenone B. Soc. Chim. France Bull. 230-243

605 Hifnawy, M. S., Aboseada, M. A., Hassan, H. M., AboulMagd, A. M., Tohamy, A. F., Abdel-
606 Kawi, S. H., Rateb, M. E., El-Naggar, E. B., Liu, M., Quinn, R. J., Alhadram, H. A.,
607 Abdelmohsen, U. R., 2020. Esticular caspase-3 and β-catenin regulators predicted via
608 comparative metabolomics and docking studies. Metabolites 10(1), 31.
609 https://doi: 10.3390/metabo10010031
610 Huang, X.A., Liang, Y.J., Cai, X.l., Feng, X.Q., Zhang, C.H.,Fu, L.W., 2009. Four new cytotoxic
611 oligosaccharidic derivatives of 12-oleanene from *Lysimachia heterogenea* Klatt. Bioorg.
612 Med. Chem. lett. 19(23), 6515-6518. https://doi: 10.1016/j.bmcl.2009.10.056
613 Huang, X-A., Shen, X-L., Hu, Y-J., Liu, Y-M., Liu, K-L., Zhang, F-X., Zhou, X-X., 2011. Two
614 New Triterpenoids from *Lysimachia heterogenea* Klatt and Evaluation of Their
615 Cytotoxicity. Molecules 16, 8076-8082. https://doi:10.3390/molecules16098076
616 Ishikura, N., 1981. Flavonoids in the petal cells of *Anagallis arvensis* f. coerulea containing a
617 blue crystalline anthocyanin. Z. Pflanzenphysiol. 103(5), 469-473.
618 https://doi: 10.1016/s0044-328x(81)80170-5
619 Jia, Z., Koike, K., Ohmoto, T., Ni, M., 1994. Triterpenoid saponins from *Ardisia crenata*.
620 Phytochemistry 37,1389-1396. https://doi.org/10.1016/S0031-9422(00)90418-7
621 Jansakul, C., Baumann, H., Kenne, L., Samuelsson, G., 1987. Ardisiacrispin A and B, two
622 utero-contracting saponins from *Ardisia crispa.* Planta Med. 53(5) 405-409. https://doi:
623 10.1055/s-2006-962758.
624 Källersjö, M., Bergqvist, G., Anderberg, A., 2000. Generic realignment in primuloid families of
625 the Ericales sl: a phylogenetic analysis based on DNA sequences from three chloroplast
626 genes and morphology. Am. J. Bot. 87(9), 1325-1341. https://doi: 10.2307/2656725
627 Kawashty, S. A., El-Garf, I. A., El-Negoumy, S. I., 1998. Chemosystematics of *Anagallis*
628 *arvensis* L. (Primulaceae). Biochem. System. Ecol. 26(6), 663-668.
629 https://doi: 10.1016/s0305-1978(98)00008-8
630 Kohda, H., Takeda, O., Tanaka, S., 1989. Molluscicidal triterpenoidal saponin from *Lysimachia*
631 *sikokiana*. Chem. Pharm. Bull. 37(12), 3304-3305. https://doi.org/10.1248/cpb.37.3304
632 Kitagawa, I., Matsuda, A., Yosioka, I., 1972. Saponin and sapogenol. VII. Sapogenol
633 constituents of five primulaceous plants. Chem. Pharm. Bull. 20(10), 2226-2234.
634 https://doi: 10.1248/cpb.20.2226
635 Kitagawa, I., Ikenishi, Y., Yoshikawa, M., Yosioka, I., 1976. Saponin and sapogenol. XVII.
636 Structure of sakuraso-saponin, a pentaglycoside of protoprimulagenin A from the root of
637 *Primula sieboldi* E. Morren. Chem. Pharm. Bull. 24(10), 2470-2479.
638 https://doi: 10.1248/cpb.24.2470
639 Koczurkiewicz, P., Czyz, J., Podolak, I. Wojcik, K. Galanty, A. Janeczko, Z., Michalik, M., 2015.
640 Multidirectional effects of triterpene saponins on cancer cells - mini-review of i*n vitro*
641 studies. Acta Biochim. Pol. 62(3), 383-393. https://doi:10.18388/abp.2015_1089

642 Lakhal, H., Kabouche, A., Alabdul Magid, A., Voutquenne-Nazabadioko, L., Harakat, D.,
643 Kabouche, Z., 2014. Triterpenoids from *Salvia argentea* var. *aurassiaca* (Pomel) Batt.&
644 Trab. and their chemotaxonomic significance. Phytochemistry 102, 145-151.
645 https://doi:10.1016/j.phytochem.2014.03.009
646 Lavaud, C., Massiot, G., Barrera, J. B., Moretti, C., Le Men-Olivier, L., 1994. Triterpene
647 saponins from *Myrsine pellucida*. Phytochemistry 37(6), 1671-1677. https://doi:
648 10.1016/s0031-9422(00)89590-4.
649 Lehbili, M., Alabdul Magid, A., Kabouche, A., Voutquenne-Nazabadioko, L., Morjani, H.,
650 Harakat, D., Kabouche, Z., 2018. Triterpenoid saponins from *Scabiosa stellata* collected
651 in North-eastern Algeria. Phytochemistry 150, 40-49.
652 https://doi: 10.1016/j.phytochem.2018.03.005
653 Liang, B., Tian, J.-K., Xu, L.-Z., Yang, S.L., 2006. Triterpenoid saponins from *Lysimachia*
654 *davurica*. Chem. Pharm. Bull. 54(10), 1380-1383. https://doi: 10.1248/cpb.54.1380
655 Liang, D., Hao, Z.Y., Zhang, G.J., Zhang, Q.J., Chen, R.Y., Yu, D.Q., 2011. Cytotoxic
656 triterpenoid saponins from *Lysimachia clethroides*. J. Nat. Prod. 74(10), 2128-2136.
657 https://doi: 10.1021/np2004038
658 López, V., Jäger, A., Akerreta, S., Covero,R., Calvo, M., 2011. Pharmacological properties of
659 *Anagallis arvensis* L.("scarlet pimpernel") and *Anagallis foemina* Mill. ("blue pimpernel")
660 traditionally used as wound healing remedies in Navarra (Spain). J. Ethnopharmacol.
661 134(3), 1014-1017. https://doi: 10.1016/j.jep.2010.12.036
662 Mahato, S.B., Sahu, N.P., Roy, S.K., Sen, S., 1991. Structure elucidation of four new
663 triterpenoid oligoglycosides from *Anagallis arvensis.* Tetrahedron 47(28), 5215-5230.
664 https://doi: 10.1016/s0040-4020(01)87133-7
665 Manns, U and Anderberg, A.A., 2009. New combinations and names in *Lysimachia*
666 (Myrsinaceae) for species of *Anagallis*, *Pelletiera* and *Trientalis*. Willdenowia 39, 49-54.
667 https://doi: org/10.3372/wi.39.39103
668 Manns, U., Anderberg, A.A., 2011. Biogeography of 'tropical Anagallis'(Myrsinaceae) inferred
669 from nuclear and plastid DNA sequence data. J. biogeogr. 38(5), 950-961.
670 https://doi:org/10.1111/j.1365-2699.2010.02454.x.
671 Mihci-Gaidi, G., Ozbey, S., Orhan, I., Sener, B., Miyamoto, T., Mirjolet, J.F., Duchamp, O.,
672 Mitaine-Offer, A.C., Lacaille-Dubois, M.A., 2010. Triterpene saponins from *Cyclamen*
673 *trocopteranthum*. Planta Med. 76(8), 818-821. https://doi:10.1055/s-0029-1240727
674 Mu, L-H., Gong, Q-Q., Zhao, H-X., Liu, P., 2010. Triterpenoid saponins from *Ardisia*
675 *gigantifolia*. Chem. Pharm. Bull. 58(9), 1248-1251 https://doi.org/10.1248/cpb.58.1248
676 Netala, V.R., Ghosh, S.B., Bobbu, P., Anitha, D., Tartte, V., 2015. Triterpenoid saponins: a
677 review on biosynthesis, applications and mechanism of their action. Int. J. Pharm.
678 Pharm. Sci. 7(1), 24-28.

679 Podolak, I., Elas, M., Cieszka, K., 1998. *In vitro* antifungal and cytotoxic activity of triterpene
680 saponosides and quinoid pigments from *Lysimachia vulgaris* L. Phytother. Res. 12, S70.
681 https://doi.org/10.1002/(SICI)1099-1573(1998)12:1+<S70::AID-PTR254>3.0.CO;2-9
682 Podolak, I., Galanty, A. Sobolewska, D., 2010. Saponins as cytotoxic agents: a review.
683 Phytochem. Rev. 9:425–474. https://doi:10.1007/s11101-010-9183-z
684 Podolak, I., Koczurkiewicz, P., Galanty, A., Michalik, M., 2013. Cytotoxic triterpene saponins
685 from the underground parts of six *Lysimachia* L. species. Biochem. System. Ecol. 47,
686 116-120. https://doi: 10.1016/j.bse.2012.10.003
687 Quezel, P., Santa, S., 1963. Nouvelle flore de l'Algérie et des régions désertiques
688 méridionales. Retrieved from French National Center for Scientific Research, pp.726-
689 727.
690 Rastogi, J., Norula, J., 1980. Chemical investigations of *Anagallis arvensis* flowers. J Indian
691 Chem. Soci. 57, 761-762.
692 Reznicek, G., Jurenitsch, J., Robien, W., Kubelka, W., 1989. Saponins in *Cyclamen* species:
693 configuration of cyclamiretin C and structure of isocyclamin. Phytochemistry 28(3), 825-
694 828. https://doi.org/10.1016/0031-9422(89)80123-2
695 Saxena, S., Rao, P., 2021. Pharmacological and phytochemical assessment of *Anagallis*
696 *arvensis* L. leaf extracts. Asian J. Chem. 33(8), 1831-1841. https://doi:
697 org/10.14233/ajchem.2021.23265
698 Shoji, N., Umeyama, A., Yoshikawa, K., Arihara, S., 1994a. Triterpenoid glycosides from
699 *Anagallis arvensis.* Phytochemistry 37(5), 1397-1402. https://doi:10.1016/s0031-
700 9422(00)90419-9
701 Shoji, N., Umeyama, A., Yoshikawa, K., Arihara, S., 1994b. Structures of anagallosaponins I-
702 V and their companion substances from *Anagallis arvensis* L. Chem. Pharm. Bull. 42(9):
703 1750-1755. https://doi: 10.1248/cpb.42.1750
704 Soberón, J.R., Sgariglia, M.A., Pastoriza, A.C., Soruco, E.M., Jäger, S.N., Labadie,
705 G.R.,Sampietro D.A., Vattuone, M.A., 2017. Antifungal activity and cytotoxicity of
706 extracts and triterpenoid saponins obtained from the aerial parts of *Anagallis arvensis* L.
707 J. Ethnopharmacol. 203, 233-240. https://doi: 10.1016/j.jep.2017.03.056
708 Stevens, P. F. (2001 onwards). Angiosperm Phylogeny Website. Version 14, July 2017 [and
709 more or less continuously updated since]. "
710 http://www.mobot.org/MOBOT/research/APweb/.
711 Tian, J.K., Xu, L.Z., Zou, Z.M., Yang, S.L., 2006. Three novel triterpenoid saponins from
712 *Lysimachia capillipes* and their cytotoxic activities. Chem. Pharm. Bull. 54(4), 567-569.
713 https://doi: 10.1248/cpb.54.567
714 Valdes, B., Talavera, S., Fernandez-Galiano, E., 1987. Flora Vascular de Andalucia
715 Occidental. Ketres editora. vol.1.pp 465

Waltho, J. P., Williams, D. H., Mahato, S. B., Pal, B. C., Barna, J.C. J., 1986. Structure elucidation of two triterpenoid tetrasaccharides from *Androsace saxifragifolia*. J. Chem. Soc. Perkin Trans. I, 1527-1531. https://doi.org/10.1039/P19860001527

Yasmeen, Z., Basit, A., Tahir, S., 2020. Traditional uses and pharmacological effects of *Anagallis arvensis* : A Review. Int. J. Front. Sci. 4, 97-100 https://doi.org/10.37978/tijfs.v4i2.294

Yosioka, I., Nishimura, T., Watani, N., Kitagawa, I., 1967. On the unexpected identity of theasapogenol D (= camelliagenin A), a minor sapogenol of tea seeds, with dihydropriverogenin A. Tetrahedron Lett. 8(52), 5343-5347. https://doi.org/10.1016/S0040-4039(01)89675-1

Zhang, X.R., Peng, S.L., Wang, M.K., Ding, L.S., 2002. A new triterpenoid saponin from *Lysimachia candida*. Zhongcaoyao 33(6), 481-483.

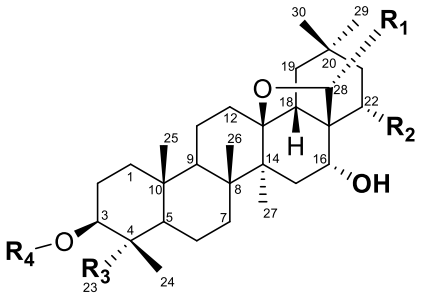
List of Figure caption

Fig. 1. Structures of compounds **1–13** isolated from *Anagallis monelli* ssp. *linifolia*

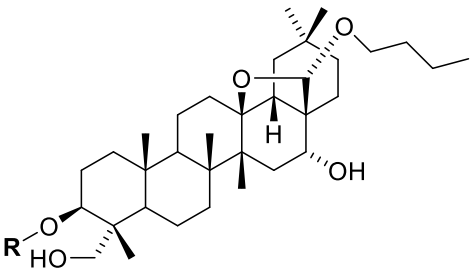
Fig. 2. Key HMBC and ROESY correlations for compound **1**.

Fig. 3. Key HMBC correlations for compound **10**.

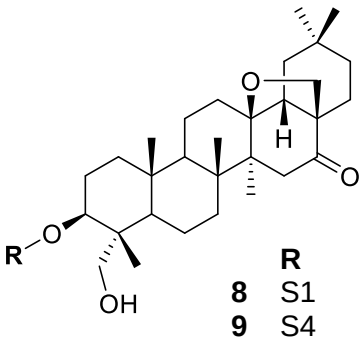
Fig. 4. The common carbohydrate chain linked on the C-3 of 13,28-epoxy-3,16-oleananediol derivatives skeleton structure of species in the Myrsinaceae and Primulaceae



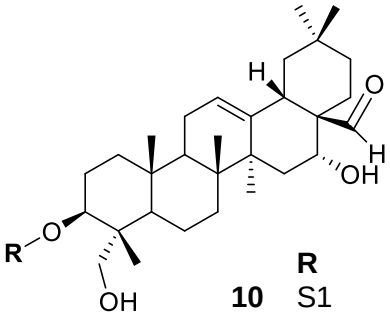
	R_1	R_2	R_3	R_4
1	H	OH	CH_3	S2
2	H	OH	CH_3	S1
3	H	H	CH_2OH	S3
4	OCH_3	H	CH_2OH	S1
5	OCH_3	H	CH_2OH	S2



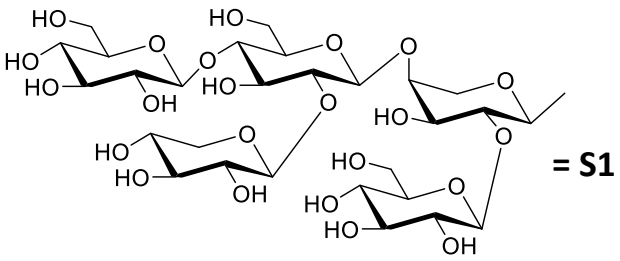
	R
6	S1
7	S2



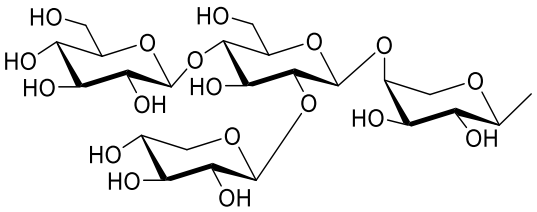
	R
8	S1
9	S4



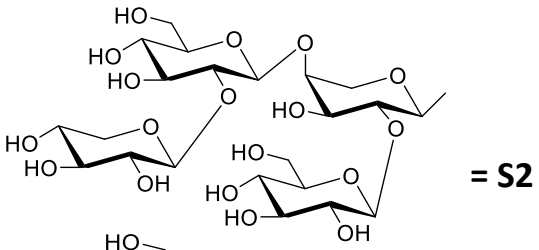
	R
10	S1
11	S2
12	S5
13	S6



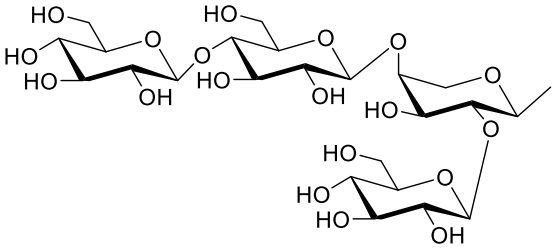
= S1



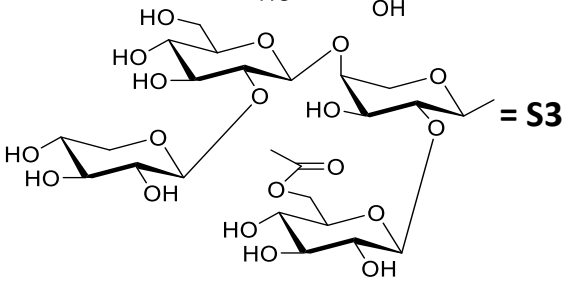
= S4



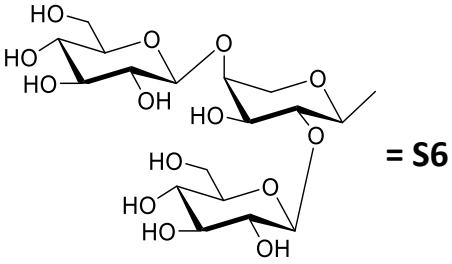
= S2



= S5



= S3



= S6

Fig. 1. Structures of compounds **1–13** isolated from *Anagallis monelli* ssp. *Linifolia*

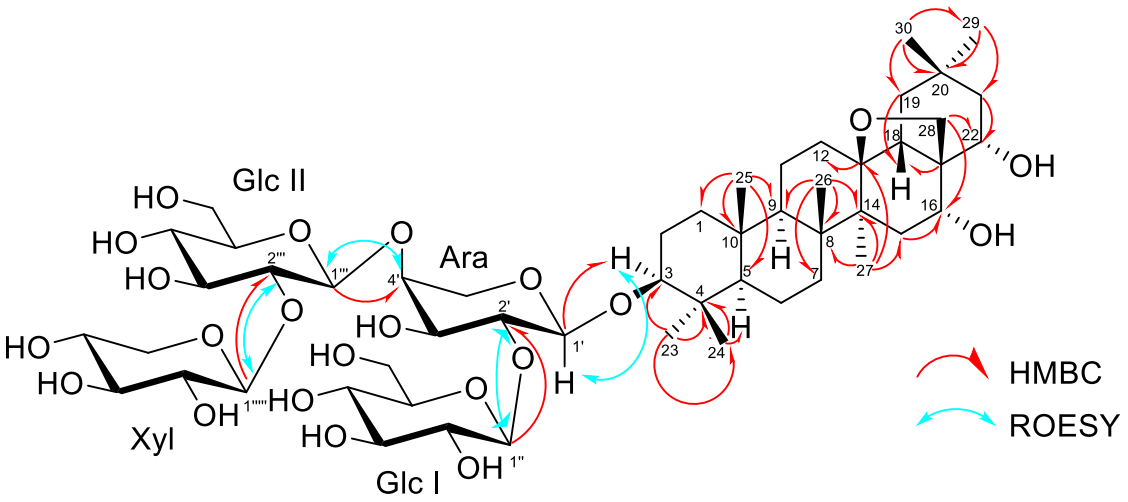


Fig. 2. Key HMBC and ROESY correlations for compound **1**.

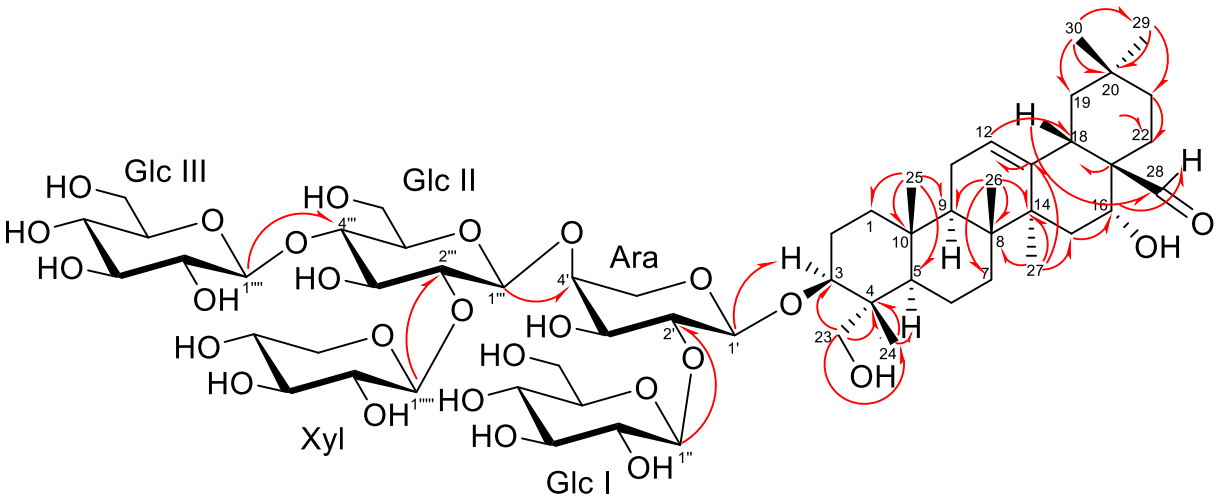


Fig. 3. Key HMBC correlations for compound **10**.

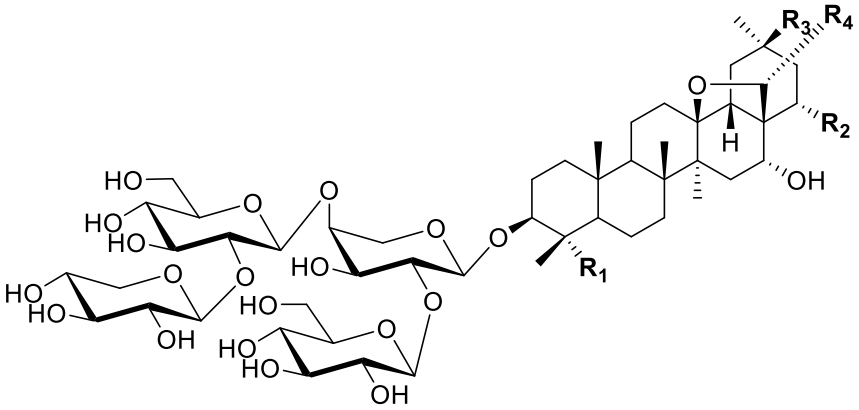


Fig. 4. The common carbohydrate chain linked on the C-3 of 13,28-epoxy-3,16-oleananediol derivatives skeleton structure of species in the Myrsinaceae and Primulaceae

Table 1

^{13}C NMR and ^{1}H NMR spectroscopic data of aglycone moieties for compounds **1**–**5** in CD_3OD.[a, b]

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	38.8	0.98 m 1.77 m	38.8	0.97 m 1.77 m	38.5	0.95 m 1.75 m	38.6	0.96 m 1.77 m	38.6	0.96 m 1.77 m
2	25.8	1.76m 1.88m	25.8	1.76 m 1.87 m	25.3	1.77 t (12.5) 1.88 m	25.2	1.80 m 1.89 m	25.2	1.80 m 1.89 m
3	90.0	3.16 dd (11.7, 4.3)	90.0	3.16 dd (11.7, 4.3)	81.9	3.58 dd (11.9, 4.7)	82.5	3.62 m	82.5	3.62 m
4	39.2	–	39.2	–	42.9	–	42.9	–	42.9	–
5	55.4	0.74 dd (9.4, 4.5)	55.4	0.74 dd (11.3, 2.8)	46.4	1.19 m	46.8	1.17 dd (9.9, 2.7)	46.8	1.17 dd (9.9, 2.7)
6	17.4	1.47 m 1.54 m	17.3	1.46 m 1.54 m	16.8	1.41 m 1.45 m	16.9	1.42 m 1.46 m	16.9	1.42 m 1.46 m
7	33.7	1.26 t (13.4) 1.56 m	33.7	1.25 m 1.56 m	33.2	1.19 m 1.67 td (13.2, 3.8)	33.2	1.19 m 1.69 m	33.2	1.19 m 1.69 m
8	42.1	–	42.1	–	41.8	–	41.9	–	41.9	–
9	50.0	1.28 m	49.9	1.27 m	49.9	1.32 m	50.0	1.29 m	50.0	1.29 m
10	36.4	–	36.4	–	36.2	–	36.2	–	36.2	–
11	18.5	1.49 m 1.64 dd (12.5, 4.4)	18.5	1.49 m 1.64 dd (12.7, 3.4)	18.5	1.49 m 1.64 m	18.6	1.47 m 1.69 m	18.6	1.47 m 1.69 m
12	32.1	1.31 m 2.06 m	32.1	1.31 m 2.06 m	31.9	1.29 m 2.07 m	32.3	1.32 m 2.01 m	32.3	1.32 m 2.01 m
13	86.9	–	86.9	–	87.0	–	87.6	–	87.6	–
14	44.5	–	44.5	–	44.0	–	42.7	–	42.7	–
15	35.5	1.28 m 2.09 m	35.5	1.27 m 2.08 m	35.6	1.23 d (15.7) 2.13 m	35.7	1.22 d (15.2) 2.01 m	35.7	1.22 d (15.2) 2.01 m
16	69.8	4.33 d (5.0)	69.8	4.32 br s	76.7	3.90 d (4.7)	75.8	3.83 d (5.2)	75.8	3.83 d (5.2)
17	49.1	–	49.1	–	43.9	–	47.9	–	47.9	–
18	50.7	1.47 dd (14.0, 2.5)	50.7	1.46 dd (12.5, 2.1)	51.0	1.52 dd (14.0, 4.7)	46.7	1.71 m	46.7	1.71 m
19	37.6	1.15 m 2.46 dd (14.1, 12.3)	37.6	1.15 m 2.45 dd (13.9, 12.5)	38.4	2.40 dd (14.0, 12.2) 1.21 d (12.6)	38.4	1.17 m 2.30 dd (14.5,12.0)	38.4	1.17 m 2.30 dd (14.5,12.0)
20	32.5	–	32.5	–	31.0	–	31.0	–	31.0	–
21	44.7	1.40 dd (12.3, 4.9) 2.20 t (12.3)	44.7	1.39 m 2.19 t (11.7)	36.0	1.15 m 2.10 m	36.0	1.15 m 2.06 t (13.3)	36.0	1.15 m 2.06 t (13.3)
22	74.2	3.74 dd (11.6, 4.9)	74.2	3.72 m	30.8	1.52 td (13.2, 4.4) 1.79 d (13.2)	25.1	1.98 m 1.42 dm (12.4)	25.1	1.98 m 1.42 dm (12.4)
23	27.0	1.08 s	27.0	1.07 s	62.9	3.21 d (11.2) 3.79 d (11.2)	63.2	3.30 d (11.5) 3.73 d (11.5)	63.2	3.30 d (11.5) 3.73 d (11.5)
24	15.3	0.87 s	15.3	0.86 s	11.9	0.68 s	11.7	0.73 s	11.7	0.73 s
25	15.3	0.92 s	15.3	0.92 s	15.8	0.93 s	15.8	0.96 s	15.8	0.96 s
26	17.4	1.17 s	17.4	1.17 s	17.4	1.17 s	17.5	1.20 s	17.5	1.20 s
27	18.7	1.28 s	18.7	1.28 s	18.5	1.27 s	18.4	1.25 s	18.4	1.25 s
28	76,7	3.67 m	76,7	3.67 s	77.3	3.14 d (7.6) 3.52 d (7.6)	105.5	4.19 s	105.5	4.19 s
29	32.3	1.00 s	32.3	1.00 s	32.5	0.97 s	32.5	0.94 s	32.5	0.94 s
30	24.6	0.98 s	24.6	0.96 s	23.5	0.93 s	23.5	0.90 s	23.5	0.90 s
OAc					171.5	-		-		-
CH_3					19.6	2.08 s	53.9	3.33 s	53.9	3.33 s

[a] in ppm, *J* in parentheses in Hz.

[b] NMR spectra recorded at 500 or 600 MHz (^{1}H) and at 125 or 150 MHz (^{13}C).

Table 2

^{13}C NMR and ^{1}H NMR spectroscopic data of the sugar moieties for compounds **1**–**5** in CD_3OD.[a, b]

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
C3	**Ara**		**Ara**		**Ara**		**Ara**		**Ara**	
1'	104.2	4.41 d (6.6)	104.2	4.42 d (6.3)	103.4	4.43 d (6.8)	103.3	4.46 d (6.3)	103.3	4.46 d (5.8)
2'	78.0	3.82 m	78.0	3.82 m	79.9	3.73 dd (8.2, 6.8)	78.3	3.79 m	78.3	3.79 dd (8.7, 5.8)
3'	72.9	3.81 m	72.9	3.81 m	73.3	3.79 d (9.0)	73.1	3.80 m	73.0	3.80 dd (5.8, 3.3)
4'	78.8	3.90 m	78.8	3.90 m	78.7	3.92 m	78.8	3.91 m	78.7	3.91 m
5'	64.4	3.55 dd (12.5, 3.8)	64.3	3.55 dm (12.5)	64.5	3.53 d (12.5)	64.4	3.55 dm (12.6)	64.4	3.55 dd (12.7, 1.2)
		4.23 dd (12.5, 2.8)		4.22 d (12.5)		4.19 dd (11.9, 5.4)		4.22 dd (12.6, 2.9)		4.24 dd (12.7, 2.5)
	Glc I		**Glc I**		**Glc I**		**Glc I**		**Glc I**	
1''	103.0	4.71 d (7.7)	103.1	4.43 d (8.3)	103.7	4.71 d (7.6)	102.9	4.73 d (7.7)	102.9	4.73 d (7.8)
2''	74.6	3.21 dd (8.9, 7.7)	73.5	3.24 t (8.9)	74.6	3.25 t (7.6)	74.6	3.24 t (9.4, 7.7)	74.6	3.22 dd (9.1, 7.8)
3''	76.4	3.39 t (9.3)	76.6	3.30 m	76.4	3.41 t (9.0)	76.4	3.39 t (9.2)	76.4	3.40 t (9.1)
4''	70.6	3.19 t (9.2)	69.9	3.32 m	69.8	3.35 t (9.5)	70.4	3.20 t (9.3)	70.4	3.21 t (9.1)
5''	76.7	3.29 m	76.7	3.30 m	76.8	3.46 m	76.7	3.29 m	76.7	3.29 m
6''	61.9	3.62 dd (12.0, 6.7)	61.0	3.68 dd (10.4, 2.6)	63.5	4.20 dd (11.5, 2.5)	61.7	3.62 dd (12.1, 6.7)	61.7	3.62 dd (11.9, 6.6)
		3.86 dd (12.0, 2.0)		3.89 m		4.34 dd (11.5, 2.0)		3.87 dd (12.1, 2.1)		3.86 dd (11.9. 4.3)
	Glc II		**Glc II**		**Glc II**		**Glc II**		**Glc II**	
1'''	103.4	4.54 d (7.8)	103.3	4.57 d (8.8)	103.2	4.56 d (7.2)	103.2	4.58 d (7.8)	103.3	4.54 d (7.8)
2'''	83.7	3.41 dd (8.9, 7.8)	83.1	3.48 t (9.0)	83.6	3.44 dd (9.0, 7.2)	83.1	3.48 dd (9.0, 7.8)	83.7	3.40 t (8.5)
3'''	76.2	3.57 t (8.9)	74.7	3.75 t (9.0)	76.2	3.56 t (9.0)	74.6	3.75 t (9.1)	76.2	3.55 t (9.3)
4'''	69.7	3.35 m	78.5	3.63 t (8.9)	69.6	3.37 t (9.0)	78.5	3.63 t (9.2)	69.7	3.35 t (9.4)
5'''	76.7	3.34 m	75.1	4.30 m	76.5	3.28 m	75.1	3.44 dt (9.6, 3.6)	76.5	3.30 m
6'''	61.2	3.69 dd (12.4, 6.2)	60.3	3.89 m	61.1	3.68 dd (12.2, 5.4)	60.3	3.88 m	61.1	3.68 dd (11.9, 5.6)
		3.88 d (12.4)		3.88 m		3.87 d (12.2, 2.2)		3.88 m		3.87 dd (11.9, 4.1)
			Glc III				**Glc III**			
1''''			102.9	4.71 d (7.3)			103.1	4.43 d (7.9)		
2''''			74.6	3.10 dd (8.9, 7.3)			73.5	3.23 dd (9.0, 7.9)		
3''''			76.4	3.39 m			76.4	3.37 t (9.0)		
4''''			70.6	3.18 t (8.9)			69.9	3.32 m		
5''''			76.7	3.30 m			76.7	3.35 m		
6''''			61.9	3.60 dd (11.0, 4.7)			61.0	3.68 dd (11.7, 5.2)		
				3.86 d (11.0)				3.89 dd (11.7, 1.9)		
	Xyl		**Xyl**		**Xyl**		**Xyl**		**Xyl**	
1'''''	105.9	4.53 d (7.6)	105.9	4.56 d (7.8)	105.9	4.55 d (6.8)	106.0	4.56 d (7.5)	105.9	4.53 d (7.8)
2'''''	74.5	3.27 dd (8.7, 7.6)	74.6	3.26 t (7.8)	74.5	3.27 dd (9.0, 6.8)	74.6	3.26 dd (8.2, 7.5)	74.5	3.27 dd (9.2, 7.8)
3'''''	76.5	3.39 m	76.1	3.37 m	76.3	3.36 t (9.0)	76.1	3.37 m	76.2	3.37 t (9.2)
4'''''	69.6	3.54 m	69.6	3.52 m	69.5	3.52 m	69.6	3.52 m	69.6	3.53 m
5'''''	66.0	3.32 m	66.0	3.32 m	66.0	3.30 m	66.0	3.32 m	66.0	3.31 m
		4.01 dd (11.3, 5.2)		4.01 dd (11.5, 5.7)		3.99 dd (11.5, 5.4)		4.00 dd (11.4, 5.2)		4.00 dd (11.4, 5.4)
OAc					171.5	-				
CH_3					19.6	2.08 S				

[a] in ppm, *J* in parentheses in Hz.

[b] NMR spectra recorded at 500 or 600 MHz (^{1}H) and at 125 or 150 MHz (^{13}C).

Table 3

^{13}C NMR and ^{1}H NMR spectroscopic data of aglycone moieties for compounds **6**–**9** in CD_3OD.[a, b]

Position	**6**		**7**		**8**		**9**	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
1	38.6	0.95 m 1.77 m	38.6	0.95 m 1.77 m	38.5	0.97 m 1.78 m	38.5	0.95 m 1.76 m
2	25.2	1.81 m 1.89 m	25.2	1.82 t (12.9) 1.90 m	25.2	1.81 m 1.90 m	25.1	1.77 m 1.90 m
3	82.5	3.62 m	82.5	3.63 m	82.3	3.63 d (8.9)	81.7	3.63 dd (12.0, 4.8)
4	42.9	–	42.9	–	42.9	–	42.7	–
5	46.8	1.17 m	46.8	1.18 m	46.6	1.18 dd (10.2, 2.9)	46.7	1.19 dd (9.5, 5.3)
6	16.9	1.42 m 1.46 m	16.9	1.42 m 1.43 m	16.7	1.47 m 1.49 m	16.7	1.47 m 1.49 m
7	33.2	1.18 m 1.68 m	33.2	1.19 m 1.68 m	32.7	1.11 dt (12.7, 3.2) 1.62 m	32.8	1.11 dt (12.7, 3.2) 1.60 m
8	41.9	–	41.9	–	42.5	–	42.5	–
9	50.0	1.28 m	49.9	1.28 m	49.8	1.26 m	49.8	1.26 m
10	36.2	–	36.2	–	36.1	–	36.1	–
11	18.6	1.47 m 1.68 m	18.6	1.47 m 1.68 m	18.3	1.57 m 1.74 m	18.3	1.57 m 1.74 m
12	32.4	1.31 m 2.02 m	32.4	1.31 t (13.6) 2.01 m	31.1	1.51 m 2.05 m	31.1	1.51 m 2.05 m
13	87.4	–	87.4	–	86.2	–	86.2	–
14	42.7	–	42.7	–	49.7	–	49.7	–
15	35.7	1.22 m 2.01 m	35.7	1.22 m 2.01 m	45.0	1.81 d (15.8) 2.80 d (15.8)	45.0	1.81 d (15.8) 2.80 d (15.8)
16	75.9	3.82 d (4.6)	75.9	3.82 m	214.3	-	214.3	-
17	48.0	–	48.4	–	55.8	–	55.8	–
18	46.7	1.76 m	46.7	1.77 m	54.5	2.02 dd (12.1, 2.7)	54.5	2.01 dd (13.8, 3.2)
19	38.5	1.17 m 2.28 t (12.8)	38.5	1.18 m 2.29 dd (14.2, 12.6)	39.6	1.36 t (13.8) 1.48 m	39.6	1.36 t (13.8) 1.48 m
20	31.1	–	31.0	–	31.1	–	31.1	–
21	36.1	1.16 m 2.04 m	36.1	1.17 m 2.05 m	35.0	1.23 m 1.57 m	35.0	1.23 m 1.57 m
22	25.2	1.41 m 2.04 m	25.2	1.41 m 2.05 m	24.2	1.25 m 2.11 d (11.7)	24.2	1.25 m 2.11 dt (12.7, 2.1)
23	63.2	3.30 m 3.72 m	63.2	3.30 m 3.73 d (11.6)	63.1	3.29 m 3,73 d (11.3)	63.1	3.31 m 3,65 d (11.1)
24	11.7	0.73 s	11.7	0.73 s	11.7	0.74 s	11.7	0.75 s
25	15.9	0.95 s	15.9	0.96 s	15.5	0.96 s	15.6	0.96 s
26	17.5	1.20 s	17.5	1.20 s	17.8	1.28 s	17.8	1.28 s
27	18.3	1.24 s	18.3	1.25 s	20.8	1.08 s	20.8	1.08 s
28	104.1	4.28 brs	104.1	4.28 brs	74.7	3.48 d (8.4) 3.93 d (8.4)	74.7	3.48 d (8.5) 3.93 d (8.5)
29	32.5	0.95 s	32.3	0.94 s	32.4	0.95 s	32.4	0.95 s
30	23.4	0.91 s	23.5	0.91 s	22.4	0.91 s	22.4	0.91 s
a	66.5	3.33 m 3.70 m	66.5	3.34 m 3.71 m				
b	31.7	1.56 t (6.5)	31.7	1.56 t (6.7)				
c	19.1	1.42 m	19.1	1.42 m				
d	12.8	0.95 t (6.9)	12.8	0.95 t (6.9)				

[a] in ppm, *J* in parentheses in Hz.

[b] NMR spectra recorded at 600 and 150 MHz (^{1}H and ^{13}C).

Table 4

^{13}C NMR and ^{1}H NMR spectroscopic data of the sugar moieties for compounds **6**–**9** in CD_3OD.[a, b]

Position	**6**		**7**		**8**		**9**	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
C3	**Ara**		**Ara**		**Ara**		**Ara**	
1'	103.3	4.46 d (6.3)	103.3	4.46 d (5.4)	103.3	4.46 d (6.1)	105.1	4.28 d (7.2)
2'	78.3	3.79 m	78.3	3.79 m	78.3	3.79 m	72.7	3.43 m
3'	73.1	3.80 m	73.1	3.80 m	73.1	3.80 m	73.2	3.47dd (9.2,4.0)
4'	78.8	3.91 m	78.7	3.90 m	78.7	3.91 m	80.0	3.85 dm (2.8)
5'	64.4	3.55 dd (11.9, 1.5)	64.4	3.54 m	64.4	3.55 m	65.5	3.56 d (12.8)
		4.22 d (11.9)		4.24 dd (12.7, 3.3)		4.22 dd (12.7, 2.8)		4.20 dd (12.8, 2.0)
	Glc I		**Glc I**		**Glc I**			
1''	102.9	4.73 d (7.7)	102.9	4.73 d (7.6)	102.9	4.72 d (7.7)		
2''	74.6	3.21 dd (9.2, 7.7)	74.6	3.22 dd (8.8, 7.6)	74.6	3.21 dd (8.9, 7.7)		
3''	76.4	3.39 m	76.4	3.39 t (9.2)	76.4	3.39 t (9.4)		
4''	70.4	3.20 m	70.4	3.21 t (9.1)	70.4	3.20 t (9.4)		
5''	76.7	3.29 m	76.7	3.30 m	76.7	3.29 m		
6''	61.7	3.62 dd (11,9, 4.5)	61.7	3.63 m	61.7	3.61 dd (11,9, 6.6)		
		3.86 dd (11,9, 2.3)		3.86 dd (11.9, 4.8)		3.86 dd (11,9, 2.0)		
	Glc II		**Glc II**		**Glc II**		**Glc II**	
1'''	103.2	4.58 d (7.7)	103.3	4.54 d (7.8)	103.2	4.58 d (7.7)	103.7	4.56 d (8.0)
2'''	83.1	3.48 dd (8.9, 7.7)	83.8	3.40 t (8.7)	83.1	3.49 dd (8.9, 7.7)	84.1	3.50 dd (9.0, 8.0)
3'''	74.6	3.74 m	76.1	3.56 m	74.6	3.74 t (9.1)	74.5	3.74 t (9.0)
4'''	78.5	3.62 t (9.2)	69.7	3.35 m	78.5	3.63 t (9.4)	78.3	3.66 t (9.2)
5'''	75.1	3.44 m	76.5	3.34 m	75.1	3.44 m	75.0	4.43 m
6'''	60.3	3.87 m	60.1	3.69 dd (11.9, 5.7)	60.3	3.87 m	60.3	3.87 m
		3.89 m		3.87 d (11.9, 4.8)		3.89 m		3.89 m
	Glc III				**Glc III**		**Glc III**	
1''''	103.1	4.43 d (8.6)			103.1	4.43 d (7.9)	103.1	4.44 d (7.6)
2''''	73.5	3.24 m			73.5	3.24 dd (8.8, 7.9)	73.5	3.24 dd (8.8, 7.6)
3''''	76.4	3.38 t (8.9)			76.1	3.37 m	76.4	3.37 t (9.0)
4''''	69.9	3.33 m			69.9	3.33 m	69.9	3.32 m
5''''	76.6	3.34 m			76.7	3.43 m	76.6	3.30 m
6''''	61.0	3.67 dd (11.6, 3.4)			60.9	3.68 dd (11.9, 5.6)	61.0	3.68 dd (12.0, 5.6)
		3.88 m				3.89 m		3.89 dd (12.0, 2.0)
	Xyl		**Xyl**		**Xyl**		**Xyl**	
1'''''	106.0	4.56 d (7.9)	105.9	4.52 d (7.6)	105.9	4.56 d (7.6)	106.6	4.52 d (7.6)
2'''''	74.6	3.26 dd (8.9, 7.9)	74.5	3.27 t (7.9)	74.6	3.25 t (8.1)	74.8	3.25 dd (9.6, 7.6)
3'''''	76.1	3.37 m	76.2	3.35 m	76.4	3.37 m	76.2	3.37 t (9.6)
4'''''	69.6	3.53 m	69.5	3.52 m	69.5	3.52 m	69.4	3.52 m
5'''''	66.0	3.32 t (11.0)	66.0	3.31 m	66.0	3.32 m	65.7	3.28 t (11.6)
		4.00 dd (11.0, 5.5)		4.00 dd (11.3, 5.4)		4.00 dd (11.4, 5.4)		4.00 dd (11.6, 5.6)

[a] in ppm, *J* in parentheses in Hz.

[b] NMR spectra recorded at 600 MHz and 150 (^{1}H and ^{13}C).

Table 5

^{13}C NMR and ^{1}H NMR spectroscopic data of the aglycone moieties for compounds **10**–**13** in CD_3OD.[a, b]

Position	**10**		**11**		**12**		**13**	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
1	38.2	1.00 m 1.65 m	38.2	1.00 m 1.66 m	38.2	1.00 m 1.66 dt (13.3, 3.6)	38.2	1.00 m 1.65 m
2	25.0	1.80 t (14.3) 1.89 m	25.0	1.80 t (12.9) 1.89 m	24.9	1.79 m 1.89 m	24.9	1.80 t (12.6) 1.89 m
3	82.5	3.63 m	82.4	3.64 dd (11.7, 4.3)	82.4	3.63 m	82.4	3.64 m
4	42.8	–	42.7	–	42.7	–	42.7	–
5	46.9	1.24 d (11.7)	46.8	1.24 d (11.7)	46.8	1.24 d (11.7)	46.8	1.24 d (10.9)
6	17.4	1.37 m 1.52 m	17.4	1.38 m 1.52 m	17.3	1.37 m 1.51 m	17.4	1.37 m 1.52 m
7	32.3	1.31 m 1.69 m	32.2	1.31 m 1.70 m	32.2	1.31 m 1.69 m	32.2	1.31 m 1.70 m
8	39.4	–	39.4	–	39.4	–	39.4	–
9	46.7	1.69 t (8.5)	46.6	1.69 m	46.7	1.68 t (8.8)	46.7	1.69 m
10	36.2	–	36.2	–	36.2	–	36.2	–
11	23.1	1.93 m 1.94 m	23.1	1.93 m 1.94 m	23.1	1.92 m 1.94 m	23.1	1.92 m 1.93 m
12	123.0	5.42 t (3.6)	123.0	5.42 brs	123.0	5.42 t (3.5)	123.0	5.42 t (3.7)
13	142.9	–	142.9	–	142.9	–	142.9	–
14	41.4	–	41.4	–	41.4	–	41.4	–
15	34.6	1.40 m 1.82 dd (14.7, 4.0)	34.5	1.40 m 1.82 d (12.9)	34.5	1.40 dd (14.2, 2.7) 1.82 dd (14.2, 3.6)	34.5	1.40 m 1.82 dd (14.5, 3.7)
16	72.5	4.29 t (3.6)	72.4	4.29 brs	72.4	4.29 t (3.5)	72.4	4.28 t (3.7)
17	50.8	–	50.8	–	50.9	–	50.8	–
18	40.4	2.68 dd (14.5, 3.9)	40.4	2.68 dd (13.8, 3.3)	40.4	2.68 dd (14.2, 4.4)	40.4	2.68 dd (13.5, 4.3)
19	46.1	1.14 dd (13.3,4.9) 2.27 t (13.3)	46.0	1.13 d (13.8) 2.27 t (13.8)	46.0	1.14 dd (12.7, 3.6) 2.27 t (14.2)	46.0	1.13 dd (13.5, 4.3) 2.27 t (13.5)
20	29.9	–	29.9	–	29.9	–	29.9	–
21	34.2	1.20 m 1.94 m	34.2	1.21 m 1.94 m	34.2	1.20 m 1.93 m	34.2	1.21 m 1.94 m
22	25.9	1.56 m	25.9	1.55 m	25.9	1.54 m	25.9	1.54 m
23	63.3	3.30 m 3.73 d (11.6)	63.2	3.30 m 3.73 d (11.4)	63.2	3.30 m 3.70 d (11.4)	63.3	3.31 m 3.68 d (11.6)
24	11.9	0.75 s	11.9	0.74 s	11.9	0.73 s	11.9	0.73 s
25	15.1	1.00 s	15.1	1.00 s	15.1	1.00 s	15.1	1.01 s
26	16.5	0.76 s	16.5	0.75 s	16.5	0.76 s	16.5	0.75 s
27	25.9	1.41 s	25.9	1.41 s	25.9	1.41 s	25.9	1.41 s
28	205.6	9.23 s	205.6	9.23 s	205.6	9.23 s	205.6	9.23 s
29	32.0	0.93 s	32.0	0.92 s	32.0	0.92 s	32.0	0.92 s
30	23.1	0.98 s	23.1	0.98 s	23.1	0.98 s	23.1	0.98 s

[a] in ppm, *J* in parentheses in Hz.

[b] NMR spectra recorded at 600 and 150 MHz (^{1}H and ^{13}C).

Table 6

^{13}C NMR and ^{1}H NMR spectroscopic data of the sugar moieties for compounds **10**–**13** in CD_3OD.[a, b]

Position	**10**		**11**		**12**		**13**	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
C3	**Ara**		**Ara**		**Ara**		**Ara**	
1'	103.3	4.46 d (6.4)	103.3	4.46 d (5.1)	102.9	4.56 d (6.2)	102.9	4.55 d (5.3)
2'	78.3	3.79 m	78.2	3.79 m	77.5	3.89 t (7.7)	77.6	3.89 m
3'	73.1	3.80 m	73.1	3.80 m	72.2	3.87 dd (8.2, 2.3)	72.3	3.87 m
4'	78.8	3.91 m	78.8	3.90 m	77.3	3.98 dd (6.6, 2.7)	77.2	3.99 m
5'	64.4	3.55 d (12.6)	64.5	3.55 m	63.4	3.57 dd (12.4, 1.9)	63.5	3.57 dd (12.4, 1.9)
		4.21 dd (12.6, 2.6)		4.24 dd (12.8, 3.3)		4.15 dd (12.4, 4.3)		4.15 dd (12.4, 4.2)
	Glc I		**Glc I**		**Glc I**		**Glc I**	
1''	103.0	4.73 d (7.7)	102.9	4.73 d (7.6)	103.1		103.0	
2''	74.6	3.21 dd (9.2, 7.7)	74.5	3.21 dd (8.9, 7.6)	74.4	4.66 d (7.8)	74.4	4.65 d (7.7)
3''	76.5	3.40 t (9.2)	76.4	3.39 t (8.9)	76.6	3.22 dd (8.9, 7.8)	76.6	3.22 dd (9.1, 7.7)
4''	70.4	3.20 t (9.2)	70.4	3.19 t (9.5)	70.4	3.37 t (8.9)	70.4	3.37 t (9.0)
5''	76.7	3.29 m	76.7	3.29 m	76.8	3.22 t (9.1)	76.9	3.22 t (9.5)
6''	61.8	3.62 dd (12.0, 6.6)	61.8	3.60 dd (12.0, 4.9)	61.6	3.28 m	61.6	3.29 m
		3.87 dd (12.0, 1.6)		3.87 dd (12.0, 4.6)		3.63 dd (12.0, 6.7)		3.63 dd (11.8, 6.6)
	Glc II		**Glc II**		**Glc II**		**Glc II**	
1'''	103.2	4.59 d (7.7)	103.4	4.54 d (7.8)	104.1	3.87 dd (12.0, 2.3)	104.3	3.87 dd (11.8, 2.4)
2'''	83.1	3.42 dd (9.2, 7.7)	83.8	3.40 m	73.8		74.0	
3'''	74.6	3.75 t (9.2)	76.2	3.56 t (9.2)	74.8		76.5	
4'''	78.5	3.64 t (9.5)	69.6	3.34 m	79.0	4.53 d (7.8)	70.1	4.53 d (7.7)
5'''	75.1	3.43 m	76.5	3.29 m	75.1	3.33 m	76.7	3.27 dd (8.9, 7.7)
6'''	60.3	3.87 d (12.4)	61.1	3.68 dd (11.7, 5.2)	60.4	3.51 t (8.9)	61.3	3.35 m
		3.89 m		3.88 m		3.59 t (8.9)		3.29 m
	Glc III				**Glc III**	3.42 m		3.29 m
1''''	103.1	4.43 d (7.9)			103.2	3.87 dm (12.5)		3.67 d (11.8, 5.5)
2''''	73.5	3.24 t (8.2)			73.5	3.91 d (12.5, 2.6)		3.88 d (11.8, 2.4)
3''''	76.5	3.39 t (8.9)			76.4			
4''''	69.9	3.33 m			69.9	4.42 d (7.8)		
5''''	76.7	3.36 m			76.6	3.23 dd (8.6, 7.7)		
6''''	61.0	3.68 dd (11.8, 5.5)			61.0	3.38 t (8.6)		
		3.89 m				3.32 m		
	Xyl		**Xyl**			3.35 m		
1'''''	106.0	4.56 d (7.9)	105,9	4.52 d (8.2)		3.68 dd (11.8, 5.5)		
2'''''	74.6	3.27 dd (9.2, 7.7)	74.5	3.26 dd (9.5, 8.2)		3.89 dd (11.8, 2.3)		
3'''''	76.1	3.37 t (9.2)	76.2	3.37 t (9.5)				
4'''''	69.6	3.53 m	69.5	3.52 m				
5'''''	66.0	3.32 m	66.0	3.32 m				
		4.01 dd (11.3, 5.3)		4.00 dd (11.4, 4.9)				

[a] in ppm, *J* in parentheses in Hz.

[b] NMR spectra recorded at 600 and 150 MHz (^{1}H and ^{13}C).

Table 7: 3-*O*-*β*-D-xyl-(1→2)-glc-(1→4)-[glc-(1→2)-]-arabinopyranosyl-13,28-epoxy-3,16-oleananediol derivatives skeleton of species in the Myrsinaceae and Primulaceae

R1	R2	R3	R4	Name of plant	Reference
Me	H	Me	H	*Cyclamen repandum*	Dall'acqua et al., 2010
				Lysimachia sikokiana	Kohda et al., 1989
				Lysimachia vulgaris	Podolack et al., 1998
				Lysimachia clethroides	Podolack et al., 2013
				Myrsine australis	Bloor and QI, 1994
CH_2OH	H	Me	H	*Anagallis arvensis*	Glombitza et al., 1987b
				Cyclamen africanum	Bencharif-Betina et al., 2012
				Cyclamen repandum	Dall'acqua et al., 2010
				Lysimachia ciliata	Podolack et al., 2013
				Lysimachia ephemerum	Podolack et al., 2013
				Lysimachia heterogenea	Huang et al., 2011
Me	H	CH_2OH	H	*Ardisia crenata*	Jia et al., 1994
				Lysimachia thyrsiflora	Podolack et al., 2013
Me	H	CHO	H	*Androsace saxifragaefolia*	Waltho et al., 1986
				Ardisia crispa	Jansakul et al., 1987
				Cyclamen africanum	Bencharif-Betina et al., 2012
				Cyclamen libanoticum	El Hosry et al., 2014
				Cyclamen persicum	El Hosry et al., 2014
				Cyclamen repandum	Dall'acqua et al., 2010
				Cyclamen spp.	Rezniek et al., 1989
				Cyclamen trocopteranthum	Mihci-Gaidi et al., 2010
				Lysimachia nummularia	Podolack et al., 2013
				Lysimachia punctata	Podolack et al., 2013
				Myrsine australis	Bloor and QI, 1994
				Myrsine pellucida	Lavaud et al., 1994
				Myrsine salicina	Bloor and QI, 1994
				Primula denticulata	Ahmad et al., 1988
CH_2OH	H	CHO	H	*Cyclamen coum var. coum*	Calis et al., 1997b
				Cyclamen mirabilis	Calis et al., 1997a
Me	H	COOH	H	*Cyclamen hederifolium*	Altunkeyik et al., 2012
Me	H	Me	OH	*Myrsine australis*	Bloor and QI, 1994
Me	OH	Me	H	*Anagallis arvensis*	Shoji et al., 1994b
Me	OAc	Me	H	*Anagallis arvensis*	Shoji et al., 1994a
				Lysimachia ciliata	Podolack et al., 2013
				Lysimachia ephemerum	Podolack et al., 2013
Me	OH	Me	OH	*Lysimachia capillipes*	Tian et al., 2006