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Essential oil composition of *Cladanthus eriolepis* (Coss. ex Maire) Oberpr. & Vogt, an endemic species to Morocco

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ABSTRACT

Cladanthus eriolepis (*C. eriolepis*) (Coss. ex Maire) Oberpr. & Vog. is endemic to High Atlas (Dades Gorge and Todgha Gorge), the Anti Atlas and Saharan Morocco. It is known under the vernacular names 'Alougjim, gtaa-eddib, laatetecha' and 'Lamghizal'. Two essential oil samples have been isolated from aerial parts and analyzed by combination of chromatographic and spectroscopic techniques [gas chromatography (GC) in combination with retention indices (RI), gas chromatography-mass spectrometry (GC/MS) and ^{13}C-NMR spectroscopy]. The compositions of both oil samples were dominated by hemiterpene esters such as isobutyl isobutyrate (21.2% and 20.8% respectively) and isobutyl angelate (22.0% and 22.4% respectively). Other esters present at appreciable contents were 2-methylallyl isobutyrate (5.3% and 5.5%), 2-methylbutyl isobutyrate (5.7% and 5.8%), 2-methylallyl angelate (4.6% and 4.9%) and 2-methylbutyl angelate (7.7% and 7.2%) beside α-pinene (9.5% and 5.8%) and β-bisabolene (2.8% and 4.0%). The compositions of the investigated oil samples from *C. eriolepis* differed substantially with literature data and with those of other *Cladanthus* species growing wild in Morocco.

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Introduction

The genus *Cladanthus* (Asteraceae) is a small genus that includes only five species, all native of the Mediterranean basin and South-Western Europe (1). Moroccan flora records five species for this genus, including *Cladanthus mixtus* (L.) Chevall. and *C. arabicus* (L.) Cass. which are also common to the Mediterranean basin while three of these species are endemic: *Cladanthus scariosus* (Ball.) Oberpr. & Vogt, *C. flahaultii* (Emb.) Oberpr. & Vogt and *C. eriolepis* (Coss. ex Maire) Oberpr. & Vogt (2).

Cladanthus eriolepis (Coss. ex Maire) Oberpr. & Vogt [synonyms: *Ormenis eriolepis* Coss. ex Maire; *Chamaemelum eriolepis* (Coss. ex Maire) Benedi] (2) is known under the vernacular names 'Alougjim, gtaa-eddib, laatetecha' and 'Lamghizal' in the region of Zagora (2).

C. eriolepis is an annual, spontaneous plant, 30 to 50 cm high. The stems are erect, branched from the base, with a basal leaf rosette quickly deciduous, ending in solitary, pedunculated flower heads from 1 to 5 cm. The peripheral flowers are sterile hemiligulated, with orange blade with three apical teeth, yellow tubulars, all fertile. The fruit is an achene, ovoid, hairless and longitudinally striated.

This species occupies the stony environments, sands and steppes of dry to arid regions. The geographic repartition area includes the High Atlas (Dades Gorge and Todgha Gorge), the Anti Atlas and Saharan Morocco (2). This plant is frequently used in traditional medicine as stomachic, anthelmintic and antidiabetic (3). In the region of Zagora, *C. eriolepis* is especially used to treat gastrointestinal diseases.

Previous studies on solvent extracts reported antibacterial (4), antileishmania (4,5) and antitumor activities (6). The methanolic extract of *C. eriolepis* displayed low cytotoxic effect on SiHa and HeLa cervical cancer cell lines (6,7). Otherwise, the antimicrobial activity of *C. eriolepis* essential oil was checked against bacterial and fungal strains. The composition of this oil sample was dominated by camphor (37.0%), beside monoterpene hydrocarbons: sabinene (10.3%), α-pinene (6.3%) and *p*-cymene (6.1%) (8). After the submission of our results, another paper (9) reported on the composition of an oil sample isolated from *C. eriolepis* whole plant, dominated by α-pinene (13.0%), isobutyl angelate (10.7%), 2-methybutyl angelate (9.5%) and germacrene D (7.1%).

We report herein the chemical compositions of two oil samples isolated from plants harvested in Southern Morocco that differ drastically from the first recently published (8) and substantially from the second one (9).

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Experimental

Plant material and essential oil isolation

Samples of wild growing *C. eriolepis* were harvested in May 2019, during flowering, from two sites in Zagora region (South of Morocco), S1: Jbal zagora, 30° 19′28.54”N, 005°48′47.33”W; 768 m above sea level; S2: Ouled ouchah, 30°24′59.21”N, 005°53′24.54”W; 749 m above sea level. Collective samples (five individual plants) were collected in a limited area.

Specimens of plants were taxonomically identified by Curator Cyrille Chatelain from the Conservatory and Botanical Garden, Department of Culture and Sport, Geneva, Switzerland. Voucher specimens from each locality are kept at the Herbarium of National Institute of Agriculture Research (INRA).

Essential oil isolation

The fresh raw material was air-dried in the shade for 5 days and then submitted to hydrodistillation in a Clevenger-type apparatus for 3 hours (mass). The yellowish essential oil (mass) was kept in glass tubes at 4°C.

GC-FID analysis

GC-FID analyses were carried out using a Clarus 500 Perkin Elmer (Perkin Elmer, Courtaboeuf, France) system equipped with a FID and two fused-silica capillary columns (50 m x 0.22 mm, film thickness 0.25 µm), BP-1 (polydimethylsiloxane) and BP-20 (polyethylene glycol). The oven temperature was programmed from 60°C to 220°C at 2°C/min and then held isothermal at 220°C for 20 min; injector temperature: 250°C; detector temperature: 250°C; carrier gas: H_2 (0.8 mL/min); split: 1/60; injected volume: 0.5 µL. The relative proportions of the oil constituents were expressed as percentages obtained by peak-area normalization, without using correcting factors. Retention indices (RI) were determined relative to the retention times of a series of n-alkanes with linear interpolation (Target Compounds software from Perkin Elmer).

GC/MS analysis

GC/MS analyses were performed on a Clarus SQ8S Perkin Elmer TurboMass detector (quadrupole), directly coupled to a Clarus 580 Perkin-Elmer Autosystem XL, equipped with a BP-1 (polydimethylsiloxane) fused-silica capillary column (60 m x 0.22 mm i.d., film thickness 0.25 µm). The oven temperature was programmed from 60°C to 230°C at 2°C/min and then held isothermal at 230°C for 45 min; injector temp., 250°C; ion-source temp.,150°C; carrier gas, He (1 ml/min); split ratio, 1:80; injection volume, 0.2 µL; ionization energy, 70 eV. The electron ionization (EI) mass spectra were acquired over the mass range 35–350 Da.

Nuclear magnetic resonance

^{13}C-NMR spectra were recorded on a Bruker AVANCE 400 Fourier Transform spectrometer operating at 100.63 MHz for ^{13}C, equipped with a 5 mm probe, in $CDCl_3$, with all shifts referred to internal TMS. The following parameters were used: pulse width = 4 µs (flip angle 45°); acquisition time = 2.7 s for 128 K data table with a spectral width of 25 000 Hz (250 ppm); CPD mode decoupling; digital resolution = 0.183 Hz/pt. The number of accumulated scans was 3000 for each sample (40 mg of essential oil in 0.5 mL of $CDCl_3$).

Identification of individual components

Identification of the individual components was carried out: (i) by comparison of their GC retention indices (RI) on polar and apolar columns with those of reference compounds compiled in a laboratory-built library and with literature data (10); (ii) on computer matching against commercial mass spectral libraries (10–12); (iii) on comparison of the signals in the ^{13}C-NMR spectra of the samples with those of reference spectra compiled in the laboratory spectral library, with the help of a laboratory-made software (13,14).

Results and discussion

Aerial parts of *C. eriolepis* harvested in two sites located at Jbal zagora and Ouled ouchah, in Zagora region (Southern Morocco), were dried and then separately submitted to hydrodistillation using a Clevenger-type apparatus. Yellowish essential oil was obtained with yields of 0.4% (S1) and 0.5% (S2) (v/dw), respectively. Both oil samples were subjected to chromatographic and spectroscopic analyses: GC(FID) on two columns of different polarity, GC/MS and ^{13}C-NMR following a computerized method developed at the University of Corsica (13,14). In total, 44 compounds have been identified, they accounted for 94.9% (S1) and 93.2% (S2) of the whole composition (Table 1, Figure 1). The two compositions were similar and they were characterized by the occurrence of esters containing one or two hemiterpene sub-structures. Indeed, the major components were isobutyl isobutyrate (21.2% and 20.8%, respectively) and isobutyl angelate (22.0% and 22.4%, respectively). Other components present at appreciable contents were 2-methylallyl isobutyrate (5.3% and 5.5%), 2-methylbutyl isobutyrate (5.7% and 5.8%), 2-methylallyl angelate (4.6% and 4.9%),

Table 1. Chemical composition of *Cladanthus eriolepis* aerial parts essential oils.

N°	Components[a]	RIa lit[b]	RIa	Rip lit[l]	RIp	S1 %	S2 %	Identification
1	Isobutyl acetate	755[c]	753	1018[m]	nd	0.2	0.2	GC(RI), GC/MS
2	Propyl isobutyrate	842[d]	838	1054[n]	1049	0.1	0.1	GC(RI), GC/MS
3	Isobutyl propionate[e]	851[e]	848	1085[m]	1083	0.9	0.8	GC(RI), GC/MS, NMR
4	2-Methylbutyl acetate	868[f]	859	1145[o]	1125	0.7	0.9	GC(RI), GC/MS
5	Isobutyl isobutyrate	899[g]	901	1095[m]	1096	21.2	20.8	GC(RI), GC/MS, NMR
6	(E)-2-Methylbutenyl propionate	-	903	-	1251	1.7	3.0	GC(RI), GC/MS, NMR
7	2-Methylallyl isobutyrate	914[h]	913	-	1184	5.3	5.5	GC(RI), GC/MS, NMR
8	α-Thujene	932	924	1025	1019	0.1	tr	GC(RI), GC/MS
9	α-Pinene	936	932	1026	1019	9.2	5.8	GC(RI), GC/MS, NMR
10	2-Methylbutyl propionate	952[g]	954	1192[p]	1193	0.5	0.5	GC(RI), GC/MS
11	Sabinene	973	967	1122	1126	0.2	0.3	GC(RI), GC/MS
12	β-Pinene	978	973	1110	1115	0.1	0.1	GC(RI), GC/MS
13	Propyl angelate	980[i]	976	-	nd	0.2	0.1	GC(RI), GC/MS
14	Myrcene	987	982	1161	1164	0.4	0.2	GC(RI), GC/MS, NMR
15	Isobutyl 2-methylbutyrate	991[j]	990	1180[p]	1183	0.8	1.2	GC(RI), GC/MS
16	Isobutyl isovalerate	989[g]	992	1167[q]	1179	0.5	0.7	GC(RI), GC/MS
17	3-Methylbutyl isobutyrate	994	996	1190[r]	1195	0.1	0.1	GC(RI), GC/MS
18	2-Methylbutyl isobutyrate	1001[j]	1003	1203[s]	1201	5.7	5.8	GC(RI), GC/MS, NMR
19	p-Cymene	1015	1013	1270	1276	1.0	0.7	GC(RI), GC/MS, NMR
20	Limonene*	1025	1022	1198	1205	2.0	1.4	GC(RI), GC/MS, NMR
21	1,8-Cineole*	1025	1022	1211	1215	0.9	1.7	GC(RI), GC/MS, NMR
22	Isobutyl angelate	1027	1036	1293[t]	1293	22.0	22.4	GC(RI), GC/MS, NMR
23	Prenyl isobutyrate	1053[k]	1040	-	nd	1.0	1.0	GC(RI), GC/MS
24	2-Methylallyl angelate	1040	1047	-	1378	4.6	4.9	GC(RI), GC/MS, NMR
25	γ-Terpinene	1051	1050	1245	1249	0.3	0.1	GC(RI), GC/MS
26	Linalool	1086	1086	1544	1550	tr	0.1	GC(RI), GC/MS
27	2-Methylbutyl 2-methylbutyrate	1090[g]	1091	-	1283	0.4	0.5	GC(RI), GC/MS, NMR
28	3-Methylbutyl angelate	1125	1133	-	1376	0.2	0.2	GC(RI), GC/MS
29	2-Methylbutyl angelate	1130	1138	1395[t]	1397	7.7	7.2	GC(RI), GC/MS, NMR
30	Terpinen-4-ol	1164	1164	1601	1605	0.1	0.1	GC(RI), GC/MS
31	α-Terpineol	1176	1175	1694	1699	0.5	0.5	GC(RI), GC/MS
32	Bornyl acetate	1270	1272	1580	1574	tr	0.1	GC(RI), GC/MS
33	Myrtenyl acetate	1313	1308	1692	1691	0.2	0.2	GC(RI), GC/MS
34	Geranyl acetate	1362	1362	1752	1751	0.3	0.8	GC(RI), GC/MS, NMR
35	(E)-β-Farnesene	1446	1449	1664	1667	tr	0.1	GC(RI), GC/MS
36	*ar*-Curcumene	1473	1472	1773	1775	0.1	0.2	GC(RI), GC/MS
37	Germacrene D	1479	1478	1708	1709	0.7	0.1	GC(RI), GC/MS, NMR
38	β-Bisabolene	1503	1503	1728	1728	2.8	4.0	GC(RI), GC/MS, NMR
39	δ-Cadinene	1520	1517	1756	1758	0.2	0.1	GC(RI), GC/MS
40	Geranyl 2-methyl butyrate	1591	1591	1904[u]	1920	0.5	0.4	GC(RI), GC/MS
41	*epi*-Cubenol	1623	1618	2068	2064	0.5	0.2	GC(RI), GC/MS, NMR
42	α-Cadinol	1643	1641	2227	2231	0.3	0.2	GC(RI), GC/MS
43	β-Bisabolol	1659	1655	2143	2152	0.2	0.2	GC(RI), GC/MS
44	α-Bisabolol	1673	1669	2214	2231	0.5	0.4	GC(RI), GC/MS, NMR
	Total					94.9	93.2	

[a]Components are listed following their order of elution on apolar column. Percentages measured on apolar column, except those with * (polar column); RIa, Rip: Retention indices on apolar and polar columns, respectively; NMR: compound identified by ^{13}C NMR, at least in one oil sample. RIa lit, apolar literature retention indices; [b] Retention indices reported in Terpenoids Library Website (35) or in references: [c] (36); [d] (37); [e] (38); [f] (39); [g] (40); [h] (34); [i] (31); [j] (41); [k] (42); RIp lit, polar literature retention indices [l] Retention indices reported in Babushok et al. (43) or in references [m] (44); [n] (45); [o] (46); [p] (47); [q] (48); [r] (49); [s] (50); [t] (51); [u] (52); nd: not determined.

2-methylbutyl angelate (7.7% and 7.2%). Beside hemiterpene esters, various monoterpene hydrocarbons, oxygenated monoterpenes sesquiterpene hydrocarbons and oxygenated sesquiterpenes have been identified at low content. Among these, only α-pinene (9.5% and 5.8%), on the one hand, and β-bisabolene (2.8% and 4.0%), on the other hand, exhibited a fair content.

Obviously, the compositions of our oil samples differed drastically for the one recently reported, dominated by camphor and monoterpene hydrocarbons and characterized by the lack of hemiterpene esters (8). They differed also substantially from that of Chibane et al. (9) by their high content of hemiterpene esters, isobutyl isobutyrate (21.2% and 20.8% *vs.* 1.9%), isobutyl angelate (22.0% and 22.04% *vs.* 10.7%) and 2-methylallyl isobutyrate (5.3% and 5.5% *vs.* 0.3%).

Otherwise, it looked opportune to compare with the composition of essential oils isolated from other Moroccan *Cladanthus* species:

- *C. scariosus* essential oil contained mainly germacrene D followed by (E)-chrysanthenyl acetate, chamazulene, sabinene, α-pinene, τ–muurolol and (E, E)-farnesyl acetate (15);
- The chemical composition of the essential oils of the aerial parts (stems and leaves/flowers) of *C. arabicus*

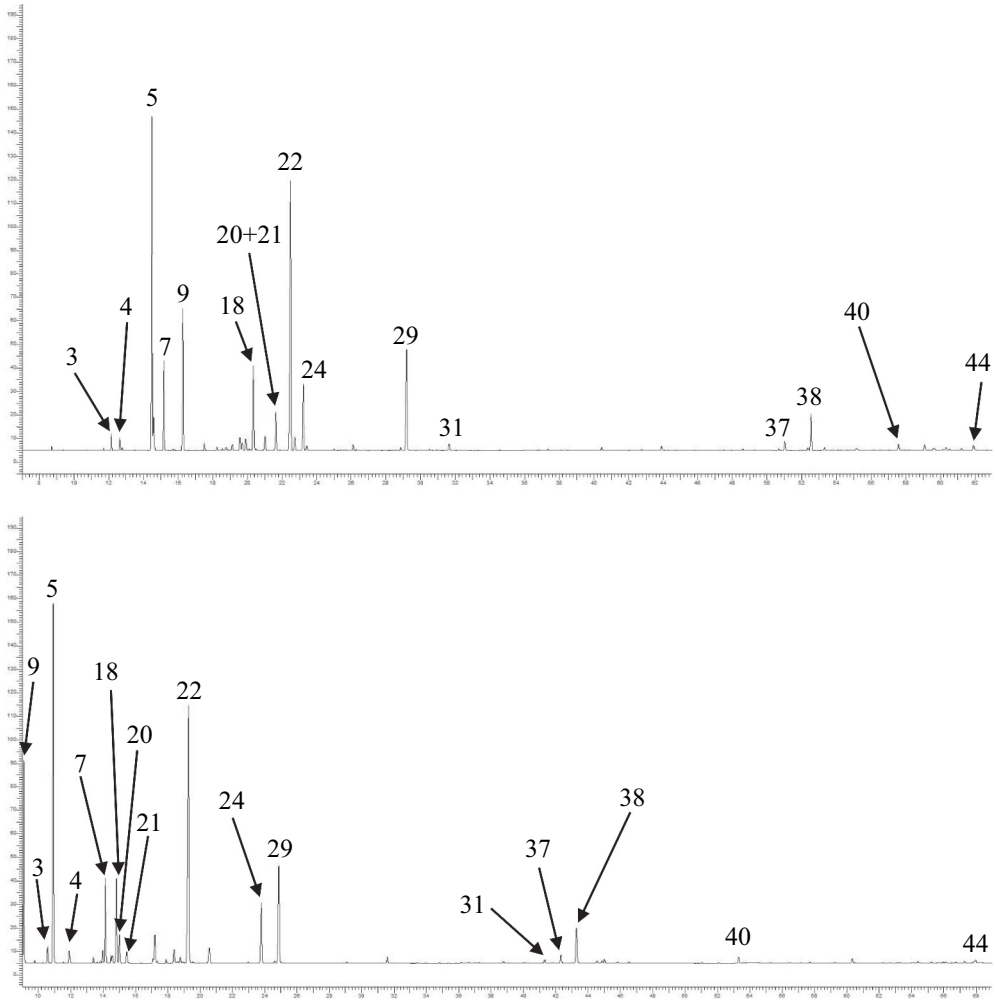

Figure 1. GC-FID chromatograms on apolar (top) and polar columns (bottom) of *Cladanthus eriolepis* essential oil (sample S1). Peak numbers correspond to ordinal numbers in Table 1.

was dominated by monoterpene hydrocarbons: sabinene; β-pinene, myrcene and at lesser extent, α-pinene, α-phellandrene and p-cymene (16,17);

- lastly, *C. mixtus*, mentioned in the literature under this name or one of its various synonyms, displayed a large chemical variability. Indeed, it seems that the chemical composition of the oil samples was dependent of the locality of harvest of the plant. Two types of essential oils could be differentiated i) those containing a major component such as bornyl acetate (45%) (18), santolina alcohol (32–55%) (19–21), (E)-β-farnesene (35.5–50.3%) (22,23); *trans*-nerolidol (44.1%) (24) or 2-methyl-2-*trans*-butenyl methacrylate (32.8–35.2%) (22,23,25) ii) those containing two or more components in the same range of percent: camphor (14,4–29%), (E)-β-farnesene (8.3%), 2-tridecanone (21.5%) (24); α-pinene (11.6%), santolina alcohol (10.2%), (E)-β-farnesene (8.6%) (26); camphor (13.6–26.3%), β-myrcene (2.5–17.4%) and santolinatriene (2.5–15.3%) (22); myrcene (26.5%), (E)-β-farnesene (17.9%) and 2-tridecanone (15.5%) (22); santolina alcohol (17.4%) and 1,8-cineole (11.6%) (22); camphor (21.4%), santolinatriene (10.1%) (27); 2-tridecanone (21.5%), camphor (14.4–29.0%) (26), germacrene D (11.5%), 1,8-cineole (10.3%), and cis-methyl isoeugenol (9.0%) (28).

Otherwise, hemiterpene esters-rich essential oils have been reported, particularly essential oils from Roman chamomile (*Chamaemelum nobile*, synonym *Anthemis nobilis*). For instance, the composition of two oil samples from *C. nobile* grown in Northern Italy was dominated by isobutyl angelate (38.5/6.3%) and 2-methylbutyl angelate (20.3/18.2%) (29). The same esters were the main components (21.6% and 14.4%, respectively) of an oil sample isolated from plants cultivated in Slovak republic, accompanied by 3-methylamyl angelate (8.4%) (30). Isobutyl angelate (25.9–29.8%) and 2-methylbutyl angelate (11.6–17.2%) dominated the composition of oil samples isolated

from plants cultivated in Iran, a third main component being propyl tiglate (10.8–13.1%) (31). Recently, a commercial oil sample contained mainly various esters of angelic acid: isobutyl angelate (44.8%), isoamyl angelate (27.4%), 2-methylallyl angelate (9.5%) and 2-methylbutyl angelate (6.6%) (32). In parallel, oil samples of Spanish *Chamaemelum fuscatum* exhibited (E)-2-methyl-2-butenyl methacrylate (18.5–27.6%) and 2-methylallyl isobutyrate (7.5–9.8%), as major components (33) while another oil sample contained mainly 2-methylallyl isobutyrate (43.1%) and (E)-2-methyl-2-butenyl methacrylate (27.6%) (34).

Conclusions

The compositions of *C. eriolepis* essential oils, isolated from plants harvested in Southern Morocco, and reported in this study differed substantially from the recently reported compositions (8,9) by their high contents (more than 75%) of hemiterpene esters. They present some originality *vs*. other Moroccan *Cladanthus* spp. oils. The combination of chromatographic and spectroscopic techniques appeared efficient for the identification of esters bearing one or two hemiterpene substructures.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

References

1. C. Oberprieler, S. Himmelreich and R. Vogt, *A new subtribal classification of the tribe Anthemideas (Compositae)*. Willdenowia, **37**(1), 89–114 (2007). doi: 10.3372/wi.37.37104
2. M. Fennane, M. Ibn Tatou and J. El Oualidi, *Flore pratique du Maroc Volume 3*. Edit., Institut Scientifique de Rabat, Rabat, Maroc, p. 517, Institut Scientifique, Rabat (2014).
3. http://www.theplantlist.org (9 December 2020).
4. J. Bellakhdar, *La pharmacopée marocaine traditionnelle. Médecine arabe ancienne et savoirs populaires*. Ibis Press, Paris, France (1997).
5. F. El Hanbali, A.S. Oulmoukhtar, M. Lemrani, M. Akssira and F. Mellouki, *Activité antileishmanienne des huiles essentielles de deux camomilles: Ormenis eriolepis et Ormenis africana*. March 16 –19. International Congress On Medicinal Plants, Errachidia, Morocco (2005).
6. L. Belayachi, C. Aceves-Luquero, N. Merghoub, Y. Bakri, S. De Mattos, S.F. Amzazi and S. P. Villalonga, *Screening of North African medicinal plant extracts for cytotoxic activity against tumor cell lines*. European Journal of Medicinal Plants, **3**(3), 310–332 (2013). doi: 10.9734/EJMP/2013/3403
7. N. Merghoub, L. Benbacer, S. Amzazi, H. Morjani and M.E. Mzibri, *Cytotoxic effect of some Moroccan medicinal plant extracts on human cervical cell lines*. Journal of Medicinal Plants Research, **3**(12), 1045–1050 (2009).
8. M. Bammou, E.D.T. Bouhlali, K. Sellam, M. Derouich, L. El-Rhaffari, J. Ibijbijen and L. Nassiri, *Chemical profile and antimicrobial properties of liquid and vapor phases of the essential oil of cladanthus eriolepis: an endemic asteraceae growing in the Moroccan oases*. Journal of Essential Oil Bearing Plants, **23**(5), 1042–1053 (2020). doi: 10.1080/0972060X.2020.1822758
9. E.M. Chibane, M. Ouknin, F. Renucci, J. Costa and L. Majidi, *Chemical profile, antioxidant and antifungal activity of essential oil from Cladanthus eriolepis*. Journal of Essential Oil Bearing Plants, **23**(6), 1296–1305 (2020). doi: 10.1080/0972060X.2020.1868349
10. W.A. Konig, D.H. Hochmuth and D. Joulain, *Terpenoids and Related Constituents of Essential Oils, Library of MassFinder 2.1*. University of Hamburg, Institute of Organic Chemistry, Hamburg, Germany (2001).
11. R.P. Adams, *Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry*, 4th edn. Allured Publ. Corp, Carol Stream, IL (2007).
12. National Institute of Standards and Technology, *PC version 1.7 Of the NIST/EPA/NIH Mass Spectral Library*. Perkin–Elmer Corp., Norwalk, CT (1999).
13. F. Tomi, P. Bradesi, A. Bighelli and J. Casanova, *Computer aided identification of individual components of essential oil using carbon-13 NMR spectroscopy*. Journal of Magnetic Resonance Analysis, **1**, 25–34 (1995).
14. F. Tomi and J. Casanova, *^{13}C-NMR as a tool for identification of individual components of essential oils from Labiatae. A review*. In "The Labiatae: Advances in Production, Biotechnology and Utilisation" Eds: Cervelli C, Ruffoni B, Dalla Guda C. Acta Horticulturae, **723**, 185–192 (2006). doi: 10.17660/ActaHortic.2006.723.21
15. V. Spadaro, F. Raimondo, M. Fennane, M. Bruno and F. Senatore, *Chemical composition of the essential oil of Cladanthus scariosus (Asteraceae) wild grown in Morocco*. 109° Congresso Societa Botanica Italiana, International Plant Science Conference (IPSC) "From Nature to Technological Exploitations" Firenze, 02-05/09/2014, Book of abstracts, p. 142 (2014).
16. F. El Hanbali, F. Mellouki, M. Akssira, B. El Hassani, M. A. Blázquez and H. Boira, *Composition and antibacterial activity of essential oils of Cladanthus arabicus cass. (Asteraceae)*. Journal of Essential Oil Bearing Plants, **8**, 213–217 (2005). doi: 10.1080/0972060X.2005.10643448
17. A. Aghraz, J. Wanner, E. Schmidt, L. Aitdra, M. Aitsidibrahim, N. Tabanca, A. Ali, A. Nafis, L. Hassani, M. Markouk, L. Jirovetz and M. Larhsini, *Chemical Composition, in vitro antioxidant, antimicrobial and insecticidal activities of essential oil from Cladanthus arabicus*. Journal of Essential Oil Bearing Plants, **20**, 601–609 (2017). doi: 10.1080/0972060X.2017.1331143

18. R. Dulou, H. Pourrat and M.M. Janot, *Essence of Ormenis multicaulis (Braun-Blanquet and Maire) grown in Morocco*. Revue de Botanique, **10**, 111–117 (1952).
19. B. Toulemonde and D. Beauvard, *Contribution à l'étude d'une camomille sauvage du Maroc*. Parfums, Cosmétiques, Arômes, **60**, 65–67 (1984).
20. S. Zrira, C. Menut, J.M. Bessiere and B. Benjilalii, *Chemical composition of the essential oils of Moroccan Ormenis mixta (L.) Dumort. ssp. multicaulis*. Journal of Essential Oil Bearing Plants, **10**, 378–385 (2007). doi: 10.1080/0972060X.2007.10643570
21. B. Satrani, M. Ghanmi, A. Farah, A. Aafi, H. Fougrach, B. Bourkhiss, D. Bousta and M. Talbi, *Composition chimique et activité antimicrobienne de l'huile essentielle de Cladanthus mixtus*. Bulletin de la Société de Pharmacie de Bordeaux, **146**, 85–96 (2007).
22. A. Elouaddari, A. El Amrani, J. Jamal Eddine, A.I. D. Correia, J.G. Barroso, L.G. Pedro and A. C. Figueiredo, *Yield and chemical composition of the essential oil of Moroccan chamomile [Cladanthus mixtus (L.) Chevall.] growing wild at different sites in Morocco*. Flavour and Fragrance Journal, **28**(6), 360–363 (2013). doi: 10.1002/ffj.3146
23. A. Elouaddari, A. El Amrani, J. Jamal Eddine, J.G. Barroso, L.G. Pedro and A.C. Figueiredo, *Intraspecific variability of the essential oil of Cladanthus mixtus from Morocco*. Natural Product Communications, **9**, 133–136 (2014). doi: 10.1177/1934578X1400900137
24. A. Elouaddari, A. El Amrani and J. Jamal Eddine, *Effect of the parts of plant material (flowers and leaves) on essential oil chemical composition of Ormenis mixta from Morocco*. Journal of Essential Oil Bearing Plants, **18**(2), 398–408 (2015). doi: 10.1080/0972060X.2014.935022
25. A. Elouaddari, A. El Amrani, M. Moutia, N. Oubrim, N. Habti and J. Jamal Eddine, *Chemical composition and evaluation of antioxidant, antimicrobial and cytotoxic activities of Moroccan Cladanthus mixtus essential oil and extracts*. Journal of Essential Oil Bearing Plants, **22**(6), 1450–1466 (2019). doi: 10.1080/0972060X.2019.1691059
26. J. Wanner, E. Schmidt, S. Bail, L. Jirovetz, G. Buchbauer, V. Gochev, T. Girova, T. Atanasova and A. Stoyanova, *Chemical composition, olfactory evaluation and antimicrobial activity of selected essential oils and absolutes from Morocco*. Natural Product Communications, **5**, 1439–1454 (2010).
27. T. Ainane, M. Elkouali, A. Ainane and M. Talbi, *Moroccan traditional fragrance based essential oils: preparation, composition and chemical identification*. Der Pharma Chemica, **6**(6), 84–89 (2014).
28. W. Ouedrhiri, M. Balouiri, S. Bouhdid, E.H. Harki, S. Moja and H. Greche, *Antioxidant and antibacterial activities of Pelargonium asperum and Ormenis mixta essential oils and their synergistic antibacterial effect*. Environmental Science and Pollution Research, **25**, 29860–29867 (2018). doi: 10.1007/s11356-017-9739-1
29. A. Antonelli and C. Fabbri, *Study on Roman Chamomile (Chamaemelum nobile L. All.) oil*. Journal of Essential Oil Research, **10**(5), 571–574 (1998). doi: 10.1080/10412905.1998.9700974
30. P. Farkas, M. Hollá, S. Vaverková, B. Stahlová, J. Tekel and E. Havránek, *Composition of the essential oil from the flowerheads of Chamaemelum nobile (L.) All. (Asteraceae) cultivated in Slovak Republic*. Journal of Essential Oil Research, **15**(2), 83–85 (2003).
31. R. Omidbaigi, F. Sefidkon and F. Kazem, *Influence of drying methods on the essential oil content and composition of Roman chamomile*. Flavour and Fragrance Journal, **19**, 196–198 (2004). doi: 10.1002/ffj.1340
32. T. Umezu, T. Sano, J. Hayashi, Y. Yoshikawa and Y. Shibata, *Identification of isobutyl angelate, isoamyl angelate and 2-methylbutyl isobutyrate as active constituents in Roman chamomile essential oil that promotes mouse ambulation*. Flavour and Fragrance Journal, **32**, 433–439 (2017). doi: 10.1002/ffj.3397
33. M. Fernández-Cervantes, M.J. Pérez-Alonso, J. Blanco-Salas, A. Cristina Soria and T. Ruiz-Téllez, *Analysis of the essential oils of Chamaemelum fuscatum (Brot.) Vasc. from Spain as a contribution to reinforce its ethnobotanical use*. Forests, **10**, 539 (2019). doi: 10.3390/f10070539
34. P. Hubert, F. Tomi, J. Casanova and A. Bighelli, *Direct identification of two major components of an essential oil using "extraction NMR"*. Analytical Chemistry Letters, **1**, 115–122 (2011). doi: 10.1080/22297928.2011.10648209
35. Terpenoids Library Website. http://massfinder.com/wiki/Terpenoids_Library (08 April 2021).
36. C.J. Lee, A.B. De Milo, D.S. Moreno and R.L. Mangan, *Identification of the volatile components of E802 Mazoferm steepwater. A condensed fermented corn extractive highly attractive to the Mexican fruit fly (Diptera: Tephritidae)*. Journal of Agricultural and Food Chemistry, **45**, 2327–2331 (1997).
37. S.A. Carle, A.L. Averill, G.S. Rule, W.H. Reissig and W. L. Roelofs, *Variation in host fruit volatiles attractive to apple maggot fly, Rhagoletis pomonella*. Journal of Chemical Ecology, **13**, 795–805 (1987). doi: 10.1007/BF01020161
38. C. Menut, T. Molangui, G.E. Lamaty and J.M. Bessière, *Aromatic plants of tropical Central Africa. 23. Chemical composition of leaf essential oils of Eucalyptus goniocalyx F. Muell. and Eucalyptus patens Benth. grown in Rwanda*. Journal of Agricultural and Food Chemistry, **43**, 1267–1271 (1995). doi: 10.1021/jf00053a026
39. G.R. Takeoka, R.G. Buttery and R.A. Flath, *Volatile constituents of Asian pear (Pyrus serotina)*. Journal of Agricultural and Food Chemistry, **40**, 1925–1929 (1992). doi: 10.1021/jf00022a040
40. S. Eri, B.K. Khoo, J. Lech and T.G. Hartman, *Direct thermal desorption-gas chromatography and gas chromatography-mass spectrometry profiling of hop (Humulus lupulus L.) essential oils in support of varietal characterization*. Journal of Agricultural and Food Chemistry, **48**, 1140–1149 (2000). doi: 10.1021/jf9911850
41. G.R. Takeoka, R.A. Flath, T.R. Mon, R. Teranishi and M. Guentert, *Volatile constituents of apricot (Prunus armeniaca)*. Journal of Agricultural and Food Chemistry, **38**, 471–477 (1990). doi: 10.1021/jf00092a031
42. M.R. Nance and W.N. Setzer, *Volatile components of aroma hops (Humulus lupulus L.) commonly used in beer brewing*. Journal of Brewing and Distilling, **2**, 16–22 (2011).
43. V.I. Babushok, P.J. Linstrom and I.G. Zenkevich, *Retention indices for frequently reported compounds of plant essential oils*. Journal of Physical and Chemical

Reference Data, **40**(4), 043101–47 (2011). doi: 10.1063/1.3653552

44. K. Umano, A. Shoji, Y. Hagi and T. Shibamoto, *Volatile constituents of peel of quince fruit, Cydonia oblonga miller*. Journal of Agricultural and Food Chemistry, **34**, 593–596 (1986). doi: 10.1021/jf00070a003
45. F. Bianchi, M. Careri, A. Mangia and M. Musci, *Retention indices in the analysis of food aroma volatile compounds in temperature-programmed gas chromatography: database creation and evaluation of precision and robustness*. Journal of Separation Science, **30**(4), 563–572 (2007). doi: 10.1002/jssc.200600393
46. S.G. Wyllie and D.N. Leach, *Aroma volatiles of Cucumis melo cv. golden crispy*. Journal of Agricultural and Food Chemistry, **38**, 2042–2044 (1990). doi: 10.1021/jf00101a008
47. D. Kourkoutas, J.S. Elmore and D.S. Mottram, *Comparison of the volatile compositions and flavour properties of cantaloupe, Galia and honeydew muskmelons*. Food Chemistry, **97**(1), 95–102 (2006). doi: 10.1016/j.foodchem.2005.03.026
48. H. Toda, K. Yamaguchi and T. Shibamoto, *Isolation and identification of banana-like aroma from banana shrub (Michellia figo Spreng)*. Journal of Agricultural and Food Chemistry, **30**, 81–84 (1982). doi: 10.1021/jf00109a017
49. R. Tressl and L. Friese, *F.Fendesack and H Köppler, Gas chromatographic–mass spectrometric investigation of hop aroma constituents in beer*. Journal of Agricultural and Food Chemistry, **26**, 1422–1426 (1978). doi: 10.1021/jf60220a037
50. E.M. Suleimenov, G.A. Atazharova, B. Demirchi, K.H. C. Baser and S.M. Adekenov, *Essential oil composition of Artemisia Lercheana and A. Sieversiana of Kazakhstan flora* in recent problems of development of new medicines of natural origin. Proceedings of Symposium, St.Petersburg - Pushkin, pp. 382–385 (2003).
51. R.P. Adams and V. Dev, *Synthesis and GC-MS analysis of angelates and tiglates as an aid to identification of these components in essential oils*. Flavour and Fragrance Journal, **25**, 71–74 (2010). doi: 10.1002/ffj.1968
52. K.H.C. Baser, B. Demirci, N. Kirimer, F. Satil Ang and G. Tumen, *The essential oils of Thymus migricus and T. fedtschenkoi var. handelii from Turkey*. Flavour and Fragrance Journal, **17**, 41–44 (2002). doi: 10.1002/ffj.1036